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Cannabis use characteristics and associations with problematic use outcomes, quitting-related factors, and mental health among US young adults

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Abstract

Objective Given the changes in trends of cannabis use (e.g., product types), this study examined latent classes of young adult use and associations with use-related outcomes.

Methods We analyzed 2023 survey data among 4,031 US young adults (M_{age}=26.29, 59.4% female, 19.0% Hispanic, 13.5% Black, 13.6% Asian). Among those reporting past-month use (48.8%), latent class analysis (LCA) indicators included: days used (1–5; 6–20; 21–30), use/day (1; 2–4; ≥5), and type usually used (herb/flower; edibles; oils/vape; concentrates/other). Multivariable regressions examined class in relation to problematic use, quitting-related factors, and mental health, controlling for sociodemographics and state non-medical cannabis laws.

Results LCA identified 4 classes of cannabis use frequency and types used: 'infrequent-herb/edibles' (41.4%), 'frequent-herb' (16.8%), 'moderate-herb' (28.0%), and 'moderate-oil/other' (13.8%). In multivariable analyses (referent group: 'moderate-herb' class), 'frequent-herb' reported less problematic use (B=-0.18, 95%CI=-0.30, -0.07), while 'moderate-oil/other' reported greater (B = 0.39, 95%CI = 0.27, 0.51). 'Infrequent-herb/edibles' had lower odds of driving post-use of cannabis (aOR = 0.28, 95%CI = 0.22, 0.37) and cannabis/alcohol (aOR = 0.52, 95%CI = 0.35, 0.76), whereas 'frequent-herb' (aOR = 1.52, 95%CI = 1.02, 2.28) and 'moderate-oil/other' (aOR = 3.98, 95%CI = 2.72, 5.82) reported greater odds of driving post-cannabis/alcohol use. 'Moderate-oil/other' reported higher quitting importance (B = 0.59, 95%CI = 0.17, 1.01), while 'frequent-herb' reported lower (B=-0.33, 95%CI=-0.99, -0.18). 'Infrequent-herb/edibles' reported higher quitting confidence (B = 0.56, 95%CI = 0.20, 0.92), whereas 'frequent-herb' (B=-1.01, 95%CI=-1.45, -0.57) and 'moderate-oil/other' (B=-1.27, 95%CI=-1.74, -0.81) reported lower. 'Infrequent-herb/edibles' reported fewer mental health symptoms (B=-0.55, 95%CI=-0.93, -0.17), while 'moderate-oil/other' reported more (B = 1.03, 95%CI = 0.53, 1.52).

Conclusions Preventing frequent and moderate use of cannabis, particularly of oils/concentrates, is crucial given the potential negative implications for problematic use, quitting, and mental health.

Keywords Cannabis, Marijuana, Risk factors, Problematic use, Epidemiology

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Introduction

The US cannabis policy and retail contexts have markedly changed in the past decade. As of March 2024, 24 states and DC legalized non-medical (i.e., recreational) cannabis [1]. During this time, use prevalence increased in adults [2, 3], particularly young adults [4], who increasingly use daily and more heavily [5]. Thus, surveillance of adverse cannabis-related outcomes among young people is essential.

Research to identify subgroups particularly at risk for negative cannabis-related consequences that has used person-centered analytical approaches (e.g., latent class analysis [LCA]) [6–10] has primarily examined cannabis use disorder (CUD) symptoms or use levels [6, 11, 12]. These approaches have limitations in their application to young adults, who may show less severe cannabis-related consequences that may not be captured by diagnostic criteria [13–15]. Further, to prevent patterns of use that may be problematic, it is important to identify young adults with early indicators of problematic use, chronic or long-term use (e.g., low motivation or confidence to quit), or mental health issues that may contribute to problematic or long-term use.

Notably, cannabis product potency and effects vary and must be considered. THC concentrations in herbal cannabis is typically ~ 6% THC in the US [16], but some types (e.g., sinsemilla) [17] are more potent (~ 17% THC) [16]. Other products that are highly potent include Cannabis resin (i.e., hashish) (~ 15–20% THC) [16, 18] and cannabis concentrates (e.g., shatter, wax, kief) produced through solvent- and nonsolvent-based extraction methods (70–80% THC) [25]. Herb and resin are typically smoked [19] or vaporized [20], which may influence THC's effects [21]. Concentrates are typically used via 'dabbing' (i.e., inhaling vapors from vaporizers or heated glass/aluminum rods), allowing immediate effects [26]. Cannabis edibles, which are increasingly prominent [22, 23], typically have lower potency but delayed onset and longer duration [24].

Furthermore, more discrete product types (e.g., edibles) may provide more opportunities for use. Thus, different types may confer differential levels of misuse and dependence risk [18, 27–30]. Prior cross-sectional studies of adults [26, 28, 29, 31, 32] (and young adults specifically [33]) during the 2010s (before expansion of non-medical cannabis markets) examining different profiles of use in relation to cannabis-related harms indicated that those who use herb versus concentrates show no difference in cannabis-related harms [31]; however, others indicate that those using cannabis concentrates present greater CUD symptoms [31], physiological dependence [26, 33], withdrawal [29], and mental health symptoms [28, 32]. These disparate findings may be due to differences in study design, sample characteristics, or measures (e.g., failure to account for both product type used and frequency of use).

LCA can help advance the literature, as it can be used to identify profiles of use behaviors, based on key dimensions (e.g., number of days used, product type, use per day), that may be associated with adverse outcomes, such as driving after use, early indicators of such outcomes (i.e., problematic use), or inability to quit using. Despite these advantages, few studies have conceptualized young adult cannabis use and related consequences using this approach. One 2017–2018 LCA of cannabis use among adults from 175 countries included product type and identified 7 classes – one representing herb use and others largely representing herb with more potent types, which showed greater dependence and mental health diagnoses, relative to the herb-only class [28]. Additionally, a 2015 study of 2,444 US young adults identified 4 past-month use classes, including heavy herb (37%) and herb/concentrate use (20%) which were more likely to drive after use, compared to 2 less frequent use groups [7]. Interestingly, a 2018–2019 LCA of 1,007 young adults identified classes based on problematic use indicators, then compared their use profiles; compared to the non-symptomatic class, the problematic use classes (e.g., moderate, severe) used more frequently, particularly via smoking, vaping, and blunts [34].

Limitations to the literature remain, as just these few studies [7, 28, 34] have accounted for product type used, and these studies have been limited in their relevance to the current cannabis policy context, representation across the US, or the range of cannabis-related outcomes that may be distinctly associated with use profiles among young adults. Such outcomes include problematic use (including risky driving-related behaviors), cessation-related factors that may be associated with chronic, long-term use (i.e., cessation-related intentions or confidence), or mental health. Thus, this study aimed to add to the literature by analyzing data from a large cohort of young adults across the US during a period when several states had legalized non-medical cannabis in order to identify distinct classes based on key use behaviors (i.e., days used, use/day, product type) and examine use class in relation to these cannabis-related outcomes.

Methods

Study design and participants

The current study analyzed baseline survey data among 4,031 young adults (ages 18–34) in the Cannabis Regulation, Marketing & Appeal (CARMA) study, which examines non-medical cannabis retail, marketing, and impact on use (approved by the George Washington University Institutional Review Board). This longitudinal study launched in June-November 2023 and involves assessments every 6 months for 2 years (June-November;

January-May). To recruit eligible individuals (18–34 years old, US resident, English-speaking), ads were posted on Facebook using images of young adults of diverse racial/ethnic backgrounds socializing, etc. (See Supplementary Fig. 1 for example ads.) After clicking on ads, a Facebook Messenger chatbot provided an abbreviated study overview and conducted preliminary eligibility screening (assessing age, country and state of residence, race, ethnicity, sex, past-month cannabis use). Purposive, quota-based sampling was used to ensure sufficient proportions representing past-month cannabis use (~ 50%), males and females (50% respectively), and racial/ethnic minorities (40%).

Individuals deemed preliminarily eligible (and still being recruited) were provided a unique link to the full study description and consent form (in Alchemer), screened to confirm eligibility, and administered the baseline survey. Those who completed the survey received an email 7 days later reiterating study procedures/timeline and were asked to "confirm" their participation. After confirming, they received their incentive ($10 Amazon e-gift card). Fraud prevention efforts, based on prior research [35, 36], included use of the chatbot (verifying each individual had a Facebook account and precluding multiple attempts), withholding details of eligibility criteria before screening, using the 7-day follow-up period to examine data validity (e.g., duplicate IP addresses, e-mail addresses, or phone numbers; illogical responses; survey completion time), and confirming validity of contact information before providing incentives.

Shown in Fig. 1, of 18,426 Facebook profiles who clicked ads, 8,098 (43.9%) began the Chatbot pre-screening, 6,908 (85.3%) completed the Chatbot pre-screening, and 6,128 (88.7%) were preliminarily eligible and provided study links. Of the 5,857 (95.6%) who responded to the consent form, 5,801 (99.0%) consented, of whom 129 (2.2%) were not allowed to advance because they either: (a) did not complete the screening ($n = 115$) or (b) were ineligible ($n = 14$, outside of age range). Of the 5,672 (97.8%) allowed to advance to the survey, 974 (17.2%) did not fully complete the survey (the majority discontinued during the sociodemographics section at the beginning

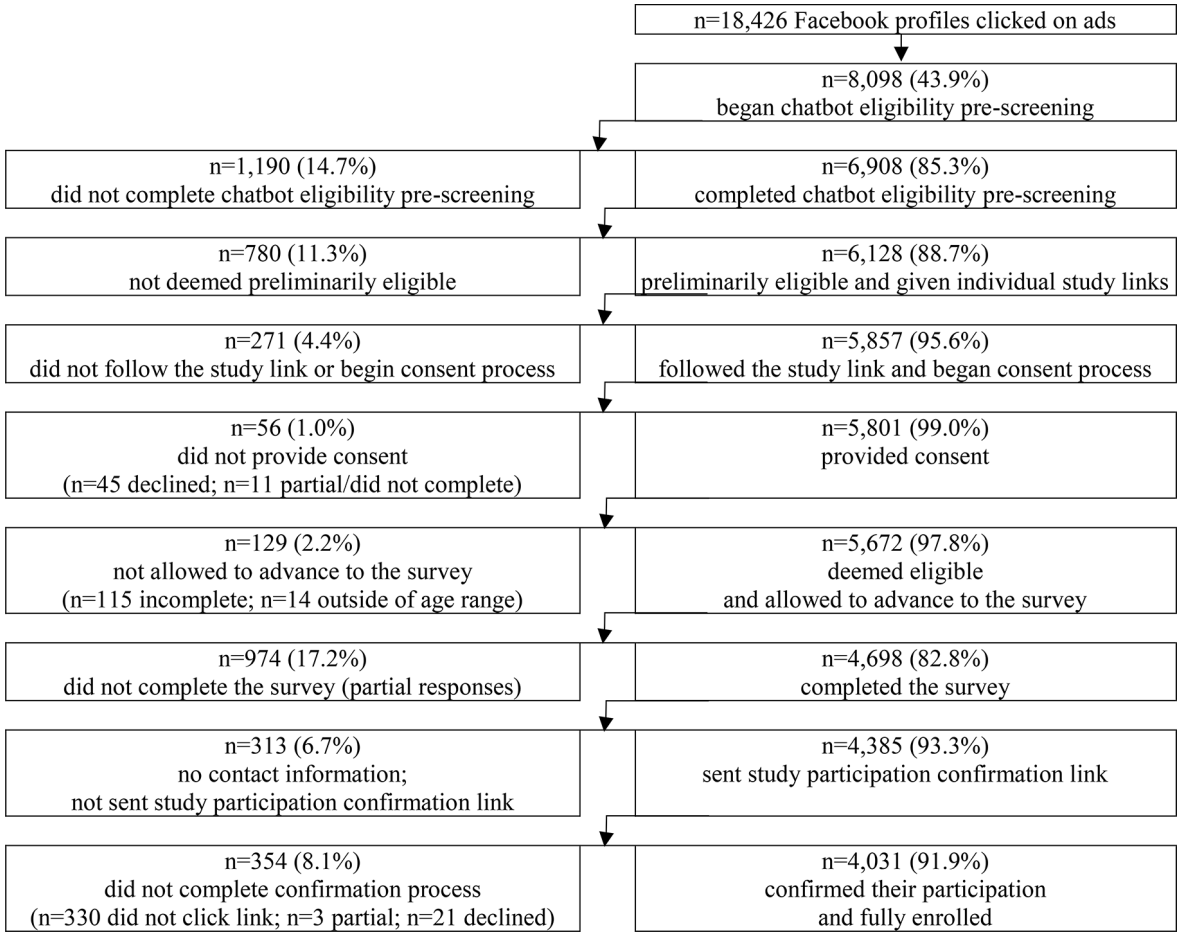

Fig. 1 Participant flowchart. Note The 4,031 participants enrolled in the study reflect 21.9% [$n = 4,031/18,426$] of Facebook profiles that clicked on ads; 49.8% [$n = 4,031/8,098$] of those who began chatbot eligibility pre-screening; 58.4% [$n = 4,031/6,908$] of those who completed chatbot pre-screening [780 of which were not deemed preliminarily eligible]); and 65.8% ($n = 4,031/6,128$) of those preliminarily eligible at the Facebook chatbot pre-screening phase

of the survey). Of the 4,698 who completed the baseline survey, 313 (6.7%) were not sent study confirmation links because they did not provide a valid email address or phone number. Of the 4,385 provided confirmation links, 4,031 (91.9%) confirmed their participation and were enrolled. We examined sociodemographic differences in relation to: (1) baseline survey completers vs. non-completers and (2) 7-day follow-up outcomes (i.e., no contact information provided vs. did not confirm vs. confirmed; Supplementary Table 1). Those reporting past-month cannabis use were less likely to fully complete the survey and confirm. The final sample who confirmed largely reflected the survey completers (i.e., only one difference – those who did not provide contact information or did not confirm differed by race).

Measures

Sociodemographics

We assessed age, birth sex, sexual orientation, ethnicity, race, education, employment, community type (e.g., rural, urban), relationship status, and whether they had children.

Substance use

Participants were provided a table with descriptions and photos of cannabis, alcohol, and tobacco products. Cannabis was described as: "Marijuana (cannabis, pot, weed) including all forms of the plant and its preparations, including: dried herb, edibles, oils, hash, kief, concentrates, marijuana drinks, tinctures, lotions, or other products. (Do not include hemp-derived cannabinoids, like Delta-8.)" We also described: (1) "Hemp-derived cannabinoids, like Delta-8 THC, Delta-10 THC, etc. (Similar to marijuana but derived from hemp; common brands are 3Chi, Cake, etc.)" [37, 38]; and (2) "CBD products, not containing THC." We assessed past-month (i.e., 30-day) use of cannabis, hemp-derived cannabinoids, CBD, alcohol, and certain tobacco products (cigarettes, e-cigarettes, cigars, hookah) [39].

Cannabis use characteristics

LCA among participants reporting past-month cannabis use was based on 3 use characteristics: (1) days used in the past month – "In the past 30 days, how many days did you use cannabis?" (response options: 0–30); (2) use per day – "On average, how many times do you use cannabis on the days that you use it?" (response options: 1–15 or more); and (3) type most often used – "How do you use marijuana most of the time?" with response options: dried herb (smoked or vaped, including joints, bowls, waterpipes); cannabis oils or liquids for vaping; cannabis oils or liquids taken orally (e.g., drops, capsules, sprays); tinctures (concentrated amounts containing alcohol ingested orally or taken under the tongue); concentrates (e.g., wax, shatter, budder); hash or kief; edibles, foods or drinks; topical ointments (e.g., lotions); and other (specify). Based on distributions/frequencies, we created categorical ordinal variables for days of use (1–5 days [36.0%], 6–20 [31.8%], 21–30 [32.3%]) and average number of times used per day (1 time/day [27.8%], 2–4 [40.8%], ≥5 [31.4%]). Based on characteristics of product types, we created a nominal categorical variable including: (1) dried herb (56.0%); (2) edibles (16.4%); (3) oils (i.e., cannabis oils or liquids for vaping, cannabis oils or liquids taken orally, tinctures; 20.3%); or (4) concentrates/other (i.e., concentrates, hash or kief, topical, other; 7.3%).

For descriptive purposes, participants were asked: (1) "Do you currently have a medical marijuana card?" (response options: no; yes); and (2) "Currently, do you use marijuana for medical or recreational purposes – or both?" (response options: only medical purposes; primarily medical but occasionally for recreational purposes; primarily recreational but occasionally for medical purposes; only recreational purposes; I'm not sure).

Problematic use indicators

Participants reporting past-month use were asked, "Rate the extent to which each item has impacted you; using marijuana has…." (response options: 1 = not at all to 5 = very much) with regard to items adapted from previously-developed measures [40, 41] assessing social-interpersonal consequences ("made people who are important to me disapprove of me"); impaired control ("impaired my judgment, endanger myself or others, or do things I regret"); risk behaviors ("gotten me in trouble with the law"); physical consequences ("made me feel bad physically, e.g., dry mouth, red eyes, racing heart"); cognitive consequences ("reduced my ability to pay attention or remember things"); psychological consequences ("had unpleasant psychological effects, e.g., mood swings, depression, paranoia"); self-care consequences ("made me less active or feel less energetic"); and academic/occupational consequences ("made me neglect obligations to family, work, or school"). Exploratory factor analysis indicated a single factor with high internal consistency (Cronbach's alpha = 0.87). Responses across items were averaged to create a summary score (range: 0–5). Participants were also asked, "During the past 6 months, how many times did you: drive a car or other vehicle when you had been using marijuana? drive a car or other vehicle when you had been using both alcohol and marijuana?" (response options: 0, 1, 2–3, 4–5, ≥6, dichotomized as any vs. none).

Quitting-related factors

We asked, "How important is it that you quit using marijuana?" and "How confident are you that you could quit

using marijuana if you wanted to?" (response options: 0 = not at all to 10 = absolutely) [42].

Mental health

Mental health symptoms were assessed using the Patient Health Questionnaire – 4 item (PHQ-4), which includes 4 items assessing depressive and anxiety symptoms (2 items each) in the past 2 weeks (response options: 0 = not at all to 3 = nearly every day) [43]. Items were summed to create a summary score (range 0–12; Cronbach's alpha = 0.89) [43].

Data analysis

First, descriptive analyses were conducted to characterize participants and examine response distributions. Second, LCA (using days used, use/day, product type) identified cannabis use classes among those reporting past-month use [44, 45]. We examined latent class solutions for models with 1–6 classes, determining the best-fitting model based on: Akaike information criterion (AIC), Bayesian information criterion (BIC), sample size adjusted BIC (SSABIC) [46], and entropy values. Lower values of AIC, BIC, and SSABIC, and larger values of entropy indicate better model fit [47]. We also used the Lo-Mendell-Rubin Adjusted Likelihood Ratio Test (LRT) to compare models with K classes to models with K-1 classes; significant p-values indicate better fit for the model with K classes [47]. Other considerations included smallest class (> 5%) and class interpretability. Robust Maximum Likelihood was used. Participants were categorized based on their most probable class.

Third, bivariate analyses (using Chi-square tests for categorical variables and ANOVAs or t-tests for continuous variables) characterized participants in relation to use status (i.e., no vs. any past-month use) and cannabis use class (per LCA, among those reporting past-month use). Fourth, sociodemographics and state non-medical cannabis legalization were examined in relation to: (1) any vs. no past-month cannabis use (binary logistic regression) among all participants; and (2) cannabis use class among those reporting past-month use (multinomial logistic regression with pairwise comparison).

Finally, multivariable regressions (controlling for state legalization of non-medical cannabis and sociodemographics) examined use class in relation to: (1) problematic use; (2) driving after cannabis use; (3) driving after cannabis/alcohol co-use; (4) quitting importance; (5) quitting confidence; and (6) mental health symptoms. All were linear regressions for continuous outcomes, except the driving-related outcomes which were dichotomous and analyzed using logistic regressions. LCA was conducted in Mplus 8.8; bivariate and regression analyses were conducted SPSS.v27.

Results

Participant characteristics

Shown in Table 1, the sample was 26.29 (SD = 4.81) years old on average, 59.4% female, 27.4% sexual minority, 19.0% Hispanic, 13.5% Black, 13.6% Asian, and 6.7% other race(s). Overall, 48.5% lived in rural areas, 22.2% were married, 17.5% were cohabitating, and 30.9% had children. Lifetime and past-month cannabis use was reported by 68.4% and 48.8%, respectively.

Results of bivariate analyses comparing those reporting past-month use versus no use are shown in Table 1. Shown in Supplementary Table 2, multivariable analyses indicated that those reporting any (vs. no) past-month use were: in legalized states, older, male, sexual minority, Black vs. White, White vs. Asian, employed full-time vs. students, urban vs. rural), cohabitating vs. single/other, and parents.

LCA among participants reporting past-month cannabis Use

The 4-class solution was chosen based on model fit indices and theoretical interpretability (Supplementary Table 3). Compared to the 3-class solution, the 4-class solution provided significantly better fit (Adjusted LRT = 34.13, $p = .004$), the lowest AIC, and classes of sufficient size (smallest class: $n = 271$, 13.8%), and also separated the moderate use class in the 3-class model into 2 meaningfully different classes, shown in Supplementary Fig. 2. The 4 use classes (characterized in Table 2) were: (1) 'infrequent-herb/edibles' (n = 815, 41.4%), who reported infrequent past-month use (M = 4.52, SD = 1.88) and use/day (M = 1.90, SD = 5.96), and primary use of herb (39.9%) and edibles (40.4%); (2) 'frequent-herb' (n = 330, 16.8%), who reported frequent past-month use (M = 29.22, SD = 1.88) and use/day (M = 10.01, SD = 8.17), and primary use of herb (74.5%); (3) 'moderate-herb' (n = 552, 28.0%), who used more than half of the days in the past month (M = 18.73, SD = 8.89), 4.05 times/day (SD = 2.90), and primarily herb (96.2%); and (4) 'moderate-oil/other product' (n = 271, 13.8%), who used about half the days (M = 15.75, SD = 9.51), 6.32 times/day (SD = 3.90), and primarily oils (75.5%) or other forms (14.1%).

Comparisons of cannabis use classes

Bivariate analyses characterizing the cannabis use classes from the LCA (among those reporting past-month use) by sociodemographics and use characteristics are shown in Tables 1 and 2, respectively. Also in Table 1, the classes differed in past-month use of other substances (e.g., highest alcohol use in 'infrequent-herb/edibles' class, highest cigarette and cigar use in 'frequent-herb' class, highest hemp-derived cannabinoids, CBD, e-cigarettes, and hookah use in 'moderate-oil/other' class). Further, shown in Table 2, those in the 'frequent-herb' and 'moderate-oil/

Table 1 US young adult participants' sociodemographic and substance use characteristics overall and by cannabis use class ($N = 4,031$)

	Among all participants				Among those with past-month use: Latent use classes				
	Total	**No past-month use**	**Any past-month use**		**Infrequent-herb/edibles**	**Frequent-herb**	**Moderate- herb**	**Moderate- oil/other**	
	N = 4,031 (100%)	**N = 2,063 (51.2%)**	**N = 1,968 (48.8%)**		**N = 815 (41.4%)**	**N = 330 (16.8%)**	**N = 552 (28.0%)**	**N = 271 (13.8%)**	
Variables	**N (%) or M (SD)**	**N (%) or M (SD)**	**N (%) or M (SD)**	**p-value**	**N (%) or M (SD)**	**N (%) or M (SD)**	**N (%) or M (SD)**	**N (%) or M (SD)**	**p-value**
State non-medical cannabis law, n (%) *				.029					.165
Not legalized	1988 (49.3)	1048 (50.8)	940 (47.8)		369 (45.3)	167 (50.6)	279 (50.5)	125 (46.1)	
Legalized	2043 (50.7)	1015 (49.2)	1028 (52.2)		446 (54.7)	163 (49.4)	273 (49.5)	146 (53.9)	
Sociodemographics									
Age, M (SD)	26.29 (4.81)	25.74 (4.94)	26.86 (4.61)	**< .001**	26.29 (4.76)	27.86 (4.16)	27.20 (4.56)	26.66 (4.53)	**< .001**
Sex, n (%)				.667					.606
Female	2394 (59.4)	1239 (60.1)	1155 (58.7)		481 (59.0)	194 (58.8)	322 (58.3)	158 (58.3)	
Male	1612 (40.0)	811 (39.3)	801 (40.7)		329 (40.4)	135 (40.9)	228 (41.3)	109 (40.2)	
Sexual identity, n (%)				**< .001**					
Heterosexual	2844 (70.6)	1547 (75.0)	1297 (65.9)		524 (64.3)	213 (64.5)	370 (67.0)	190 (70.1)	.051
Sexual minority §	1105 (27.4)	456 (22.1)	649 (33.0)		276 (33.9)	116 (35.2)	180 (32.6)	77 (28.4)	
Hispanic, n (%)				**.005**					.197
No	3204 (79.5)	1677 (81.3)	1527 (77.6)		625 (76.7)	269 (81.5)	428 (77.5)	205 (75.6)	
Yes	766 (19.0)	352 (17.1)	414 (23.4)		173 (21.2)	59 (17.9)	119 (21.6)	63 (23.2)	
Race, n (%)				**< .001**					**< .001**
White	2525 (62.6)	1312 (63.6)	1213 (61.6)		500 (61.3)	221 (67.0)	335 (60.7)	157 (57.9)	
Black	545 (13.5)	188 (9.1)	357 (18.1)		103 (12.6)	73 (22.1)	124 (22.5)	57 (21.1)	
Asian	549 (13.6)	379 (18.4)	170 (8.6)		117 (14.4)	4 (1.2)	24 (4.3)	25 (9.2)	
Other ^	269 (6.7)	110 (5.3)	159 (8.1)		59 (7.2)	23 (7.0)	53 (9.6)	24 (8.9)	
Education level, n (%)				**< .001**					**< .001**
<Bachelor's degree	2306 (57.2)	1022 (49.5)	1284 (65.2)		410 (50.3)	288 (87.3)	413 (74.8)	173 (63.8)	
≥Bachelor's degree	1725 (42.8)	1041 (50.5)	684 (34.8)		405 (49.7)	42 (12.7)	139 (25.2)	98 (36.2)	
Employment status, n (%)				**< .001**					**< .001**
Full-time	1438 (37.5)	718 (34.8)	720 (36.6)		330 (40.5)	104 (31.5)	182 (33.0)	104 (38.4)	
Part-time	539 (13.4)	222 (10.8)	317 (16.1)		123 (15.1)	44 (13.3)	96 (17.4)	54 (19.9)	
Student	1103 (27.4)	675 (32.7)	428 (21.7)		217 (26.6)	42 (12.7)	107 (19.4)	62 (22.9)	
Unemployed	951 (23.6)	448 (27.1)	503 (25.6)		145 (17.8)	140 (42.4)	167 (30.3)	51 (18.8)	
Community type, n (%)				.128					**.002**
Rural (< 10,000)	845 (21.0)	435 (21.1)	410 (20.8)		141 (17.3)	94 (28.5)	107 (19.4)	68 (25.1)	
Suburban/micropolitan (10,000–49,999)	1228 (30.5)	657 (31.8)	571 (29.0)		252 (30.9)	87 (26.4)	167 (30.3)	65 (24.0)	
Urban (50,000+)	1954 (48.5)	968 (46.9)	986 (50.1)		422 (51.8)	149 (45.2)	227 (50.2)	138 (50.9)	
Relationship status, n (%)				**< .001**					**< .001**
Single/never married/other #	2429 (60.3)	1258 (61.0)	1171 (59.5)		510 (62.6)	184 (55.8)	307 (55.6)	170 (62.7)	

Table 1 (continued)

	Among all participants				Among those with past-month use: Latent use classes				
	Total	**No past-month use**	**Any past-month use**		**Infrequent-herb/edibles**	**Frequent-herb**	**Moderate- herb**	**Moderate- oil/other**	
	N = 4,031 (100%)	**N = 2,063 (51.2%)**	**N = 1,968 (48.8%)**		**N = 815 (41.4%)**	**N = 330 (16.8%)**	**N = 552 (28.0%)**	**N = 271 (13.8%)**	
Variables	**N (%) or M (SD)**	**N (%) or M (SD)**	**N (%) or M (SD)**	**p-value**	**N (%) or M (SD)**	**N (%) or M (SD)**	**N (%) or M (SD)**	**N (%) or M (SD)**	**p-value**
Married	896 (22.2)	543 (26.3)	353 (17.9)		161 (19.8)	42 (12.7)	100 (18.1)	50 (18.5)	
Cohabitating	706 (17.5)	262 (12.7)	444 (22.6)		144 (17.7)	104 (31.5)	145 (26.3)	51 (18.8)	
Parent/has child(ren), n (%)				**< .001**					**< .001**
No	2784 (69.1)	1512 (73.3)	1272 (64.6)		613 (75.2)	177 (53.6)	315 (57.1)	167 (61.6)	
Yes	1247 (30.9)	551 (26.7)	696 (35.4)		202 (24.8)	153 (46.4)	237 (42.9)	104 (38.4)	
Past-month substance use, n (%)									
Cannabis	1968 (48.8)	0 (0.0)	1968 (100.0)	**< .001**	--	--	--	--	**--**
Hemp-derived cannabinoids	984 (24.4)	86 (4.2)	898 (45.6)	**< .001**	286 (35.1)	164 (49.7)	290 (52.5)	158 (58.3)	**< .001**
CBD	907 (22.5)	151 (7.3)	756 (38.4)	**< .001**	258 (31.7)	133 (40.2)	223 (40.4)	142 (52.4)	**< .001**
Alcohol	2427 (60.2)	987 (47.8)	1440 (73.2)	**< .001**	631 (77.4)	208 (63.0)	404 (73.2)	197 (72.7)	**< .001**
Cigarettes	916 (22.7)	135 (6.5)	781 (39.7)	**< .001**	178 (21.8)	203 (61.5)	279 (50.5)	121 (44.6)	**< .001**
E-cigarettes	1071 (26.6)	184 (8.9)	887 (45.1)	**< .001**	262 (32.1)	181 (54.8)	275 (49.8)	169 (62.4)	**< .001**
Cigars	541 (13.4)	57 (2.8)	484 (24.6)	**< .001**	91 (11.2)	137 (41.5)	165 (29.9)	91 (33.6)	**< .001**
Hookah	474 (11.8)	40 (1.9)	434 (22.1)	**< .001**	95 (11.7)	106 (32.1)	140 (25.4)	93 (34.3)	**< .001**

Notes M: mean. SD: standard deviation. P-values are based on Chi-square tests for categorical variables and ANOVAs or t-tests for continuous variables

* Legalized non-medical adult use as of March 2023: Alaska, Arizona, California, Colorado, Connecticut, District of Columbia, Illinois, Maine, Maryland, Massachusetts, Michigan, Missouri, Montana, Nevada, New Jersey, New Mexico, New York, Oregon, Rhode Island, Vermont, Virginia, Washington. [§] Bisexual, lesbian/gay, other. ^ Race: other (i.e., American Indian or Alaskan Native, Native Hawaiian or Pacific Islander, Multiracial, other). [#] Relationship: other (i.e., single/never married, divorced, separated, widowed, other). Responses categorized separately for multivariable regressions. Sex: other ($n = 1$), prefer not to answer ($n = 24$). Sexual identity: prefer not to answer ($n = 82$). Ethnicity: don't know ($n = 9$), prefer not to answer ($n = 52$). Race: don't know ($n = 48$), prefer not to answer ($n = 95$). Community: other ($n = 4$)

Table 2 Cannabis use characteristics, problematic use indicators, quitting-related factors, and mental health among US young adults reporting past 30-day cannabis use, overall and by cannabis use class (*N* = 1,968)

	Any past-month use	Infrequent-herb/edibles	Frequent-herb	Moderate-herb	Moderate-oil/other	
	N = 1,968 (100%)	N = 815 (41.4%)	N = 330 (16.8%)	N = 552 (28.0%)	N = 271 (13.8%)	
Variables	N (%) or M (SD)	N (%) or M (SD)	N (%) or M (SD)	N (%) or M (SD)	N (%) or M (SD)	p-value
Cannabis use characteristics						
Number of days used in the past 30 days, M (SD)	14.19 (11.30)	4.52 (4.87)	29.22 (1.88)	18.73 (8.89)	15.75 (9.51)	**<.001**
1–5 days, n (%)	708 (36.0)	642 (78.8)	0 (0)	26 (4.7)	40 (14.8)	
6–20 days	625 (31.8)	166 (20.4)	0 (0)	305 (55.3)	154 (56.8)	
≥ 21 days	635 (32.3)	7 (0.9)	330 (100)	221 (40.0)	77 (28.4)	
Average number of time used per day, M (SD)	4.47 (6.22)	1.90 (5.96)	10.01 (8.17)	4.05 (2.90)	6.32 (3.90)	**<.001**
1 time/day, n (%)	546 (27.8)	524 (64.5)	0 (0)	16 (2.9)	6 (2.2)	
2–4 times/day	800 (40.8)	288 (35.5)	19 (5.8)	406 (73.6)	87 (32.1)	
≥ 5 times/day	617 (31.4)	0 (0)	309 (94.2)	130 (23.6)	178 (65.7)	
Product type used most often, n (%) *						**<.001**
Dried herb	1102 (56.0)	325 (39.9)	246 (74.5)	531 (96.2)	0 (0.0)	
Edibles, foods or drinks	399 (20.3)	329 (40.4)	22 (6.7)	20 (3.6)	28 (10.3)	
Oils:	322 (16.5)	119 (14.7)	0 (0)	0 (0)	203 (75.5)	
Oils or liquids for vaping	230 (11.7)	87 (10.7)	0 (0.0)	0 (0.0)	143 (52.8)	
Oils or liquids taken orally	53 (2.7)	18 (2.2)	0 (0.0)	0 (0.0)	35 (12.9)	
Tinctures	39 (2.0)	14 (1.7)	0 (0.0)	0 (0.0)	25 (9.2)	
Concentrates/other:	133 (6.8)	34 (4.2)	61 (18.5)	0 (0)	38 (14.1)	
Concentrates	68 (3.5)	10 (1.2)	41 (12.4)	0 (0.0)	17 (6.3)	
Hash or kief	31 (1.6)	5 (0.6)	13 (3.9)	0 (0.0)	13 (4.8)	
Topical ointments	34 (1.7)	19 (2.3)	7 (2.1)	0 (0.0)	8 (3.0)	
Medical cannabis card, n (%) £						**<.001**
No	1590 (80.8)	695 (85.3)	256 (77.6)	458 (83.0)	181 (66.8)	
Yes	309 (15.7)	84 (10.3)	69 (20.9)	75 (13.6)	81 (26.2)	
Prefer not to answer	69 (3.5)	36 (4.4)	5 (1.5)	19 (3.4)	9 (3.3)	
Use for medical or recreational purposes, n (%) &						**<.001**
Only medical	166 (8.4)	74 (9.1)	22 (6.7)	30 (5.4)	40 (14.8)	
Primarily medical but occasionally recreational	482 (24.5)	138 (16.9)	108 (32.7)	149 (27.0)	87 (32.1)	
Primarily recreational but occasionally medical	625 (31.8)	183 (22.5)	142 (43.0)	219 (39.7)	81 (29.9)	
Only recreational	588 (29.9)	355 (43.6)	50 (8.5)	128 (23.2)	55 (20.3)	
Problematic use indicators						
Problematic use score, M (SD) #	1.99 (0.86)	2.04 (0.80)	1.67 (0.77)	1.91 (0.81)	2.36 (1.04)	**<.001**
Driving after cannabis use, n (%)	686 (35.3)	140 (7.2)	165 (51.6)	247 (45.3)	134 (50.2)	**<.001**
Driving after cannabis/alcohol co-use, n (%)	279 (14.3)	55 (6.8)	55 (16.8)	74 (13.5)	95 (35.3)	**<.001**
Quitting-related factors						
Importance of quitting, M (SD) ^	2.20 (2.99)	2.17 (3.02)	1.62 (2.87)	2.21 (2.89)	2.99 (3.10)	**<.001**

Table 2 (continued)

	Any past-month use	Infrequent-herb/edibles	Frequent-herb	Moderate-herb	Moderate-oil/other	
	N = 1,968 (100%)	N = 815 (41.4%)	N = 330 (16.8%)	N = 552 (28.0%)	N = 271 (13.8%)	
Variables	N (%) or M (SD)	N (%) or M (SD)	N (%) or M (SD)	N (%) or M (SD)	N (%) or M (SD)	p-value
Confidence to quit, M (SD) ^	7.48 (3.29)	8.16 (3.03)	6.61 (3.70)	7.59 (3.03)	6.27 (3.41)	**< .001**
Mental health (per PHQ-4), M (SD)	4.23 (3.28)	3.78 (3.27)	4.40 (3.78)	4.30 (3.46)	5.28 (3.50)	**< .001**

Notes M: mean. SD: standard deviation. P-values are based on Chi-square tests for categorical variables and ANOVAs or t-tests for continuous variables

* For LCA, categorized as: (1) dried herb, (2) edibles, foods or drinks, (3) oil (i.e., cannabis oils or liquids for vaping, cannabis oils or liquids taken orally, tinctures), or (4) concentrates/other (i.e., concentrates, hash or kief, topical ointments, other). # Average of items on scale of 1 = not at all to 5 = very much. Cronbach's alpha = 0.87. ^ 0 = not at all to 10 = absolutely. Other/prefer not to answer responses: * Product type used most often: other (n = 12). £ Medical card: prefer not to answer (n = 69). & Medical vs. recreational purposes: not sure (n = 60), prefer not to answer (n = 47)

other' classes were the most likely to have a medical cannabis card and use for medical purposes.

Multinomial logistic regression analyses characterized differences in sociodemographic factors among all classes (Table 3). First, all other classes were compared to the 'infrequent-herb/edibles' use class (referent). Other classes had greater odds of identifying as Black (vs. White; 'frequent-herb': aOR = 1.59, 95%CI = 1.10, 2.32; 'moderate-herb': aOR = 1.75, 95%CI = 1.28, 2.40; "moderate-oil/other': aOR = 1.74, 95%CI = 1.18. 2.57) and being parents ('frequent-herb': aOR = 1.93, 95%CI = 1.37, 2.71; 'moderate-herb': aOR = 1.85, 95%CI = 1.39, 2.47; "moderate-oil/other': aOR = 1.84, 95%CI = 1.29, 2.63), and lower odds of being ≥ Bachelor's-educated ('frequent-herb': aOR = 0.19, 95%CI = 0.13, 0.28; 'moderate-herb': aOR = 0.40, 95%CI = 0.31, 0.54; "moderate-oil/other': aOR = 0.64, 95%CI = 0.46, 0.91). 'Frequent-herb' and 'moderate-herb' classes were older (aOR = 1.07, 95%CI = 1.03, 1.10; aOR = 1.03, 95%CI = 1.003, 1.06), had greater odds of being male (aOR = 1.66, 95%CI = 1.22, 2.27; aOR = 1.47, 95%CI = 1.15, 1.90) and cohabitating (vs. single/other; aOR = 1.64, 95%CI = 1.16, 2.31; aOR = 1.49, 95%CI = 1.11, 2.00), and lower odds of being Asian (vs. White; aOR = 0.33, 95%CI = 0.11, 0.99; aOR = 0.53, 95%CI = 0.32, 0.86). 'Frequent-herb' had lower odds of being employed part-time or students (vs. employed full-time; aOR = 0.60, 95%CI = 0.39, 0.95; aOR = 0.62, 95%CI = 0.40, 0.97) and single/other (vs. married; aOR = 0.58, 95%CI = 0.37, 0.89). 'Moderate-oil/other' had lower odds of living in suburban or urban settings (vs. rural; aOR = 0.58, 95%CI = 0.38, 0.88; aOR = 0.73, 95%CI = 0.50, 1.07).

Compared to the 'moderate-herb' class, the 'frequent-herb' class had lower odds of being ≥ Bachelor's-educated (aOR = 0.47, 95%CI = 0.31, 0.71), employed part-time (vs. full-time; aOR = 0.61, 95%CI = 0.39, 0.96) and suburban (aOR = 0.66, 95%CI = 0.44, 0.97). 'Moderate-oil/other' class had greater odds of being ≥ Bachelor's-educated (aOR = 1.59, 95%CI = 1.10, 2.31) and lower odds of being unemployed (vs. full-time; aOR = 0.63, 95%CI = 0.41,0.97), suburban or urban (vs. rural; aOR = 0.50, 95%CI = 0.33, 0.78; aOR = 0.60, 95%CI = 0.40, 0.89), and cohabitating (vs. single/other; aOR = 0.66, 95%CI = 0.45, 0.97).

Compared to the 'frequent-herb' class, 'moderate-oil/other' was younger (aOR = 0.94, 95%CI = 0.90, 0.98), had lower odds of identifying as sexual minority (vs. heterosexual; aOR = 0.68, 95%CI = 0.47, 0.98), students (vs. employed full-time: aOR = 0.58, 95%CI = 0.37, 0. 92), and cohabitating (vs. single/other; aOR = 0.60, 95%CI = 0.39, 0.91), and had greater odds of being Asian (vs. White; aOR = 4.35, 95%CI = 1.43, 13.23), ≥Bachelor's-educated (aOR = 3.40, 95%CI = 1.10, 2.31), and employed part-time (vs. full-time; aOR = 1.79, 95%CI = 1.07, 2.99).

Cannabis use class in relation to use-related outcomes

Bivariate analyses characterizing the classes with regard to use-related outcomes are shown in Table 2. Shown in Table 4, multivariable regression analyses (controlling for state cannabis law and sociodemographics) examined use classes, relative to the 'moderate-herb' class (referent group), in relation to the use-related outcomes. 'Frequent-herb' reported less problematic use (B=-0.18, 95%CI=-0.30, -0.07) and 'moderate-oil/other' reported greater (B = 0.39, 95%CI = 0.27, 0.51). 'Infrequent-herb/edibles' had lower odds of driving post-use of cannabis (aOR = 0.28, 95%CI = 0.22, 0.37) and cannabis/alcohol (aOR = 0.52, 95%CI = 0.35, 0.76); 'frequent-herb' (aOR = 1.52, 95%CI = 1.02, 2.28) and 'moderate-oil/other' (aOR = 3.98, 95%CI = 2.72, 5.82) reported lower odds of driving post-cannabis/alcohol co-use. 'Moderate-oil/other' reported higher quitting importance (B = 0.59, 95%CI = 0.17, 1.01); 'frequent-herb' reported lower (B=-0.33, 95%CI=-0.99, -0.18). 'Infrequent-herb/edibles' reported higher quitting confidence (B = 0.56, 95%CI = 0.20, 0.92); 'frequent-herb' (B=-1.01, 95%CI=-1.45, -0.57) and 'moderate-oil/other' (B=-1.27, 95%CI=-1.74, -0.81) reported lower. 'Infrequent-herb/edibles' reported fewer mental health symptoms

Table 3 Multinomial logistic regression assessing sociodemographic correlates of cannabis use class among US young adults reporting past 30-day use ($N = 1,968$)

	Frequent-herb (vs. Infrequent-herb/edibles)			Moderate-herb (vs. Infrequent-herb/edibles)			Moderate-oil/other (vs. Infrequent-herb/edibles)		
Variables	**aOR**	**95% CI**	**p**	**aOR**	**95% CI**	**p**	**aOR**	**95% CI**	**p**
State non-medical cannabis law									
Legalized (ref: not legalized)	1.19	0.89,1.58	.241	1.01	0.80, 1.28	.934	1.11	0.83, 1.49	.485
Sociodemographics									
Age	1.07	1.03, 1.10	**<.001**	1.03	1.003, 1.06	**.030**	1.00	0.97, 1.04	.826
Male sex (ref: female)	1.66	1.22, 2.27	**.001**	1.47	1.15, 1.90	**.003**	1.21	0.89, 1.65	.226
Sexual minority (ref: heterosexual)	1.19	0.88, 1.62	.252	1.00	0.78, 1.29	.979	0.81	0.59, 1.11	.190
Hispanic (ref: non-Hispanic)	0.78	0.54, 1.14	.198	0.93	0.69, 1.24	.601	1.14	0.80, 1.63	.459
Race (ref: White)									
Black	1.59	1.10, 2.32	**.015**	1.75	1.28, 2.40	**.001**	1.74	1.18, 2.57	**.005**
Asian	0.33	0.11, 0.99	**.048**	0.53	0.32, 0.86	**.011**	0.94	0.56, 1.56	.806
Other	0.75	0.44, 1.28	.291	1.15	0.76, 1.74	.512	1.18	0.70, 1.99	.535
Education ≥ Bachelor's degree (ref: <)	0.19	0.13, 0.28	**<.001**	0.40	0.31, 0.54	**<.001**	0.64	0.46, 0.91	**.011**
Employment status (ref: full-time)									
Part-time	0.60	0.39, 0.95	**.027**	0.99	0.70, 1.41	.963	1.08	0.71, 1.65	.716
Student	0.62	0.40, 0.97	**.037**	0.93	0.66, 1.30	.666	0.88	0.59, 1.32	.542
Unemployed	1.41	0.98, 2.03	.067	1.30	0.94, 1.80	.110	0.82	0.53, 1.26	.359
Community type (ref: rural)									
Suburban/micropolitan (10,000–49,999)	0.76	0.51, 1.12	.168	1.16	0.83, 1.63	.398	0.58	0.38, 0.88	**.010**
Urban (50,000+)	0.87	0.60, 1.25	.444	1.23	0.88, 1.70	.222	0.73	0.50, 1.07	**.110**
Relationship (ref: single/other)									
Married	0.58	0.37, 0.89	**.014**	0.85	0.61, 1.20	.359	0.74	0.49, 1.12	.158
Cohabitating	1.64	1.16, 2.31	**.005**	1.49	1.11, 2.00	**.009**	0.98	0.67, 1.44	.909
Parent/has child(ren) (ref: no)	1.93	1.37, 2.71	**<.001**	1.85	1.39, 2.47	**<.001**	1.84	1.29, 2.63	**.001**
	Frequent-herb (vs. Moderate-herb)			**Moderate-oil/other (vs. Moderate-herb)**			**Moderate-oil/other (vs. Frequent-herb)**		
	aOR	**95% CI**	**p**	**aOR**	**95% CI**	**p**	**aOR**	**95% CI**	**p**
State non-medical cannabis law									
Legalized (ref: not legalized)	1.18	0.88, 1.57	.269	1.10	0.81, 1.49	.548	0.94	0.66, 1.32	.701
Sociodemographics									
Age	1.03	1.00, 1.07	.060	0.97	0.94, 1.00	.143	0.94	0.90, 0.98	**.004**
Male sex (ref: female)	1.13	0.82, 1.54	.457	0.82	0.59, 1.14	.240	0.73	0.50, 1.06	.097
Sexual minority (ref: heterosexual)	1.19	0.88, 1.62	.266	0.81	0.58, 1.13	.206	0.68	0.47, 0.98	**.041**
Hispanic (ref: non-Hispanic)	0.85	0.59, 1.23	.387	1.24	0.85, 1.80	.267	1.46	0.94, 2.25	.090
Race (ref: White)									
Black	0.91	0.64, 1.30	.601	0.99	0.68, 1.46	.977	1.09	0.71, 1.68	.685
Asian	0.41	0.14, 1.24	.113	1.79	0.95, 3.36	.072	4.35	1.43, 13.23	**.010**
Other	0.65	0.38, 1.11	.115	1.03	0.60, 1.75	.923	1.58	0.84, 2.97	.158
Education ≥ Bachelor's degree (ref: <)	0.47	0.31, 0.71	**<.001**	1.59	1.10, 2.31	**.014**	3.40	2.13, 5.44	**<.001**
Employment status (ref: full-time)									
Part-time	0.61	0.39, 0.96	**.031**	1.09	0.70, 1.69	.701	1.79	1.07, 2.99	**.027**
Student	0.67	0.42, 1.06	.087	0.95	0.62, 1.47	.819	1.42	0.84, 2.39	.187
Unemployed	1.08	0.76, 1.55	.671	0.63	0.41, 0.97	**.035**	0.58	0.37, 0.92	**.021**
Community type (ref: rural)									
Suburban/micropolitan (10,000–49,999)	0.66	0.44, 0.97	**.035**	0.50	0.33, 0.78	**.002**	0.77	0.48, 1.23	.265
Urban (50,000+)	0.71	0.49, 1.02	.065	0.60	0.40, 0.89	**.012**	0.85	0.55, 1.30	.447
Relationship (ref: single/other)									
Married	0.67	0.43, 1.05	.083	0.87	0.56, 1.35	.528	1.29	0.77, 2.16	.339
Cohabitating	1.10	0.79, 1.54	.566	0.66	0.45, 0.97	**.036**	0.60	0.39, 0.91	**.017**
Parent/has child(ren) (ref: no)	1.04	0.75, 1.45	.814	0.99	0.69, 1.43	.970	0.95	0.64, 1.43	.820

Notes aOR: adjusted odds ratio. CI: confidence interval. Nagelkerke R-square = 0.203

Table 4 Multivariable regressions assessing cannabis use class in relation to use-related outcomes among US young adults reporting past 30-day use (*N* = 1,968)

	Problematic use			**Driving after cannabis use**			**Driving after cannabis/alcohol co-use**		
Variables	**B**	**95% CI**	**p**	**aOR**	**95% CI**	**p**	**aOR**	**95% CI**	**p**
Cannabis use class (ref: moderate-herb)									
Infrequent-herb/edibles	0.02	-0.07, 0.12	.606	0.28	0.22, 0.37	**<.001**	0.52	0.35, 0.76	**.001**
Frequent-herb	-0.18	-0.30, -0.07	**.002**	1.32	0.99, 1.77	.058	1.52	1.02, 2.28	**.041**
Moderate-oil/other	0.39	0.27, 0.51	**<.001**	1.30	0.96, 1.77	.095	3.98	2.72, 5.82	**<.001**
State non-medical cannabis law									
Legalized (ref: not legalized)	0.06	-0.01, 0.14	.098	0.69	0.56, 0.85	**<.001**	0.74	0.56, 0.99	**.043**
Sociodemographics									
Age	-0.02	-0.03, -0.01	**<.001**	1.02	0.99, 1.04	.228	0.99	0.96, 1.03	.561
Male sex (ref: female)	0.12	0.04, 0.20	**.003**	1.62	1.29, 1.03	**<.001**	2.27	1.69, 3.06	**<.001**
Sexual minority (ref: heterosexual)	-0.09	-0.17, -0.01	**.038**	0.81	0.65, 1.02	.071	0.49	0.35, 0.69	**<.001**
Hispanic (ref: non-Hispanic)	0.05	-0.05, 0.14	.303	0.98	0.76, 1.26	.895	1.06	0.74, 1.51	.751
Race (ref: White)									
Black	-0.07	-0.17, 0.03	.162	1.51	1.16, 1.98	**.003**	2.21	1.59, 3.09	**<.001**
Asian	0.16	0.02, 0.30	**.026**	0.69	0.44, 1.08	.101	0.58	0.32, 1.08	.088
Other	0.10	-0.03, 0.24	.141	1.13	0.78, 1.65	.521	1.17	0.68, 1.99	.577
Education ≥ Bachelor's degree (ref: <)	0.15	0.06, 0.24	**.002**	0.80	0.61, 1.04	.090	1.05	0.74, 1.48	.794
Employment status (ref: full-time)									
Part-time	-0.04	-0.15, 0.08	.514	0.68	0.49, 0.93	**.016**	0.68	0.43, 1.07	.092
Student	0.12	0.01, 0.22	**.031**	1.01	0.75, 1.36	.952	1.17	0.80, 1.72	.426
Unemployed	-0.06	-0.16, 0.04	.252	0.63	0.47, 0.83	**.001**	0.61	0.41, 0.91	**.016**
Community type (ref: rural)									
Suburban/micropolitan (10,000–49,999)	0.02	-0.09, 0.13	.701	1.09	0.81, 1.46	.575	1.11	0.72, 1.71	.640
Urban (50,000+)	0.01	-0.09, 0.11	.853	0.97	0.73, 1.28	.803	1.41	0.95, 2.09	.091
Relationship (ref: single/other)									
Married	0.01	-0.10, 0.12	.863	1.18	0.88, 1.60	.270	1.32	0.88, 1.98	.177
Cohabitating	-0.13	-0.22, -0.04	**.007**	0.89	0.69, 1.16	.393	0.81	0.55, 1.12	.293
Parent/has child(ren) (ref: no)	-0.01	-0.10, 0.08	.857	1.41	1.10, 1.81	**.008**	1.16	0.82, 1.62	.408
Adjusted R-square		*.100*			*.204**			*.219**	
	Importance of quitting			**Confidence in quitting**			**Mental health symptoms (PHQ-4)**		
	B	**95% CI**	**p**	**B**	**95% CI**	**p**	**B**	**95% CI**	**p**
Cannabis use class (ref: moderate-herb)									
Infrequent-herb/edibles	-0.21	-0.54, 0.12	.206	0.56	0.20, 0.92	**.002**	-0.55	-0.93, -0.17	**.005**
Frequent-herb	-0.33	-0.99, -0.18	**.005**	-1.01	-1.45, -0.57	**<.001**	-0.01	-0.48, 0.46	.968
Moderate-oil/other	0.59	0.17, 1.01	**.006**	-1.27	-1.74, -0.81	**<.001**	1.03	0.53, 1.52	**<.001**
State non-medical cannabis law									
Legalized (ref: not legalized)	-0.10	-0.37, 0.16	.439	0.08	-0.21, 0.37	.583	-0.03	-0.34, 0.28	.863
Sociodemographics									
Age	-0.05	-0.09, -0.02	**.001**	0.07	0.03, 0.10	**<.001**	-0.02	-0.06, 0.02	.261
Male sex (ref: female)	0.14	-0.14, 0.42	.319	-0.34	-0.66, -0.03	**.030**	-0.78	-1.11, -0.45	**<.001**
Sexual minority (ref: heterosexual)	-0.74	-1.02, -0.46	**<.001**	0.34	0.02, 0.65	**.035**	0.60	0.26, 0.93	**<.001**
Hispanic (ref: non-Hispanic)	0.70	0.37, 1.03	**<.001**	-0.27	-0.64, 0.10	.148	-0.18	-0.57, 0.21	.363
Race (ref: White)									
Black	1.14	0.79, 1.49	**<.001**	-0.61	-1.00, -0.22	**.002**	-0.85	-1.27, -0.44	**<.001**
Asian	0.47	-0.03, 0.97	.063	-0.20	-0.75, 0.36	.485	-0.39	-0.98, 0.20	.191
Other	0.32	-0.16, 0.80	.193	-0.47	-1.00, 0.07	.086	-0.26	-0.82, 0.31	.377
Education ≥ Bachelor's degree (ref: <)	0.72	0.39, 1.04	**<.001**	-0.08	-0.74, 0.91	.646	-0.31	-0.69, 0.07	.110
Employment status (ref: full-time)									
Part-time	-0.01	-0.41, 0.39	.945	0.12	-0.32, 0.56	.601	0.25	-0.21, 0.72	.287
Student	0.44	0.07, 0.82	**.020**	0.23	-0.18, 0.65	.270	0.36	-0.08, 0.08	.105
Unemployed	-0.17	-0.53, 0.19	.365	-0.49	-0.89, -0.09	**.017**	0.60	0.17, 1.02	**.006**

Table 4 (continued)

Community type (ref: rural)									
Suburban/micropolitan (10,000–49,999)	-0.02	-0.39, 0.36	.924	0.24	-0.18, 0.65	.265	-0.12	-0.56, 0.32	.596
Urban (50,000+)	-0.23	-0.59, 0.13	.203	0.08	-0.31, 0.47	.690	-0.41	-0.83, 0.01	.053
Relationship (ref: single/other)									
Married	0.26	-0.13, 0.64	.188	-0.11	-0.53, 0.32	.619	0.05	-0.40, 0.49	.838
Cohabitating	-0.26	-0.59, 0.07	.127	0.36	-0.003, 0.73	.052	-0.27	-0.66, 0.12	.169
Parent/has child(ren) (ref: no)	0.08	-0.24, 0.41	.616	0.06	-0.30, 0.42	.750	-0.42	-0.80, -0.04	**.032**
Adjusted R-square		*.090*			*.075*			*.077*	

Notes aOR: adjusted odds ratio. CI: confidence interval. * Nagelkerke R-square. *In alternative analyses using frequent-herb use class as referent group (rather than the moderate-herb class)*: Problematic use – each of the other groups reported more problematic use; Driving after cannabis use – infrequent-herb/edibles had lower odds but no differences between frequent-herb vs. moderate-herb or moderate-oil/other; Driving after cannabis and alcohol use – infrequent-herb/edibles and moderate-herb had lower odds, while moderate-oil/other had greater odds; Importance of quitting – no differences except moderate-oil/other reported greater importance; Confidence in quitting – infrequent-herb/edibles and moderate-herb were more confident, no differences between frequent-herb and moderate-oil/other classes; Mental health – infrequent-herb/edibles fewer symptoms, no differences between frequent-herb and moderate-herb classes, more mental health symptoms in moderate-oil/other

(B=-0.55, 95%CI=-0.93, -0.17); 'moderate-oil/other' reported more (B = 1.03, 95%CI = 0.53, 1.52).

Regarding other factors, living in legalized non-medical cannabis states was associated with less likelihood of driving after cannabis use (with or without alcohol); men and those identifying as Black reported more problematic use and driving-related risks and lower confidence in quitting; sexual minority individuals reported less problematic use and driving-related risks; and parents reported greater odds of driving after cannabis use – after adjusting for cannabis use class membership (Table 4).

Discussion

This study underscores the importance of assessing cannabis use frequency and product type when considering use-related risks [26, 29, 31–33], specifically among young adults [7, 28, 34]. These findings reflect what is known – infrequent cannabis use confers the least risky profile, with risk compounding with more frequent use [6–12]. However, current findings show that, accounting for sociodemographic factors, even moderate use of more potent products (e.g., concentrates) can reflect some risks similar to or greater than frequent use of less potent products (e.g., herb).

Similar to prior studies [7, 28, 34], the largest class used infrequently and primarily less potent products (herb, edibles). Another large class primarily used dried herb (in this case, moderate use), and 2 smaller groups represented the greatest risk profiles – those frequently using (primarily herb) and those using more potent products (oils, concentrates) [7, 28, 34]. Aligning with prior research, the 'infrequent-herb/edibles' use class generally showed the least risk across outcomes [6–12]. Meanwhile, the 'moderate-oil/other' class reported the most problematic use [26, 29, 31, 33] and mental health symptoms [28, 32], and were the most likely to have medical cannabis cards and use primarily for medical purposes. In addition, reflecting prior research [7], compared to the 'infrequent-herb/edibles' use class, the other classes had greater odds of driving after cannabis use, reporting roughly equal likelihood; however, current findings add to the literature, showing that the 'moderate-oil/other' class reported the greatest risk for driving after cannabis/alcohol co-use. Another novel finding is that the 'moderate-oil/other' class reported the highest importance of quitting but were the least confident. The 'frequent-herb' class showed the second greatest risk profile, being less confident and had greater odds of driving after cannabis/alcohol co-use relative to the 'infrequent-herb/edibles' and 'moderate-herb' classes. However, the 'frequent-herb' class also showed similarities to 'moderate-herb', including likelihood of driving after cannabis use, importance of quitting, and mental health.

Notably, analysis of problematic use, which potentially signal a range of symptoms that align with CUD [48], showed unexpected results – the 'frequent-herb' class reported the lowest problematic use, the 'infrequent-herb/edibles' and 'moderate-herb' classes did not differ, and 'moderate-oil/other' reported the greatest. We further explored this: the 'moderate-oil/other' class reported the highest average scores across items while the 'frequent-herb' class reported the lowest for each except legal consequences. Reasons for this may be that frequent users seek to alleviate symptoms of CUD [48], are more accustomed to cannabis' effects and thus perceive fewer negative physical, psychological, and/or cognitive effects interfering with normal functioning [49], or may have unique social contexts that enable use (e.g., fewer were college-educated and married).

Regarding sociodemographics, as suggested by prior research [2–4, 50], the cannabis market may have negative implications for groups disproportionately impacted by other licit drug markets [51, 52]: those reporting past-month use and higher use levels were male and Black, and those reporting past-month use were also more likely urban and sexual minority. Notably, while residing in states with legalized non-medical cannabis was associated with any past-month use (shown previously [53,

54]), it was not associated with use class, suggesting that illegal cannabis markets also have diverse and highly-potent products [55]. Another important finding is that those in states with legalized non-medical cannabis had lower odds of driving post-cannabis use (with or without alcohol), which coincides with some studies [56, 57] but conflicts with others [58, 59], perhaps reflecting differences in assessments of driving-related behaviors. Furthermore, parents had greater odds of reporting cannabis use, using more often, and driving after use, underscoring the significant consequences adult cannabis use can have on children [60, 61] and the need for parental education regarding cannabis (e.g., child safety, communication skills [62]), particularly as regulatory contexts evolve.

Findings have implications for research, practice, and policy. Future research should use longitudinal designs and consider these and other dimensions of cannabis use behaviors to understand their collective impact on cannabis-related harms over time. These findings and future studies should inform policies regarding limits on product potency, required warnings on cannabis products regarding use frequency and of high-potency products, and other regulations to reduce negative individual- and population-level impacts of cannabis.

Limitations

This study is limited in generalizability, given social-media based recruitment and purposive sampling of ~50% young adults reporting past-month cannabis use. Furthermore, based on preliminary analyses, we chose categories of use characteristics (e.g., vaping/orally consuming oils, days used) prior to conducting LCA and summarized problematic use items as a single score (based on the high correlations among items); however, operationalizing the data in these ways may have impacted findings. Self-reported measures introduce potential bias and are not inclusive of all potential determinants of cannabis use outcomes. Additionally, there is the possibility of fraudulent/invalid responses, despite multiple efforts to detect/address such issues (e.g., verifying email and phone numbers; scrutinizing data for indications of duplicates [e.g., similar names, emails, addresses, etc.] or concerning survey completion metrics (e.g., completion time/duration, IP address, illogical responses]). Finally, data were cross-sectional, precluding causal inference.

Conclusions

Young adults are increasingly using cannabis, including high-potency products. Thus, it is critical to monitor cannabis use and related consequences among young people, especially as the cannabis market expands and diversifies. This study assessed cannabis use profiles based on use frequency, product types, and daily use patterns, and their associations with adverse outcomes, including driving after use, problematic use, and mental health symptoms. One key finding was that even moderate use of high-potency cannabis products can carry risks equal to or greater than frequent use of less potent varieties. This finding underscores the need for preventive strategies for both frequent and moderate use, particularly of oils and concentrates, to reduce the likelihood of mental health issues, problematic cannabis use, and related injuries, including those from motor vehicle accidents.

Abbreviations

CARMA	Cannabis Regulation, Marketing & Appeal
CUD	Cannabis use disorder
LCA	Latent class analysis
US	United States

Supplementary Information

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Supplementary Material 1

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Author contributions

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Data availability

The datasets used and/or analyzed in the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

This study was approved by the George Washington University Institutional Review Board (NCR224124). All participants provided informed consent.

Consent for publication

N/A.

Competing interests

The authors declare no competing interests.

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