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State marijuana policies and vaping associated lung injuries in the US

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Abstract

Background: The United States' 2019 outbreak of e-cigarette or vaping-associated lung injuries (EVALI) was linked to an additive most common in informally-sourced vaporizable marijuana concentrates. This study estimates how states' recreational and medical marijuana policies related to their 2019 EVALI incidence and residents' likelihood of vaping as their primary mode of marijuana use.

Methods: Multivariable negative binomial regressions estimated associations between states' total 2019 EVALI cases and marijuana policies: recreational legalization, medical legalization only, and whether medical-only policies allowed home cultivation, prohibited combustible use, or had operational dispensaries. Logistic regressions used survey data from the Behavioral Risk Factor Surveillance System's 2016–2019 marijuana supplements to assess how these policies related to past-30-day marijuana users' selection of vaping as their primary mode of use.

Results: EVALI incidence was 42% lower in recreational marijuana states (95%CI=0.339,0.993), versus a positive but statistically insignificant association with medical legalization alone. Adjusting for policy attributes revealed heterogeneity: among medical-marijuana-only states, EVALI incidences were > 60% lower where laws allowed home cultivation (aIRR=0.374; 95%CI=0.196, 0.715). Similarly, among past-30-day marijuana users, odds of vaping as one's primary mode of use were > 40% lower in medical-only states where home cultivation was allowed versus prohibited (aOR=0.588; 95%CI=0.365,0.946).

Conclusions: Marijuana policy attributes linked to lower EVALI incidences were also associated with reduced likelihoods of vaping as one's primary mode of use. As additives in informally-sourced vaping concentrates could drive future EVALI cases, marijuana policy design

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CRediT authorship contribution statement

Dr. Friedman conceptualized and designed this study, compiled the EVALI data, conducted all statistical analyses, and wrote the manuscript's first draft. Dr. Morean conducted substantive revisions of the manuscript for important intellectual content. Both authors revised the manuscript and approved its final draft.

Conflicts of Interest

Dr. Friedman has no conflicts of interest related to this research. Dr. Morean holds a restricted stock agreement with Gofire, Inc.

should account for effects on mode of use in licit and illicit markets, to limit the scope of future outbreaks.

Keywords

EVALI; Vaping Associated Lung Injuries; Marijuana; Vaping; Policy; Public Health

1. Introduction

The United States' 2019 outbreak of e-cigarette or vaping-associated lung injuries (EVALI) sickened over 2800 patients, causing 68 deaths (Centers for Disease Control and Prevention, 2020b). The geographic distribution of cases was consistent with a contaminant in locally-distributed products (Friedman, 2020). CDC ultimately identified vitamin E acetate—an additive most commonly found in informally-sourced vaporizable marijuana concentrates—as the outbreak's primary cause (CDC 2020 b). Although CDC stopped collecting EVALI case data in February 2020, future outbreaks remain a threat as vitamin E acetate and other chemicals unsafe for inhalation still can be added to informally-sourced marijuana products.

State marijuana laws may offer a means to reduce the scale of such outbreaks if they influence the market penetration of contaminated marijuana concentrates or the types of marijuana products consumers use. Prior work on the relationship between state marijuana policies and EVALI suggests that the case prevalence was lower in states that had legalized recreational marijuana (RM) but higher where only medical marijuana (MM) had been legalized (Wing et al., 2020). However, MM policies are not homogenous, and specific policy details are known to influence marijuana use and abuse (Pacula et al., 2015). With vaping as the second most popular mode of marijuana use after smoking (Baldassarri et al., 2020), policy attributes that might affect mode of use—e. g., restrictions on home cultivation, restrictions on combustible marijuana use, the presence of operational dispensaries—could be particularly consequential. Simply put, decreasing the number of people who vape marijuana concentrates should decrease a state's EVALI incidence when contaminated marijuana concentrates enter its market.

Given the potential importance of marijuana policy details for consumer use and EVALI, this study's objective was to estimate the relationship of states' 2019 EVALI prevalence to their recreational and medical marijuana policies, accounting for medical marijuana policy attributes that might affect mode of use.

2. Material and methods

2.1. Data

Total (confirmed plus probable) EVALI cases were obtained for each US state via government websites and departments of health as of the second week of January 2020 (01/12/20 – 01/18/20) to ensure inclusion of cases reported over the winter holidays. (Many states did not update their reports over the winter holidays and first posted new case counts after the first week of January 2020). These data were matched to the implementation dates of states' RM and MM laws, as well as three specific MM policy attributes — allowing

home cultivation, having operational dispensaries, and prohibiting combustible use — (See Appendix Table A1), with indicator variables for each defined to capture whether the policy/policy attribute was in effect as of August 1, 2019. This cutoff ruled out reverse causality by ensuring that the marijuana policies considered here were not implemented in response to the EVALI outbreak: CDC first issued its recommendation that all clinicians report cases of unexplained pulmonary disease among people with a history of vaping on August 2nd, 2019 (CDC, 2019). Population data from the US Census were used to account for differences in state population sizes (U. S. Census Bureau, 2020).

State-representative survey data from the 2016–2019 Behavioral Risk Factor Surveillance System (BRFSS) marijuana modules (CDC, 2020a)—fielded in 21 states—were also matched to the aforementioned marijuana policies. These data were used to estimate associations between marijuana policy attributes and respondents' reports of vaping as their primary mode of marijuana use. Neither the marijuana module data nor the EVALI case counts covered Washington, D.C.

2.2. Statistical analysis

We used Stata (version 17.0; StataCorp, College Station, TX) for all analyses. First, we mapped EVALI case counts alongside state marijuana policies to clarify geographic variation. Multivariable negative binomial regression was then used to estimate the relationship between states' total 2019 EVALI cases and two mutually exclusive marijuana policy indicators: RM+MM legalization and MM-only legalization. (All 10 states with legal RM also had legalized MM [RM+MM], while 23 states had legalized MM alone.) The count data exposure variable was set to the number of state residents ages 13–64 years, covering the vast majority of EVALI case ages (Centers for Disease Control and Prevention, 2020b). To clarify the potential implications of policy attributes, a second specification added three binary covariates, indicating MM-only states that (a) allowed home cultivation, (b) had an open dispensary, and (c) prohibited combustible marijuana use as of August 1, 2019.

Four sensitivity checks were considered. First, we added a covariate for the percent of state residents under age-35, the age-group responsible for 76% of EVALI cases (Krishnasamy et al., 2020). This addresses the possibility that larger youth/young adult populations might impact the informal market for cannabis, allowing for greater market penetration of contaminated vaping products. Second, to increase confidence that findings were not driven by state differences in EVALI case detection or reporting practices, regressions were repeated with case counts limited to hospitalized EVALI cases, as states were asked to report hospitalized EVALI case numbers to CDC regularly in December 2019 and January 2020 (N = 36; we could not confirm the hospitalized case count for 14 states). Finally, to ensure that findings were not driven by key outliers, sensitivity checks repeated the full sample regression for both all EVALI cases and hospitalized cases only, first without Ohio and Pennsylvania, whose dispensaries sold flower despite prohibiting combustible use, and then without Utah and West Virginia, whose MM laws went into effect before residents could legally obtain MM in-state. Robustness checks repeated all analyses as linear regressions, specifying the outcome as EVALI cases per 100,000 residents aged 13–64.

Finally, BRFSS analyses assessed whether policies associated with more EVALI cases were also associated with a higher likelihood of people who use marijuana choosing vaping as their primary mode of use. Limiting consideration to respondents who reported past-30-day marijuana use and adjusting for complex survey design, sample-weighted multivariable logistic regressions estimated associations between a binary indicator for respondents' selection of vaping as their primary mode of use and indicators for state marijuana policies (RM+MM, MM only, and the aforementioned policy attributes) at the respondent's interview date. Covariates adjusted for interview year to capture national time trends in product choice/availability, census region to capture time-invariant regional differences in attitudes towards marijuana use and access, and respondent sociodemographics (fixed effects for sex, age-group, race, Hispanic ethnicity, and completed ≥1 year of college). Sensitivity checks added three binary covariates for MM-only laws that allowed home cultivation, that had operational dispensaries, and that forbade smoking as a mode of use. Robustness checks repeated these analyses with a vaping-or-dabbing indicator as the outcome variable. (Dabbing via a "dab pen" is functionally equivalent to vaping marijuana concentrates, though dabbing with a "dab nail" may involve combustion.).

Yale University's IRB deemed this study exempt from review (protocol #2000026893).

3. Results

Despite broad variation in marijuana policies across the US, states in the highest EVALI-quintile tended to either ban all marijuana use or have MM laws prohibiting home cultivation (Fig. 1). In contrast, most states with legal RM fell into the lower two quintiles for EVALI prevalence. Massachusetts, in the highest EVALI quintile despite RM legalization, was a notable exception. This finding may be explained by the fact that Massachusetts' RM law went into effect almost two years before its first licensed dispensary opened, a delay that could have strengthened the informal market in the interim.

Across regression specifications, EVALI incidence was about 40% lower in states with RM legalization (Fig. 2). While a binary indicator for MM legalization was positively, albeit not significantly, associated with EVALI cases (Fig. 2, "Simple Marijuana Policy Analysis"), this association became significant when adjusting for policy-attributes (aIRR = 2.489, 95% CI: 1.031, 6.007; Fig. 2, "Policy Attribute Analysis"). Furthermore, one MM policy attribute showed a significant association with EVALI cases: EVALI incidence was over 60% lower in states with MM-only laws permitting home cultivation relative to those forbidding it (aIRR = 0.374, 95% CI: 0.196, 0.715). That finding held when adjusting for the percent of state residents under age-35, considering the hospitalized EVALI case count as the outcome (See Fig. 2), and in sensitivity tests omitting Ohio and Pennsylvania (the two states whose dispensaries sold flower despite forbidding combustible use) and dropping Utah and West Virginia (the two states whose residents could not legally obtain marijuana in-state as of August 1, 2019 despite having an MM law in effect) (Appendix Table A4). Results were similar when assessed via linear regression of EVALI cases per capita (Fig. 3 and Appendix Table A5).

Among states with medical marijuana policies, having operational dispensaries yielded statistically insignificant estimates in all specifications. However, forbidding combustible use showed a positive, significant association with hospitalized EVALI cases when omitting states that prohibited combustible use yet sold marijuana flower in dispensaries. This held in both the negative binomial analysis [aIRR= 1.797, 95% CI:1.033, 3.129; See Appendix Table A4] and the linear cases per capita specification [$\hat{\beta}$ = 1.730, 95% CI: 0.045, 3.414; See Appendix Table A5].

BRFSS analyses of respondents who reported past-30-day marijuana use found that both RM+MM and MM-only laws were positively associated with vaping as a primary mode of marijuana use, with adjusted odds ratios (aOR) of 1.848 (95% CI: 1.224,2.789) and 1.776 (95% CI: 1.355,2.329), respectively (See Table 1). Further adjusting for MM-only laws' policy attributes revealed heterogeneity: while the general MM-only coefficient became smaller and statistically insignificant, MM-only states that allowed home cultivation showed a dampened relationship to marijuana vaping (aOR=0.588; 95% CI: 0.365,0.946) as those with operational dispensaries exhibited an elevated association (aOR=1.718; 95% CI: 1.256,2.351). Further adjusting for MM-only policies that prohibited combustible use (and dropping respondents living in Ohio, the only state that fielded a BRFSS marijuana module while prohibiting combustible marijuana use but allowing dispensaries to sell marijuana flower) yielded a positive but non-significant association for that policy attribute (aOR=1.287; 95% CI: 0.977,1.694; p-value=0.07). All other policy attribute associations retained the same direction but with reduced statistical significance (p = 0.004 for operational dispensaries and p = 0.072 for allowing home cultivation), consistent with reduced statistical power when omitting an MM-only state and adding more controls to subset the remaining ones. Repeating these analyses with an indicator for vaping or dabbing as the outcome yielded adjusted odds ratios in the same direction, but with statistically significant estimates for both allowing home cultivation and having operational dispensaries even when adjusting for combustible use prohibitions: aOR= 0.612 (95% CI: 0.394,0.951) and aOR= 1.711 (95% CI: 1.177,2.485), respectively (See Table 1, column 6).

4. Discussion

This study is the first to show a relationship between MM policy attributes and EVALI. It also replicates prior findings on the relationship between RM and EVALI (Wing et al., 2020): states that legalized RM by August 1, 2019 had a lower EVALI incidence. Given that EVALI cases stemmed primarily from informally-sourced vaporizable marijuana concentrates, these results are consistent with crowd-out, whereby introduction of one market (legal marijuana) displaces utilization of another (informally-sourced marijuana products). Simply put, if the public can obtain products legally from reputable sources, there is less demand for illicit market products. Thus, RM legalization could have dampened market penetration of tainted marijuana concentrates by reducing consumption of informally-sourced marijuana products more generally.

Findings for MM legalization, however, were more nuanced: among states with MM only, laws allowing home cultivation were associated with fewer EVALI cases relative to those prohibiting it. This might be expected if home cultivation increases the availability of

marijuana flower while decreasing reliance on commercial marijuana markets, reducing exposure when tainted marijuana concentrates are introduced. Specifically, patients and caregivers who can grow their entire marijuana supply at home would be less likely to consume illicit market products. The resulting reduction in demand for marijuana flower on the illicit market should depress its price, such that individuals who continue to rely on the illicit market face financial incentives to consume flower over vaping concentrates, based on the change in their relative prices. Both of these effects—directly on MM patients' and caregivers' likelihood of exposure to tainted products and, via price, on product choice among consumers who remain in the informal market—should reduce exposure to tainted marijuana concentrates.

An additional policy attribute, prohibitions on smoking as a mode of MM use, was also associated with increases in hospitalized EVALI cases when excluding states that had this policy attribute but allowed sales of marijuana flower, effectively enabling combustible use. This might be explained by impacts on mode of use. Specifically, given that vaping is the second most popular mode of marijuana consumption after smoking (Baldassarri et al., 2020), restrictions on combustible use could lead to increased use of vaporizable marijuana. For MM patients, this could occur via both new MM users initiating with vaporizable marijuana products and established MM users switching from smoking to vaping. Effects could also extend to non-medical users if consumers interpret the prohibition as a signal that vaporizable marijuana products are safer or switch to vaping as a means to evade detection of illicit use. Indeed, devices used to vaporize marijuana concentrates are often indistinguishable from nicotine e-cigarettes and produce less odor than smoking marijuana, making them easier to conceal (Malouff et al., 2014; Morean et al., 2017). Consequent increases in the share of people who vape concentrates would be expected to increase the number of EVALI cases when a contaminated product enters the informal market.

Analyses of adults' self-reported mode of marijuana use were consistent with these mechanisms. Among those living in MM-only states, allowing home cultivation was associated with reduced odds of reporting vaping as one's primary mode of use, consistent with increased reliance on home cultivation and/or reduced prices of marijuana flower. Concurrently, operational dispensaries were associated with increased odds of vaping as the primary mode of use, consistent with increased access to marijuana concentrates as well as potential effects on perceptions of vaping marijuana as a safe mode of use. Further adjusting for MM-only states that prohibited combustible use found a positive but statistically non-significant association between this restriction and marijuana vaping ($p=0.07$), although limited power may have influenced the ability to detect a significant finding.

Variation in MM policy attributes' associations with both EVALI case counts and adults' mode of marijuana use suggests that understanding the implications of such policy details is critical for informing marijuana regulatory decisions. Indeed, analyses suggest different relationships when using a single yes-no indicator of MM legalization versus adjusting for the laws' policy attributes. These policy details may also be politically malleable: they can be modified via legislative amendments without requiring the full repeal of existing MM laws, which are often quite popular with the electorate (Daniller, 2019).

This study improves upon prior analyses of states' marijuana policies and the prevalence of EVALI in three important ways. First, while others relied on binned case data (i.e., ranges), we used exact case counts, removing a potential source of bias (Wing et al., 2020). Second, we assessed the role of MM policy attributes in this relationship, revealing greater nuance in the MM-EVALI relationship by identifying specific policy details that may be consequential for EVALI and subject to amendment in established legislation. Third, we considered how these attributes related to adults' self-reported mode of marijuana use to clarify the mechanism behind the MM-EVALI relationship.

This study's primary limitation was related to available data on marijuana vaping. BRFSS, the US's only annual, state-representative adult dataset that asks about mode of marijuana use, did not field this question in all states. Moreover, its wording did not clearly differentiate vaping marijuana concentrates from vaporizing marijuana flower (i.e., heating it to a temperature that releases cannabinoids without combustion). This distinction is critical: while vaping marijuana concentrates was implicated in EVALI, vaping flower was not. As even pre-EVALI analyses suggest that vaping marijuana flower poses lower health risks than vaping marijuana concentrates (Russell et al., 2018), future research will require nationally representative data that clearly distinguishes these modes of use.

A second limitation was the potential for differences in case detection between states. Reassuringly, findings held when limiting consideration to hospitalized EVALI case counts, which state and local health departments regularly reported to the CDC over December 2019 and January 2020. Moreover, to drive this study's results, case detection would have to have been systematically lower in states that legalized recreational marijuana use or medical use with home cultivation. It is not clear why that would be so.

A third limitation was our inability to assess variation in recreational marijuana policy attributes. Specifically, among the 10 states that implemented recreational marijuana legalization prior to 2020—excluding Washington DC, which was not in our data—none prohibited combustible use, only one forbade home cultivation (Washington state), and three (Maine, Michigan, and Vermont) lacked recreational retailers (though medical dispensaries were operating) as of August 1, 2019. Beyond concerns about generalizability and limited statistical power with variation based on so few states, none of those four states fielded the BRFSS marijuana module between 2016 and 2019, precluding estimation of RM policy attributes' associations with mode of use. Thus, we leave consideration of recreational marijuana policy attributes to future work.

Although this study's findings are not causal, they provide direction to states that have passed or are considering MM legalization. Specifically, to the extent that such policies affect licit and illicit marijuana use, policymaking not only must ensure the safety of legal products but also should consider potential impacts on illicit market offerings. In particular, incentivizing or restricting a particular mode of marijuana use based on presumed or demonstrated health effects with unadulterated product may have unexpected consequences if the proposed "less harmful" mode of use involves a product that is more vulnerable to adulteration, as was likely the case for vaporizable marijuana concentrates during the 2019

EVALI outbreak. This is relevant to RM states as well, since youth who cannot purchase marijuana legally may turn to informal sources.

To the extent that these findings reflect causal relationships, carefully-crafted marijuana legalization policies may provide a means to reduce the scope of future EVALI outbreaks, whether due to vitamin E acetate or other additives. More work is needed in this area, as the stakes for getting these policy details right are high: with over 17% of Americans ages 12-and-up reporting past-year marijuana use (Substance Abuse and Mental Health Services Administration, 2020), population health depends on it.

5. Conclusions

While the federal government stopped collecting EVALI case data in February 2020, future outbreaks remain a threat to public health. Marijuana policies may offer a means to reduce the scale of such outbreaks if they impede the market penetration of contaminated products or affect the types of marijuana products consumers use. This analysis finds that recreational marijuana laws were associated with reduced EVALI incidence, whereas the relationship's direction for medical marijuana laws depended on their policy attributes. Specifically, policy attributes expected to incentivize smoking marijuana relative to vaping it (e.g., allowing home cultivation) were associated with fewer EVALI cases and a reduced likelihood of self-reporting vaping as one's primary mode of marijuana use. Associations were reversed for attributes expected to incentivize marijuana vaping over smoking (e.g., prohibiting combustible use). Thus, to the extent that policymakers seek to leverage marijuana policies as a means to reduce the risk of future outbreaks, close attention to these laws' details, particularly those expected to affect mode of use, will be critical.

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None: funders were not involved in the design, execution, or reporting of this research. Contributors: Dr. Abigail S Friedman and Dr. Meghan E. Morean.

Appendix A

see Fig. A1 and Tables A1–A5.

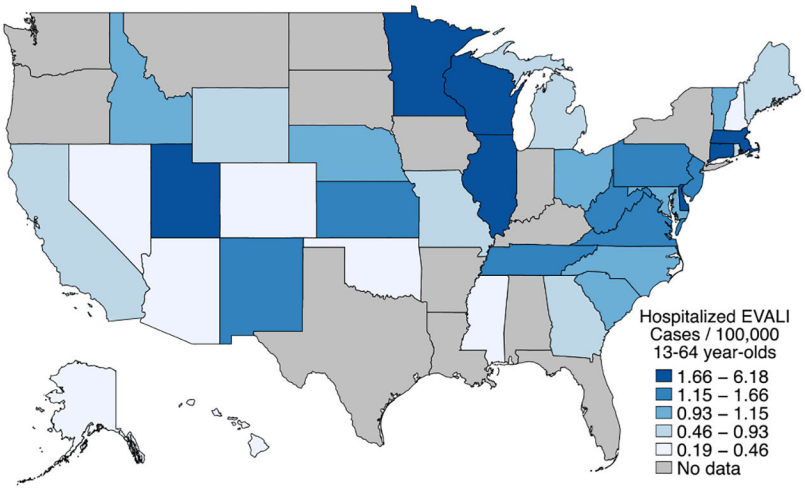

Fig. A1.

Hospitalized EVALI Cases Per Capita as of the Second Week in January 2020. Notes: Quintiles of hospitalized EVALI cases per 100,000 state residents ages 13–64 are depicted based on reports between January 12th and 18th, 2020. Hospitalized case counts were ascertained for 36 states.

Table A1

State medical and recreational marijuana policies in effect by March 1st, 2020.

	Medical Legalization				Recreational Legalization
State	**Effective Date**	**First Open Dispensary**	**Allowed Home Cultivation**	**Allowed Combustible Use**	**Effective Date**
AL	.	.	.	.	.
AK	3/4/99	10/29/16	3/4/99	3/4/99	2/24/15
AZ	4/14/11	12/6/12	4/14/11 *	4/14/11	.
AR	11/9/16	5/1/19	.	11/9/16	.
CA	11/6/96	1/1/04	11/6/96	11/6/96	11/9/16
CO	7/1/01	6/1/10	7/1/01	7/1/01	1/1/14
CT	10/1/12	8/20/14	.	10/1/12	.
DE	7/1/11	6/26/15	.	7/1/11	.
FL	1/3/17	7/23/16	.	3/18/19	.
GA	.	.	.	.	.
HI	12/28/00	8/9/17	12/28/00	12/28/00	.
ID	.	.	.	.	.
IL	1/1/14	11/1/15	1/1/20	1/1/14	1/1/20
IN	.	.	.	.	.
IA	.	.	.	.	.
KS	.	.	.	.	.
KY	.	.	.	.	.
LA	5/19/16	8/1/19	.	.	.

	Medical Legalization				Recreational Legalization
State	**Effective Date**	**First Open Dispensary**	**Allowed Home Cultivation**	**Allowed Combustible Use**	**Effective Date**
ME	12/22/99	4/2/11	12/22/99	12/22/99	1/30/17
MD	6/1/14	12/1/17	.	6/1/14	.
MA	1/1/13	6/24/15	1/1/13	1/1/13	12/15/16
MI	12/4/08	10/1/18	12/4/08	12/4/08	12/6/18
MN	5/30/14	7/1/15	.	.	.
MS	.	.	.	.	.
MO	12/6/18	10/17/20	12/6/18	12/6/18	.
MT	11/2/04	†	11/2/04	11/2/04	.
NE	.	.	.	.	.
NV	10/1/01	7/31/15	10/1/01 *	10/1/01	1/1/17
NH	7/23/13	5/1/16	.	7/23/13	.
NJ	7/18/10	12/6/12	.	7/18/10	.
NM	7/1/07	6/1/09	7/1/07	7/1/07	.
NY	7/5/14	1/7/16	.	. §	.
NC	.	.	.	.	.
ND	12/8/16	3/1/19	.	12/8/16	.
OH	9/8/16	1/16/19	.	. ‡	.
OK	7/27/18	10/26/18	7/27/18	6/26/18	.
OR	12/3/98	3/1/14	12/3/98	12/3/98	7/1/15
PA	5/13/16	2/15/18	.	. ‡	.
RI	1/3/06	4/19/13	1/3/06	1/3/06	.
SC	.	.	.	.	.
SD	.	.	.	.	.
TN	.	.	.	.	.
TX	.	.	.	.	.
UT	12/1/18 ‖	3/1/20	.	.	.
VT	7/1/04	6/1/13	7/1/04	5/26/04	7/1/18
VA	.	.	.	.	.
WA	11/3/98	7/1/14	11/3/98	11/3/98	12/6/12
WV	4/19/17 ‖	.	.	. §	.
WI	.	.	.	.	.
WY	.	.	.	.	.

* Home cultivation only allowed if residence > 25 miles from a state-licensed dispensary.

† While many dispensaries opened after Montana's medical marijuana law went into effect in 2004, the legislation did not clearly establish their legal status. In 2011, the state passed a law whose restrictions effectively made dispensaries illegal (e.g., restricting caregivers to no more than 3 patients each), which was quickly challenged in court, with many of the provisions blocked until the Montana Supreme Court ruled in favor of the 2011 law in February of 2016. Restrictions on dispensaries went into effect on August 31, 2016. In November 2016, voters passed a ballot initiative (I-182) to revise the state's medical marijuana law, removing the 3 patient limit and establishing a regulatory structure for dispensaries. On December 7th, 2016, a Montana district judge ruled that I-182 should go into effect immediately.

‡ Ohio and Pennsylvania allowed the sale of marijuana flower which, though ostensibly for use with a vaporizer, can be smoked.

[§] New York and West Virginia initially banned marijuana flower sales but subsequently loosened their sales restrictions—while continuing to prohibit combustible use—after August 1, 2019.

[//] While their medical marijuana laws technically went into effect by August 1, 2019, neither Utah nor West Virginia had operational dispensaries by that date, and both forbade home cultivation. However, for Utah at least, it seems that there may have been some leeway for patients with a qualifying condition to obtain medicinal marijuana from other states. Utah Department of Health (2019). "Utah Medical Cannabis: Answers to Frequently Asked Questions." Retrieved 15 December 2020 from: <https://health.utah.gov/wp-content/uploads/MedCanFAQ4-8-19.pdf>.

Table A2

Negative binomial estimates of the association between EVALI cases & state marijuana laws, Incident Rate Ratio/(95% Confidence Interval)/[Average marginal effect].

Case Count:	**Total**	**Total**	**Total**	**Hospitalized**
Sample States:	**All**	**All**	**All**	**States with Confirmed Hospitalized Case Counts**
	(1)	**(2)**	**(3)**	**(4)**
RM + MM	0.580 * (0.339, 0.993)	0.582 * (0.339, 0.999)	0.617 (0.340, 1.121)	0.655 (0.364, 1.177)
	[− 26.076 *]	[− 20.337 *]	[− 18.815]	[− 13.601]
MM-only	1.194 (0.779, 1.830)	2.489 * (1.031, 6.007)	2.241 * (1.042, 4.817)	2.574 * (1.050, 6.315)
	[12.021]	[72.467]	[61.005]	[62.058]
Open Dispensary | MM-only		0.525 (0.246, 1.121)	0.610 (0.312, 1.192)	0.590 (0.275, 1.265)
		[− 69.995]	[− 50.348]	[− 48.739]
Home Cultivation | MM-only		0.374 ** (0.196, 0.715)	0.378 ** (0.202, 0.707)	0.355 ** (0.172, 0.731)
		[− 78.525 *]	[− 71.120 *]	[− 69.069 *
No Combustible Use Allowed | MM-only		0.985 (0.528, 1.836)	0.953 (0.530, 1.715)	1.157 (0.581, 2.304)
		[− 1.831]	[− 5.174]	[15.652]
Percent Under Age-35			25.156 (0.035, 18244.035)	
N	50	50	50	36
Pseudo-R^2	0.015	0.043	0.045	0.061

Notes: To consider the relationship between marijuana legalization policies and 2019 EVALI cases, negative binomial regressions test how states' marijuana legalization policies relate to their number of EVALI cases in 2019, taking the number of 13–64 year-old state residents as the exposure variable. All covariates are listed aside from the constant (≈0.000 in all cases). RM = Recreational Marijuana Legalization. MM=Medical Marijuana Legalization. AME=Average Marginal Effects calculated for MM conditioned variables as if MM-only= 1 and, for specification 3 only, at the average for percent under-age-35.

*(**) denote statistical significance at the 0.05(0.01) level.

Table A3

Linear regression estimates of the association between EVALI cases per capita & state marijuana laws, Coefficient/(95% Confidence Interval).

Cases Considered:	**All**	**All**	**All**	**Hospitalized**
Sample:	**All States**	**All States**	**All States**	**States with Confirmed Hospitalized Case Counts**
	(1)	**(2)**	**(3)**	**(4)**
RM + MM	−0.605 * (−1.146, −0.064)	−0.605 * (−1.165, −0.045)	−0.414 (−1.183, 0.355)	−0.419 (−0.974, 0.136)
MM-only	0.288 (−0.422, 0.999)	1.890 (−0.777, 4.556)	1.922 * (0.094, 3.751)	1.766 (−0.957, 4.489)
Open Dispensary | MM-only		−1.394 (−3.909, 1.122)	−1.133 (−2.716, 0.449)	−1.120 (−3.688, 1.447)
Home Cultivation | MM-only		−1.312 ** (−2.277, −0.346)	−1.423 ** (−2.285, −0.561)	−1.268 * (−2.310, −0.226)
No Combustible Use Allowed | MM-only		0.033 (−1.270, 1.335)	−0.135 (−1.296, 1.025)	0.436 (−1.206, 2.078)
Under Age-35 (%)			13.685 (−0.597, 27.968)	
Constant	1.407 ** (1.027, 1.787)	1.407 ** (1.014, 1.800)	−4.889 (−11.489, 1.710)	1.166 ** (0.806, 1.525)
N	50	50	50	36
R^2	0.088	0.301	0.398	0.395

Notes: To consider the relationship between marijuana regulations and EVALI cases, linear regressions test how states' marijuana legalization policies relate to the number of EVALI cases per 100,000 13–64 year-olds, respectively. All covariates are listed. RM = Recreational Marijuana Legalization. MM=Medical Marijuana Legalization.

*(**) denote statistical significance at the 0.05(0.01) level.

Table A4

Sensitivity tests: negative binomial estimates of the association between EVALI cases & state marijuana laws, Incident Rate Ratio/(95% Confidence Interval)/[Average Marginal Effect].

Case Count:	**Total Cases**		**Hospitalized Cases**	
Sample	**All States**		**States with Confirmed Hospitalized Case Counts**	
Omitted States:	**Drop OH & PA**	**Drop UT & WV**	**Drop OH & PA**	**Drop UT & WV**
	(1)	**(2)**	**(3)**	**(4)**
RM + MM	0.582 * (0.339, 0.999)	0.582 (0.339, 1.000)	0.655 (0.364, 1.179)	0.656 (0.364, 1.180)
	[− 21.016 *]	[− 22.553 *]	[− 14.403]	[− 14.561]
MM-only	2.204 (0.914, 5.318)	1.813 (0.878, 3.745)	1.869 (0.894, 3.909)	2.139 (0.941, 4.858)
	[60.531]	[43.891]	[36.307]	[48.143]
Open Dispensary | MM-only	0.594 (0.279, 1.265)	0.721 (0.409, 1.271)	0.812 (0.460, 1.434)	0.709 (0.363, 1.386)
	[− 52.123]	[− 30.546]	[− 15.470]	[− 29.386]

Case Count:	Total Cases		Hospitalized Cases	
Sample	All States		States with Confirmed Hospitalized Case Counts	
Omitted States:	Drop OH & PA	Drop UT & WV	Drop OH & PA	Drop UT & WV
	(1)	(2)	(3)	(4)
Home Cultivation | MM-only	0.381 ** (0.200, 0.726)	0.394 ** (0.200, 0.775)	0.378 ** (0.185, 0.774)	0.367 * (0.170, 0.795)
	[− 71.195 *]	[− 61.711 *]	[− 51.693 *]	[− 60.637]
No Combustible Use Allowed | MM-only	1.155 (0.552, 2.418)	0.940 (0.490, 1.806)	1.797 * (1.033, 3.129)	1.106 (0.525, 2.328)
	[16.937]	[− 5.876]	[59.608]	[9.428]
N	48	48	34	34
Pseudo-R^2	0.046	0.031	0.071	0.044

Notes: To consider the relationship between marijuana legalization policies and 2019 EVALI cases, negative binomial regressions test how states' marijuana legalization policies relate to their number of EVALI cases in 2019, taking the number of 13–64 year-old state residents as the exposure variable. All covariates are listed aside from the constant (≈0.000 in all cases). RM = Recreational Marijuana Legalization. MM=Medical Marijuana Legalization. AME=Average Marginal Effects calculated for MM conditioned variables as if MM-only= 1.

*(**)denote statistical significance at the 0.05(0.01) level.

Table A5

Sensitivity tests: linear regression estimates of the association between EVALI cases per capita & state marijuana laws, Coefficient/(95% Confidence Interval).

Y-Variable:	EVALI Cases/100,000 13–64 year-olds		Hospitalized EVALI Cases/100,000 13–64 year-olds	
Sample	All States		States with Confirmed Hospitalized Case Counts	
Omitted States:	Drop OH & PA	Drop UT & WV	Drop OH & PA	Drop UT & WV
	(1)	(2)	(3)	(4)
RM + MM	−0.605 * (−1.167, −0.043)	−0.605 * (−1.167, −0.043)	−0.419 (−0.979, 0.141)	−0.419 (−0.979, 0.141)
MM-only	1.643 (−0.957, 4.242)	0.747 (−0.230, 1.725)	0.853 (−1.130, 2.835)	0.889 (−0.142, 1.919)
Open Dispensary | MM-only	−1.147 (−3.590, 1.297)	−0.251 (−0.662, 0.159)	−0.207 (−1.966, 1.551)	−0.243 (−0.716, 0.230)
Home Cultivation | MM-only	−1.276 * (−2.232, −0.321)	−1.148 * (−2.042, −0.254)	−1.116 * (−2.107, −0.125)	−1.122 * (−2.087, −0.157)
No Combustible Use Allowed | MM-only	0.385 (−1.335, 2.105)	−0.163 (−1.463, 1.136)	1.730 * (0.045, 3.414)	0.193 (−1.482, 1.867)
Constant	1.407 ** (1.012, 1.802)	1.407 ** (1.012, 1.802)	1.166 ** (0.803, 1.529)	1.166 ** (0.803, 1.529)
N	48	48	34	34
R^2	0.321	0.220	0.497	0.321

Notes: To consider the relationship between marijuana regulations and EVALI cases, linear regressions test how states' marijuana legalization policies relate to the number of EVALI cases per 100,000 13–64 year-olds, respectively. All covariates are listed. RM = Recreational Marijuana Legalization. MM=Medical Marijuana Legalization.

*(**)denote statistical significance at the 0.05(0.01) level.

References

Baldassarri SR, Camenga DR, Fiellin DA, Friedman AS, 2020. Marijuana vaping in U.S. adults: evidence from the behavioral risk factor surveillance system. Am. J. Prev. Med 59 (3), 449–454. [PubMed: 32684361]

Centers for Disease Control and Prevention, 2020a. Behavioral Risk Factor Surveillance System Survey Data, 2016–2019. U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, Atlanta, Georgia, p. 2020. Accessed October 13.

Centers for Disease Control and Prevention, 2019. CDC clinician outreach and communication activity. 〈https://web.archive.org/web/20190817233029/https://emergency.cdc.gov/newsletters/coca/081619.htm〉 . Accessed July 28, 2021.

Centers for Disease Control and Prevention, 2020b. Outbreak of lung injury associated with the use of e-cigarette, or vaping, products. 〈https://www.cdc.gov/tobacco/basic_information/e-cigarettes/severe-lung-disease.html〉 Accessed July 26, 2021.

Daniller A, 2019. Two-thirds of Americans Support Marijuana Legalization. Pew Research Center, Washington, D.C, p. 2021 (November 14, 2019). 〈https://www.pewresearch.org/fact-tank/2019/11/14/americans-support-marijuana-legalization/〉 .

Friedman AS, 2020. Association of vaping-related lung injuries with rates of e-cigarette and cannabis use across US states. Addiction 116 (3), 651–657. 10.1111/add.15235. [PubMed: 32840932]

Krishnasamy VP, Hallowell BD, Ko JY, Board A, Hartnett KP, Salvatore PP, Danielson M, Kite-Powell A, Twentyman E, Kim L, Cyrus A, 2020. 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 69, 90–94. [PubMed: 31971931]

Malouff JM, Rooke SE, Copeland J, 2014. Experiences of marijuana-vaporizer users. Subst. Abuse 35 (2), 127–128.

Morean ME, Lipshie N, Josephson M, Foster D, 2017. Predictors of adult e-cigarette users vaporizing cannabis using e-cigarettes and vape-pens. Subst. Use Misuse 52 (8), 974–981. [PubMed: 28323498]

Pacula RL, Powell D, Heaton P, Sevigny EL, 2015. Assessing the effects of medical marijuana laws on marijuana use: the devil is in the details. J. Policy Anal. Manag 34 (1), 7–31.

Russell C, Rueda S, Room R, Tyndall M, Fischer B, 2018. Routes of administration for cannabis use - basic prevalence and related health outcomes: A scoping review and synthesis. Int J Drug Policy 52, 87–96. [PubMed: 29277082]

Substance Abuse and Mental Health Services Administration, 2020. Key substance use and mental health indicators in the United States: Results from the 2019 National Survey on Drug Use and Health (HHS Publication No. PEP20-07-01-001, NSDUH Series H-55). Center for Behavioral Health Statistics and Quality. Substance Abuse and Mental Health Services Administration,, Rockville, MD.

U.S. Census Bureau. SC-EST2019-AGESEX-CIV: Annual estimates of the civilian population by single year of age and sex for the United States and States: April 1, 2010,” June 2020. [Online]. 〈https://www.census.gov/data/tables/time-series/demo/popest/2010s-state-detail.html#par_textimage_673542126〉 . Accessed July 21, 2021.

Wing C, Bradford AC, Carroll AE, Hollingsworth A, 2020. Association of state marijuana legalization policies for medical and recreational use with vaping-associated lung disease. JAMA Netw. Open 3 (4), e202187. [PubMed: 32250431]

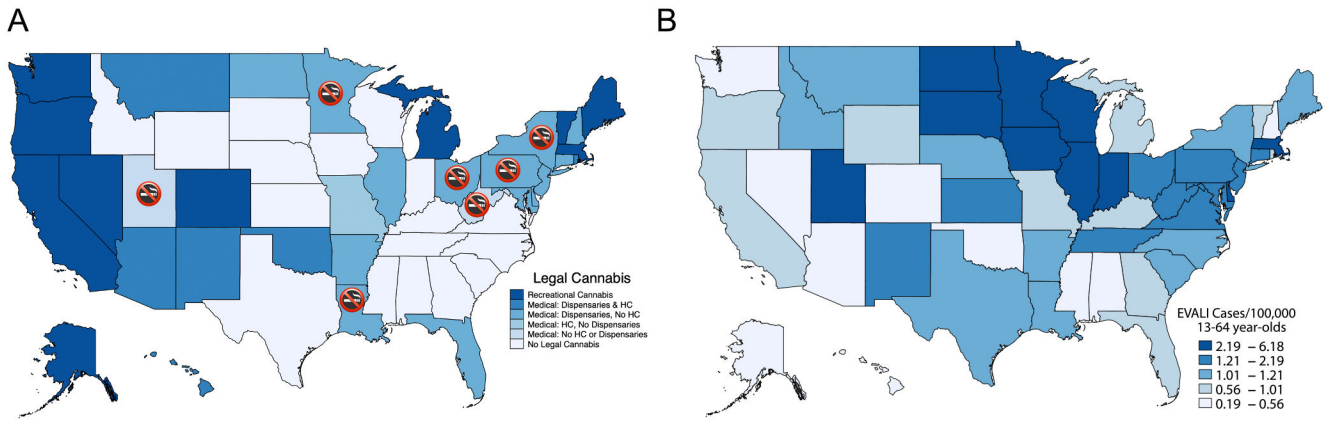

Fig. 1.

States' Marijuana Policies and EVALI Cases per Capita. Notes: Maps illustrate state variation in marijuana laws (1A) and EVALI cases per 100,000 residents ages 13–64 (1B). Fig. 1A's shading indicates each states' most liberal marijuana policy (recreational > medical) in effect as of August 1, 2019, distinguishing medical marijuana laws that did versus did not allow home cultivation (HC), and those that did versus did not have an operational dispensary as of that date. The no-smoking symbol indicates states whose medical marijuana laws prohibited smoking as a mode of consumption. However, dispensaries in two of those states—Ohio and Pennsylvania—sold marijuana flower as of August 1, 2019, for use with a vaporizer. Similarly, while Utah and West Virginia's medical marijuana programs had technically gone into effect, their dispensaries were not operational as of August 1, 2020 (See Appendix Table A1). Fig. 1B's data are based on total reported (confirmed + probable) EVALI cases as of the second full week of January 2020 (January 12th through 18th). This timing was selected in order to capture total 2019 cases; that is, to ensure coverage of cases identified in late December, as many states did not update reports over the winter holidays and first posted new case counts after the first week of January 2020. See Appendix Fig. A1 for a corresponding map of hospitalized EVALI case counts.

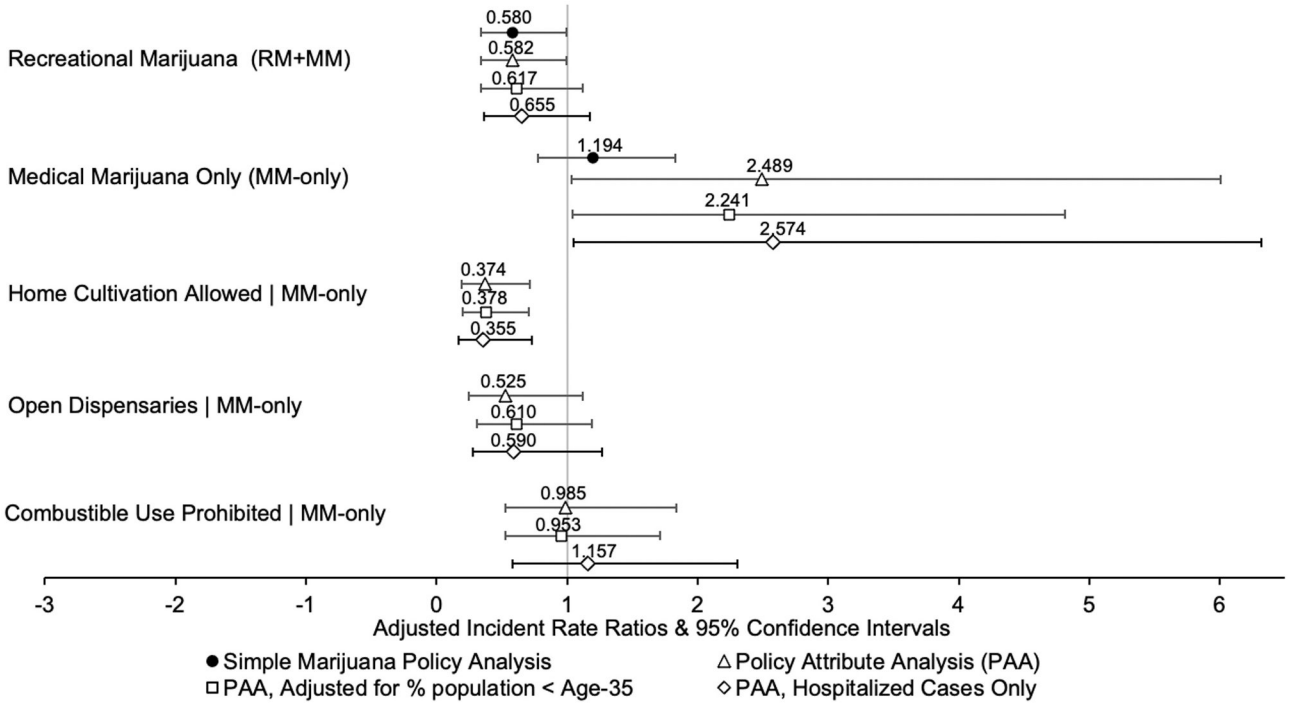

Fig. 2.

Negative Binomial Regression Estimates: Associations between States' Marijuana Laws & 2019 EVALI Cases. Notes: The figure plots incidence rate ratios and their 95% confidence intervals from multivariable negative binomial regressions estimating how states' marijuana legalization policies relate to their total number of 2019 EVALI cases (based on confirmed+probable reports from the second full week of January 2020), with state population ages 13–64 as the exposure variable. Policy variables in the simple marijuana policy analysis regression were binary indicators for recreational and medical marijuana legalization. Policy attribute analyses added covariates indicating whether the medical marijuana-only policies allowed home cultivation, had operational dispensaries, and prohibited combustible use as of August 1, 2019. Corresponding variables' coefficients capture the added association between these attributes and the outcome (above and beyond the MM-only coefficient). Appendix Table A2 presents these results in table form.

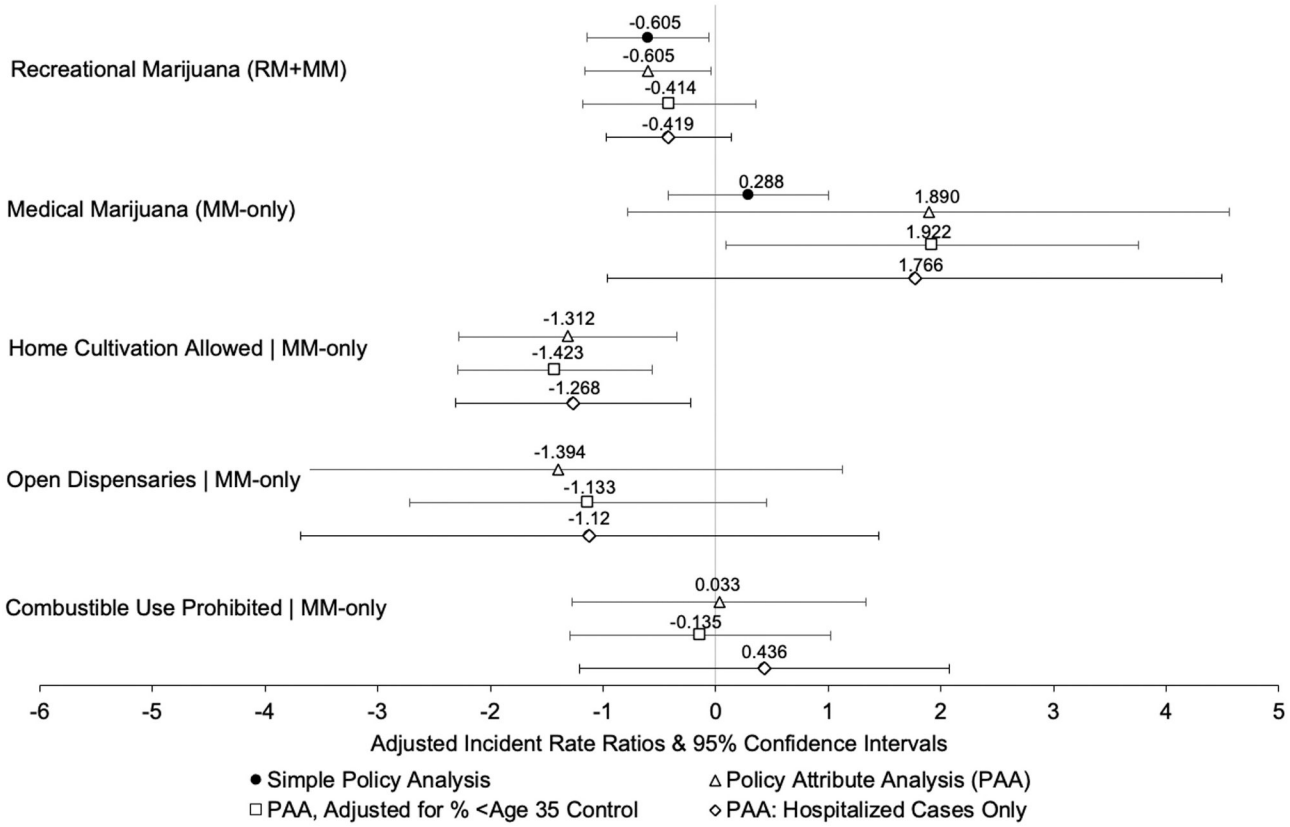

Fig. 3.

Linear Regression Estimates: States' 2019 EVALI Cases per Capita & Marijuana Laws. Notes: The figure plots coefficient estimates and their 95% confidence intervals from multivariable linear regressions estimating how states' marijuana legalization policies relate to their 2019 EVALI cases per 100,000 13–64 year-old residents (based on confirmed+probable reports from the second full week of January 2020). Policy attribute analyses added covariates indicating whether the medical marijuana-only policies allowed home cultivation, had operational dispensaries, and prohibited combustible use as of August 1, 2019. Corresponding variables' coefficients capture the added association between these attributes and the outcome (above and beyond the MM-only coefficient). Appendix Table A3 presents these results in table form.

Table 1

State marijuana policies and vaping as the primary mode of marijuana use, Adjusted Odds Ratio/(95% Confidence Interval).

	Primary Mode of Use: Vaping			**Primary Mode of Use: Vaping or Dabbing**		
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Analytic Sample	**Full**	**Full**	**Drop Ohio†**	**Full**	**Full**	**Drop Ohio†**
RM+MM	1.848 **	1.483 *	1.469 *	1.691 **	1.329	1.333
	1.224,2.789	1.022,2.154	1.004,2.150	1.171,2.441	0.965,1.831	0.962,1.847
MM-only	1.776 ***	1.269	1.017	1.671 ***	1.298	1.087
	1.355,2.329	0.901,1.788	0.655,1.578	1.312,2.127	0.958,1.760	0.740,1.596
Home cultivation allowed, MM-only		0.588 *	0.693		0.525 **	0.612 *
		0.365,0.946	0.429,1.121		0.339,0.813	0.394,0.951
Dispensaries operational, MM-only		1.718 ***	1.895 **		1.624 ***	1.711 **
		1.256,2.351	1.232,2.915		1.225,2.153	1.177,2.485
Combustible use prohibited, MM-only			1.287			1.248
			0.977,1.694			0.963,1.617
Year & Census Region Fixed Effects?	Yes	Yes	Yes	Yes	Yes	Yes
$N_{\text{Analytic Sample}}$	22,351	22,351	21,333	22,380	22,380	21,362
Outcome Prevalence $_{\text{Analytic Sample}}$	10.3%	10.3%	10.6%	12.7%	12.7%	13.0%

Notes: Sample-weighted multivariable logistic regressions adjusted for complex survey design use pre-August 2019 data from the 2016–2019 BRFSS marijuana modules on people who reported past-30-day marijuana use, to assess the association between state marijuana policies and vaping as a primary mode of use. This analytic sample includes data on 21 states: AK, CA, CO, FL, CA, ID, IL, MD, MN, MS, MT, NE, NH, ND, OH, OK, SC, TN, UT, WV, WY. Covariates not indicated above include a constant and fixed effects for respondent sex, age-group (18–20, 21–29, and ten year age groups thereafter until 80 +), race (White, Black, Asian, AIAN, NHOPI, Other, Multiracial, race missing), Hispanic ethnicity, and whether the respondent completed ≥ 1 year of college, as well as missing-value indicators for each of these. Analyses in column 1–3 drop the 29 respondents with missing education data, as missingness perfectly predicts the outcome.

*$p < 0.05$,

**$p < 0.01$,

***$p < 0.001$

†Specifications in columns 3 and 6 drop respondents living in Ohio, the only state in this sample that prohibited combustible marijuana use but allowed dispensaries to sell marijuana flower.

States in the 2016–2019 BRFSS marijuana module data by marijuana policy category at the survey date for a respondent in that state:

RM+MM: AK, CA, CO, IL

MM-only: CA, FL, IL, MD, MN, MT, NH, ND, OH, OK, UT, WV

Neither: FL, GA, ID, MS, NE, OH, OK, SC, TN, WY

MM-only, No home cultivation: FL, IL, MD, MN, ND, NH, OH, UT, WV

MM-only, Operational dispensaries: CA, FL, IL, MD, MN, MT, ND, NH, OH, OK

MM-only, Combustible use prohibited: FL, MN, OH, UT, WV