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Associations of U.S. state-level COVID-19 policies intensity with cannabis sharing behaviors in 2020

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Abstract

Background Cannabis use before the COVID-19 pandemic for many involved sharing prepared cannabis for inhalation, practices that were less prevalent during the pandemic. State-level COVID-19 containment policies may have influenced this decrease. This study examined the extent to which the intensity of state-level COVID-19 policies were associated with individual-level cannabis sharing. Findings have the potential to guide harm reduction policies for future respiratory pandemics and seasonal respiratory virus waves.

Methods This study used cross-sectional individual-level data from the COVID-19 Cannabis Study, an anonymous U.S.-based web survey on cannabis use disseminated during the early phase of the pandemic (Full sample $N = 1,883$). We combined individual-level data with state-level policy data from Kaiser Family Foundation's State COVID-19 Data and Policy Actions for three time-points from June to August 2020 that overlapped with the survey period. Cannabis sharing was dichotomized as any versus no sharing. We adapted a previously published coding framework to score the intensity of COVID-19 policies implemented in each U.S. state and averaged the policy score across the time period. We then used Poisson regression models to quantify the associations of the average state-level COVID-19 policy score with cannabis sharing during the pandemic.

Results Participants ($n = 925$) reporting using inhalation as a mode for cannabis use were included in this analysis. Most respondents were male (64.1%), non-Hispanic White (54.3%), with a mean age of 33.7 years (SD 8.8). A large proportion (74.9%) reported sharing cannabis during the pandemic. Those who shared cannabis more commonly lived in states with a lower average policy score (16.7, IQR 12.3–21.5) compared to those who did not share (18.6, IQR 15.3–25.3). In adjusted models, the prevalence ratio of any cannabis sharing per every 5-unit increase in the average COVID-19 policy score was 0.97 (95% CI 0.93, 1.01).

Conclusions Fewer individuals shared cannabis in states with more intense COVID-19 containment policies compared to those in states with less intense policies. Individuals who use cannabis may be willing to make changes

to their behavior and may further benefit from specific and directed public health messaging to avoid sharing during respiratory infection outbreaks.

Keywords Cannabis, Policy evaluation, COVID-19, Respiratory, Pandemic, Public Health, Harm reduction

Introduction

The prevalence of cannabis use among individuals aged 12 and older in the United States continues to increase with nearly one-fifth of the population reporting use in 2021, marking a significant trend with implications for public health research [1]. Cannabis is associated with adverse cardiovascular, pulmonary, and bronchial system problems with recommendations to avoid combusted cannabis inhalation and deep inhalation practices [2–5]. Nevertheless, inhalation of cannabis is the predominant mode of consumption, encompassing various methods such as smoked cigarettes (joint/blunts), pipes, water pipes, cannabis vaporizers, e-cigarettes, and rigs (wax/dabs)-- a pattern that remained during the coronavirus disease (COVID-19) pandemic [6–8]. Moreover, cannabis social practices before the pandemic involved using and/or sharing inhaled cannabis (having more than one person put the same device or products in their mouth to inhale) with friends and sometimes with strangers [9–15]. Sharing behaviors of paraphernalia for cannabis and other substances are a risk factor for respiratory infections [7–17]. This risk of infection may also be true for SARS-CoV-2, the virus that causes COVID-19, through droplets and airborne transmission [16–20]. Thus, avoiding sharing of cannabis for inhalation during the pandemic serves as an example of a risk mitigation behavior as it reduces direct exposure to others' oral fluids that may transmit COVID-19.

Prior work showed that sharing of cannabis shifted for some from higher levels of sharing (always sharing, sharing most of the time) to lower levels (never sharing) during the COVID-19 pandemic compared to before [21]. It is important to assess what factors may influence sharing behaviors, specifically for those who reported never sharing during the pandemic, to better tailor harm reduction and public health strategies during future respiratory pandemics and seasonal respiratory waves. One such factor is policies implemented during the COVID-19 pandemic aimed at decreasing or limiting person-to-person contact, e.g., limitations on mass gatherings, stay-at-home orders, closure of non-essential workspaces and schools, and face covering guidance [18, 22]. While the U.S. Centers for Disease Control and Prevention (CDC) recommended COVID-19-related policies, policies were ultimately implemented by state and local officials based on conditions relevant to that jurisdiction allowing for variation between states in policy intensity, timing, and duration [23–26]. For instance, some states prohibited or placed restrictions on the size of large gatherings, closed bars, and limited restaurants to takeout or delivery only [27].

This study aimed to quantify the magnitude of associations of state-level COVID-19 policy intensity with individual-level sharing of cannabis. We hypothesized that fewer individuals in states with more intense COVID-19 policies reported sharing compared to those in states with less intense policies. Although this study focuses on the COVID-19 pandemic, findings have the potential to guide harm reduction policies for future respiratory pandemics and seasonal respiratory virus waves. For instance, COVID-19 policy could have indirect or spillover to other health behaviors such as limiting opportunities to share cannabis with others. On other hand, future policies or public health messaging could be more directed to sharing of cannabis during respiratory pandemics such "Puff, Puff, Don't Pass" as a harm reduction strategy [9, 15, 28, 29].

Methods

Data

This study used data from the cross-sectional COVID-19 Cannabis Study, an anonymous U.S.-based web survey on cannabis and cannabidiol (CBD) related behaviors disseminated from August 2020 to September 2020. Detailed methods for this survey have been previously described [8]. Briefly, survey respondents included in the full study were 18 years of age or older, reported non-medical cannabis, cannabis for medical use, and/or CBD use in the last 12 months, and resided in the U.S. (n=1,883). Respondents were recruited through online forums (e.g., Reddit, Bluelight, Craigslist, and Twitter), received $5 USD for their participation, and were prevented from "ballot stuffing" by limiting participation to a unique internet protocol (IP) address. In this single survey, participants were asked to recall their non-medical cannabis use behaviors at two 3-month time points: before the COVID-19 pandemic (January to mid-March 2020) and during an early phase of the COVID-19 pandemic (prior 3 months at the time of the survey, June to August 2020; referred to as during the pandemic for the remainder of the paper). Data from this survey include non-medical cannabis frequency of use, mode of use, sharing of cannabis, and demographics (age, sex, education, race/ethnicity, sexual orientation, and state residency). Only respondents who reported a mode of inhalation received questions on sharing behaviors in the survey. Thus, we restricted this study to respondents who reported non-medical cannabis use and self-reported a

mode of inhalation for cannabis use at both time points in the following ways: smoking (joint/blunt/bong/pipe), vaporizing plant, wax/dab, or vaping oil/concentrates ($n=925$).

We then drew state-level exposure and covariate data from three different sources. The first data source was from the Kaiser Family Foundation's (KFF) State COVID-19 Data and Policy Actions accessed through GitHub repositories [27]. Specifically, we used information from 3 time-points (June 4, July 10, August 8, 2020) that overlapped with the survey's study period "during the pandemic" (June – August 2020). We used dates similarly spaced across the months that could capture variations in policy changes across the period. Data from June 2020 included the following policies: stay-at-home orders; non-essential business closures; larger gathering ban; and restaurant limits. Data from July and August 2020 included all the policies from June, plus the following policies: bar closures and face covering requirements.

The second data source for state-level data was the Johns Hopkins University and Medicine COVID-19 Dashboard by the Center for Systems Science and Engineering with data stored in a GitHub repository from April 4, 2020, until January 12, 2022 [30]. COVID-19 data included confirmed infections, deaths, recovered infections, active infections, testing, and hospitalizations by state. For this study, we used the state-level prevalence of confirmed COVID-19 infections from May 24, 2020.

The final data source was from the U.S. Census, which included state population size in 2020, state age distributions in 2020, and state percent urbanicity in 2010 [31, 32]. At the time of the analysis, the Census did not have state percent urbanicity beyond 2010.

Ethics
This study received institutional review board approval from the University of California, Los Angeles (#20-001164). All respondents provided online informed consent.

Variable coding and definitions
The outcome of interest was respondents' self-reported sharing of cannabis during the COVID-19 pandemic. Respondents used a Likert-scale for agreement with the following question, "I shared joints, blunts, bongs, pipes, vaporizers, or vape pens used for cannabis (marijuana)," with answer choices being never, sometimes, about half the time, most of the time, and always. Because we do not know who was sharing with whom, we dichotomized sharing of cannabis to no sharing (never shared) and any sharing (sometimes, about half the time, most of the time, and always shared).

The exposure of interest was the intensity of state-level COVID-19 policy actions. We scored policies by intensity by adapting a proposed coding framework ranging from 0 to 5, as suggested by Lane et al., and the CDC's recommended stay-at-home orders [23, 33]. In short, a policy scored 5 if the mandate was very high (i.e., all actions prohibited) and 0 for no recommendations or rules implemented for that policy [33]. The KFF State COVID-19 Data and Policy Actions data source had policy information on six policies for each U.S. state. These policies included stay-at-home orders, non-essential business closures, bans of large gatherings, restaurant limits, bar closures, and face-covering requirements. For instance, stay-at-home orders included statewide orders, new stay-at-home orders, high-risk groups, rolled back to high-risk groups, lifted, and no state orders. We coded 'statewide orders' and 'new stay-at-home orders' as 5, 'high-risk groups' and 'rolled back to high-risk groups' as 4, and 'lifted' or 'no state order' as 0. Detailed coding of state policies can be found in Table Supplement 1. Since the totals differed by month (June had a maximum score of 20, and July and August had maximum scores of 30), we multiplied the June score by 30/20 to make it comparable to July and August. We then summed the values for the three months and divided them by three to get the average across the time frame, with a maximum score of 30.

Covariates
Models were adjusted for potential confounders, encompassing population-level and individual-level variables that may affect the exposure (state COVID-19 policies) and the outcome (individual-level sharing of cannabis). Figure 1 graphically demonstrates these relationships in a directed acyclic graph. These variables included state-level cannabis legality status (as of 2020), COVID-19 infection prevalence, percent urbanicity, age distribution, and state's Census region; and individual-level age, sex, self-reported race/ethnicity, education, and sharing of cannabis before the COVID-19 pandemic. State-level cannabis legality status was categorized as legal for adult use (non-medical use), legal for medical use only, and illegal for medical and adult use (CBD only or fully illegal) [34]. State-level COVID-19 infection prevalence was drawn from May 24, 2020, as this precedes the dates used for state's COVID-19 policy and the outcome (June to August) to minimize issues of temporality. Prevalence was calculated per 100,000 persons given the population size of that state. State's census region was categorized as West, Midwest, Northeast, and South. Finally, individual-level variables, respondent's age, sex, race/ethnicity, and education, were used to capture variation in the outcome [10–13]. Age was recentered at the mean and rescaled per 10-year increases. Race/ethnicity was used as a proxy control for experiences of racism and social, economic, and structural disparities between groups [35, 36]. We categorized race/ethnicity as Hispanic/Latinx,
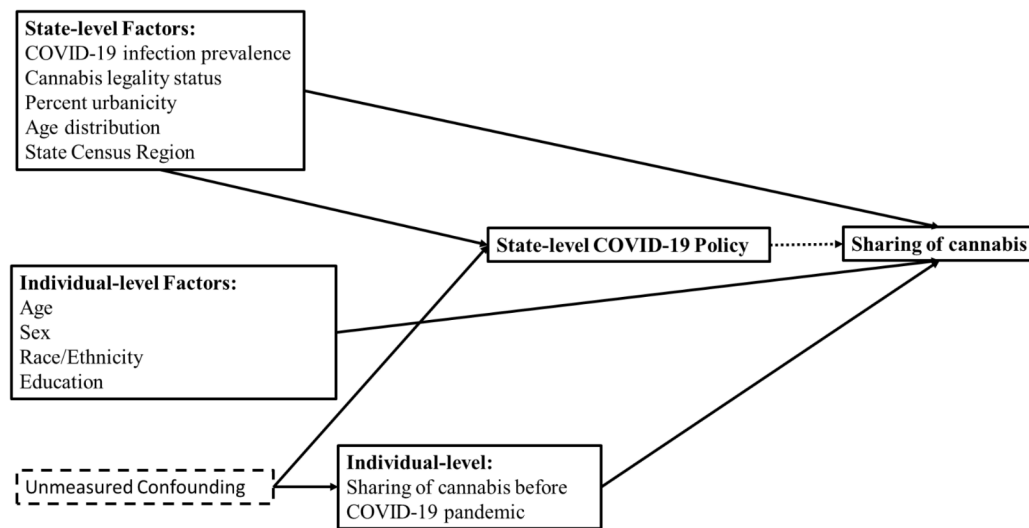
Fig. 1 A directed acyclic graph is presented to demonstrate confounders at the population and individual level that may affect the exposure (state's COVID-19 policy) and the outcome (individual level sharing of cannabis) of interest. These variables included state-level cannabis legality status, state-level COVID-19 infection prevalence, state-level percent urbanicity, state's Census level region, state-level age distribution, and individual-level age, sex, race/ethnicity, education, and sharing of cannabis before the COVID-19 pandemic. Measured variables are indicated with a solid box around the variable and unmeasured variables have a dashed box around them. Solid arrows depict the causal pathway and dotted arrows depict the measure of interest

non-Hispanic White, non-Hispanic Black, and non-Hispanic other (American Indian/Alaska Native, Native Hawaiian/Pacific Islander, Asian, two or more races, and another race not listed). The latter is a heterogeneous group but was collapsed because of small sample size and unstable estimates. Education was dichotomized as high school/less than high school or greater than high school. Sharing of cannabis before the pandemic was used to control for potential unmeasured confounding. We asked respondents to self-report their cannabis sharing behaviors before the pandemic. Respondents used a Likert-scale for agreement with the following question, "In the 3 months before the pandemic (January 2020 to mid-March 2020), I shared joints, blunts, bongs, pipes, vaporizers, or vape pens used for cannabis (marijuana)," with answer choices being never, sometimes, about half the time, most of the time, and always. We dichotomized sharing as no sharing (never shared) and any sharing (sometimes, about half the time, most of the time, and always shared).

Statistical analyses

We calculated frequency distributions, mean with standard deviation (SD), and median with interquartile range (IQR) for demographic variables, policy score, state-level factors, and cannabis behaviors overall and by sharing (no sharing versus any sharing).

We then conducted unadjusted and adjusted Poisson regression models with robust standard errors to examine the association of the average state-level COVID-19 policy score from June to August 2020 with cannabis sharing during the COVID-19 pandemic. Given that sharing

of cannabis was prevalent (greater than 10%), we used Poisson regression models to compute prevalence ratios. Model 1 was an unadjusted analysis of the average state-level COVID-19 policy association with sharing of cannabis. Model 2 was adjusted for state-level factors: cannabis legality status, COVID-19 infection prevalence, percent urbanicity, state's census region, and age distribution. Model 3 was adjusted for state-level factors and individual-level variables (age, sex, race/ethnicity, and education). Last, model 4 was adjusted for state-level factors and individual-level variables and included individual cannabis sharing behaviors before the COVID-19 pandemic. As a sensitivity analysis, we ran these models for state-level policy scores in June, July, and August separately to assess variation across the study period. For all models, we rescaled the primary predictor variable so that coefficients would represent the change per 5-unit increase in the COVID-19 policy score. As an additional sensitivity analysis, we computed models 1 through 4 for the average policy score of June to August 2020 per every 10-unit increase in score.

We calculated bivariate Spearman's correlations between each pair of COVID-19 policies implemented for June, July, and August 2020. This was done to assess whether policies co-occurred in a state given that governments may implement multiple policies to a single issue simultaneously [26, 37, 38].

Overall, missing data were minimal in our study. Data on sharing of cannabis during the pandemic was missing for 0.4% ($n=4$) of our sample. Missing data for age ($n=10$, 1.0%), sex ($n=12$, 1.2%), race/ethnicity ($n=23$, 2.4%), education ($n=13$, 1.3%) were minimal, with no missing data

on non-medical cannabis use during the pandemic. Thus, we conducted complete case analyses. This study aimed to reach individuals in every state, but we did not receive any responses from individuals living in Wyoming. Wyoming was, therefore, excluded from the analysis.

All analyses were performed using SAS software Version 9.4 of the SAS System for Windows (SAS Institute Inc., Cary, NC, USA). Mapping of the average COVID-19 policy intensity score by state was performed using R Statistical Software (v4.1.2; R Core Team 2021).

Table 1 Frequency distribution of demographics overall and by cannabis sharing among a national sample of those reporting non-medical cannabis use, August 2020 - September 2020

	Overall	Non-Medical Cannabis[a]	
		No Sharing	Any Sharing
	n (%)	n (%)[b]	n (%)[b]
Total	1883 (100.0)	232 (25.1)	693 (74.9)
Demographics			
Age, years			
Mean (Standard Deviation)	33.7 (8.8)	35.6 (12.4)	32.5 (7.9)
Sex			
Female	666 (35.9)	85 (37.1)	221 (32.1)
Male	1188 (64.1)	144 (62.9)	467 (67.9)
Sexual orientation			
LGBQ	576 (31.2)	52 (22.8)	223 (32.6)
Heterosexual	1269 (68.8)	176 (77.2)	462 (67.5)
Race/Ethnicity			
Hispanic/Latino	511 (27.8)	44 (20.1)	228 (33.2)
NH Asian	36 (2.0)	7 (3.2)	10 (1.5)
NH Black	202 (11.0)	27 (12.3)	50 (7.3)
NH American Indian or Alaska Native	51 (2.8)	2 (0.9)	10 (1.5)
NH Native Hawaiian or Pacific Islander	17 (0.9)	1 (0.5)	4 (0.6)
NH White	998 (54.3)	131 (59.8)	376 (54.7)
NH Other [c]	24 (1.3)	7 (3.2)	9 (1.3)
Education			
Less than High School	160 (8.6)	12 (5.3)	73 (10.6)
High school	215 (11.6)	48 (21.1)	75 (10.9)
Some college credit, no degree	357 (19.3)	53 (23.3)	130 (18.9)
Associates degree	530 (28.6)	32 (14.0)	197 (28.6)
College graduate or higher	589 (31.8)	83 (36.4)	213 (31.0)
Census Region			
West	709 (37.7)	122 (52.6)	233 (33.6)
Midwest	221 (11.7)	27 (11.6)	84 (12.1)
Northeast	335 (17.8)	39 (16.8)	142 (20.5)
South	618 (32.8)	44 (19.0)	234 (33.8)

Abbreviations LGBQ=Lesbian, Gay, Bisexual, and Queer; NH=non-Hispanic

[a]Sharing of cannabis paraphernalia is a sub-question asked only to those who reported using a mode of inhalation based on a check all that apply for smoking (joint/blunt/bong/pipe), vaporizing plant, vaping oil/concentrates, or wax/dab

[b]May not add to 100% because of missing data

[c]Non-Hispanic Other=those who reported other race or two or more races

Results

Sample characteristics

Most participants in the overall sample were male (64.1%) and non-Hispanic White (54.3%), with a mean age of 33.7 years (SD 8.8). Among respondents reporting a mode of inhalation for non-medical cannabis use, 810 (87.6%) reported sharing before the pandemic and 693 (74.9%) reported sharing of cannabis during the pandemic. Those who reported sharing during the pandemic were younger than those who did not share, with a mean age of 32.5 (SD 7.9) compared to 35.6 (SD 12.4), respectively. Of those reporting any sharing during the pandemic, 67.9% were male, 33.6% were from the West, and 78.5% reported greater than high school education. On the other hand, 62.9% of those reporting no sharing were male, 52.6% were from the West, and 73.6% reported greater than high school education (Table 1).

State characteristics and COVID-19 policy score

Every U.S. state including the District of Columbia was represented in this study except for Wyoming. Figure 2 shows the average COVID-19 policy score from June to August 2020 by state. Overall, the median of the average policy score was 16.7 (IQR 13.2–21.5). The median policy scores for June, July, and August were 16.5 (IQR 12-22.5), 18 (IQR 13–22) and 18 (IQR 14–21), respectively. More of those who reported sharing cannabis lived in states with a lower average policy score (16.7, IQR 12.3–21.5) compared to those who did not share (18.6, IQR 15.3–25.3). Moreover, 46.0% of individuals who reported sharing lived in states with policies for legalized adult use (non-medical / recreational) cannabis laws compared to 60.8% of those who did not share (Tables 2 and 3). Details on the average COVID-19 policy score for June to August 2020, the policy score for each month separately, state-level percent urbanicity, state-level age distribution, state-level cannabis legality, and state-level COVID-19 infection prevalence by state are shown in Table Supplement 2. COVID-19 policies were moderately to strongly correlated for June, July, and August limiting evaluation of policies separately (Table Supplement 3–5).

Primary analysis

In the unadjusted model (Model 1), the prevalence ratio of any cannabis sharing per every 5-unit increase in the average COVID-19 policy score was 0.94 (95% confidence interval [CI] 0.92, 0.97). After adjusting for state-level factors, the prevalence ratio of any cannabis sharing per 5-unit increase in the average COVID-19 policy score was 0.95 (95% CI 0.90, 0.99) (Model 2). After adjusting for both state-level and individual's age, sex, race/ethnicity, and education, the prevalence ratio of any cannabis sharing per 5-unit increase was 0.95 (95% CI 0.90, 0.99) (Model 3). Finally, after adjusting for covariates and after
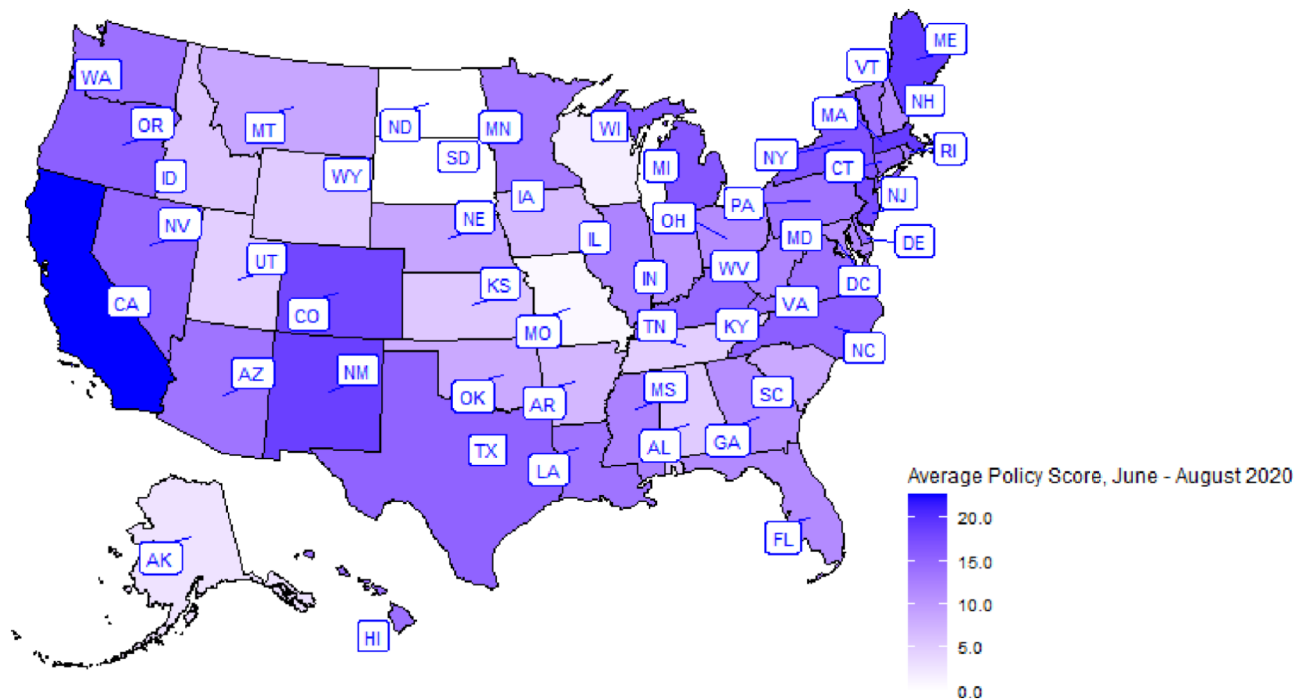
Fig. 2 The maximum average policy score is 30

accounting for individual's cannabis sharing before the pandemic (Model 4), the prevalence ration of any cannabis sharing per every 5-unit increase in the average COVID-19 policy score was 0.97 (95% CI 0.93, 1.01) (Table 4).

Sensitivity analysis

Results were similar when assessing the COVID-19 policy score for each month (June, July, and August) separately. In Model 4, the prevalence ratio of any cannabis sharing per every 5-unit increase in June policy score were 0.99 (95% CI 0.96, 1.02), 0.97 (95% CI 0.93, 1.01) per 5-unit increase in July policy score, and 0.97 (95% CI 0.93, 1.00) per 5-unit increase in August policy score (Table 4). In our second sensitivity analysis, we rescaled the change in policy score to every 10-unit increase. In the unadjusted model (model 1), the prevalence ratio of any cannabis sharing per every 10-unit increase in the average COVID-19 policy score was 0.88 (95% CI 0.84, 0.94). In model 4, the prevalence ratio of any cannabis sharing per every 10-unit increase in the average COVID-19 policy score was 0.94 (95% CI 0.87, 1.02) (Table 5).

Discussion

Overall, our study found that individuals in states with more intense COVID-19 policies had a lower prevalence of sharing cannabis compared to those in states with less intense policies. This relationship remained after adjustment for state-level and individual's age, sex, race/ethnicity, and education covariates. Although, confidence

intervals crossed the null when controlling for individual's cannabis sharing before the pandemic, most of the interval remained negative compatible with a protective association for cannabis sharing [39]. Though, this association was minimal. These findings were consistent for COVID-19 policies in June, July, and August despite changes in policies across these three time-points. Intensity of COVID-19 policy scores in July and August were similar between the two months with variation between states and may explain the comparable point estimates. On the other hand, there may have been less variation in intensity of policy between states in June compared to July and August driving the point estimate closer to one. When the policy score of intensity increased per every 10 units, we found larger point estimates with 95% CIs largely compatible with a protective association on cannabis sharing though the interval crossed 1. Both sensitivity analyses offer variations in approach and contribute to the robustness of the original analysis. Previous studies have assessed state-level COVID-19 policies, masking, and stay-at-home orders on population-level behaviors and found decreases in population movement and COVID-19 infection rates by policy stringency [23–25, 33, 40, 41].

However, few studies have assessed the association of COVID-19 policy on substance use and related behaviors. Most studies that aimed to assess the association of COVID-19 policy, such as stay-at-home orders, did so by comparing waves before and during lockdowns or assessing individual behaviors during lockdowns [42–44]. For

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Table 2 Distributions of cannabis behavior by cannabis sharing among a national sample of those reporting cannabis use, August 2020 - September 2020

	No Sharing	Any Sharing
	n (%)[a]	n (%)[a]
Total	232 (100.0)	693 (100.0)
Sharing prepared cannabis & cannabis related paraphernalia		
Sharing before COVID-19 pandemic		
No sharing	107 (46.1)	8 (1.2)
Sometimes	80 (34.5)	324 (46.8)
About half the time	18 (7.8)	160 (23.1)
Most of the time	22 (9.5)	158 (22.8)
Always	5 (2.2)	43 (6.2)
Sharing during COVID-19 pandemic		
No sharing	232 (100.0)	–
Sometimes	–	365 (52.7)
About half the time	–	199 (28.7)
Most of the time	–	105 (15.2)
Always	–	24 (3.5)
Frequency of non-medical cannabis use		
Frequency before COVID-19 pandemic		
Once or twice	33 (14.2)	157 (22.7)
Monthly	60 (25.9)	169 (24.4)
Weekly	61 (26.3)	231 (33.3)
Daily or almost daily	78 (33.6)	136 (19.6)
Frequency during COVID-19 pandemic		
Once or twice	23 (9.9)	123 (17.8)
Monthly	45 (19.4)	175 (25.3)
Weekly	60 (25.9)	256 (36.9)
Daily or almost daily	104 (44.8)	139 (20.1)
Mode of non-medical cannabis use[b]		
Most reported mode of use before COVID-19 pandemic		
Inhalation	220 (94.8)	656 (94.7)
Non-inhalation	12 (5.2)	37 (5.3)
Most reported mode of use during COVID-19 pandemic		
Inhalation	210 (90.5)	640 (92.4)
Non-inhalation	22 (9.5)	53 (7.8)

[a]May not add to 100% because of missing data

[b]Inhalation=Smoking (joint/blunt/bong/pipe), vaporizing plant, vaping oil/concentrates, wax/dab; non-inhalation=Edibles, other oral products (example: pill, tincture, beverage)

Table 3 Frequency distribution of policy, state characteristics, and COVID-19 cases by cannabis sharing among a national sample of those reporting non-medical cannabis use, August 2020 - September 2020

	No Sharing	Any Sharing
	n (%)	n (%)
Policy Level Factors		
COVID-19 Policy (Median [IQR])		
Average June-August	18.6 (15.3–25.3)	16.7 (12.3–21.5)
June	19.5 (13.5–24.0)	16.5 (12.0–22.5)
July	19.0 (15.0–26.0)	17.0 (12.0–21.0)
August	19.0 (17.0–26.0)	18.0 (13.0–21.0)
State's Legality		
Legal for adult use (non-medical)	141 (60.8)	319 (46.0)
Legal for medical use only	54 (23.3)	205 (29.6)
Legal for CBD use only	34 (14.7)	163 (23.5)
Illegal for all forms of use	3 (1.3)	6 (0.9)
State Characteristics		
State Age Distribution (median [IQR])	37.9 (37.0–39.6)	38.9 (37.0–39.6)
State Percent Urban (median [IQR])	87.9 (81.0–95.0)	87.2 (75.1–92.0)
COVID-19 Prevalence per 100,000 (median [IQR])	241.0 (241.0–433.9)	257.3 (236.2–542.6)

Abbreviations IQR=interquartile range; CBD=Cannabidiol

order to control for these factors, we aimed to assess the impacts of the intensity of a collection of COVID-19 containment policies and the variations between U.S. states on individuals' behaviors while accounting for the prevalence of COVID-19 infection at the time.

We found that reported sharing of cannabis was lower among individuals living in states with more intense COVID-19 policies compared to those in states with less intense COVID-19 policy. There may be many mechanisms that could explain this association. First, cannabis use can be a social behavior for some and involves sharing cannabis with others [9–15]. COVID-19 policy, such as stay-at-home orders, closure of bars, and large gathering bans, may limit social opportunity for others to connect with friends or strangers. Enforced closure of these public spaces and individual adherence to stay-at-home orders changes where people may have spent their time and reduces one's opportunity to share cannabis with others, a similar conclusion noted in tobacco studies during the pandemic [42, 45]. These policies may have disrupted social relationships, particularly weak social ties or casual relationships which were lost or worsened during the pandemic [46]. Second, messaging and policies for COVID-19 may drive perception and emotion (i.e., fear, worry) about COVID-19 infection [47, 48]. In turn, these perceptions may influence sharing behaviors [45]. Third, there may be unmeasured confounding that was not accounted for or fully controlled (residual confounding) in our study which may partially explain differences

instance, one longitudinal study assessed tobacco use among young adults during COVID-19 stay-at-home orders compared to before and found reductions in use [42]. One challenge in these studies is separating the effect of the pandemic (infection/transmission, socio-economic consequences, etc.) compared to the effect of COVID-19-related policy. Another challenge is accounting for the variation in intensity, duration, and correlation of implemented COVID-19 containment and closure policies between U.S. states and U.S. counties [26]. In

Table 4 Unadjusted and adjusted Poisson regression for sharing of prepared cannabis and cannabis-related paraphernalia during the COVID-19 pandemic among a sample of those reporting non-medical cannabis use in the United States, August 2020 - September 2020

	Cannabis Sharing	
	n	PR (95% CI)
Average COVID-19 Policy Score (June to August)		
[a]Model 1	898	0.94 (0.92, 0.97)
[b]Model 2	898	0.95 (0.90, 0.99)
[c]Model 3	898	0.95 (0.90, 0.99)
[d]Model 4	898	0.97 (0.93, 1.01)
COVID-19 Policy June		
[a]Model 1	898	0.96 (0.93, 0.98)
[b]Model 2	898	0.96 (0.93, 1.00)
[c]Model 3	898	0.96 (0.93, 1.00)
[d]Model 4	898	0.99 (0.96, 1.02)
COVID-19 Policy July		
[a]Model 1	898	0.94 (0.92, 0.97)
[b]Model 2	898	0.95 (0.91, 1.00)
[c]Model 3	898	0.95 (0.91, 1.00)
[d]Model 4	898	0.97 (0.93, 1.01)
COVID-19 Policy August		
[a]Model 1	898	0.94 (0.92, 0.97)
[b]Model 2	898	0.95 (0.91, 0.99)
[c]Model 3	898	0.95 (0.91, 0.99)
[d]Model 4	898	0.97 (0.93, 1.00)

Abbreviations PR=prevalence ratio; CI=confidence interval

Poisson regression models of sharing prepared cannabis and cannabis-related paraphernalia during the COVID-19 pandemic; modeling prevalence ratio of any sharing to no sharing per every 5 unit increase in COVID-19 state policy

[a]Model 1: Unadjusted Poisson regression

[b]Model 2: Adjusted model controlling for state cannabis regulation status, state's percent urbanicity, state's age distributions, state's COVID-19 infection prevalence, and state's census region

[c]Model 3: Adjusted model 2 plus adjustment for individual age, sex, race/ethnicity, and education

[d]Model 4: Adjusted model 3 plus adjustment for cannabis sharing behaviors before the COVID-19 pandemic

Table 5 Sensitivity analysis (per 10-unit increases): Unadjusted and adjusted Poisson regression for sharing of prepared cannabis and cannabis-related paraphernalia during the COVID-19 pandemic

	Cannabis Sharing	
	n	PR (95% CI)
Average COVID-19 Policy Score (June to August)		
[a]Model 1	898	0.88 (0.84, 0.94)
[b]Model 2	898	0.90 (0.82, 0.98)
[c]Model 3	898	0.90 (0.82, 0.98)
[d]Model 4	898	0.94 (0.87, 1.02)

Abbreviations PR=prevalence ratio; CI=confidence interval

Poisson regression models of sharing prepared cannabis and cannabis-related paraphernalia during the COVID-19 pandemic; modeling prevalence ratio of any sharing to no sharing per every 10 unit increase in COVID-19 state policy

[a]Model 1: Unadjusted Poisson regression

[b]Model 2: Adjusted model controlling for state cannabis regulation status, state's percent urbanicity, state's age distributions, state's COVID-19 infection prevalence, and state's census region

[c]Model 3: Adjusted model 2 plus adjustment for individual age, sex, race/ethnicity, and education

[d]Model 4: Adjusted model 3 plus adjustment for cannabis sharing behaviors before the COVID-19 pandemic

effects" that policies may have on other health behaviors such as cannabis sharing. Sharing of paraphernalia for cannabis, tobacco, and crack cocaine inhalation have been shown to be risk factors for respiratory viral and bacterial infections [49–59]. Therefore, strategies to reduce or limit sharing during a pandemic of a respiratory illness are important to identify. In the early stage of the pandemic (March – September 2020), messaging with tag lines such as "Puff, Puff, Don't Pass" and alternatives to sharing cannabis were proposed in newspaper articles, social media community threads, and by national grassroots organizations [9, 15, 28, 29]. Additionally, messaging from the World Health Organization and those in tobacco research noted the risk of sharing tobacco products during the pandemic with recommendation to not share [56–59]. As cannabis use continues to increase in the United States, tailored public health and harm reduction messaging (i.e., "Puff, Puff, Don't Pass") may be important to implement during respiratory viral peaks [28]. Interventions for promoting harm reduction messaging for cannabis sharing may include state or county public health departments working with national cannabis grassroots organizations and regulated cannabis dispensaries to provide educational material [21].

Limitations
There are several limitations to this study. First, the data come from a non-representative convenience sample of highly educated, primarily White male individuals who reported cannabis use and therefore may not be generalizable to all those reporting cannabis use in the U.S. Therefore, we are unable to include those who initiated

in sharing by states with more intense COVID-19 policy compared to those with less intense policy. For instance, there may be a difference in access to cannabis given cannabis legality laws across U.S. states that may allow for those in states with fully legalized cannabis to obtain their own supply compared to those in states without a legalized market. Although we controlled for cannabis legalization by state, there may still be residual confounding that is not accounted for.

Findings from this study may be important during future spikes in COVID-19, during influenza and other respiratory virus seasonal waves, and during future viral respiratory pandemics. This study identified an association with COVID-19 state policy on a behavior that was not the primary aim of policies nor public health messaging. This shows the potential unintended effects or "side

cannabis use during the pandemic and cannot make any claims about their sharing experiences. However, this is the only sample, to our knowledge, that assessed cannabis sharing during the pandemic. Second, we do not know with whom sharing was occurring and cannot make conclusions on how this impacted COVID-19 risk. Sharing between intimate partners or household members likely held different risks because of ongoing high levels of exposure whereas sharing with non-household members and people with whom there is no other physical intimacy represents a broader pattern of risk behavior that we were not able to capture. Third, there may be differences in policy actions within states (i.e., at the level of counties/cities) that are not captured here because of data availability on policies in these specific counties at the time of the study [26]. Fourth, COVID-19 policies were correlated with one another, and we are unable to look at any single policies association with cannabis sharing alone. Thus, we are limited to assessing the level of COVID-19 policy intensity as a single score [26, 37, 38]. Fifth, this was a cross-sectional study. We did not have repeated measures on individuals and state-level policy. We could not control for fixed effects in our model nor conduct a true quasi-experimental analysis like difference-in-differences (pre/post analyses, interrupted time series analyses, etc.). Finally, we only looked at one time-point early on during the COVID-19 pandemic (June – August 2020), limiting the generalizability of findings to other periods of the pandemic.

Conclusion

We found that sharing of cannabis was minimally associated with more intense state-level COVID-19 policies; fewer individuals in states with more intense policies reported sharing compared to those in states with less intense policies. These findings highlight that sharing behaviors may have changed even though COVID-19 policy/messaging was not directed at this behavior. Individuals who use cannabis may be willing to make changes to their behavior and may further benefit from specific and directed messaging to not share during peaks of respiratory infections. There exists a space for collaboration as national grassroots organizations and social media threads proposed messaging to not share early during the pandemic. Future public health messaging should consider harm reduction strategies for cannabis, especially as use continues to increase in the United States.

Abbreviations

COVID-19	Coronavirus disease 2019
CDC	United States Centers for Disease Control and Prevention
CBD	Cannabidiol
IP	Internet protocol
KFF	Kaiser Family Foundation
SD	Standard deviation
IQR	Interquartile range
CI	Confidence interval

Data availability

The dataset with individual-level data used and/or analyzed during the current study are available from the corresponding author on reasonable request. Kaiser Family Foundation's State COVID-19 Data and Policy Actions and Johns Hopkins University and Medicine COVID-19 Dashboard by the Center for Systems Science and Engineering are publicly accessible through GitHub. U.S. Census data is publicly accessible through the U.S. Census Bureau.

Declarations

Ethics approval and consent to participate

This study received institutional review board approval from the University of California, Los Angeles (IRB#20-001164). All respondents provided online informed consent.

Consent for publication

Not applicable.

Disclosures

The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

Competing interests

The authors declare that they have no competing interests.

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