International Journal of Drug Policy 134 (2024) 104618

Contents lists available at ScienceDirect

International Journal of Drug Policy

journal homepage: www.elsevier.com/locate/drugpo

Cannabis legalization and changes in cannabis and tobacco/nicotine use and co-use in a national cohort of U.S. adults during 2017–2021

Vira Pravosud [a,b,*], Stanton Glantz [c], Salomeh Keyhani [a,d], Pamela M. Ling [e,f], Lauren K. Lempert [e], Katherine J. Hoggatt [a,d], Deborah Hasin [g], Nhung Nguyen [e,f], Francis Julian L. Graham [d,h], Beth E. Cohen [a,d]

[a] Center for Data to Discovery and Delivery Innovation, San Francisco VA Health Care System, 4150 Clement Street, San Francisco, CA 94121, United States
[b] Northern California Institute for Research and Education, 4150 Clement Street, San Francisco, CA 94121, United States
[c] University of California San Francisco, Professor of Medicine (retired), San Francisco, United States
[d] School of Medicine, University of California San Francisco, 4150 Clement Street, San Francisco, CA 94121 (111A1), United States
[e] Center for Tobacco Control Research and Education, University of California San Francisco, San Francisco, CA 94143, United States
[f] School of Medicine, Department of Medicine, Division of General Internal Medicine, University of California San Francisco, San Francisco, CA 94143, United States
[g] Epidemiology in Psychiatry, Columbia University Medical Center, 722 W. 168th Street, New York, NY 10032, United States
[h] San Francisco VA Health Care System, 4150 Clement Street, San Francisco, CA 94121 (111A1), United States

ARTICLE INFO

Keywords:
Cannabis legalization
Medical cannabis
Recreational cannabis
Cannabis and tobacco/nicotine use and co-use

ABSTRACT

Background: Little is known about whether cannabis legalization impacts cannabis use uptake or has spillover effects on co-use of cannabis and tobacco/nicotine (using both in the past 30 days). We determined associations of cannabis legalization with self-reported (1) current (past 30-day) cannabis use; (2) current ("now") tobacco/nicotine use (smoking or electronic cigarette use); and (3) current co-use of cannabis and tobacco/nicotine and how prevalence is changing over time.

Methods: In this longitudinal study, a web-based survey was administered to a nationally representative, population-based panel of US adults in 2017, 2020, and 2021. We used weighted unadjusted binomial logistic GEE models to assess changes in prevalence of cannabis, tobacco/nicotine use and co-use and weighted, adjusted binary logistic GEE models to assess associations of cannabis legalization with cannabis, tobacco/nicotine use and co-use.

Results: A total of 9003 participants (age range = 18–94, mean age = 47.9 [±17.4 SD] years; 4696 females [weighted 52.0 %]) completed the survey in 2017; 5979/8529 (70.1 %) in 2020 and 5420/7305 (74.2 %) in 2021 from the original cohort who remained available. Current cannabis use significantly increased +3.3 % between 2017 and 2021, while tobacco/nicotine use significantly declined (−1.9 %); co-use of cannabis and tobacco/nicotine did not change significantly (+0.2 %). Both *medical* and *recreational* cannabis legalization was associated with increased current cannabis use; the independent effect of recreational cannabis legalization was 1.13 times larger than medical. There were no statistically significant differences in tobacco/nicotine use and co-use prevalence by legalization status.

Conclusion: Cannabis legalization increases cannabis use but is not associated with changes in tobacco/nicotine use or co-use. Legalization should be coupled with public health efforts.

Introduction

Cannabis use and co-use with tobacco, defined as currently using both substances, has been increasing in the U.S. since 2000 (Agrawal et al., 2012; Caulkins, 2024; Hublet et al., 2015; Substance Abuse and Mental Health Services Administration, 2018). Despite emerging evidence of health effects of frequent cannabis use (Andréasson et al., 1987; Arseneault et al., 2002, 2004; Bailly et al., 2010; Ghasemiesfe et al., 2018; Jeffers et al., 2024; Jouanjus et al., 2017; Qiu et al., 2023; Renard et al., 2014; Wang et al., 2016b), many people in the US perceive

* Corresponding author at: Center for Data to Discovery and Delivery Innovation, San Francisco VA Medical Center, Northern California Institute for Research and Education, 4150 Clement Street, Build. 6 Rm. 300, San Francisco, CA 94121, United States.
E-mail addresses: vira.pravosud@va.gov, vira.pravosud@ucsf.edu (V. Pravosud).

https://doi.org/10.1016/j.drugpo.2024.104618

Available online 4 November 2024

cannabis as less risky than tobacco (Chambers et al., 2023; Han et al., 2021; Nguyen et al., 2023). Expansion of medical and recreational cannabis legalization could have contributed to these increases in use. As of September 2023, 38 states had legalized medical cannabis and 30 subsequently or simultaneously legalized recreational cannabis (Carnevale Associates LLC, 2020; DISA, 2023). Several studies using data from 2005 to 2019 among US adults (Bae & Kerr, 2020; Cerdá et al., 2020; Choi et al., 2019; Hasin et al., 2017, 2023; Kerr et al., 2017, 2018; Martins et al., 2021; Wen et al., 2015; Zellers et al., 2023) showed medical and/or recreational cannabis legalization was associated with increased cannabis use or cannabis use disorder.

Except for Zellers and colleagues, who prospectively assessed longitudinal cohorts of discordant twins and found that increased cannabis use was attributable to recreational cannabis legalization (Zellers et al., 2023), previous research was mostly based on data from single or repeated cross-sectional surveys (Bae & Kerr, 2020; Cerdá et al., 2020; Choi et al., 2019; Hasin et al., 2017, 2023; Kerr et al., 2017, 2018; Martins et al., 2021; Wen et al., 2015) that limit causal inferences. Furthermore, past studies examining the association of cannabis legalization and use assessed the effect of medical cannabis laws only (Choi et al., 2019; Hasin et al., 2017; Martins et al., 2021; Wen et al., 2015) or reported a combined effect of recreational plus medical cannabis legalization (Bae & Kerr, 2020; Cerdá et al., 2020; Hasin et al., 2023; Kerr et al., 2017, 2018; Zellers et al., 2023). Compared to medical legalization, recreational cannabis laws and, especially, commercialization of recreational cannabis may have a greater impact on increased availability and access to cannabis products because these policies remove requirements for recommendations from a medical provider, leading to greater exposure to cannabis marketing and advertisements (Lipperman-Kreda & Grube, 2018) and increased social acceptance of cannabis use (Baumbusch & Sloan Yip, 2022; Smart & Pacula, 2019). Past research has not assessed the independent additional effect of recreational cannabis legalization on adult cannabis use above the effect of medical cannabis legalization.

Another concerning trend among US adults is the increasing co-use of cannabis and tobacco, which is associated with higher health risks compared to single substance use (Meier & Hatsukami, 2016). There are biological (e.g., age, sex, genetics), psychological (e.g., internalizing and externalizing disorders), and socio-economic (e.g., price) factors that can lead to co-use of cannabis and tobacco (Agrawal et al., 2012). The use of each substance can increase the risk of dependence of the other: tobacco smoking increases the risk of cannabis dependence (Hindocha et al., 2015) and cannabis use increases the risk of nicotine dependence (Agrawal et al., 2008; Wang et al., 2016a). Though a 2013 national survey of adults and adolescents found that current cigarette and cannabis co-use was more prevalent in states with legalized medical cannabis (Wang et al., 2016a), most past studies in US adults just focused on associations of cannabis legalization with cannabis use (Bae & Kerr, 2020; Cerdá et al., 2020; Hasin et al., 2017; Martins et al., 2021; Zellers et al., 2023). The few studies examining the impact of cannabis laws on adult tobacco use suggested decreases in cigarette smoking following medical (Choi et al., 2019) and recreational (Kerr et al., 2017, 2018) cannabis legalizations. However, these studies were from a few states or geographic areas and used a sample of young adults only (Kerr et al., 2017, 2018), limiting generalizability, or were focused exclusively on medical (Choi et al., 2019) or recreational (Kerr et al., 2017, 2018) cannabis laws, limiting our understanding of the independent effects that each policy can have on tobacco/nicotine use and co-use with cannabis considering possible substitution or complementarity of these products. Past studies were also based on data from 2008 to 2016 and thus, did not assess the impact of cannabis legalization on changes in electronic cigarette (e-cigarette) use, which has substantially increased since then (Cornelius et al., 2023; Erhabor et al., 2023; King et al., 2018), despite significant declines of cigarette smoking among US adults (Cornelius et al., 2023).

Data in prior studies examining the impact of cannabis legalization on adult substance use were collected before the major disruption of the coronavirus disease 2019 (COVID-19) pandemic, which was associated with increased perceived risk of tobacco use (Benowitz et al., 2022; Gaiha et al., 2020; Yang et al., 2021). Similarly, the 2019 EVALI outbreak (E-cigarette, or vaping product use associated lung injury) increased public awareness of harms from e-cigarette and vapor cannabis product use (Blount et al., 2020; Moritz et al., 2019). To provide updated prospective studies on adult cannabis use in association with expanded medical and recreational cannabis legalization and potential spillover effects of cannabis legalization on adult tobacco/-nicotine use and co-use with cannabis, we conducted a longitudinal survey of a large, nationally representative sample of US adults to examine the association of medical and recreational legalization with current use of cannabis and/or tobacco/nicotine (cigarettes or e-cigarettes) between 2017 and 2021.

The unique contribution of this study lies in the longitudinal nature of the national survey data that allowed us to account for within-person differences in the analysis, which aimed to (1) describe changes in current cannabis and tobacco/nicotine use and co-use over time; (2) examine whether living in the states with medical or recreational cannabis legal status was associated with higher odds of current cannabis and tobacco/nicotine use and co-use compared to a non-legal status; and (3) determine the independent (additional) effect of enacting recreational cannabis above legalizing medical cannabis. We hypothesized that the independent additional effect of recreational cannabis legalization on adult cannabis use would be larger than the effect of medical cannabis legalization.

Methods

Study design and sample

As previously described in detail (Chambers et al., 2023; Keyhani et al., 2018), the survey was conducted using the web-enabled Ipsos KnowledgePanel®, a probability-based panel designed to be representative of the US population. No one can volunteer to participate; participants are chosen by a random selection of telephone numbers and residential addresses covering 97 % of the US. Persons in selected households are then invited by telephone or mail to participate in the web-enabled KnowledgePanel. People are contacted up to three times to complete the baseline survey and up to five times to complete subsequent questionnaires. For those who agree to participate but do not already have Internet access, Ipsos provides a free laptop or netbook and internet connection. People who already have computers and Internet service are permitted to participate using their own equipment. Panelists receive unique log-in information for accessing surveys online, and then are sent emails inviting them to participate in research.

Participants received no monetary incentive for completing the baseline questionnaire and a $5 US dollar incentive for subsequent surveys. People who agreed to participate in this survey were stratified by state cannabis legalization status in 2017 (medical, recreational, or not legal; eTable 1). The analytic sample included 9003 respondents ≥18 years old in 2017 (wave 1, 55.3 % response rate of $N = 16,280$), 5979 respondents aged ≥20 years in 2020 (wave 2, 70.1 % response rate of 8529 individuals contacted), and 5420 respondents aged ≥21 in 2021 (wave 3, 74.2 % response rate of 7305 individuals contacted)—eFig. 1. The second and third waves of the survey were administered to those respondents of the original survey who remained available for contact. We used year-specific weights provided by Ipsos to match the geodemographic distributions of the US population 20 years old and over accounting for nonresponse (Keyhani et al., 2018).

Measures

Outcomes

We examined three yes/no outcomes (see eTable 2 for survey

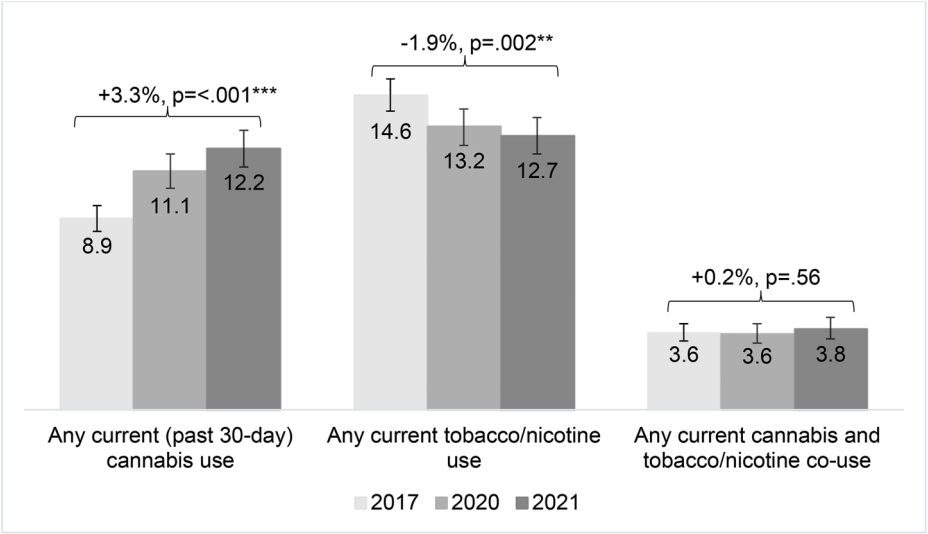

Fig. 1. Changes in any current cannabis and tobacco/nicotine use and co-use among U.S. adults between 2017 and 2021 ($n_{2017} = 9003$; $n_{2020} = 5979$; $n_{2021} = 5420$) by year, comparing 2017 and 2021.
Error bars represent 95 % confidence intervals for the prevalence of use. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$—indicate results that remained significant after adjustment for multiple comparisons using Bonferroni correction.

questions), including: (1) any current (past 30-day) cannabis use (smoking, vaporing, edibles, concentrates, or topicals); (2) any current ("now") tobacco/nicotine use (smoking or e-cigarette/vapor products use); (3) current co-use of cannabis and tobacco/nicotine, not necessarily simultaneously (Chu et al., 2023).

Socio-demographic characteristics

Respondents provided data regarding their age; sex (female or male); education (less than high school; high school; some college; or bachelor's degree or higher); and past 12-month household income before tax, categorized as <$30,000; $30,000–$74,999; $75,000–$124,999; or ≥$125,000 (Chambers et al., 2023; Keyhani et al., 2018; Nguyen et al., 2022). Ipsos created a combined race and ethnicity variable to match the U.S. Census Bureau's Current Population Survey benchmarks, which are used in survey weighting (Black, Non-Hispanic; White, Non-Hispanic; Other, Non-Hispanic; two or more races, Non-Hispanic; or Hispanic). Ethnicity was assessed by asking, "Are you of Hispanic, Latino, or Spanish origin?" Based on the responses to the race question, those responding 'no' to the ethnicity question were categorized as non-Hispanic Black, non-Hispanic White, non-Hispanic other race, or non-Hispanic Multiracial (i.e., respondents who chose two or more race responses). Non-Hispanic Other race includes American Indian or Alaska Native, Asian, Native Hawaiian or Pacific Islander, or a different race response for the race question. Individuals who self-identified as "Hispanic" were classified as a separate category in the combined variable for all race responses.

Statistical analysis

We used SAS version 9.4 (SAS Institute, Cary, NC) for all analyses, which were conducted from September 2021 through September 2024. Two-tailed $p < 0.05$ was considered statistically significant.

Change in cannabis and tobacco/nicotine use during 2017–2021

We used weighted generalized estimating equations (GEE) models that provide population-averaged estimates to account for repeated-measures and correlated data in a longitudinal study. We used SAS PROC GLIMMIX with R-side effects and the empirical covariance estimators to minimize bias of potentially incorrect selection of covariance structure. To describe changes in cannabis and tobacco/nicotine use and co-use, we assessed prevalence for each outcome by year (2017, 2020, and 2021) and fit binomial logistic regression GEE models with time as the main effect. We used listwise deletion of missing values in all models as the percentages of missing values for cannabis, tobacco/nicotine use and co-use questions in each of the three years of data collection were small (<1.7 %, see eTable 3). We tested for changes between 2017 and 2021, treating the year of data collection as a 3-level categorical variable (the year of 2017 as a reference category) in the total sample ($n = 9003$ in 2017, $n = 5979$ in 2020, and $n = 5420$ in 2021) and among those who responded to all three years of follow-up ($n = 5053$)—sensitivity models. We also report results from all pair-wise comparisons (2021 vs. 2020 and 2020 vs. 2017) in the supplement (eTable 4).

Cannabis legalization and associations with cannabis and tobacco/nicotine use and co-use

We carried out two series of weighted, binary logistic GEE models, including the exposure variable of interest—time-varying current cannabis legalization status in the state in each year (eTable 1). In the first series of models, cannabis legalization status was a 3-level categorical variable, categorizing the states of respondents' residence based on laws that had been enacted by the survey date (Carnevale Associates LLC, 2020; DISA, 2023) as 'not legal', 'medical only', and 'recreational+medical.'

Because no state enacted recreational cannabis legalization without first or concurrently enacting medical cannabis legalization, the second series of models used two independent variables for medical and recreational legalization. Specifically, the first variable was coded 1 if medical cannabis was legal (0 otherwise) and the second coded 1 if recreational cannabis was legal. Thus, if only medical cannabis was legal, the first variable was coded 1 and the second 0. If both medical and recreational cannabis were legal, both variables were set to 1. If neither was legal, both variables were 0. This coding quantifies the independent effect of initial medical legalization followed by the independent additional effect of legalizing recreational cannabis above the effects of legalizing medical cannabis. There was no serious collinearity between medical and recreational legalization status variables (VIFs in all three models ranged 1.50–1.55).

We assessed adjusted odds ratios (AOR) and 95 % confidence intervals (CI) as measures of association of cannabis legalization status with cannabis and tobacco/nicotine use and co-use, controlling for socio-demographic characteristics and data collection year (as a continuous variable centered on 2017) to account for secular trends and

other events happing during that time frame.

Sensitivity analyses

We conducted five sensitivity analyses. First, we repeated the analyses while treating the year of data collection as a categorical variable. Second, we repeated the analyses limiting our sample to those who responded in all three years of the follow-up ($n = 5053$) using normalized 2021-year weights to account for the effective number of observations. Respondents with missing data in 2020 and 2021 were excluded. Third, we repeated our analyses using all available data, while adjusting models with the current cannabis use outcome for current tobacco/nicotine use. Fourth, we conducted sensitivity models for all available data, while separately examining current cigarette smoking and e-cigarette use outcomes in association with cannabis legalization, as opposed to using a combined tobacco use outcome variable in the primary analysis.

The fifth sensitivity analysis examined changes in cannabis legalization status between 2017 and 2021 and associations with changes in cannabis and tobacco/nicotine use and co-use over time. During the study period, only 13 states had a change in legal status, and this involved different types of changes associated with increased cannabis legalization occurring at different times: from not legal to medical ($n = 3$), from not legal to medical + recreational ($n = 1$), and from medical to recreational ($n = 9$) (eTable 5). Because the "control" states, which did not have changes, had different legal statuses, we created a 4-level variable indicating four legalization groups: a combined group of states with increasing legalization ($n = 13$), states with stable non-legal cannabis status ($n = 16$), stable medical ($n = 13$), and stable recreational ($n = 9$) (eTable 5).

We ran weighted, binary logistic GEE models that included a variable indicating four legalization groups (eTable 5) and an interaction of this variable with time (i.e., data collection year as a continuous variable centered on 2017), while including the main effect of year of data collection and adjusting for sociodemographic characteristics. As a proxy for difference-in-difference analysis, this approach allowed to examine whether our 4-level cannabis legalization status change was associated with changes in cannabis, tobacco/nicotine use and co-use during 2017–2021. We reported estimates and their standard errors, Type III and estimate-specific *p*-values for the interactions by the three outcomes (cannabis, tobacco/nicotine use and co-use), and presented graphs showing the change in the use outcomes across the study period for the four legalization groups. Significant Type III *p*-values indicated a significant *overall* effect of the 4-level cannabis legalization status change*year interaction variable on changes in use over time; estimate-specific *p*-values indicated a significant simple effect of a cannabis legalization status change on changes in use over time, compared to the reference level of the interaction term.

Results

Socio-demographic characteristics

At baseline, there were 9003 respondents: 47.9 ± 17.4 (SD) years old and 3.2 % of young adults under the age of 21 in 2017; 52 % female; 11.9 % Black, 15.9 % Hispanic, and 64.1 % White (Table 1). Approximately one third of respondents had a bachelor's degree or higher (31.7 %, $n = 3658$) and an income of $30,000–$74,999 (33.2 %, $n = 3172$). The distribution of socio-demographic characteristics was consistent in the subsequent waves. As described elsewhere (Keyhani et al., 2018), the distribution of our sample was similar to national US data based on the National Survey on Drug Use and Health (NSDUH), except participants in our sample had higher income than NSDUH participants (48 % in our sample vs 35 % of NSDUH respondents reported annual household income of ≥$75,000).

Table 1
Respondent characteristics: U.S. adults, 2017–2021.

Variable	Wave 1 (2017) ($n = 9003$)	Wave 2 (2020) ($n = 5979$)	Wave 3 (2021) ($n = 5420$)
Socio-demographic characteristics *n* (%)			
Age (range; mean, SD)	18–94; 47.9 (17.4)	20–96; 49.1 (17.2)	21–98; 49.7 (17.0)
Female	4696 (52.0)	3020 (51.9)	2684 (52.0)
Race-ethnicity			
Black, non-Hispanic	666 (11.9)	399 (11.8)	344 (11.5)
White, Non-Hispanic	6828 (64.1)	4659 (64.2)	4258 (64.6)
Multiracial, Non-Hispanic[a]	247 (1.3)	129 (1.4)	118 (1.7)
Other, Non-Hispanic	344 (6.8)	235 (6.8)	206 (6.6)
Hispanic	918 (15.9)	557 (15.8)	494 (15.6)
Education			
Less than high school	448 (10.9)	209 (9.2)	180 (9.9)
High school	2029 (28.8)	1242 (28.1)	1101 (27.1)
Some college	2868 (28.6)	1814 (27.8)	1622 (29.7)
Bachelor's degree or higher	3658 (31.7)	2714 (34.9)	2517 (33.3)
Annual household income			
<30,000	1775 (19.2)	947 (16.8)	825 (15.6)
30,000–74,999	3172 (33.2)	2094 (32.4)	1832 (31.8)
75,000–124,999	2341 (25.1)	1625 (24.9)	1499 (25.7)
≥125,000	1715 (22.5)	1313 (25.8)	1264 (26.9)
Cannabis legalization status (3-level categorical variable)			
Not legal	3059 (35.8)	1751 (32.4)	1424 (29.5)
Medical only	2575 (43.4)	1703 (40.0)	1082 (26.9)
Medical+Recreational	3369 (20.8)	2525 (27.6)	2914 (43.6)
Current cannabis, tobacco/nicotine use and co-use			
Current cannabis use[b]	781 (8.9)	633 (11.1)	617 (12.2)
Current tobacco/nicotine use[c]	1132 (14.6)	619 (13.2)	528 (12.7)
Current cigarette smoking[d]	988 (12.8)	502 (10.6)	426 (10.0)
Current e-cigarette use[e]	289 (3.9)	175 (4.0)	147 (4.3)
Current cannabis and tobacco/nicotine co-use[f]	253 (3.6)	161 (3.6)	148 (3.8)

Numbers shown are unweighted frequencies and weighted percentages for categorical variables and weighted means (SD: standard deviations) for continuous variables.

[a] Respondents who chose two or more race responses and identified as non-Hispanic.

[b] Any self-reported past 30-day cannabis use: smoking, vaporing, edibles, concentrates, or topicals.

[c] Any current ("now") tobacco/nicotine use, including smoking or e-cigarette/vapor products.

[d] Any self-reported current ("now") cigarette smoking.

[e] Any self-reported current ("now") electronic cigarette (e-cigarette) or vapor products use.

[f] Any concurrent use of both cannabis and tobacco/nicotine on single occasion or simultaneously.

Change in prevalence of cannabis and tobacco/nicotine use during 2017–2021

Between 2017 and 2021, the prevalence of current cannabis use significantly increased from 8.9 % to 12.2 % (+3.3 %, $p < 0.001$), while current tobacco/nicotine use declined from 14.6 % to 12.7 % (−1.9 %, $p = 0.002$) with no significant change in co-use of cannabis and tobacco/nicotine (from 3.6 % to 3.8 %, +0.2 %, $p = 0.56$) (Fig. 1). Both cannabis and tobacco/nicotine use changed significantly from 2017 to 2020 (+2.2 %, $p < 0.0001$ and −1.4 %, $p = 0.01$, respectively), but not from

2020 to 2021 (1.1 %, $p = 0.08$ and −0.4 %, $p = 0.49$, respectively) (eTable 4). Sensitivity analysis using respondents with data for all three years of follow-up confirmed the findings for the changes between 2017 and 2021 with the exception that the decline in tobacco/nicotine use was no longer statistically significant (eFig. 2).

Exposure to medical or recreational cannabis legalization were associated with higher odds of cannabis but not tobacco/nicotine use and co-use

US adults residing in states with medical only and medical plus recreational cannabis legalization status had higher odds of current cannabis use, compared to those residing in non-legal states (AOR = 1.27, 95 %CI = 1.03–1.56, $p = 0.02$ and AOR = 1.82, 95 %CI = 1.48–2.23, $p < 0.001$, respectively) (Table 2), controlling for data collection year and socio-demographic characteristics (eTable 6).

Enactment of recreational cannabis legalization either concurrently or following medical legalization was associated with increased odds of current cannabis use among US adults (AOR = 1.43, 95 %CI = 1.18–1.73, $p < 0.001$) compared to medical legalization alone, controlling for data collection year and socio-demographic characteristics (eTable 7). Because medical legalization always occurred before or concurrently with recreational legalization, as before, medical legalization alone was significantly associated with increased odds of current cannabis use compared to no legalization (AOR = 1.27, 95 %CI = 1.03–1.56, $p = 0.02$).

Neither medical nor recreational cannabis legalization was significantly associated with tobacco/nicotine use or co-use of cannabis and tobacco/nicotine (Table 2 and eTable 7).

Table 2
Association of cannabis legalization status with cannabis and tobacco/nicotine use and co-use in U.S. adults during 2017–2021 in the total sample ($n_{2017} = 9003$; $n_{2020} = 5979$; $n_{2021} = 5420$) and for those who completed all 3 years of follow-up ($n = 5053$).

Outcome	Cannabis legalization status	Prevalence (%)	AOR (95 % CI)	*P value*
Total sample: $n_{2017} = 9003$; $n_{2020} = 5979$; $n_{2021} = 5420$				
Current cannabis use[a]	Not legal	6.5	Ref.	
	Medical only	8.1	1.27 (1.03–1.56)	0.02
	Recreational + medical	11.1	1.82 (1.48–2.23)	<0.001
Current tobacco/ nicotine use[b]	Not legal	12.9	Ref.	
	Medical only	13.0	1.01 (0.84–1.20)	0.93
	Recreational + medical	11.5	0.88 (0.72–1.08)	0.21
Current cannabis and tobacco/ nicotine co-use[c]	Not legal	2.1	Ref.	
	Medical only	2.6	1.25 (0.90–1.72)	0.18
	Recreational + medical	2.7	1.26 (0.87–1.84)	0.22
People who completed all 3 years of follow-up: $n = 5053$				
Current cannabis use[a]	Not legal	6.7	Ref.	
	Medical only	7.5	1.14 (0.86–1.51)	0.37
	Recreational + medical	10.8	1.69 (1.28–2.23)	<0.001
Current tobacco/ nicotine use[b]	Not legal	12.1	Ref.	
	Medical only	11.3	0.92 (0.72–1.19)	0.53
	Recreational + medical	10.5	0.86 (0.65–1.12)	0.26
Current cannabis and tobacco/ nicotine co-use[c]	Not legal	1.8	Ref.	
	Medical only	2.2	1.23 (0.77–1.96)	0.40
	Recreational + medical	2.5	1.38 (0.83–2.31)	0.21

All models included year of data collection (continuous year variable, centered at baseline of 2017) and socio-demographic characteristics including age, sex, education, income, and race-ethnicity.

[a] Any self-reported past 30-day use of cannabis (smoking, vaporing, edibles, concentrates, or topicals).

[b] Any self-reported current ("now") tobacco/nicotine use (smoking or e-cigarette/vapor products use).

[c] Any concurrent use of both cannabis and tobacco/nicotine on single occasion or simultaneously.

Abbreviations: AOR, adjusted odds ratio; CI, confidence interval.

Sensitivity analyses

The first sensitivity analysis, where we treated the year covariate as a categorical variable, provided identical results for the effects of cannabis legalization in both models for all respondents with available data (eTable 8).

The second sensitivity analysis, where we limited our sample to respondents who completed all three surveys ($n = 5053$), provided similar results of the primary analysis and confirmed positive associations of recreational cannabis legalization with current cannabis use. Associations with medical cannabis legalization were also positive as in the primary analysis but not statistically significant. Sensitivity models were also consistent in not finding associations of medical or recreational cannabis legalization with tobacco/nicotine use or co-use of cannabis and tobacco/nicotine (eTables 9 and 10).

The third sensitivity analysis confirmed that medical and recreational cannabis legalization were associated with higher odds for current cannabis use with and without adjustments for current tobacco/nicotine use (eTable 11).

The fourth sensitivity analysis revealed no significant associations of either medical or recreational cannabis legalization with current e-cigarette use and no associations for medical cannabis legalization and cigarette smoking, confirming the findings of the primary analysis with a combined current tobacco/nicotine use outcome (eTable 11). Recreational cannabis legalization was associated with lower odds of current cigarette smoking (eTable 11).

The fifth sensitivity analysis revealed that the effect of cannabis legalization change between 2017 and 2021 on use did not vary over the time (see Type III *p*-values in eTable 12). States that remained recreational had the highest and constantly increasing prevalence of cannabis use for all three years of the survey (eFig. 3). In 2017, the second highest prevalence of cannabis use was in states that remained medical, followed by the group of states that had changed their legalization status between 2017 and 2021; however, in 2021, cannabis use was higher in states that had increased legalization during our study time compared to states that remained medical (eFig. 3). There was a significant decrease in tobacco/nicotine use in states, where cannabis remained medically legal during the study period ($b = -0.44 \pm 0.15$, $p = 0.004$, eTable 12), but this single significant result may be an artifact of doing 18 tests for interaction.

Discussion

The current study using national longitudinal data revealed statistically significant increases in current cannabis use among US adults between 2017 and 2021, decreases in current tobacco/nicotine use and no statistically significant changes in co-use of cannabis and tobacco/nicotine. After adjusting for year of data collection and socio-demographic characteristics, medical cannabis legalization was independently associated with higher odds of current cannabis use compared to no legalization. There was a significant independent additional effect of recreational cannabis legalization above the effect of legalizing medical cannabis. Specifically, medical cannabis legalization increased the odds of current cannabis use by a factor of 1.27 compared to no legal use; legalization of recreational cannabis in addition to medical legalization increased the odds of current use by an additional factor of 1.43, bringing the odds of current cannabis use to 1.82 compared to no legalization of medical or recreational use.

This is a novel finding; previous analyses focused solely on medical cannabis legalization (Hasin et al., 2017; Martins et al., 2021; Wen et al., 2015) or examined the combined effect of recreational and medical cannabis legalization on adult use (Bae & Kerr, 2020; Cerdá et al., 2020; Zellers et al., 2023). Recreational cannabis legalization increases the availability of cannabis products and its social acceptance beyond medical cannabis legalization (Baumbusch & Sloan Yip, 2022), likely because medical provider recommendations are not required for recreational cannabis access, and because commercialization of recreational cannabis leads to more sophisticated cannabis products and marketing (Bowling et al., 2020; Lipperman-Kreda & Grube, 2018). A higher density of cannabis dispensaries and delivery services have been associated with greater cannabis demand (Morrison et al., 2014), frequency and increased current cannabis use (Freisthler & Gruenewald, 2014). This, in turn, may change perceived social norms and beliefs about cannabis use, increasing social tolerance and decreasing risk perception.

US adults have lower risk perceptions of cannabis vs. tobacco smoking (Chambers et al., 2023; Nguyen et al., 2023), including in our sample (Chambers et al., 2023). Because our data were collected between 2017 and 2021, increased public awareness of respiratory harms and perceived risks associated with tobacco use and COVID-19 mortality during the pandemic (Benowitz et al., 2022; Gaiha et al., 2020; Yang et al., 2021) could have contributed to the observed shifts in use, potentially resulting in declines in tobacco use. Interestingly, previous analysis of our sample in 2020 revealed mixed findings when participants were asked about changes in cannabis use due to the COVID-19 pandemic: 16.1 % of respondents reported an increase, 14.8 % reported a decrease, and the majority (65.1 %) reported no changes in use (Nguyen et al., 2022). Simultaneous use of cannabis with tobacco was associated with increased cannabis use during COVID-19, while there were no differences by cannabis legalization status (Nguyen et al., 2022). Furthermore, the impact of the EVALI outbreak that also happened during the time of our study remains unclear. Public concerns about the risk of the lung injury associated with any e-cigarettes and then emerging evidence linking EVALI to vitamin E acetate found in cannabis e-cigarettes (Blount et al., 2020; LeBouf et al., 2021; Moritz et al., 2019) could have contributed to decreases in use not only of cannabis but non-cannabis e-cigarettes as well. However, the impact was likely short-term considering the rapid response and development of safety guidance and educational campaigns to inform the public about lung injury risks associated with e-cigarette use.

Although tobacco/nicotine use remains more prevalent than cannabis in all states (Substance Abuse and Mental Health Services Administration, 2022), findings of our study are consistent with past research (Compton et al., 2023; Cornelius et al., 2023; Hasin et al., 2017; Mennis et al., 2021) that indicate falling tobacco use concurrent with increasing rates of cannabis use among US adults. The decline in the overall prevalence of tobacco/nicotine use (smoking or e-cigarette use) observed in our study, however, may not be the result of increasing cannabis legalization. Our analyses revealed mixed findings indicating no significant associations of medical and recreational cannabis legalization with any current tobacco/nicotine use or e-cigarette use, while we observed a significant decrease in tobacco/nicotine use in states with a stable medical cannabis legal status between 2017 and 2021 and saw that legalization of recreational cannabis was associated with lower odds for current cigarette smoking in the sensitivity models. Some may hypothesize that people are substituting cannabis for tobacco due to lower perceived harms of cannabis versus tobacco, especially following the legalization of recreational cannabis (Lucas et al., 2019; McClure et al., 2019), but the effect of recreational cannabis laws on such substitution remains unclear. Our study was designed to test overall trends but not formally test the substitution hypothesis. This and the mixed nature of our findings warrant future investigation to parse out the impact of cannabis legalization on substitution of tobacco/nicotine products with cannabis.

Multiple studies have demonstrated that people increasingly view cannabis as safe, especially compared to tobacco (Chambers et al., 2023; Han et al., 2021; Keyhani et al., 2018; Nguyen et al., 2023) and medicinal cannabis can be beneficial for management of neuropathic pain Allan et al. (2018); Fisher et al. (2021), nausea and vomiting in cancer patients (Allan et al., 2018), and refractory epilepsy of childhood (de Carvalho Reis et al., 2020; Talwar et al., 2023). However, cannabis also has harmful effects, including on cardiovascular (Bailly et al., 2010; Jeffers et al., 2024; Jouanjus et al., 2017; Qiu et al., 2023; X. Wang et al., 2016; Varughese et al., 2024) and respiratory systems (Ghasemiesfe et al., 2018) and neuropsychiatric disorders, especially in young people (Andréasson et al., 1987; Arseneault et al., 2002, 2004; Renard et al., 2014). Frequent cannabis use is associated with cannabis use disorder (Robinson et al., 2022). Therefore, researchers and public health officials have called for legalization of cannabis based on best practices from tobacco control (Barry & Glantz, 2018; Orenstein & Glantz, 2018, 2020), including educational campaigns similar to those used in tobacco to reduce increases in smoking and vaping of cannabis.

Limitations and strengths

First, cannabis use was defined as use in any form (e.g., smoking, e-cigarette, dabbing, edibles) and we did not account for the specific mode of use. Second, we do not have detailed information on cannabis potency. Third, tobacco was defined as smoking cigarettes and/or using e-cigarettes/vapor products (the most prevalent forms of tobacco/nicotine use among US adults Cornelius et al. (2023)); our sample does not include data on other forms of tobacco use. Fourth, these self-reported data of cannabis use measures are subject to social-desirability bias and could have varied pre- versus post-legalization. Fifth, state classification was based on the laws' effective dates, and it could take time to develop functioning legal cannabis marketplaces, which likely biased our findings toward the null. Future research is needed to evaluate whether recreational cannabis commercialization leads to higher social acceptance of cannabis and, subsequently, to higher rates of cannabis experimentation, initiation, and use.

Sixth, the lack of behavioral data before we launched our survey in 2017 did not allow us to formally test the impact of pre- to post-legalization of medical and recreational cannabis on trends in use as many states ($n = 22$) had enacted cannabis legalization policies before our baseline. As an alternative, we ran sensitivity models to examine the impact of increased cannabis legalization (either from not legal to medical/recreational or from medical to recreational) on changes in use between 2017 and 2021, while accounting for those states where cannabis legalization status remained unchanged. Our findings suggested that there was an impact of legalization on increased cannabis use over time; however, our study was underpowered to detect the significant effect given that nine out of 13 states that had a change between 2017 and 2021, increased cannabis legalization status from medical to recreational, and behavioral data pre-legalization were not available before 2017. Furthermore, many states that changed cannabis legalization status during our study time, did so in 2020, providing us only a year of behavioral data post-legalization. Future studies with a longer follow-up time or available data on both pre- and post-legalization are recommended to address this limitation.

Seventh, our study included respondents 18 years and older, which is important to note because the legal age of medicinal cannabis use and possession in most states is 18, and the legal age for recreational cannabis use and possession is 21. However, the percentages of respondents <21 was small (3.2 % in 2017, 0.4 % in 2020, and 0 % in 2021), so including these participants would create minimal or no bias in our estimates. Eighth, there were non-respondents in follow up surveys; however, our response rate was high relative to other longitudinal surveys and comparisons of respondents versus non-respondents revealed small effect sizes for the differences in respondent characteristics. In addition, we used survey weights to address non-response and the results from regression analysis using all available data were similar

to sensitivity models limited to those respondents who participated in all three years of the follow-up. Despite the limitations, the strength of our study is its prospective longitudinal design and the use of a large, nationally representative sample.

Conclusions

This longitudinal survey study of US adults revealed significant increases in current cannabis use between 2017 and 2021 concurrent with declines in tobacco/nicotine use. We did not observe statistically significant changes in co-use of cannabis and tobacco/nicotine. Legalization of medical cannabis was independently associated with increased current cannabis use and legalizing recreational cannabis was associated with a significant additional increase in the odds of current cannabis use beyond medical legalization alone. The odds of tobacco/nicotine use and co-use with cannabis were not associated with cannabis legalization. While decriminalization of cannabis for possession may have social justice benefits in terms of incarceration, the increasing prevalence of cannabis use increases disease risk. Cannabis legalization legislation should incorporate best practices from tobacco control, including market structure and licensing, restrictions on retail cannabis stores, advertising, price and tax measures and protection of nonusers by including inhaled cannabis use in smokefree laws (Barry & Glantz, 2016, 2018; Orenstein & Glantz, 2018, 2020) as well as educational campaigns to increase public awareness on the health risks of cannabis.

Funding

The study was supported by the Tobacco-Related Disease Research Program (#T30IR0988). The content is solely the responsibility of the authors.

Availability of data and material (data transparency)

De-identified data may be made available upon reasonable request to the Principal Investigator, Beth E. Cohen.

Code availability

N/A.

CRediT authorship contribution statement

Vira Pravosud: Writing – original draft, Visualization, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Stanton Glantz:** Writing – review & editing, Methodology, Investigation, Conceptualization. **Salomeh Keyhani:** Writing – review & editing, Methodology, Investigation, Conceptualization. **Pamela M. Ling:** Writing – review & editing. **Lauren K. Lempert:** Writing – review & editing. **Katherine J. Hoggatt:** Writing – review & editing. **Deborah Hasin:** Writing – review & editing. **Nhung Nguyen:** Writing – review & editing. **Francis Julian L. Graham:** Writing – review & editing, Project administration. **Beth E. Cohen:** Writing – review & editing, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization.

Declaration of competing interest

None declared. SG reported receiving personal fees from the World Health Organization outside the submitted work. NN is supported by the California Tobacco-Related Disease Research Program (#T32KT5071) and IPA HSR & D from the US Department of Veterans Affairs Health Services.

Acknowledgments

We thank research participants, research team, and research staff members (including Anne Woods for initial data curation and conducting preliminary analysis).

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.drugpo.2024.104618.

References

Agrawal, A., Budney, A. J., & Lynskey, M. T. (2012). The co-occurring use and misuse of cannabis and tobacco: A review. *Addiction, 107*(7), 1221–1233. https://doi.org/10.1111/j.1360-0443.2012.03837.x

Agrawal, A., Lynskey, M. T., Pergadia, M. L., Bucholz, K. K., Heath, A. C., Martin, N. G., & Madden, P. A. (2008). Early cannabis use and DSM-IV nicotine dependence: A twin study. *Addiction, 103*(11), 1896–1904. https://doi.org/10.1111/j.1360-0443.2008.02354.x

Allan, G. M., Caitlin, R. F., Joey, T., Danielle, P., Jamil, R., Karyn, C., Adrienne, J. L., Christina, K., & Michael, R. K. (2018). Systematic review of systematic reviews for medical cannabinoids. *Canadian Family Physician, 64*(2), e78. http://www.cfp.ca/content/64/2/e78.abstract.

Andréasson, S., Engström, A., Allebeck, P., & Rydberg, U. (1987). Cannabis and schizophrenia a longitudinal study of Swedish conscripts. *The Lancet, 330*(8574), 1483–1486. https://doi.org/10.1016/S0140-6736(87)92620-1

Arseneault, L., Cannon, M., Poulton, R., Murray, R., Caspi, A., & Moffitt, T. E. (2002). Cannabis use in adolescence and risk for adult psychosis: Longitudinal prospective study. *BMJ, 325*(7374), 1212–1213. https://doi.org/10.1136/bmj.325.7374.1212

Arseneault, L., Cannon, M., Witton, J., & Murray, R. M. (2004). Causal association between cannabis and psychosis: Examination of the evidence. *British Journal of Psychiatry, 184*(2), 110–117. https://doi.org/10.1192/bjp.184.2.110

Bae, H., & Kerr, D. C. R. (2020). Marijuana use trends among college students in states with and without legalization of recreational use: Initial and longer-term changes from 2008 to 2018. *Addiction, 115*(6), 1115–1124. https://doi.org/10.1111/add.14939

Bailly, C., Merceron, O., Hammoudi, N., Dorent, R., & Michel, P. L. (2010). Cannabis induced acute coronary syndrome in a young female. *International Journal of Cardiology, 143*(1), e4–e6. https://doi.org/10.1016/j.ijcard.2008.11.200

Barry, R. A., & Glantz, S. (2016). A public health framework for legalized retail marijuana based on the US experience: Avoiding a new tobacco industry. *PLoS Medicine, 13*(9), Article e1002131. https://doi.org/10.1371/journal.pmed.1002131

Barry, R. A., & Glantz, S. A. (2018). Marijuana regulatory frameworks in four US states: An analysis against a public health standard. *American Journal of Public Health, 108*(7), 914–923. https://doi.org/10.2105/ajph.2018.304401

Baumbusch, J., & Sloan Yip, I. (2022). Older adults experiences of using recreational cannabis for medicinal purposes following legalization. *International Journal of Drug Policy, 108*, Article 103812. https://doi.org/10.1016/j.drugpo.2022.103812

Benowitz, N. L., Goniewicz, M. L., Halpern-Felsher, B., Krishnan-Sarin, S., Ling, P. M., O'Connor, R. J., Pentz, M. A., Robertson, R. M., & Bhatnagar, A. (2022). Tobacco product use and the risks of SARS-CoV-2 infection and COVID-19: Current understanding and recommendations for future research. *The Lancet Respiratory Medicine, 10*(9), 900–915. https://doi.org/10.1016/S2213-2600(22)00182-5

Blount, B. C., Karwowski, M. P., Shields, P. G., Morel-Espinosa, M., Valentin-Blasini, L., Gardner, M., Braselton, M., Brosius, C. R., Caron, K. T., Chambers, D., Corstvet, J., Cowan, E., De Jesús, V. R., Espinosa, P., Fernandez, C., Holder, C., Kuklenyik, Z., Kusovschi, J. D., Newman, C., … Pirkle, J. L. (2020). Vitamin E acetate in bronchoalveolar-lavage fluid associated with EVALI. *The New England Journal of Medicine, 382*(8), 697–705. https://doi.org/10.1056/NEJMoa1916433

Bowling, C. M., Hafez, A. Y., & Glantz, S. A. (2020). Public health and medicine's need to respond to cannabis commercialization in the United States: A commentary. *Journal of Psychoactive Drugs, 52*(4), 377–382. https://doi.org/10.1080/02791072.2020.1761040

Carnevale Associates LLC. (2020). *Status of State Marijuana Legalization*. Retrieved September 25 from https://www.carnevaleassociates.com/our-work/status-of-state-marijuana-legalization.html.

Caulkins, J. P. (2024). Changes in self-reported cannabis use in the United States from 1979 to 2022. *Addiction*. https://doi.org/10.1111/add.16519

Cerdá, M., Mauro, C., Hamilton, A., Levy, N. S., Santaella-Tenorio, J., Hasin, D., Wall, M. M., Keyes, K. M., & Martins, S. S. (2020). Association between recreational marijuana legalization in the United States and changes in marijuana use and cannabis use disorder from 2008 to 2016. *JAMA Psychiatry, 77*(2), 165–171. https://doi.org/10.1001/jamapsychiatry.2019.3254

Chambers, J., Keyhani, S., Ling, P. M., Hoggatt, K. J., Hasin, D., Nguyen, N., Woods, A., Ryder, A., & Cohen, B. E. (2023). Perceptions of safety of daily cannabis vs tobacco smoking and secondhand smoke exposure, 2017–2021. *JAMA Network Open, 6*(8), Article e2328691. https://doi.org/10.1001/jamanetworkopen.2023.28691

Choi, A., Dave, D., & Sabia, J. J. (2019). Smoke gets in your eyes: Medical marijuana laws and tobacco cigarette use. *American Journal of Health Economics, 5*(3), 303–333.

Chu, A., Chaiton, M., Kaufman, P., Goodwin, R. D., Lin, J., Hindocha, C., Goodman, S., & Hammond, D. (2023). Co-use, simultaneous use, and mixing of cannabis and

tobacco: A cross-national comparison of Canada and the US by cannabis administration type. *International Journal of Environmental Research and Public Health, 20*(5). https://doi.org/10.3390/ijerph20054206

Compton, W. M., Flannagan, K. S. J., Silveira, M. L., Creamer, M. R., Kimmel, H. L., Kanel, M., Blanco, C., & Volkow, N. D. (2023). Tobacco, alcohol, cannabis, and other drug use in the US before and during the early phase of the COVID-19 pandemic. *JAMA Network Open, 6*(1), Article e2254566. https://doi.org/10.1001/jamanetworkopen.2022.54566

Cornelius, M. E., Loretan, C. G., Jamal, A., Davis Lynn, B. C., Mayer, M., Alcantara, I. C., & Neff, L. (2023). Tobacco product use among adults—United States, 2021. *MMWR Morbidity and Mortality Weekly Report, 72*(18), 475–483. https://doi.org/10.15585/mmwr.mm7218a1

de Carvalho Reis, R., Almeida, K. J., da Silva Lopes, L., de Melo Mendes, C. M., & Bor-Seng-Shu, E. (2020). Efficacy and adverse event profile of cannabidiol and medicinal cannabis for treatment-resistant epilepsy: Systematic review and meta-analysis. *Epilepsy & Behavior, 102*, Article 106635. https://doi.org/10.1016/j.yebeh.2019.106635

DISA. (2023). *Marijuana legality by state*. Retrieved September 25 from https://disa.com/marijuana-legality-by-state.

Erhabor, J., Boakye, E., Obisesan, O., Osei, A. D., Tasdighi, E., Mirbolouk, H., DeFilippis, A. P., Stokes, A. C., Hirsch, G. A., Benjamin, E. J., Rodriguez, C. J., El Shahawy, O., Robertson, R. M., Bhatnagar, A., & Blaha, M. J. (2023). E-cigarette use among US adults in the 2021 behavioral risk factor surveillance system survey. *JAMA Network Open, 6*(11), Article e2340859. https://doi.org/10.1001/jamanetworkopen.2023.40859

Fisher, E., Moore, R. A., Fogarty, A. E., Finn, D. P., Finnerup, N. B., Gilron, I., Haroutounian, S., Krane, E., Rice, A. S. C., Rowbotham, M., Wallace, M., & Eccleston, C. (2021). Cannabinoids, cannabis, and cannabis-based medicine for pain management: A systematic review of randomised controlled trials. *Pain, 162*, S45–S66. https://doi.org/10.1097/j.pain.0000000000001929

Freisthler, B., & Gruenewald, P. J. (2014). Examining the relationship between the physical availability of medical marijuana and marijuana use across fifty California cities. *Drug and Alcohol Dependence, 143*, 244–250. https://doi.org/10.1016/j.drugalcdep.2014.07.036

Gaiha, S. M., Lempert, L. K., & Halpern-Felsher, B. (2020). Underage youth and young adult e-cigarette use and access before and during the coronavirus disease 2019 pandemic. *JAMA Network Open, 3*(12), Article e2027572. https://doi.org/10.1001/jamanetworkopen.2020.27572

Ghasemiesfe, M., Ravi, D., Vali, M., Korenstein, D., Arjomandi, M., Frank, J., Austin, P. C., & Keyhani, S. (2018). Marijuana use, respiratory symptoms, and pulmonary function. *Annals of Internal Medicine, 169*(2), 106–115. https://doi.org/10.7326/m18-0522%m 29971337

Han, B. H., Funk-White, M., Ko, R., Al-Rousan, T., & Palamar, J. J. (2021). Decreasing perceived risk associated with regular cannabis use among older adults in the United States from 2015 to 2019. *Journal of the American Geriatrics Society, 69*(9), 2591–2597. https://doi.org/10.1111/jgs.17213

Hasin, D. S., Sarvet, A. L., Cerdá, M., Keyes, K. M., Stohl, M., Galea, S., & Wall, M. M. (2017). US adult illicit cannabis use, cannabis use disorder, and medical marijuana laws: 1991–1992 to 2012–2013. *JAMA Psychiatry, 74*(6), 579–588. https://doi.org/10.1001/jamapsychiatry.2017.0724

Hasin, D. S., Wall, M. M., Choi, C. J., Alschuler, D. M., Malte, C., Olfson, M., Keyes, K. M., Gradus, J. L., Cerdá, M., Maynard, C. C., Keyhani, S., Martins, S. S., Fink, D. S., Livne, O., Mannes, Z., Sherman, S., & Saxon, A. J. (2023). State cannabis legalization and cannabis use disorder in the US veterans health administration, 2005 to 2019. *JAMA Psychiatry, 80*(4), 380–388. https://doi.org/10.1001/jamapsychiatry.2023.0019

Hindocha, C., Shaban, N. D., Freeman, T. P., Das, R. K., Gale, G., Schafer, G., Falconer, C. J., Morgan, C. J., & Curran, H. V. (2015). Associations between cigarette smoking and cannabis dependence: A longitudinal study of young cannabis users in the United Kingdom. *Drug and Alcohol Dependence, 148*, 165–171. https://doi.org/10.1016/j.drugalcdep.2015.01.004

Hublet, A., Bendtsen, P., de Looze, M. E., Fotiou, A., Donnelly, P., Vilhjalmsson, R., Baska, T., Aasvee, K., Franelic, I. P., Nic Gabhainn, S., & ter Bogt, T. F. (2015). Trends in the co-occurrence of tobacco and cannabis use in 15-year-olds from 2002 to 2010 in 28 countries of Europe and North America. *European Journal of Public Health, 25*(Suppl 2), 73–75. https://doi.org/10.1093/eurpub/ckv032

Jeffers, A. M., Glantz, S., Byers, A. L., & Keyhani, S. (2024). Association of cannabis use with cardiovascular outcomes among US adults. *Journal of the American Heart Association, 13*(5), Article e030178. https://doi.org/10.1161/jaha.123.030178

Jouanjus, E., Raymond, V., Lapeyre-Mestre, M., & Wolff, V. (2017). What is the current knowledge about the cardiovascular risk for users of cannabis-based products? A systematic review. *Current Atherosclerosis Reports, 19*(6), 26. https://doi.org/10.1007/s11883-017-0663-0

Kerr, D. C., Bae, H., Phibbs, S., & Kern, A. C. (2017). Changes in undergraduates' marijuana, heavy alcohol and cigarette use following legalization of recreational marijuana use in Oregon. *Addiction, 112*(11), 1992–2001.

Kerr, D. C. R., Bae, H., & Koval, A. L. (2018). Oregon recreational marijuana legalization: Changes in undergraduates' marijuana use rates from 2008 to 2016. *Psychology of Addictive Behaviors, 32*(6), 670–678. https://doi.org/10.1037/adb0000385

Keyhani, S., Steigerwald, S., Ishida, J., Vali, M., Cerdá, M., Hasin, D., Dollinger, C., Yoo, S. R., & Cohen, B. E. (2018). Risks and benefits of marijuana use: A national survey of U.S. adults. *Annals of Internal Medicine, 169*(5), 282–290. https://doi.org/10.7326/m18-0810

King, B. A., Gammon, D. G., Marynak, K. L., & Rogers, T. (2018). Electronic cigarette sales in the United States, 2013–2017. *JAMA, 320*(13), 1379–1380. https://doi.org/10.1001/jama.2018.10488

LeBouf, R. F., Ranpara, A., Ham, J., Aldridge, M., Fernandez, E., Williams, K., Burns, D. A., & Stefaniak, A. B. (2021). Chemical emissions from heated vitamin E acetate-insights to respiratory risks from electronic cigarette liquid oil diluents used in the aerosolization of Δ(9)-THC-containing products. *Frontiers in Public Health, 9*, Article 765168. https://doi.org/10.3389/fpubh.2021.765168

Lipperman-Kreda, S., & Grube, J. W. (2018). Impacts of marijuana commercialization on adolescents' marijuana beliefs, use, and co-use with other substances. *The Journal of Adolescent Health, 63*(1), 5–6. https://doi.org/10.1016/j.jadohealth.2018.05.003

Lucas, P., Baron, E. P., & Jikomes, N. (2019). Medical cannabis patterns of use and substitution for opioids & other pharmaceutical drugs, alcohol, tobacco, and illicit substances; results from a cross-sectional survey of authorized patients. *Harm Reduction Journal, 16*(1), 9. https://doi.org/10.1186/s12954-019-0278-6

Martins, S. S., Segura, L. E., Levy, N. S., Mauro, P. M., Mauro, C. M., Philbin, M. M., & Hasin, D. S. (2021). Racial and ethnic differences in cannabis use following legalization in US states with medical cannabis laws. *JAMA Network Open, 4*(9), Article e2127002. https://doi.org/10.1001/jamanetworkopen.2021.27002

McClure, E. A., Tomko, R. L., Salazar, C. A., Akbar, S. A., Squeglia, L. M., Herrmann, E., Carpenter, M. J., & Peters, E. N. (2019). Tobacco and cannabis co-use: Drug substitution, quit interest, and cessation preferences. *Experimental and Clinical Psychopharmacology, 27*(3), 265–275. https://doi.org/10.1037/pha0000244

Meier, E., & Hatsukami, D. K. (2016). A review of the additive health risk of cannabis and tobacco co-use. *Drug and Alcohol Dependence, 166*, 6–12. https://doi.org/10.1016/j.drugalcdep.2016.07.013

Mennis, J., Stahler, G. J., & McKeon, T. P. (2021). Young adult cannabis use disorder treatment admissions declined as past month cannabis use increased in the U.S.: An analysis of states by year, 2008–2017. *Addictive Behaviors, 123*, Article 107049. https://doi.org/10.1016/j.addbeh.2021.107049

Moritz, E. D., Zapata, L. B., Lekiachvili, A., Glidden, E., Annor, F. B., Werner, A. K., Ussery, E. N., Hughes, M. M., Kimball, A., DeSisto, C. L., Kenemer, B., Shamout, M., Garcia, M. C., Reagan-Steiner, S., Petersen, E. E., Koumans, E. H., Ritchey, M. D., King, B. A., Jones, C. M., … Chatham-Stephens, K. (2019). Update: Characteristics of patients in a national outbreak of E-cigarette, or vaping, product use-associated lung injuries—United States, October 2019. *MMWR Morbidity and Mortality Weekly Report, 68*(43), 985–989. https://doi.org/10.15585/mmwr.mm6843e1

Morrison, C., Gruenewald, P. J., Freisthler, B., Ponicki, W. R., & Remer, L. G. (2014). The economic geography of medical cannabis dispensaries in California. *International Journal of Drug Policy, 25*(3), 508–515. https://doi.org/10.1016/j.drugpo.2013.12.009

Nguyen, N., Holmes, L. M., Pravosud, V., Cohen, B. E., & Ling, P. M. (2023). Changes in perceived harms of tobacco and cannabis and their correlations with use: A panel study of young adults 2014–2020. *Addictive Behaviors, 144*, Article 107758. https://doi.org/10.1016/j.addbeh.2023.107758

Nguyen, N., Keyhani, S., Ling, P. M., Hoggatt, K. J., Hasin, D., & Cohen, B. E. (2022). Self-reported changes in cannabis use due to the COVID-19 pandemic among US adults. *Journal of Psychoactive Drugs, 54*(4), 295–299. https://doi.org/10.1080/02791072.2022.2058897

Orenstein, D. G., & Glantz, S. A. (2018). Regulating cannabis manufacturing: applying public health best practices from tobacco control. *Journal of Psychoactive Drugs, 50*(1), 19–32. https://doi.org/10.1080/02791072.2017.1422816

Orenstein, D. G., & Glantz, S. A. (2020). Cannabis legalization in state legislatures: Public health opportunity and risk. *Marquette Law Review, 103*(4), 1313–1400.

Qiu, H., Zhang, H., Han, D. D., Derakhshandeh, R., Wang, X., Goyal, N., Navabzadeh, M., Rao, P., Wilson, E. E., Mohammadi, L., Olgin, J. E., & Springer, M. L. (2023). Increased vulnerability to atrial and ventricular arrhythmias caused by different types of inhaled tobacco or marijuana products. *Heart Rhythm, 20*(1), 76–86. https://doi.org/10.1016/j.hrthm.2022.09.021

Renard, J., Krebs, M.-O., Le Pen, G., & Jay, T. M. (2014). Long-term consequences of adolescent cannabinoid exposure in adult psychopathology [Review]. *Frontiers in Neuroscience, 8*. https://doi.org/10.3389/fnins.2014.00361

Robinson, T., Ali, M. U., Easterbrook, B., Coronado-Montoya, S., Daldegan-Bueno, D., Hall, W., Jutras-Aswad, D., & Fischer, B. (2022). Identifying risk-thresholds for the association between frequency of cannabis use and development of cannabis use disorder: A systematic review and meta-analysis. *Drug and Alcohol Dependence, 238*, Article 109582. https://doi.org/10.1016/j.drugalcdep.2022.109582

Smart, R., & Pacula, R. L. (2019). Early evidence of the impact of cannabis legalization on cannabis use, cannabis use disorder, and the use of other substances: Findings from state policy evaluations. *The American Journal of Drug and Alcohol Abuse, 45*(6), 644–663. https://doi.org/10.1080/00952990.2019.1669626

Substance Abuse and Mental Health Services Administration. (2018). *The 2018 national survey on drug use and health: Detailed tables*. Substance Abuse Center for Behavioral Health Statistics and Quality. Retrieved December 14 from https://www.samhsa.gov/data/report/2018-nsduh-detailed-tables.

Substance Abuse and Mental Health Services Administration. (2022). *Key substance use and mental health indicators in the United States: Results from the 2021 national survey on drug use and health (HHS publication no. PEP22-07-01-005, NSDUH series H-57)*. Substance Abuse and Mental Health Services Administration. Retrieved October 3 from https://www.samhsa.gov/data/report/2021-nsduh-annual-national-report.

Talwar, A., Estes, E., Aparasu, R., & Reddy, D. S. (2023). Clinical efficacy and safety of cannabidiol for pediatric refractory epilepsy indications: A systematic review and meta-analysis. *Experimental Neurology, 359*, Article 114238. https://doi.org/10.1016/j.expneurol.2022.114238

Varughese, V. J., Mathai, Y., Cara, J., & Carlyle, L. (2024). Adverse cardiovascular outcomes in young cannabis users: A nationwide analysis. *Hearts, 5*(4), 421–428. https://doi.org/10.3390/hearts5040030

Wang, J. B., Ramo, D. E., Lisha, N. E., & Cataldo, J. K. (2016a). Medical marijuana legalization and cigarette and marijuana co-use in adolescents and adults. *Drug and Alcohol Dependence, 166*, 32–38. https://doi.org/10.1016/j.drugalcdep.2016.06.016

Wang, X., Derakhshandeh, R., Liu, J., Narayan, S., Nabavizadeh, P., Le, S., Danforth, O. M., Pinnamaneni, K., Rodriguez, H. J., Luu, E., Sievers, R. E., Schick, S. F., Glantz, S. A., & Springer, M. L. (2016b). One Minute of Marijuana Secondhand Smoke Exposure Substantially Impairs Vascular Endothelial Function. *Journal of the American Heart Association, 5*(8). https://doi.org/10.1161/jaha.116.003858

Wen, H., Hockenberry, J. M., & Cummings, J. R. (2015). The effect of medical marijuana laws on adolescent and adult use of marijuana, alcohol, and other substances. *Journal of Health Economics, 42*, 64–80. https://doi.org/10.1016/j.jhealeco.2015.03.007

Yang, Y., Lindblom, E. N., Salloum, R. G., & Ward, K. D. (2021). Perceived health risks associated with the use of tobacco and nicotine products during the COVID-19 pandemic. *Tobacco Induced Diseases, 19*, 46. https://doi.org/10.18332/tid/136040

Zellers, S. M., Ross, J. M., Saunders, G. R. B., Ellingson, J. M., Anderson, J. E., Corley, R. P., Iacono, W., Hewitt, J. K., Hopfer, C. J., McGue, M. K., & Vrieze, S. (2023). Impacts of recreational cannabis legalization on cannabis use: A longitudinal discordant twin study. *Addiction, 118*(1), 110–118. https://doi.org/10.1111/add.16016