Use of highly-potent cannabis concentrate products:
more common in U.S. states with recreational or medical cannabis laws.

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None.

Abstract

Background: Highly-potent cannabis products, e.g., concentrates, entail greater risks of cannabis-related harms than lower-potency products such as plant or flower material. However, little information is available on whether individuals in U.S. states with recreational cannabis laws (RCL) or medical cannabis laws (MCL) are more likely than individuals in U.S. states without cannabis legalization (no-CL) to use highly-potent forms of cannabis.

Methods: Cannabis-using adults in a 2017 online survey (N=4,064) provided information on state of residence and past-month cannabis use, including types of products used, categorized as low-potency (smoked or vaped plant cannabis) or high-potency (vaping or dabbing concentrates). Multivariable logistic regression models generated adjusted odds ratios (aOR) and 95% confidence intervals (CI) for use of high-potency cannabis products by state cannabis legalization status (RCL, MCL, no-CL).

Results: Compared to participants in no-CL states, participants in RCL states had greater odds of using high-potency concentrate products (aOR=2.61;CI=1.77-3.86), as did participants in MCL-only states (aOR=1.55;CI=1.21-1.97). When participants in RCL states and MCL states were directly compared, those in RCL states had greater odds of using high-potency concentrate products (aOR=1.69;CI=1.27-2.42).

Discussion: Although the sample was not nationally representative and the cross-sectional data precluded determining the direction of effect, results suggest that use of high-potency cannabis concentrates is more likely among those in RCL states. Clinicians in RCL states should screen cannabis users for harmful patterns of use. Policymakers in states that do not yet have RCL should consider these findings when drafting new cannabis laws, including the specific products permitted and how best to regulate them.

Keywords: Cannabis, marijuana, potency, legalization, vaping, concentrates

1. Introduction

In the United States (US), laws and attitudes towards cannabis are changing, as evidenced by the legalization of medical cannabis use in 36 states since 1996, and recreational cannabis use in 18 states since 2012. Although Americans increasingly believe that cannabis use is harmless (Chiu et al., 2021; Compton et al., 2016), a meta-analysis shows that ~20% of cannabis users develop cannabis use disorder (CUD) (Leung et al., 2020), with greatest risk among frequent users (Leung et al., 2020), while CUD is associated with considerable impairment, as shown on a widely used functional impairment scale (Hasin et al., 2016), and CUD is also with multiple psychosocial and health problems (Gutkind et al., In Press). Cannabis use is also associated with other problems, including impaired driving (Dahlgren et al., 2020; Preuss et al., 2021; Sevigny, 2021), mental disorders (Hasin et al., 2016; Hines et al., 2020), hyperemesis syndrome (Perisetti et al., 2020) and cardiovascular events (Sun et al., 2020; Yang et al., 2021). Frequent adult cannabis use and related problems have increased in recent years (Brown et al., 2017; Chiu et al., 2021; Compton et al., 2016; Hasin et al., 2015). These increases are greater in states that legalized cannabis for medical or recreational use (Cerda et al., 2020; Chiu et al., 2021; Cook et al., 2020; Fink et al., 2020; Hasin et al., 2017). Determining the factors underlying these increases is an important public health priority.

One potential underlying factor is the potency of the products used. While cannabis is composed of many compounds, the potency of cannabis products is typically characterized by concentration of delta 9-tetrahydrocannabinol (THC), the major psychoactive compound (ElSohly et al., 2021; Radwan et al., 2021). Studies consistently show that on average, cannabis concentrates have substantially higher THC potency than plant/flower cannabis products (Daniulaityte et al., 2017; ElSohly et al., 2016; Mehmedic et al., 2010; Smart et al., 2017), including a recent meta-analysis of 12 studies conducted in 7 countries (Freeman et al., 2021). Further, while cannabis concentrates could theoretically contain predominantly cannabidiol (CBD) rather than THC, CBD products constituted only 5% of the cannabis market (BDS Analytics, 2019) as recently as 2017, most CBD products are not marketed as concentrates, and while CBD product use has increased since 2017, THC products remain the dominant product in the cannabis market (Research and Markets, 2021). Thus, reported use of a cannabis concentrate is very likely to involve use of a high-THC product. Cannabis products with higher

THC concentrations (i.e., higher-potency products) are associated with greater risk of harms (Brunette et al., 2018; Chiu et al., 2021; Englund et al., 2017; Freeman and Winstock, 2015; Rigucci et al., 2016), including more rapid progression to first symptoms of CUD (Arterberry et al., 2019), CUD severity(Freeman and Winstock, 2015), anxiety disorders(Hines et al., 2020), psychotic disorders(Di Forti et al., 2015), and other cannabis-related problems (e.g., with memory (Freeman and Winstock, 2015; Hines et al., 2020), family or friends(Hines et al., 2020)). Although flower products remain the most commonly used, cannabis concentrates are increasing in popularity (Bidwell et al., 2021; Schaneman, 2021; Spindle et al., 2019). Thus, determining whether state cannabis legalization status is associated with use of cannabis concentrate products, with their high likelihood of having higher THC potency than plant/flower cannabis, is an important element in understanding the public health impact of changing cannabis laws.

Surprisingly little is known about adult likelihood of using a high-potency product by state cannabis legalization status, i.e., states with a recreational cannabis law (RCL), a medical cannabis law (MCL) or neither (no-CL). Instead, most studies examined RCL/MCL and route of administration (e.g., smoking vs. vaping). For example, in a 2014-2015 online national survey of cannabis users (Borodovsky et al., 2016), those in MCL states (but not RCL states) were more likely to report that they ever vaped cannabis than those in no-CL states. In a 2016 12-state survey (Schauer et al., 2020) (including 3 RCL states), living in a MCL or RCL state was not consistently associated with routes of administration. A 2020 US study of routes of administration showed that vaping was more likely in RCL and MCL states than in no-CL states (Shi, 2021). A 2018 study in Canada and the US (Goodman et al., 2020) did differentiate products used from routes of administration, showing that participants in US RCL states were more likely to vape plant cannabis than those in other US states, although they did not differ in their use of concentrates. However, this study grouped MCL states together with no-CL states. Because MCL and no-CL states have been shown to differ on many cannabis outcomes (Fink et al., 2020; Hasin et al., 2017; Martins et al., 2016; Mauro et al., 2019; Wen et al., 2015), grouping MCL with no-CL states may have obscured some distinctions. Finally, a Twitter-based survey found that those residing in RCL or MCL-only states were more likely than others to use cannabis concentrates (Daniulaityte et al., 2018). Thus, while studies suggest that MCL or RCL alter the likelihood of different routes of administration, only one study addressed whether living in RCL or MCL-only states affected the likelihood of using high-potency concentrate cannabis products. Because different Web-based platforms for survey recruitment can introduce differences in participant selection and

characteristics (Daniulaityte et al., 2018), additional studies are needed about state cannabis legalization and use of high-potency cannabis products such as concentrates. Accordingly, we analyzed data from cannabis users in a large U.S. adult online sample recruited via Facebook to provide more information about the relationship of RCL, MCL and no-CL to adult use of high-potency cannabis products, i.e., those involving concentrates.

2. Methods

2.1 Recruitment and Sample

As described elsewhere (Borodovsky et al., 2020), adults age ≥18 years in the 50 U.S. states and Washington, D.C. (DC) were recruited to participate in an online survey between 08/14/2017 and 10/01/2017 via targeted Facebook social media advertisements (see Supplementary Appendix 1). The Dartmouth Committee for the Protection of Human Subjects approved the survey. Two different advertisement strategies were used to increase the proportion of cannabis users in the survey (Borodovsky et al., 2018). The first advertised a cannabis-specific research study without mentioning any incentive to recruit more frequent users. The second strategy advertised generic information about a research study and a chance to be randomly selected to win a $10 Amazon gift code upon survey completion to recruit less frequent users. Via a URL in the advertisement, potential participants were directed to an electronic consent page that briefly explained the study and confidentiality. After consenting, participants completed an anonymous questionnaire covering demographic characteristics, state and ZIP code of residence, and cannabis use behaviors. Of the original sample (Borodovsky et al., 2020), the present analytic subset included the 4,064 participants who used cannabis at least once in the prior 30 days, had complete information on control variables (2 were excluded due to incomplete information) and provided responses on routes of administration involving plant cannabis or concentrates.

2.2 Measures

2.2.1 State Cannabis Law Status

Our main predictors consisted of state cannabis laws at the time data were collected. Participants were asked their current state of residence, and effective state law status was coded based on whether legislation had gone into effect by the time of the survey in 2017. RCL and MCL enactment was determined by publicly available state legislative policies (Ballotpedia; Britannica ProCon, 2017; Marijuana Policy Project; National Organization for the

Reform of Marijuana Laws; Prescription Drug Abuse Policy System, February 1 2017). Only states with laws permitting use of cannabis products containing THC for medical purposes were classified as MCL states; states with CBD-only laws were not considered MCL states. Note that all states with RCL also had MCL. Two variables were created to operationalize state law status. The first indicated the presence or absence of RCL: participants living in states with an RCL were coded as positive, and all others as negative. The second was a 3-level variable. Participants were categorized as living in a state with an RCL, living in a state with an MCL but no RCL (MCL-only), or living in a state without RCL or MCL (no-CL).

2.2.2 Classification of Cannabis Products Used

Initial survey questions on cannabis use covered lifetime use of particular cannabis products and their routes of administration (see Supplementary Appendix 2), including four categories: smoking; vaping plant material; vaping concentrates; and using concentrates with a dab rig, referred to hereafter as dabbing. Because the question on smoking did not specify that the product smoked was plant/flower, but smoking concentrates is a very atypical method of using them, we classified participants who endorsed smoking as users of plant/flower. Among all participants acknowledging lifetime use of smoking, vaping plant material, vaping concentrates, or dabbing concentrates, questions covered the frequency of their use within the past 30 days. For example, participants who endorsed lifetime smoking and lifetime vaping of concentrates were asked about the frequency of both smoking and vaping of concentrates within the past 30 days. The 30-day period was used to improve recall by covering a recent period. Endorsement of use of any concentrate in the prior 30 days, either by vaping or dabbing, was considered an indicator of high-potency use. Endorsement of any smoking or vaping of plant/flower was considered an indicator of low-potency use. All participants who had any use of concentrates (vaping or dabbing) in the prior 30 days were classified as users of high-potency products. All others were classified as users of low-potency products only.

We created variables for a sensitivity analysis designed to provide a more nuanced indicator of prior-month high-potency use by indicating the proportion of all use that was high-potency. For this, we constructed an outcome variable as follows. Frequency of any prior-month use was assessed by asking "How many days have you used cannabis (marijuana) in the past 30 days?", with 8 response options: 0 days, 1-2 days, 3-5 days, 6-9 days, 10-

19 days, 20-25 days, 26-29 days, or 30 days, assigned values of 0-7, respectively. Analogous questions assessed the frequency of vaping or dabbing concentrates. To calculate the proportion of participants' total prior-month use that was high-potency, the frequency of high-potency use was divided by the frequency of any prior-month use. For example, a respondent with high-potency use for 3-5 days in the prior month (category 2), and any prior-month use of 20-25 days (category 5) was assigned a value of 2/5=0.4. The values of this variable could range from 0.0-1.0. Among participants reporting more frequent high-potency use than any prior-month use (n=59), the proportion of high-potency use was capped at 1.0.

2.2.3 Covariates

Individual-level sociodemographic control variables included age (18-20; 21-29; 30-44; 45-64; 65+), race/ethnicity (White; Black; Hispanic; other), gender (male; female; other), employment status (any full or part-time job; none), and education level (some high school or less; high school graduate or more). As in prior studies using these data (Borodovsky et al., 2020), advertising recruitment strategy was also included as a covariate. We also included a dichotomized age variable to explore the effect of being underage (i.e., age 18-20) vs. age 21 and older in sensitivity analyses.

State-level control variables created with 2017 U.S. census data from the American Community Survey provided by Geolytics (Geolytics, 2021) included gender (% of state population that was male); race/ethnicity (% non-Hispanic While); age (% aged <30 years); and urbanicity (state population density). Additional state-level control variables included % of population in poverty (United States Census Bureau, 2018); state unemployment rate, 2017 (United States Department of Labor, 2018); and percent used cannabis in the past month (average of 2016-2017 and 2017-2018 estimates from the National Survey on Drug Use and Health) (Substance Abuse and Mental Health Data Archive).

2.2.4 Analysis

After generating descriptive statistics of the sample characteristics, logistic regression was used to assess the association of state cannabis laws with use of high-potency cannabis products/concentrates by modeling the state law variables as predictors. Separate analyses were conducted for the 2-level RCL predictor (yes/no) and

for the 3-level predictor (RCL, MCL-only, no-CL). Unadjusted models were run, and then models adjusted for the individual- and state-level control covariates, producing unadjusted odds ratios (OR) or adjusted odds ratios (aOR) and 95% confidence intervals (CI). For analyses involving the 3-level cannabis law predictor, to determine if the effects of RCL vs. no-CL and MCL-only vs. no-CL differed, contrasts were conducted using Wald tests. All analyses used SAS 9.4 software (SAS Institute Inc, Copyright © 2013).

In one sensitivity analysis, the proportion of use that was high-potency was analyzed as an alternative outcome. Since the proportional measure best fit the normal distribution, linear regression was used. Regression coefficients are reported, with 95% CIs, considered significant if not overlapping with 0. To determine if the effects of RCL vs. no-CL and MCL-only vs. no-CL differed, contrasts were conducted using F-tests.

In additional sensitivity analyses regarding age, we first removed all participants who were underage for legal use, i.e., age 18-20, and re-ran the analyses on the subset of remaining participants. Next, in models of CL effects in the full sample (all ages included), we added interaction (age 18-20 vs. 21 and older) by state law predictor terms in order to determine whether the state cannabis laws had significantly different effects in these age groups.

3. Results

3.1 Sample characteristics

Participants lived in all 50 states and Washington, D.C., with a range of 3 participants in D.C. to 442 participants in California (Figure 1). Of the sample (Table 1), 52.0% were male, 68.2% aged <30 years, 21.3% non-White, 54.2% unemployed, and 36.7% had high school education or less. Over a quarter (26.5%) resided in an RCL state, 41.1% in an MCL-only state, and 32.4% in a no-CL state. Nearly all (98.4%) reported using smoking or vaping plant cannabis (Table 2), with 96.9% reporting smoking and 29.1% reporting vaping. Use of concentrates was reported by 54.2%, with 44.9% reporting vaping concentrates, and 35.7% reporting dabbing. Of those using concentrates, the vast majority (97.2%) also reported using low-potency products. Prevalence of daily cannabis use was 40.3%, with 66.2% using 20 or more days a month.

3.2 State cannabis law status and high-potency use (Table 3)

Analysis of the 2-level cannabis law predictor indicated that compared to participants in states with no RCL, participants in RCL states had greater odds of using high-potency concentrates in unadjusted (OR=1.94; CI=1.68, 2.24) and adjusted models (aOR=1.61;CI=1.22, 2.13). Using the 3-level cannabis law predictor, compared to participants in no-CL states, participants in RCL states had greater odds of using high-potency concentrates in unadjusted (OR=2.41;CI=2.04, 2.85) and adjusted models (aOR=2.61;CI=1.77, 3.86) as did participants in MCL-only states in unadjusted (OR=1.48; 95% CI=1.28, 1.71) and adjusted models (aOR=1.55; CI=1.21, 1.97). Wald tests indicated that the RCL effect was stronger than the MCL-only effect (unadjusted: χ^2= 36.38; p<0.0001; adjusted: χ^2=13.24; p=0.0003), and compared to participants in MCL-only states, participants in RCL states had greater odds of using high-potency concentrates in unadjusted (OR=1.63;CI=1.39, 1.91) and adjusted models (aOR=1.69;CI=1.27, 2.42).

3.3 Sensitivity analyses

In models of the proportion of past 30-day use that involved use of high-potency concentrates (Table 4), analysis of the 2-level cannabis law predictor indicated that compared to participants in states with no RCL, the proportion of high-potency use was greater among participants in RCL states (adjusted beta=0.09, 95% CI=0.04, 0.13). In analysis of the 3-level cannabis law predictor, compared to participants in no-CL states, the proportion of high-potency use was greater among participants in RCL states (adjusted beta=0.16, 95% CI=0.09, 0.22) and greater among those in MCL-only states (adjusted beta=0.06, 95% CI=0.02, 0.10). F-tests showed that the effect of RCL was greater than MCL-only (f=16.74,p=<0.0001). The proportion of high-potency concentrate use was greater among participants in RCL states than in MCL-only states (adjusted beta=0.09, 95% CI=0.04, 0.14).

Of the participants, 37.7% (n=1,533) were age 18-20 and 62.3% (n=2,531) were 21 years or older. Removing the participants who were age 18-20 had essentially no effect on the results (Supplementary Tables 1 and 2). There was no significant interaction between state law predictors and age (18-20 vs 21+) for any use of a high-potency cannabis concentrate product (Supplementary Table 3) or the proportion of cannabis use that involved high-potency concentrates (Supplementary Table 4), indicating that being underage did not modify the effects of the state cannabis laws.

4. Discussion

This study is the first to examine the relationship of state recreational cannabis laws (RCL) and medical cannabis laws (MCL-only) to the use of high-potency cannabis concentrate products in a large sample of cannabis users. Data were analyzed from 4,064 adult cannabis users age ≥18 years in the 50 U.S. states and D.C. who participated in a 2017 online survey. Study measures differeniated smoking, vaping plant material, vaping concentrates, and dabbing concentrates in the prior 30 days, with participants with any use of concentrates characterized as users of high-potency cannabis products. Overall, participants living in states with an RCL at the time of the survey were more likely than others to use high-potency cannabis concentrates, results that were robust to control for multiple individual- and state-level control covariates, including whether participants were underage (age 18-20) or not. Further, when participants in RCL states, MCL-only states, and states with no cannabis legalization (no-CL) were compared, participants in RCL as well as MCL-only states were more likely to use high-potency concentrates than those in no-CL states. Further, participants in RCL states were more likely to use high-potency concentrates than participants in MCL-only states.

Previous studies of adults suggested that legalization of cannabis use for medical or recreational purposes is associated with routes of administration, but few studies specified the products used and their potencies. Results were somewhat inconsistent. A Canadian/US study did not show a difference in use of concentrates between residents of RCL and other states (Goodman et al., 2020), but this study combined participants in MCL-only and no-CL states. A Twitter-based survey found that those in both RCL and MCL-only states were more likely than others to use cannabis concentrates (Daniulaityte et al., 2018). Our results are consistent with this latter study. The many studies showing differences between MCL and no-CL states on multiple cannabis outcomes (Fink et al., 2020; Hasin et al., 2017; Martins et al., 2016; Mauro et al., 2019; Wen et al., 2015) suggest the importance of continuing to differentiate MCL-only from no-CL states, and of conducting additional studies using a variety of sample designs.

Policy experts have speculated that the emergence of a legal cannabis retail market via RCLs would provide wider access to more potent cannabis products (Hall and Lynskey, 2020; Matheson and Le Foll, 2020), but noted current gaps in knowledge and the need for more studies (Hall et al., 2019). The present study takes a step in the direction of filling these gaps by exploring differences in high-potency cannabis use among those living in RCL, MCL and no-CL states.

In interpreting our results, an important consideration is that the associations are based on cross-sectional data from a single year (2017) and do not indicate the direction of effect (i.e., did state laws lead to high-potency use, or did increasingly common high-potency use within certain states lead to public support for RCL passage and enactment?). A more informative design would involve multiple years of data analyzed with difference-in-difference or synthetic control statistical methods. These would allow comparing pre-post change in prevalence of using high-potency products in states that changed their laws to contemporaneous changes in states that did not change their laws. Future studies should utilize such methods as data become available. In the meantime, the present study provides novel and important information on an issue that is highly salient to evaluating potential health effects of the rapidly changing legal status of cannabis in the U.S.

Studies have shown that individuals can partially titrate their THC exposure from higher-potency products by varying their cannabis self-administration behaviors to limit the dose to which they are exposed (Freeman et al., 2014; van der Pol et al., 2014). If such dose-reducing behaviors always occurred, this would reduce the public health relevance of state laws as a factor in state-level variation in use of high-potency products. However, such behaviors do not fully compensate for variation in THC concentrations, and therefore, greater THC concentrations deliver higher THC doses to the user (Freeman et al., 2021). Further, users of concentrates have been shown to select these products for reasons such as "stronger intoxication effect", "effects last longer" and "fewer hits are necessary" (Loflin and Earleywine, 2014), suggesting that many concentrate users are not only exposed to higher doses of THC but in fact, deliberately seek out these products because of their potency. Given that high-potency products are associated with higher risk of cannabis-related harms, state-level factors associated with use of high-potency concentrates such as state cannabis laws are thus highly relevant to public health.

Potential mechanisms can be posited for both possible directions of effect for our findings. RCL could have led to increased use of high-potency concentrate use by stimulating growth of an active, commercialized industry that developed and marketed novel, high-potency cannabis products (Chiu et al., 2021; Hall and Lynskey, 2020; Hall et al., 2019). Such a mechanism is plausible since state RCLs have often been followed by a proliferation of online and retail outlets and dispensaries that make high-potency products more easily accessible (Smart et al., 2017) and possibly normalize their use, increasing their popularity with consumers. Even MCL-only in the

absence of RCL may impact use of specific cannabis products through increased availability due to the proliferation of cannabis dispensaries (Borodovsky et al., 2017; Shi, 2021). Alternatively, the other direction of effect could be explained if a growing demand for high-potency types of cannabis within certain states prior to MCL or RCL (perhaps due to influences of informal social networks or social media) contributed to the likelihood of enacting MCL or RCL within those states, leading to a higher supply of these products to meet the demand. Additional data are needed to answer these questions.

Study limitations are noted. Participants came from an online sample recruited through two distinct social media advertisements and targeting strategies (Borodovsky et al., 2020). This permitted assembling a large sample efficiently at relatively low cost. However, the mechanics underlying algorithmically-based dissemination of social media advertisements are unclear, and thus the nature of the selection biases that produced this sample are also unclear. Note that the study was not designed or funded to produce a nationally representative sample, and its demographic distribution differed from that of a nationally representative sample of frequent cannabis users in 2017 (see Supplementary Table 5), e.g., our sample had greater representation of females and those age 18-20, but lower representation of Black, Hispanic, and employed persons. Findings should be interpreted accordingly. Additional limitations include that reasons for use of higher- and lower-potency products, where or how participants obtained them, or whether participants had received medical authorizations were not ascertained; future studies should do so. Further, we made the assumption that "smoking" involved the use of plant/flower products, since smoking concentrates is a very atypical way to use them, and we also assumed that use of concentrates represented use of high-potency THC products, because only 5% of the 2017 cannabis market consisted of CBD products[25] and CBD products are typically not marketed as concentrates. Future studies should use questionnaires that carefully delineate what is smoked, and whether products used were primarily THC, primarily CBD, or some combination. In addition, the study did not ascertain further nuances in the state cannabis laws or their enactment, e.g., whether the states had retail stores in 2017, but future studies should address such issues. Finally, quantities of cannabis used were not assessed. Although our study was not focused on amounts of use, additional information on quantity could be useful. Measuring cannabis quantity accurately is challenging, especially in non-laboratory studies, but this is an important aspect of future cannabis research. Studies should implement improved, validated quantity measures as soon as they become available.

5. Conclusions

Use of highly potent cannabis products is rapidly gaining in popularity (Bidwell et al., 2021; Schaneman, 2021; Spindle et al., 2019), and our results suggest that use of such products is especially likely in RCL and MCL-only states. Because high-potency products are associated with greater risk of CUD and other harms, states and localities should consider this accumulating evidence when formulating laws, policies and public health messaging about the potency of permitted products. Policies to consider that may promote the sale and purchase of less-potent cannabis products include minimum unit pricing and taxes driven by potency rather than price (Caulkins et al., 2015; Shover and Humphreys, 2019; Smart et al., 2017). Clinicians in outpatient and emergency settings (Bollom et al., 2018) should be alert to these issues, especially in RCL states, regularly screening for potentially harmful cannabis products analogous to the screening for harmful or binge drinking that is now widely recommended (Heather, 2010; National Institute on Alcohol Abuse and Alcoholism, 2005). The increasingly common belief that cannabis is harmless may be based (at least partially) on assumptions arising from the weak, low-potency forms that were most commonly used in the 20th century. However, these beliefs may no longer be tenable given the increasing use of higher- potency forms. The U.S. is currently in a period of rapidly expanding public support for legalization of cannabis use, and additional states are likely to legalize recreational or medical cannabis use in the next few years. How these legal changes will affect the use of highly-potent forms of cannabis, their potential health harms and which policies will best promote public health requires careful ongoing public health research and monitoring.

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Table 1. Sample characteristics (N=4,064)		
	n	**%**
Sociodemographic		
Age		
18-20	1,533	37.7
21-29	1,240	30.5
30-44	655	16.1
45-64	549	13.5
65+	87	2.1
Gender		
Male	2,116	52.1
Female	1,874	46.1
Other	74	1.8
Race/ethnicity		
White	3,201	78.8
Black	127	3.1
Hispanic	311	7.7
Other	425	10.5
Employment		
Any	1,860	45.8
None	2,204	54.2
Education		
High school or less	1,494	36.8
More than high school	2,570	63.2
Advertising/recruitment strategy		
Focused on non-frequent users[a]	1,032	25.4
Focused on frequent users[b]	3,032	74.6
State cannabis law status		
Recreational cannabis law (RCL)[c]	1,077	26.5
Medical cannabis law (MCL-only)[d]	1,669	41.1
No cannabis law (no-CL)	1,318	32.4
a Generic advertisement to Facebook accounts of less-frequent cannabis users that incentivized survey completion with an online raffle for a $10 Amazon gift code. b Cannabis-specific advertisements directed to Facebook accounts of frequent cannabis users c Respondent was living in a state with a recreational cannabis law enacted by 2017: Alaska, California, Colorado, DC, Maine, Massachusetts, Nevada, Oregon, Washington. All these states also had an MCL enacted by 2017. d Respondent was living in a state with a medical cannabis law enacted by 2017: Arizona, Arkansas, Connecticut, Delaware, Florida, Hawaii, Illinois, Maryland, Michigan, Minnesota, Montana, New Hampshire, New Jersey, New Mexico, New York, North Dakota, Ohio, Pennsylvania, Rhode Island, Vermont, West Virginia		

Table 2: Characteristics of past-month cannabis use (N=4,064)		
Frequency of any past-month cannabis use	**n**	**%**
1-2 days	368	9.1
3-5 days	292	7.2
6-9 days	240	5.9
10-19 days	472	11.6
20-25 days	494	12.2
26-29 days	559	13.8
30 days (daily)	1,639	40.3
Daily/near daily[a]	2,198	54.1
Frequently[b]	2,692	66.2
Frequency of smoking plant material		
Daily	1,396	34.4
Daily/near daily[a]	1,859	45.7
Frequently[b]	2,341	57.6
Frequency of vaping plant material		
Daily	77	1.9
Daily/near daily[a]	109	2.7
Frequently[b]	165	4.1
Frequency of vaping concentrates		
Daily	167	4.1
Daily/near daily[a]	227	5.6
Frequently[b]	358	8.8
Frequency of dabbing concentrates		
Daily	170	4.2
Daily/near daily[a]	224	5.5
Frequently[b]	337	8.3
Cannabis product potency and method of administration		
Low-potency (plant material)		
Vaping	1,185	29.2
Smoking	3,939	96.9
Any use of plant material	3,999	98.4
High-potency (concentrates)		
Vaping	1,825	44.9
Dabbing	1,451	35.7
Any use of concentrates	2,203	54.2
Combined potency		
Used high-potency concentrates only	65	1.6
Used both high and low potency products	2,138	52.6
Used low-potency plant products only	1,861	45.8
a 26-30 days in the past month b 20 or more days in the past month		

Table 3. Recreational cannabis laws (RCL), medical cannabis laws (MCL) and use of high-potency cannabis concentrate products in the past month (n=4,064)			
	Participants with use of high-potency products	Odds ratio (95% CI)	
2-level cannabis law variable	% (SE)	Unadjusted	Adjusted[a]
RCL[b]	65.9 (1.44)	1.94 (1.68, 2.24)	1.61 (1.22, 2.13)
No RCL	50.0 (0.91)	reference	reference
3-level cannabis law variable			
RCL[b]	65.9 (1.44)	2.41 (2.04, 2.85)	2.61 (1.77, 3.86)
MCL-only[c]	54.3 (1.22)	1.48 (1.28, 1.71)	1.55 (1.21, 1.97)
No-CL (no RCL or MCL)	44.5 (1.37)	reference	reference
Contrasts between RCL and MCL effects		*Wald χ^2 (dof=1), p-value*	
		36.38, <0.0001	13.24, 0.0003

CI=confidence interval; RCL=recreational cannabis law; MCL=medical cannabis law; dof = degrees of freedom

a Adjusted for: individual-level (age, gender, race/ethnicity, employment, education, advertising strategy) and state-level (past month cannabis use, age, gender, race/ethnicity, unemployment, poverty, population density). ORs with 95% CI above 1 are significant at the p<0.05 level.
b Respondent was living in a state with a recreational cannabis law (and medical cannabis law) enacted by 2017: Alaska, California, Colorado, DC, Maine, Massachusetts, Nevada, Oregon, Washington
c Respondent was living in a state with a medical cannabis law enacted by 2017: Arizona, Arkansas, Connecticut, Delaware, Florida, Hawaii, Illinois, Maryland, Michigan, Minnesota, Montana, New Hampshire, New Jersey, New Mexico, New York, North Dakota, Ohio, Pennsylvania, Rhode Island, Vermont, West Virginia
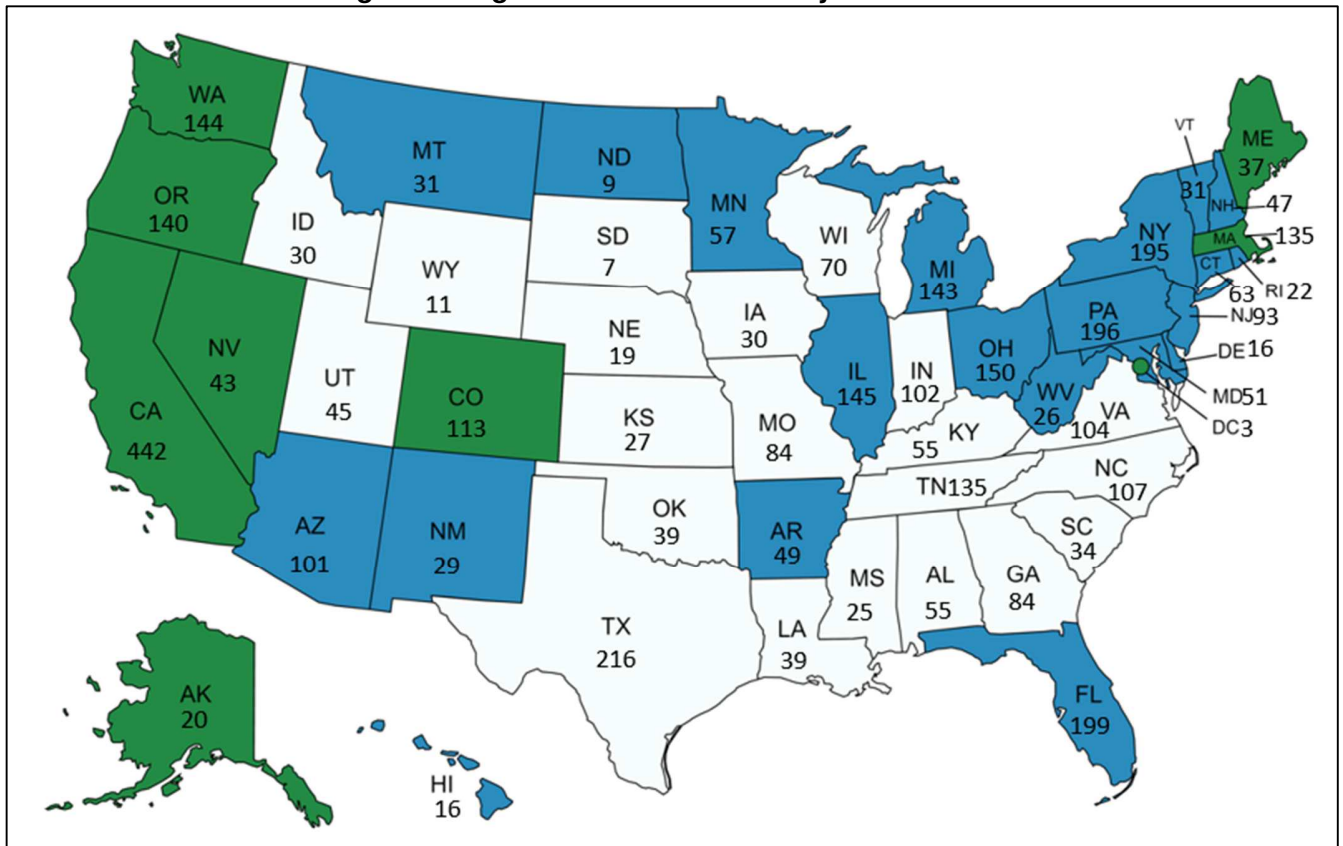
Table 4. Recreational cannabis laws (RCL), medical cannabis laws (MCL) and proportion of all cannabis use in the past 30 days that was of high-potency cannabis concentrate products (n=4,064)			
	Proportion of days used cannabis involving high potency use[a], past 30 days	Regression coefficient (95% CI)	
2-level cannabis law variable	Mean (SE)	Unadjusted	Adjusted[b]
RCL[c]	0.41 (0.01)	0.15 (0.12, 0.17)	0.09 (0.04, 0.13)
No RCL	0.26 (0.01)	reference	reference
3-level cannabis law variable			
RCL[c]	0.41 (0.01)	0.19 (0.16, 0.22)	0.16 (0.09, 0.22)
MCL-only[d]	0.30 (0.01)	0.07 (0.05, 0.10)	0.06 (0.02, 0.10)
No-CL (no RCL or MCL)	0.23 (0.01)	reference	reference
Contrasts between RCL and MCL effects		*F-test (dof=1), p-value*	
		72.96, <0.0001	16.74, <0.0001

CI=confidence interval; RCL=recreational cannabis law; MCL=medical cannabis law; dof = degrees of freedom
a Prior-month days of using a high-potency cannabis concentrate divided by prior-month days of any cannabis use
b Adjusted for: individual-level (age, gender, race/ethnicity, employment, education, advertising strategy) and state-level (past month cannabis use, age, gender, race/ethnicity, unemployment, poverty, population density). Regression coefficients with 95% CI above 0 are significant at the p<0.05 level.
c Respondent was living in a state with a recreational cannabis law (and medical cannabis law) enacted by 2017: Alaska, California, Colorado, DC, Maine, Massachusetts, Nevada, Oregon, Washington
d Respondent was living in a state with a medical cannabis law enacted by 2017: Arizona, Arkansas, Connecticut, Delaware, Florida, Hawaii, Illinois, Maryland, Michigan, Minnesota, Montana, New Hampshire, New Jersey, New Mexico, New York, North Dakota, Ohio, Pennsylvania, Rhode Island, Vermont, West Virginia

Figure 1. Legal status of cannabis by state in 2017

WA
144

OR
140

MT
31

ND
9

MN
57

WI
70

MI
143

VT

ME
37

NH 47

NY
195

MA 135

CT

63 RI 22

NJ 93

DE 16

MD 51

DC 3

ID
30

WY
11

SD
7

IA
30

IL
145

IN
102

OH
150

PA
196

NV
43

UT
45

CO
113

NE
19

KS
27

MO
84

KY
55

WV
26

VA
104

CA
442

AZ
101

NM
29

OK
39

AR
49

TN 135

NC
107

SC
34

MS
25

AL
55

GA
84

TX
216

LA
39

FL
199

AK
20

HI
16

Legend:

Recreational

Medical Only

Illegal

*Ns correspond to number of participants analyzed in that state.