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Cannabis Vape Product Sales in California Following CDC's Initial Advisory About Lung Injuries

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Abstract

Introduction: The 2019 outbreak of e-cigarette or vaping product use-associated lung injury (EVALI) is believed to have been caused by vitamin E acetate, an additive used in some cannabis vaporizer products. Previous studies have primarily focused on changes in sales of electronic nicotine delivery systems following the initial advisory issued by the Centers for Disease Control (CDC) on August 17, 2019. The present study is intended to examine variation by age groups in sales of regulated cannabis vape products in the state of California before, during, and after the outbreak.

Methods: Weekly sales revenue of cannabis vape products (from January 1, 2018, to December 31, 2020) was obtained from a sample of recreational cannabis retailers licensed in California. An interrupted time series analysis, using AutoRegressive, Integrated, Moving Average methods, was employed to estimate changes in the sales and market share of cannabis vape products in the weeks following the CDC advisory.

Results: The total volume of regulated cannabis vape product sales increased substantially over the 3-year study period (2018–2020). Sales and market share of cannabis vape products, however, declined in both young and older adults immediately following the advisory, rebounding to pre-EVALI levels only for the young adults. For sales, the potential EVALI effect following the CDC's advisory equates to an 8.0% and 2.2% decline below expected levels in the older and young adults, respectively.

Conclusions: The differential age effect on sales may reflect concerns regarding health effects of cannabis vaping products and greater awareness of the outbreak among older adults. Findings highlight the importance of informing consumers about health risks associated with using cannabis vape products acquired from regulated versus illicit sources.

Keywords: ENDS; lung injuries (EVALI); cannabis vape; sales; time series analysis

Introduction

The outbreak of e-cigarette or vaping product use-associated lung injury (EVALI), which peaked in September 2019,[1] was the first major health crisis that had the potential for drastically altering public perceptions, sales, and use of cannabinoid-containing vaporizer products and electronic nicotine delivery systems (ENDS). The first advisory about EVALI was issued by the Centers for Disease Control (CDC) on August 17, 2019,[2,3] which was preceded by national news in July about eight teenagers who were hospitalized for severe lung damage.[4] By January 14, 2020, the CDC reported that among the 2022 EVALI cases with substance use data, 82% used a tetrahydrocannabinol (THC)-containing vaporizer product and 57% used a nicotine-containing vaporizer product.[5] Among the cases that reported product source, most (78%) acquired products from informal sources such as a dealer or

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friend. While vitamin E acetate was strongly associated with the EVALI outbreak,[6] other vape product additives may have contributed to the acute lung injuries.[7]

The CDC's initial recommendation to abstain from using any e-cigarette or vaping device, along with media coverage of the outbreak,[8–10] may have contributed to misperceptions about EVALI[11] and ENDS health risks.[12] East et al. reported that the peak in the upward trend in U.S. youths' exposure to negative news stories about ENDS (64.6%) coincided with the nadir in perceiving a lower risk of ENDS (vs. cigarettes) (34.0%) immediately following the EVALI outbreak (February–March 2020). The conflation of risks of lung injury associated with vaping nicotine and vaping cannabis raised concern that cigarette smokers might be reluctant to use ENDS for harm reduction purposes.[11,13]

The decline in nationwide sales of ENDS during the EVALI outbreak[14] may reflect greater awareness of harm associated with vaping or declining perception of potential harm reduction benefits by current or former smokers. Also, tobacco control policies enacted in the wake of the outbreak could have affected the availability and sales of ENDS. Liber et al. addressed this issue by developing first-differenced panel regression models to differentiate effects of the outbreak from subsequent state-level policy changes. Notwithstanding, local tobacco flavor bans and the federal government's announcement on September 11, 2019, to ban the sales of most flavored ENDS[15] may have impacted ENDS sales.

The present study focuses exclusively on changes in sales of regulated cannabis vape products unaffected by recent tobacco-related policy changes. California legalized possession of nonmedical cannabis in 2016 and recreational retail sales began in January 2018, launching a period of rapid expansion of legal commerce and sales of a growing array of cannabis products, including products intended for vaporization. Although California's municipalities have the authority to regulate their local cannabis industry, cannabis delivery was legal throughout the state during our study period (December 2018 to November 2020).[16] Furthermore, only Contra Costa County and Pomona, which comprise 3.3% of California's population, restricted sale of cannabis vape products or related accessories in 2019;[17] in 2020, Watsonville prohibited sales of flavored products for inhalation or vaporization.

Between June 18, 2019, and February 23, 2020, 210 individuals were hospitalized for lung injuries in California.[18] Based on the EVALI caseload and few restrictions on cannabis vape sales, California is an ideal setting for the present study. We tested for a change in sales of cannabis vape products separately in young and older age groups, given differential risk perceptions by age[19] and a young median age of EVALI patients (24 years).[1] Based on their higher risk perceptions, we hypothesize that older consumers were more likely to curtail their purchases of cannabis vape products following the CDC's initial advisory about lung injuries.

Materials and Methods

Data source

Retail sales data originated from Headset, a company that tracks cannabis point-of-sale retail transactions in several U.S. states and Canada. Weekly sales data and consumer demographics for this study were obtained from a custom Headset dataset of licensed cannabis recreational retailers in California for the years 2018–2020 (156 weeks). Each licensed retailer was provided an inventory system that collects real-time sales data by SKU (stock keeping unit). Consumer data, such as birth dates for loyalty programs, were added at the discretion of the retailers. Over the 3-year period, Headset's market coverage of cannabis retailers in California averaged 20.63% (17.63% in 2018, 19.85% in 2019, and 24.34% in 2020).

Headset's sales data were divided into nine product categories: concentrates, flower, pre-roll, edibles, beverages, tinctures and sublinguals, capsules, topicals, and vapor pens, which encompass multiple cannabis vape products. Within the vapor pen category, Headset tracked sales of vaporizer cartridges (73.02% of category revenue), all-in-one disposable vaporizers (8.17% of revenue), all-in-one rechargeable vaporizers sold as cartridges with detachable batteries that could be reused with another cartridge (0.03% of revenue), refills/e-juice, that is, cannabis products marketed for refilling depleted vaporizer cartridges (0.02% of revenue), and other or unknown (18.75% of revenue). We combined these subcategories in analyzing weekly sales revenue for cannabis vape products and vape market share (i.e., vape sales divided by total sales across all categories).

Age groups and control variables

Analyses were conducted separately for two age groups defined by the year cannabis was purchased by the younger consumers (23- to 25-year-olds) and older consumers ($\geq$26-year-olds). Inspection of the sales data for ages 21 and 22 showed gradual increases

from January 1 to December 31, which likely reflected the accumulation of a study population over time rather than the full population aged 21 (or 22) at the start of each calendar year. The irregularity may have arisen from Headset's collection of data on persons whose 21st (or 22nd) birthday occurred in that calendar year, rather than persons who purchased cannabis at age 21 (or 22). Thus, the 21- and 22-year-olds were excluded from all analyses. To protect confidentiality, Headset only provided buyer birth year, not birth date, for each transaction. Thus, for estimating buyer age, we subtracted birth year (available for 78.2% of revenue) from purchase year. The dataset covered the purchase years 2018–2020, which corresponded to the birth years 1993–1997 for young adults.

The three control variables were weekly cannabis sales, weekly cannabis sales as a percentage of state sales (Headset market coverage), and the percentage of California's population living in jurisdictions that allowed storefront cannabis retailers. For the latter, we obtained local law information using Fyllo's CannaRegs commercial database (discontinued on March 31, 2023), municipal law web sites, and direct contact with city or county officials. For each week, we identified municipalities with an ordinance allowing storefront cannabis retailers that was in effect for at least 4 days in the given week, summed those jurisdictions' populations, and divided the sum by California's total population[20] to estimate the percentage of the state's population living where storefront cannabis retailers were allowed.

Interrupted time series analyses

Testing a potential effect of EVALI on sales required comparing observed weekly vape sales with "expected" (i.e., counterfactual) values had the CDC's advisories not affected vape sales. A straightforward ordinary-least-squares approach to derive these expected values can lead to substantial bias when the outcome shows strong temporal patterns.[21] In the case of cannabis sales, a simple plot (Fig. 1) indicates strong temporal patterns that would call for a more nuanced control strategy. As described in the Results section, vape sales show a strong trend as well as the tendency for high (or low) values to persist, although in diminishing amounts, into subsequent weeks. The counterfactual for weekly vape sales, therefore, is not the mean of past vape sales. To address this temporal patterning, we used AutoRegressive, Integrated, Moving Average (ARIMA) time series methods. Epidemiologists and health services researchers increasingly use these methods,[22,23] devised by Box et al.,[24] to estimate responses to "interruptions" in a time series. These models "fit" patterning (e.g., trend, seasonality) in the dependent variable.

We first used the Box–Jenkins ARIMA methods, implemented using Scientific Computing Associates software package (River Forest, IL), to identify and model autocorrelation in vape sales for the 85 weeks before the CDC's first EVALI report (i.e., January 1, 2018, to August 17, 2019). This "base model" incorporated the three aforementioned control variables. We defined the 95% detection interval of the residual series as the product of 1.96 and the residual series' standard deviation. We applied the model, with parameter values fixed to those estimated from the ARIMA model, to weekly sales for 156 weeks spanning January 1, 2018, to December 31, 2020.

Next, we combined the residuals of vape sales for all 156 weeks and examined whether vape sales fell below the 95% detection interval in the 12 weeks immediately following the first EVALI report. Examination of residual values in the 12-week period was based on the approximate period of rapid decline of ENDS sales reported in other studies.[25,26] Cannabis vape sales were separately examined using total volume of vape sales and vape sales adjusted for the overall volume of cannabis sales (i.e., market share). The latter was examined to account for the possibility that the market share of vape products decreased while total vape sales increased over time, attributed to California's rapidly expanding cannabis market.

Results

Approximately 25% of the $1.5 billion revenue from cannabis sales in our sample (2018–2020) was attributed to cannabis vape products. Buyers aged 23–25 years accounted for 10.0% of total revenue and 11.7% of vape product revenue. Figure 1A and B shows that total volume of legal cannabis vape product sales exhibited a strong increase over the test period for both young adults (23–25 years) and older adults (>25 years). This trend was rather stable for young adults until the onset of COVID-19 (week 115 = March 9–15, 2020), which precipitated a sharp rise in sales. By contrast, cannabis vape sales for older adults exhibited an interruption in the rising trend after the CDC's EVALI report on August 17, 2019 (week 85), which was followed by slow growth in sales.

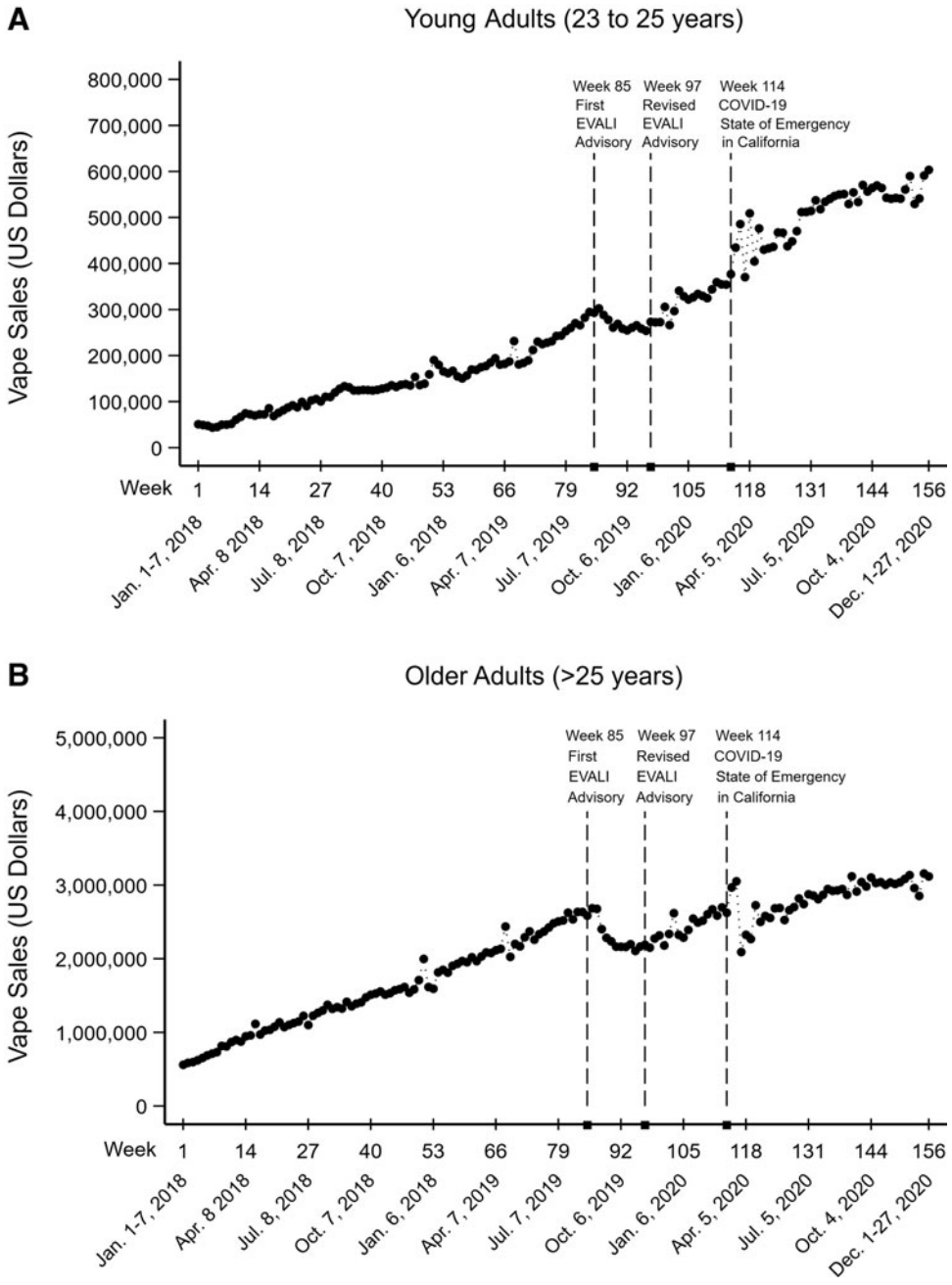

FIG. 1. Weekly sales revenue for vape products in California for 156 weeks spanning January 1, 2018, to December 31, 2020, in young adults (Panel **A**) and older adults (Panel **B**).

As indicated in the plot of vape sales as a proportion of total sales (Fig. 2), the market share of cannabis vape products increased similarly for young and older adults in the first 18 months of legal sales in 2018 and 2019 but diverged thereafter. Vape products were more popular (as a fraction of total cannabis sales) for young adults relative to older adults, especially from late summer 2019 onward. Furthermore, the market share of cannabis vape products fell abruptly for older adults in early September 2019 (week 88 = September 2–8, 2019) and remained low throughout 2020, almost a year after EVALI. The market share of cannabis vape

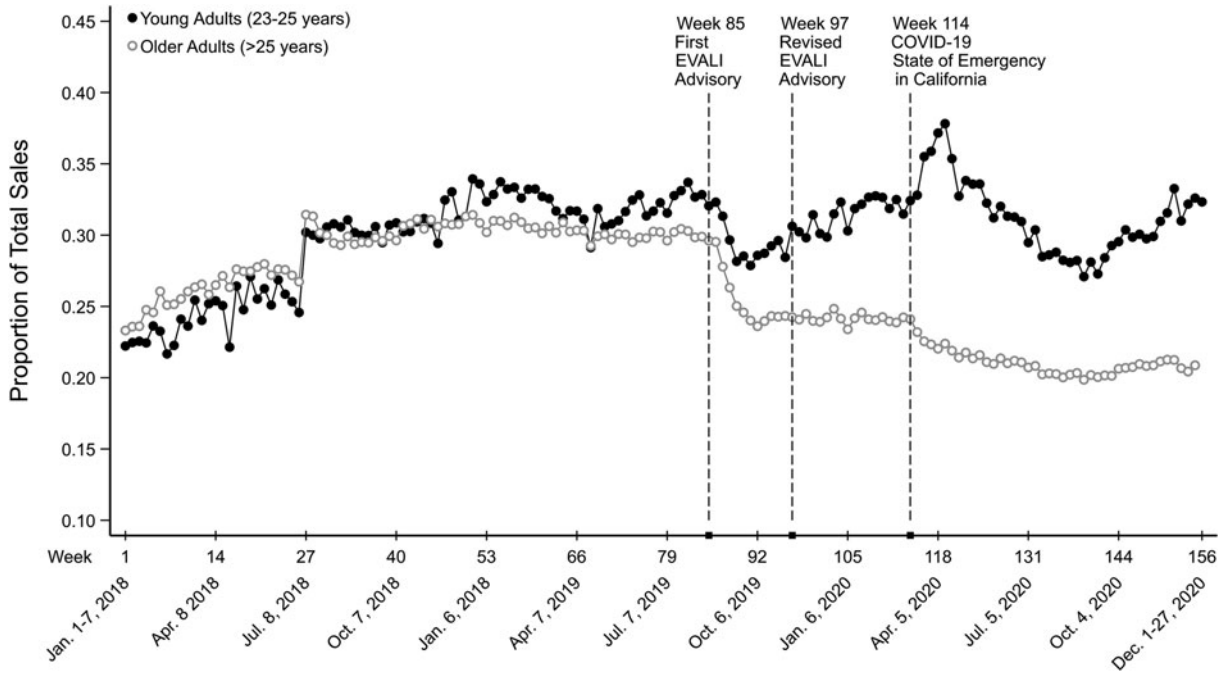

FIG. 2. Weekly sales revenue for vape products as a proportion of total sales in California for 156 weeks spanning January 1, 2018, to December 31, 2020, by age group.

products for young adults also fell in early September 2019 but gradually returned to pre-September 2019 levels.

Inspection of total cannabis vape product sales (Fig. 1) and market share (Fig. 2), leading up to but not including the EVALI interruption (i.e., 85 weeks spanning January 1, 2018, to August 17, 2019), revealed nuanced forms of autocorrelation. These patterns required the inclusion of ARIMA parameters in the error term, which differed depending on the age group and outcome examined (Table 1). The resulting residual values from these four base models had a mean of 0 and exhibited no autocorrelation.

As shown in Figure 3, the residual plots of vape sales for young adults (Fig. 3A) and older adults (Fig. 3B) indicate that residuals fell below the lower bound of the 95% detection interval for young adults in one of the 8 weeks following the initial EVALI report. For older adults, residuals fell below the 95% detection interval for 17 consecutive weeks from week 87 through week 104 (i.e., August 26, 2019, to December 29, 2019). The residual plot of vape sales, when controlling for overall sales, indicates an acute decline in market share for young adults (Fig. 4A) in the 3 weeks immediately following the initial EVALI report and then a return to expected levels. Residuals among older adults, by contrast, fell below expected levels in week 86 (i.e., 1 week after the EVALI report) and never returned to pre-EVALI levels.

Using the time series plot in Figure 3B, the mean weekly decline in vape sales in the 12 weeks following the initial EVALI report was $206,810. The potential EVALI "effect" over this period equates to an 8.0% and 2.2% decline below expected levels in the older and young adults, respectively; for the latter, revenue subsequently returned to expected levels. In actual terms, revenue from cannabis vape purchased by the older and young adults declined over the period by 16.9% and 7.3% relative to revenue generated in the week before the CDC's report; in the full sample, revenue declined by 16.0%.

Discussion

Legalization of cannabis products for nonmedical use in California led to a steady increase in legal sales from 2018 to 2020. Despite this rise, the CDC's EVALI advisory in August 2019 may have curbed interest in cannabis vape products among older adults. Residuals from the interrupted time series analyses

Table 1. Time Series Base Models Predicting Weekly Values of Selected Indicators of Cannabis Vape Sales in California for Young Adults (23–25 Years) and Older Adults (>25 Years) as a Function of Control Variables, After Removal of Autocorrelation (January 1, 2018, to August 17, 2019)

		Vape product sales with two control variables				Vape product sales with three control variables			
		Younger adults		Older adults		Younger adults		Older adults	
Parameter	Lag (weeks)	Coefficient	SE	Coefficient	SE	Coefficient	SE	Coefficient	SE
Constant	—	2538.1**	836.2	25,730.3**	1707.1	—	—	−1,788,800**	251,030
Weekly cannabis sales in dataset	0	—	—	—	—	0.24**	0.01	0.27**	0.007
Weekly cannabis sales in dataset as a percentage of state sales	0	272.4	1240.9	8535.0	5631.3	1239.8*	512.4	13,539.6**	3414.6
Percentage of state population with access to cannabis storefront retailers	0	4090.5	4470.2	−22,308.3	17,117.7	3762.3**	1703.9	38,896.2**	6926.3
AR	1	—	—	—	—	—	—	0.60**	0.09
I	1	✓	✓	✓	✓	✓	✓	—	—
MA	1	0.40**	0.10	0.88**	0.05	0.22*	0.10	—	—

Seasonality was not detected.
*$p < 0.05$; **$p < 0.01$.
AR, AutoRegressive; I, Integrated; MA, Moving Average; SE, standard error.

indicate a decline in cannabis vape sales and vape market share, particularly among adults older than 25 years. For older adults, the reduction in market share of cannabis vape products persisted following dissemination of the CDC's advisory and never returned to pre-EVALI levels. The actual declines in sales of cannabis vape in the full sample (16.0%) and older adults (16.9%) were lower than the decline in sales of ENDS (29%) from August 2019 to January 2020.[14] Since the Nielsen Company does not provide buyer age, there is no research to the best of our knowledge that has reported on EVALI-related declines in nationwide sales of ENDS by buyer age. Thus, we do not know if the differential sales effect by age also occurred for ENDS.

A recent qualitative study on why young adults continued to use ENDS throughout the EVALI outbreak[27] may shed light on our findings of the group's persistent use. Yang et al. reported that young adults rationalized their behavior on the basis of their low frequency of ENDS use or their avoidance of "fake" cannabis obtained from unregulated sources. Individuals also expressed positive sentiment about vaping on Twitter,[28] which remained high and even exceeded negative sentiment in the summer 2019. While age was not significantly associated with perceptions about ENDS hazards among current users during the outbreak,[26] young adult nonusers had lower odds than non-using youth of having such negative perceptions. In a similar vein, age moderated the association between a lower risk perception of ENDS (vs. cigarettes) and subsequent use of ENDS,[29] such that the association was more pronounced in older adults (55+ years; odds ratio [OR] = 2.82 [2.15–3.70]) compared with young adults (18–24 years; OR = 1.81 [1.44–2.27]). In other words, the behavior of older adults was more influenced by risk perception, which could account for the differential age effect.

Misperceptions about EVALI have persisted since the peak of the outbreak exemplified by only ∼17% of adult smokers who correctly perceived that cannabis/THC vape products were used by a majority of EVALI patients.[11] Although media coverage on cannabis vape products and vitamin E acetate significantly increased since the CDC revised its advisory to include only THC-containing vapes/e-cigarettes (November 8, 2019), news articles recommending the discontinuation of vaping THC increased slightly.[10] The absence of age-specific sales data on cannabis vapes from illicit sources precluded a thorough examination of potential changes in purchasing behaviors throughout the EVALI outbreak. We can, however, conclude that many young adults who continued to purchase cannabis vaping products were adhering to the California Department of Public Health's (CDPH) recommendation to purchase such products from licensed cannabis retailers.[30]

Older adults' declining preference for cannabis vape products may reflect a more perisistent impact of EVALI messaging regarding vaping. Some older adults may have heeded the CDPHs advice of avoiding all vaping products as the safest course of action

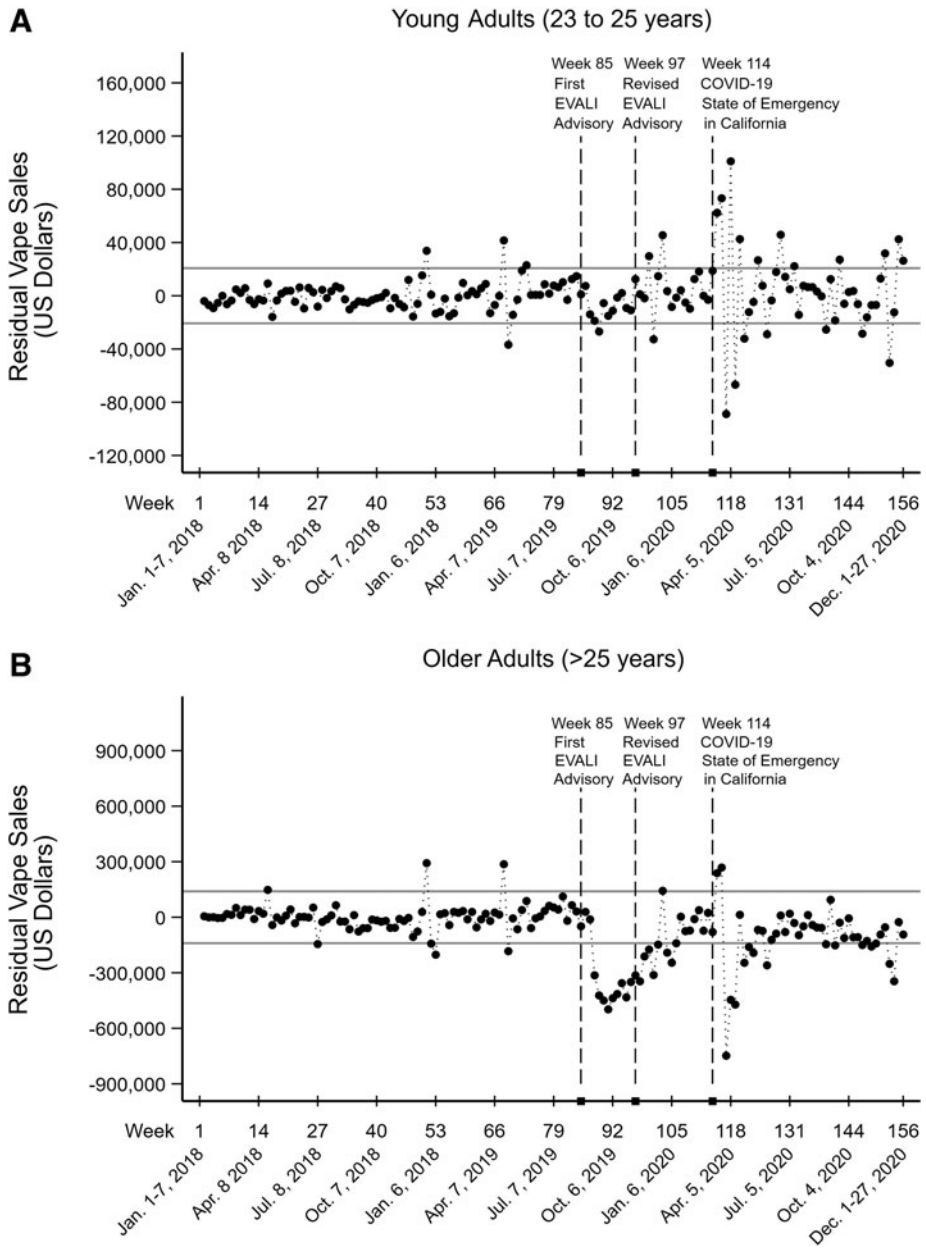

FIG. 3. Residual weekly values of cannabis vape sales over 156 weeks (January 1, 2018, to December 31, 2020) after removing autocorrelation and controlling for weekly cannabis sales in dataset as a percentage of state sales, and percentage of state population with access to cannabis storefront retailers. Note: The horizontal lines represent the 95% detection interval **(A**: ±20,723; **B**: ±139,981**)**.

and switched to consuming cannabis using modes of administration that vary in risk. Some might argue that the older adults' declining preference for cannabis vape products reflects fewer harm reduction options, as outlined in the National Institutes of Health's Lower-Risk Cannabis Use Guidelines.[31] The third recommendation states that alternative delivery methods, such as vaporization, may be less harmful to the respiratory system than smoking. However, the guidelines caution against inhalation

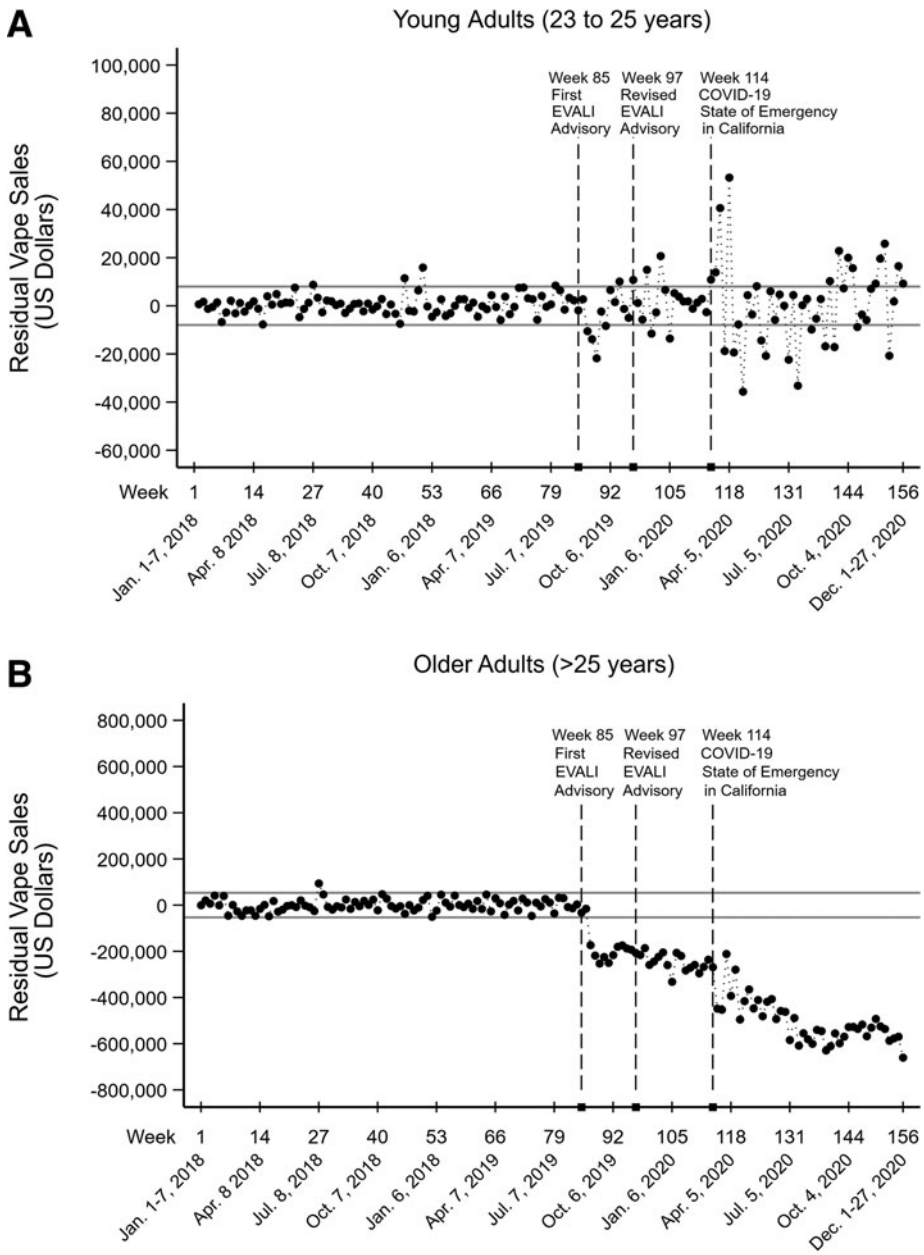

FIG. 4. Residual weekly values of cannabis vape sales over 156 weeks (January 1, 2018, to December 31, 2020) after removing autocorrelation and controlling for weekly cannabis sales in dataset, weekly cannabis sales in dataset as a percentage of state sales, and percentage of state population with access to cannabis storefront retailers. Note: The horizontal lines represent the 95% detection interval **(A**: ±7979; **B:** ±53,074**)**.

of high-potency cannabis extracts that may potentially cause adverse physical and mental effects, such as dependency and psychosis.[32] Emerging evidence also suggests that physical components of vaporizers, such as heating coils, are a potential source of heavy metal contamination.[33] California regulations recently expanded the definition of allowable "terpene" additives in inhaled products to include flavonoids, polyphenols, and other phytochemicals.[34]

Strengths and limitations

This study benefited from strong internal validity stemming from the few restrictive measures that affected the availability and sales of cannabis vaping products in California during the study period. It is possible that temporary local bans on cannabis vape products, such as the proposed moratorium in Los Angeles,[35] had a short-term effect on sales. Yet, cannabis vape products in California were subjected to far fewer sales restrictions during the EVALI outbreak compared with ENDS at the local or national level. Despite this advantage, our analysis of sales data at the state level precluded the assessment of local policies that either restricted the sales of cannabis vape products or accessories (Contra Costa County, Pomona) or restricted marketing, accessibility, or other ordinances affecting young adults.[17] Another limitation of our study was the analysis of sales data from only licensed recreational cannabis retailers in Headset's custom dataset.

Consequently, we could not compare the effect of age on vape sales between licensed and unlicensed retailers. While the decline in legal sales of cannabis vape was lower than the decline in ENDS sales,[14,25] the absence of data from the large illicit market for cannabis in California precludes inferences on overall product sales. The true decline in sales of cannabis vape may have been higher due to the warnings about illicit sources of cannabis vape disseminated by public health officials in California.[30] Comparing the sales trajectories of cannabis vape and ENDS is further complicated by the absence of data on consumer age and sales of ENDS in California. Finally, our study was limited by the exclusion of sales to 21- and 22-year-olds due to data irregularities observed during the analyses. Their inclusion would have provided better representation of changes in sales to young adults.

Conclusions

The initial decline in sales of cannabis vaping products, following the first EVALI advisory, may be attributed to misperceived harms of cannabis vape products acquired from licensed retailers. This finding highlights the importance of disseminating information about purchasing cannabis products from licensed retailers versus illicit sources. Regulated cannabis products are subjected to manufacturing standards and testing requirements that can be evaded by unlicensed retailers in California.[36] However, the full health implications of legalizing cannabis and allowing unfettered product diversification are largely unknown. Furthermore, little is known about the long-term health effects of inhaling additives allowed in cannabis vaporizer products. More information is still urgently required to fully understand the relative harms associated with the various modes of cannabis use, especially by age group. To resolve the issues, a more proactive regulatory approach and additional research are needed to guide policy and better inform consumers.

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Author Disclosure Statement

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References

1. Krishnasamy VP, Hallowell BD, Ko JY, et al. Update: Characteristics of a nationwide outbreak of e-cigarette, or vaping, product use-associated lung injury—United States, August 2019–January 2020. MMWR Morb Mortal Wkly Rep 2020;69(3):90–94; doi: 10.15585/mmwr.mm6903e2
2. Centers for Disease Control and Prevention. Outbreak of Lung Injury Associated with the Use of E-Cigarette, or Vaping, Products. 2021. Available from: www.cdc.gov/tobacco/basic_information/e-cigarettes/severe-lung-disease.html
3. CDC, States Investigating Severe Pulmonary Disease Among People Who Use E-Cigarettes [press release]. August 17, 2019. Available from: https://www.cdc.gov/media/2019 [Last accessed: January 8, 2023].
4. Scutti S. 8 Wisconsin Teens Hospitalized with Severe Lung Damage due to Vaping, Doctors Suspect. CNN; 2019. Available from: www.cnn.com/2019/07/26/health/wisconsin-8-teens-lung-damage/index.html [Last accessed: January 12, 2023].
5. Centers for Disease Control and Prevention. Outbreak of Lung Injury Associated with the Use of E-Cigarette, or Vaping, Products: Office on Smoking and Health, National Center for Chronic Disease Prevention and Health Promotion. 2020. Available from: www.cdc.gov/tobacco/basic_information/e-cigarettes/severe-lung-disease.html [Last accessed: January 15, 2023].
6. Blount BC, Karwowski MP, Shields PG, et al. Vitamin E acetate in bronchoalveolar-lavage fluid associated with EVALI. N Engl J Med 2020;382(8):697–705; doi: 10.1056/NEJMoa1916433
7. Muthumalage T, Friedman MR, McGraw MD, et al. Chemical constituents involved in e-cigarette, or vaping product use-associated lung injury (EVALI). Toxics 2020;8(2); doi: 10.3390/toxics8020025
8. Jeong M, Singh B, Wackowski OA, et al. Content analysis of e-cigarette news articles amidst the 2019 vaping-associated lung injury (EVALI) outbreak in the United States. Nicotine Tob Res 2022;24(5):799–803; doi: 10.1093/ntr/ntab203
9. Leas EC, Nobles AL, Caputi TL, et al. News coverage of the e-cigarette, or vaping, product use associated lung injury (EVALI) outbreak and internet searches for vaping cessation. Tob Control 2021;30(5):578–582; doi: 10.1136/tobaccocontrol-2020-055755
10. Algiers O, Wang Y, Laestadius L. Content analysis of U.S. newspaper coverage of causes and solutions to vaping-associated lung injury. Subst Use Misuse 2021;56(4):522–528; doi: 10.1080/10826084.2021.1883663

11. Wackowski OA, Gratale SK, Jeong M, et al. Over 1year later: Smokers' EVALI awareness, knowledge and perceived impact on e-cigarette interest. Tob Control 2022; doi: 10.1136/tobaccocontrol-2021-057190
12. East K, Reid JL, Burkhalter R, et al. Exposure to negative news stories about vaping, and harm perceptions of vaping, among youth in England, Canada, and the United States before and after the outbreak of e-cigarette or vaping-associated lung injury ("EVALI"). Nicotine Tob Res 2022;24(9): 1386–1395; doi: 10.1093/ntr/ntac088
13. Balfour DJK, Benowitz NL, Colby SM, et al. Balancing consideration of the risks and benefits of e-cigarettes. Am J Public Health 2021;111(9):1661–1672; doi: 10.2105/AJPH.2021.306416
14. Liber AC, Cahn Z, Diaz MC, et al. The EVALI outbreak and tobacco sales in the USA, 2014–2020. Tob Control 2021; doi: 10.1136/tobaccocontrol-2021-056807
15. Kaplan S. Trump Administration Plans to Ban Flavored E-Cigarettes. The New York Times September 11, 2019.
16. Silver LD, Naprawa AZ, Padon AA. Assessment of incorporation of lessons from tobacco control in city and county laws regulating legal marijuana in California. JAMA Netw Open 2020;3(6):e208393; doi: 10.1001/jamanetworkopen.2020.8393
17. Padon AA, Young-Wolff KC, Avalos LA, et al. Local laws regulating cannabis in California two years post legalization: Assessing incorporation of lessons from tobacco control. Cannabis 2022;5:47–60.
18. Armatas C, Heinzerling A, Wilken JA. Notes from the field: E-cigarette, or vaping, product use-associated lung injury cases during the COVID-19 response—California, 2020. MMWR Morb Mortal Wkly Rep 2020;69(25): 801–802; doi: 10.15585/mmwr.mm6925a5
19. Fong GT, Elton-Marshall T, Driezen P, et al. U.S. adult perceptions of the harmfulness of tobacco products: descriptive findings from the 2013–2014 baseline wave 1 of the path study. Addict Behav 2019;91:180–187; doi: 10.1016/j.addbeh.2018.11.023
20. State of California Department of Finance. Report E-1 Population Estimates for Cities, Counties, and the State. January 1, 2018 and 2019. Available from: https://dof.ca.gov/forecasting/demographics/estimates/
21. Chatfield C. Chapter 2: Basics of Time-Series Analysis. CRC Press: New York; 2000.
22. Schaffer AL, Dobbins TA, Pearson SA. Interrupted time series analysis using AutoRegressive Integrated Moving Average (ARIMA) models: A guide for evaluating large-scale health interventions. BMC Med Res Methodol 2021;21(1):58; doi: 10.1186/s12874-021-01235-8
23. Trinh NTH, Bruckner TA, Lemaitre M, et al. Association between national treatment guidelines for upper respiratory tract infections and outpatient pediatric antibiotic use in France: An interrupted time-series analysis. J Pediatr 2020;216:88–94 e4; doi: 10.1016/j.jpeds.2019.09.017
24. Box G, Jenkins G, Reinsel G, et al. Time Series Analysis: Forecasting and Control. 5th Edition. John Wiley & Sons: New York; 2015.
25. Janmohamed K, Nakamura-Sakai S, Soale AN, et al. News events and their relationship with US vape sales: An interrupted time series analysis. BMC Public Health 2022;22(1):479; doi: 10.1186/s12889-022-12858-x
26. Kreslake JM, Diaz MC, Shinaba M, et al. Youth and young adult risk perceptions and behaviours in response to an outbreak of e-cigarette/vaping-associated lung injury (EVALI) in the USA. Tob Control 2022;31(1):88–97; doi: 10.1136/tobaccocontrol-2020-056090
27. Yang JS, Sou A, Faruqui A, et al. A qualitative examination of e-cigarette use among California young adults during the EVALI outbreak. Prev Med Rep 2021;24:101506; doi: 10.1016/j.pmedr.2021.101506
28. Kasson E, Singh AK, Huang M, et al. Using a mixed methods approach to identify public perception of vaping risks and overall health outcomes on Twitter during the 2019 EVALI outbreak. Int J Med Inform 2021;155: 104574; doi: 10.1016/j.ijmedinf.2021.104574
29. Elton-Marshall T, Driezen P, Fong GT, et al. Adult perceptions of the relative harm of tobacco products and subsequent tobacco product use: Longitudinal findings from waves 1 and 2 of the population assessment of tobacco and health (PATH) study. Addict Behav 2020;106:106337; doi: 10.1016/j.addbeh.2020.106337
30. Egel C. Another death in California and investigation into e-cigarette and vaping-associated illnesses continues as potential chemical of concern is identified. California Department of Public Health; November 13, 2019.
31. Fischer B, Robinson T, Bullen C, et al. Lower-Risk Cannabis Use Guidelines (LRCUG) for reducing health harms from non-medical cannabis use: A comprehensive evidence and recommendations update. Int J Drug Policy 2022;99:103381; doi: 10.1016/j.drugpo.2021.103381
32. D'Souza DC, DiForti M, Ganesh S, et al. Consensus paper of the WFSBP task force on cannabis, cannabinoids and psychosis. World J Biol Psychiatry 2022;23(10):719–742; doi: 10.1080/15622975.2022.2038797
33. McDaniel C, Mallampati SR, Wise A. Metals in cannabis vaporizer aerosols: Sources, possible mechanisms, and exposure profiles. Chem Res Toxicol 2021;34(11):2331–2342; doi: 10.1021/acs.chemrestox.1c00230
34. California Department of Cannabis Control. Department of Cannabis Control Medicinal and Adult-Use Commercial Cannabis Regulations. 2023.
35. MJBizDaily Staff. Possible L.A. vaping ban could be "extinction event" for some marijuana firms, California industry executives say. MJBizDaily September 27, 2019.
36. Unger JB, Vos RO, Wu JS, et al. Locations of licensed and unlicensed cannabis retailers in California: A threat to health equity? Prev Med Rep 2020;19:101165; doi: 10.1016/j.pmedr.2020.101165

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Abbreviations Used

ARIMA = AutoRegressive, Integrated, Moving Average
CDC = Centers for Disease Control
CDPH = California Department of Public Health
ENDS = electronic nicotine delivery systems
EVALI = e-cigarette or vaping product use-associated lung injury
THC = tetrahydrocannabinol