Research Article

Cannabis Products and Use Patterns Associated with Cannabis Use Disorder Symptoms Among Youth in Southern California

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ABSTRACT

Objective: Cannabis use is common among adolescents. Limited research has examined how specific cannabis use behaviors may differentially increase cannabis use disorder (CUD) risk. **Method:** Data were from two waves of a prospective cohort of Southern California adolescents who used cannabis in the past six months (N= 420; Fall 2022, Spring 2023). Multivariable logistic regression models were used to examine the association of each cannabis use behavior at baseline (number of modes of cannabis administration used, product type used first and most often, cannabinoid formulation used most often, past 30-day frequency, quantity) with probable CUD at a six-month follow-up (measured using the Cannabis Abuse Screening Test), adjusting for sociodemographic factors, other substance use, and probable CUD at baseline. **Results:** Most adolescents (69.8%) used >1 mode of cannabis in the past six-months; concentrates (vaped or dabbed) were the product type used most often (37.5%). Greater odds of CUD were observed for each additional cannabis product used in the past 6 months (vs. only one; adjusted odds ratio [AOR] range = 2.83-4.13; ps < .05), and for frequent past 30-day cannabis use (10+ days/month vs. 1-2 days/month; AOR = 2.87, 95%CI = [1.31,6.27]). No other cannabis behaviors or characteristics were associated with CUD in adjusted models. **Conclusions:** Frequent past-month cannabis use and using multiple modes of administration were predictors of probable CUD. In addition to monitoring the overall presence of adolescent cannabis use, these results demonstrate the importance of raising awareness about specific use behaviors associated with CUD risk among youth, particularly in regions with well-developed cannabis markets.

Key words: = cannabis; adolescents; cannabis use disorder; youth; cannabis use

Cannabis use is highly prevalent among adolescents in the United States (U.S.), with 29% of U.S. 12th graders reporting past-year use in 2023, and 12% of all 12th graders reporting daily use for more than a month (Miech et al., 2023). Adolescent cannabis use is linked to various adverse health outcomes, including an increased risk of mental health disorders (Onaemo et al., 2021), disruptions in working memory (Schweinsburg et al., 2008) and brain

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development (Jacobus & Tapert, 2014), and alterations in cognitive functioning that may have a greater impact compared to cannabis use during adulthood (Quinn et al., 2008). Individuals are also at a higher risk of developing cannabis use disorder (CUD) when cannabis use is initiated during adolescence compared to adulthood (Winters & Lee, 2008). CUD is characterized by problematic use of cannabis and can lead to clinically significant impairment, distress, or co-occurrence with mental health disorders like mood or anxiety disorders (Hasin & Walsh, 2020; Gendy et al., 2023; Onaemo et al., 2021; Zaman et al., 2015). CUD cases often become evident during youth and young adulthood (Kosty et al., 2017). For example, among adolescents aged 12-17 who have ever used cannabis, the prevalence of past-year CUD was 16% in 2015-2017 pooled data (Han et al., 2019). There is limited information on more recent trends among youth. Following legalization of recreational cannabis for adults, the prevalence of CUD increased from 2.2% to 2.7% among adolescents residing in states where recreational cannabis is legal (Cerdá et al., 2020). Yet, there is a dearth of data available to explain such increases. Such data are critically needed to identify cannabis use behaviors and products that may increase the risk of CUD among adolescents to inform interventions and potential regulation of cannabis products to protect youth.

Legalization of cannabis for adult use in multiple U.S. states has expanded the range of products available on the market, many of which appeal to youth (Goodman et al., 2019; Tan et al., 2022). Although adolescents cannot purchase cannabis legally, the proliferation of cannabis commercialization may make access to novel products, such as vape devices, easier through informal channels or third-party purchasing. Youth residing in states with adult-use cannabis legalization report that cannabis is more accessible post-legalization (Harpin et al., 2018). Despite these changes to the cannabis market, few studies have attempted to characterize use behaviors within adolescent populations, including frequency of use, number of administration methods, preferred products (including which product types are tried first and used most often), or quantities of cannabis used per use session. Such data are needed to understand the impact of these factors on CUD among youth.

Existing research indicates that certain cannabis use behaviors and product types may elevate the risk of problematic use and CUD. Greater frequency, quantity, and different product types have each been associated with adverse outcomes such as CUD risk or psychological distress. Prior studies suggest a possible dose-response relationship between cannabis use frequency and CUD (Leadbeater et al., 2019); however, much of the research regarding the effects of cannabis use frequency is outdated (Chen et al., 1997) and not reflective of products currently on the market, many of which contain higher potency levels than in the past. Cannabis vaping is also becoming more common as a route of administration among adolescents (Keyes et al., 2022), yet research on its effects compared to other routes of administration is lacking. Emerging evidence shows that among adolescents who use cannabis, those who vape tend to use cannabis more frequently than those who exclusively use other routes of administration (Mitchell et al., 2024), and that cannabis vaping is associated with psychological distress (Mattingly et al., 2024). However, the risk profile of using cannabis concentrates, including vapes or dabs, compared to other commonly used routes of administration (e.g., edibles or flower) remains unknown. In addition to product types, quantity may differentially contribute to CUD risk; adolescents may be more sensitive to the effects of cannabis compared to adults, with smaller quantities leading to more pronounced acute cognitive effects (Murray et al., 2022) and a higher likelihood of developing cannabis dependence compared to adults (Chen et al., 1997), establishing dose-dependent impairments. However, little is known about how different cannabis use behaviors within adolescents, including frequency, types of products used, and average use quantities (e.g., joints or vape sessions per day), relate to cannabis-related risks, including CUD.

The current study assessed patterns of cannabis use among adolescents in Southern California within the context of a highly developed, legal commercialized cannabis market for adults. We examined a wide range of cannabis use behaviors among a sample of youth reporting past 6-month cannabis use at baseline, including routes of administration, frequency of use, and quantity of use within a given use session. We

then estimated the association of cannabis use behaviors with the risk of probable CUD six months later. We hypothesized that (1) higher past-month frequency and greater average quantities of cannabis use in the past month would be associated with greater odds of probable CUD at follow-up, and (2) youth using cannabis through multiple modes of administration (vs one) or concentrate products as their most-used product type (vs edibles or flower) would demonstrate greater odds of CUD at follow-up.

METHODS

Participants

Data were from two waves of a prospective cohort study of Southern California high school students. In the Fall semesters of 2020 and 2021, the study recruited 9th grade students from eleven schools across five Southern California counties (graduating class of 2024 and class of 2025). Students completed self-administered, online surveys at school twice each academic year (once per semester) with questions on substance use and behavioral health. The current study used data from the Fall 2022 survey as baseline (September – December 2022), and the Spring 2023 survey as follow-up (January – May 2023) when participants were in 10th/11th grade. We chose to analyze these waves because they introduced more detailed questions about specific cannabis product types into the survey. The timing of the surveys was also such that cannabis had been legal and available for adult purchase for approximately 5 years (i.e., first licensed recreational dispensaries opened in California in January 2018). Additional information pertaining to study recruitment procedures is detailed elsewhere (Harlow et al., 2022).

Participants were eligible for the current study if they reported past 6-month cannabis use at baseline and had non-missing data on all baseline covariates and the outcome at follow-up. Of the 3,831 participants who completed the baseline survey, 456 (12%) used cannabis during the past 6 months at baseline and had complete covariate data; of these, 420 (92%) had outcome data at follow-up and constituted the analytic sample. We used listwise deletion for missing data on specific cannabis use behaviors. Prior studies indicate that listwise deletion performs similarly (and sometimes better) than multiple imputation in the case of covariate-adjusted regression models (Pepinsky, 2018).

Measures

Predictors, cannabis use behaviors. In this survey, participants reported past 6-month and past 30-day frequency of the following four modes of use: smoking, edibles, vaping, or CBD or hemp products (i.e., modes of use not including THC). We assessed the number modes of use (coded 1-4), and past 30-day use frequency using the highest value across modes (0 days, 1-2 days, 3-9 days, 10+ days).

Among those who reported any past six-month cannabis use, participants reported the product they used first at the age of onset and product they used most often: blunts, joints/dry pipes, bongs, goods, drinks, dry flower vapes, vape pens, dabs, tinctures, topicals, capsules, or another products not listed. We created the following collapsed categories by product type: vaped concentrates [vape pens, dabbing], plant material/flower [blunts, joints/dry pipes, bongs, dry flower vapes], edibles [food or drinks], or other [tinctures, topicals, capsules, or another product not listed]. Participants also reported cannabinoid formulation used most often in the past 30-days (mostly CBD, mostly THC, a mix of THC and CBD, or don't know). Finally, we assessed average use quantity in the past 30 days for smoking and vaping, with an item querying the average number of joints/bowls smoked per use day among those who used flower. Among those who vaped, two items assessed the average number of times vape was used per day, and number of hits taken per use session.

In our addition to our primary predictors of cannabis use behaviors, we included additional cannabis use variables for descriptive purposes, including from where youth obtained cannabis (select all that apply: self-grown, free from someone, buy from someone, buy from an in-person dispensary without a medical card, an online dispensary, a delivery service, buy from a dispensary with a real medical card, buy from a dispensary with a fake medical card, other), locations where they used cannabis (select all that apply: at home, on or near school campus including specific places on school campuses for those who used cannabis at school, friend/family

member's home, restaurants, outdoor public spaces, indoor public spaces, in a vehicle, at work, other), and who they primarily used cannabis with (mutually exclusive: alone, with friends, siblings/cousins, other family members, significant other, co-workers, other).

Outcome, cannabis use disorder (CUD). Probable CUD was assessed using the Cannabis Abuse Screening Test (CAST), a previously validated measure used to screen for cannabis-related disorders (El Malki et al., 2024; Legleye, 2018). The CAST was administered at baseline and follow-up to all participants who endorsed past 6-month use of any cannabis. The CAST includes six questions related to problematic use in the past six months: using cannabis before midday, using cannabis while alone, having memory problems while using cannabis, having friends/family suggest that cannabis use should be cut down or stopped, unsuccessful attempts to quit or reduce use, and problems related to using cannabis (e.g., arguments or problems at school or work). Each of the six questions are rated on a 5-point scale capturing the frequency each problem was experienced in the past six months (0 = never, 1 = rarely, 2 = sometimes, 3 = quite often, 4 = very often). Following clinical cutoff points identified in a prior reliability and validity study of the CAST with DSM-IV CUD in a sample of adolescents (Legleye et al., 2011), the present study used a score of 4+ as a binary cutoff point representing probable past six-month CUD.

Covariates. The following sociodemographic characteristics collected at baseline were included: gender identity (male or masculine, female or feminine, transgender or nonbinary, decline to answer), race (Asian, White, Multi-racial, another race), ethnicity (Hispanic, not Hispanic), highest parental educational attainment (< high school, high school, some college, college graduate, advanced degree, don't know, decline to answer), perceived financial status (pretty well off, about average, financially struggling/in poverty, it varied), and sexuality (heterosexual, gay/lesbian, bisexual/pansexual, another identity, decline to answer). We also included any past 30-day use of nicotine products (including cigarettes, e-cigarettes, IQOS, snus, pouches, gum/lozenges, cigars, or cigarillos) or alcohol (yes/no) at baseline as covariates. Finally, in the adjusted model examining the number of cannabis modes used, we additionally adjusted for product type used most often (including a missing category), given the potential conceptual overlap between primary product type and use of multiple modes

Statistical Analysis

First, we generated descriptive statistics of covariates and all cannabis use variables. Logistic regression was used to assess the association between cannabis use behaviors at baseline with probable CUD at follow-up. We fit unadjusted models, followed by models adjusting for demographic characteristics, baseline probable CUD status, and baseline past 30-day nicotine or alcohol use. Unadjusted odds ratios (ORs), adjusted odds ratios (aORs), and 95% confidence intervals (CIs) are reported. For variables with a natural order, we chose the lowest category as the reference group. When selecting the reference group for product type variables, we chose edibles based on our a-priori hypothesis that edibles would be associated with lower odds of probable CUD as compared to concentrates or flower. Similarly, for cannabinoid formulation used most often, we selected 'mostly CBD' as the reference group because we hypothesized it would also be associated with the lowest likelihood of probable CUD. We conducted a sensitivity analysis examining associations between cannabis use behaviors at baseline and each of the six CAST items, individually, at follow-up. All analyses were conducted using SAS 9.4 software (SAS Institute Inc., 2017).

RESULTS

Sample Characteristics

Among adolescents who reported cannabis use in the past 6-months at baseline, approximately half (51.4%) identified as female (Table 1). Most participants identified as Hispanic (53.1%), or White (25.5%). Most identified as heterosexual (58.8%), with an appreciable proportion identifying as bisexual or pansexual (24.8%). Parental education was distributed across all categories, and a plurality expressed their perceived socioeconomic status as about average (46.4%).

Table 1. *Sociodemographic Characteristics and Substance Use Behaviors of Adolescents Who Used Cannabis in the Past Six Months at Baseline (N = 420)*

Characteristic	*N* (col %)
Sociodemographic Characteristics	
Gender identity	
Male or masculine	152 (36.2)
Female or feminine	216 (51.4)
Transgender or non-binary[a]	39 (9.3)
Prefer not to disclose	13 (3.1)
Race/Ethnicity[b]	
American Indian or Alaska Native	9 (2.1)
Asian	31 (7.4)
Black or African American	10 (2.4)
Native Hawaiian or Pacific Islander	7 (1.7)
White	107 (25.5)
Hispanic or Latinx	223 (53.1)
Multi-racial	30 (7.1)
Another race	3 (0.7)
Sexual identity	
Straight/Heterosexual	247 (58.8)
Gay or lesbian	14 (3.3)
Bisexual or pansexual	104 (24.8)
Another sexual minority[c]	44 (10.5)
Prefer not to disclose	11 (2.6)
Highest parental educational attainment	
<High school	43 (10.2)
High school graduate	64 (15.2)
Some college	83 (19.8)
College graduate	119 (28.3)
Advanced degree	93 (22.1)
Don't know	11 (2.6)
Prefer not to disclose	7 (1.7)
Perceived socioeconomic status	
Pretty well off financially	96 (22.9)
About average	195 (46.4)
Financially struggling or in poverty	39 (9.3)
It varied	90 (21.4)
Baseline substance use behaviors	
Past 30-day cannabis use	
Yes	282 (67.1)
No	138 (32.9)
Probable CUD	
Yes	141 (33.6)
No	279 (66.4)
Past 30-day nicotine use	
Yes	170 (40.5)
No	250 (59.5)
Past 30-day alcohol use	
Yes	207 (49.3)
No	213 (50.7)

Note. [a]Includes those who identified as transgender male, transgender female, or gender variant/non-binary, or another gender identity not listed. [b]In regression models, race was collapsed to the following categories: Asian, White, Multiracial, another race. [c]Includes those who identified as asexual, queer, questioning, or another sexual identity not listed.

Of our sample of adolescents reporting past 6-month cannabis use at baseline, most (67.1%) also reported past 30-day cannabis use, and 33.6% screened positive for probable CUD at baseline. A majority of the sample also reported past 30-day nicotine use (59.5%) or alcohol use (50.7%).

Cannabis Use Behaviors

Nearly one-third (30.2%) of participants used only one type of cannabis product in the past six months, while 24.8% used two, 20.5% used three, and 24.5% used all four types (smoking, vaping, edibles, and CBD/hemp; Table 2). Cannabis concentrates, including vape pens or dabs (vs flower, edibles, or other), were the product type most commonly used first (33.0%), and also the product type used most often in the past 6 months (37.5%). Among those reporting use of edibles most often, nearly all used food-based products (e.g., gummies, baked goods), and within the concentrate group, almost all reported using vape pens rather than dab rigs (e-Table 2). Use of plant material/flower was more evenly distributed across blunts, joints, bongs, and vaporizers. Probable CUD prevalence at follow-up varied across specific product types, with the highest observed among bong users (46.7%) and the lowest among those using topicals or capsules (≤15%).

Table 2. *Association Between Cannabis Behaviors at Baseline and Probable CUD at Follow-Up (N = 420)*

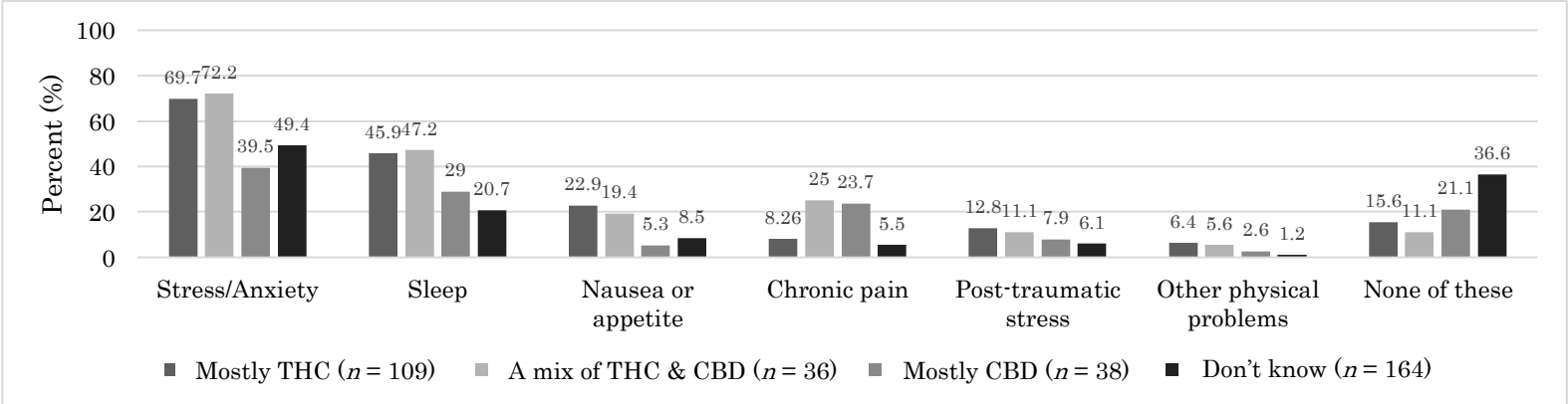
Characteristic	Baseline Total (*n*, col %)	Probable CUD at follow-up (*n*, row %)	Model Results	
			Unadjusted OR (95% CI)	Adjusted[a] aOR (95% CI)
	420 (100)	100 (23.8)		
Among all past 6-month users at baseline:				
Number of modes used in the past six months[b], *n* = 420				
1 mode	127 (30.2)	11 (8.7)	Ref	Ref
2 modes	104 (24.8)	24 (23.1)	**3.16 (1.47, 6.82)**	**2.67 (1.13, 6.28)**
3 modes	86 (20.5)	27 (31.4)	**4.83 (2.24, 10.4)**	**3.41 (1.41, 8.27)**
4 modes	103 (24.5)	38 (36.9)	**6.17 (2.95, 12.9)**	**4.37 (1.82, 10.5)**
Product type first used, *n* = 315				
Edibles	74 (23.5)	22 (29.7)	Ref	Ref
Plant material/flower	92 (29.2)	28 (30.4)	1.03 (0.53, 2.02)	0.98 (0.45, 2.11)
Concentrates	104 (33.0)	34 (32.7)	1.15 (0.60, 2.19)	0.94 (0.44, 1.98)
Other	57 (18.1)	9 (15.8)	0.44 (0.19, 1.06)	0.58 (0.22, 1.50)
Product type used most often in the past 6 months, *n* = 315				
Edibles	57 (18.1)	14 (24.6)	Ref	Ref
Plant material/flower	87 (27.6)	26 (29.9)	1.31 (0.61, 2.79)	0.65 (0.26, 1.63)
Concentrates	118 (37.5)	44 (37.3)	1.83 (0.90, 3.71)	1.07 (0.47, 2.46)
Other	53 (16.8)	8 (15.1)	0.55 (0.21, 1.43)	0.48 (0.16, 1.39)
Among past 30-day users at baseline				
Cannabinoid formulation used most often in the past 30 days, *n* = 347				
Mostly CBD	38 (11.0)	8 (21.1)	Ref	Ref
Mostly THC	109 (31.4)	43 (39.5)	**2.44 (1.02, 5.83)**	1.62 (0.61, 4.28)
A mix of THC and CBD	36 (10.4)	15 (41.7)	2.68 (0.96, 7.45)	1.74 (0.56, 5.43)
Don't know	164 (47.3)	25 (15.2)	0.67 (0.28, 1.64)	0.67 (0.25, 1.77)

Past 30-day use frequency, n = 282				
1-2 days	120 (42.6)	19 (15.8)	Ref	Ref
3-9 days	76 (27.0)	24 (31.6)	**2.45 (1.23, 4.89)**	1.45 (0.65, 3.21)
10+ days	86 (30.5)	43 (50.0)	**5.32 (2.78, 10.2)**	**2.87 (1.31, 6.27)**
Combustible cannabis: no. joints, blunts, bowls smoked per use day in the past 30 days, n = 213				
1 per day	130 (61.0)	31 (23.8)	Ref	Ref
2 per day	37 (17.4)	17 (45.9)	**2.72 (1.27, 5.82)**	1.81 (0.75, 4.37)
3 per day	29 (13.6)	13 44.8)	**2.60 (1.13, 5.98)**	1.15 (0.44, 3.02)
4+ per day	17 (7.4)	6 (35.3)	1.74 (0.60, 5.10)	0.64 (0.18, 2.28)
Vaped THC: no. times vape device picked up per use day in the past 30 days, n = 191				
1 per day	95 (49.7)	26 (27.4)	Ref	Ref
2 per day	35 (18.3)	12 (34.3)	1.39 (0.60, 3.18)	0.73 (0.28, 1.90)
3 per day	25 (13.1)	15 (60.0)	**3.98 (1.59, 9.97)**	2.01 (0.70, 5.77)
4+ per day	36 (18.8)	16 (44.4)	2.12 (0.96, 4.71)	1.10 (0.43, 2.79)
Vaped THC: no. puffs taken before putting device away in the past 30 days, n = 196				
1 puff	48 (24.5)	10 (20.8)	Ref	Ref
2 puffs	54 (27.6)	22 (40.7)	**2.61 (1.08, 6.32)**	1.41 (0.50, 3.96)
3 puffs	60 (30.6)	26 (43.3)	**2.91 (1.23, 6.89)**	1.17 (0.42, 3.22)
4+ puffs	34 (17.3)	13 (38.2)	2.35 (0.88, 6.28)	0.91 (0.29, 2.89)

Note. [a]Adjusted for race/ethnicity, highest parental education, gender identity, sexuality, financial status, baseline CUD, past 30-day nicotine use, past-30 day alcohol use. [b]Additionally adjusted for product type used most often.

Most participants answered "don't know" to the cannabinoid formulation they used most often in the past 30-days (47.3%), followed by mostly THC (31.4%). Overall, stress/anxiety was the most commonly endorsed reason for using cannabis, followed by sleep (Figure 4). Endorsement of use for stress/anxiety or sleep was more common among adolescents using mostly THC or a mix of THC and CBD, compared to those using mostly CBD. In contrast, chronic pain was more frequently reported as a reason for use among those using mostly CBD or a THC/CBD mix than among those using mostly THC.

Figure 4. *Reasons for Using Cannabis by Cannabinoid Formulation Used Most Often (n = 347)*[a]

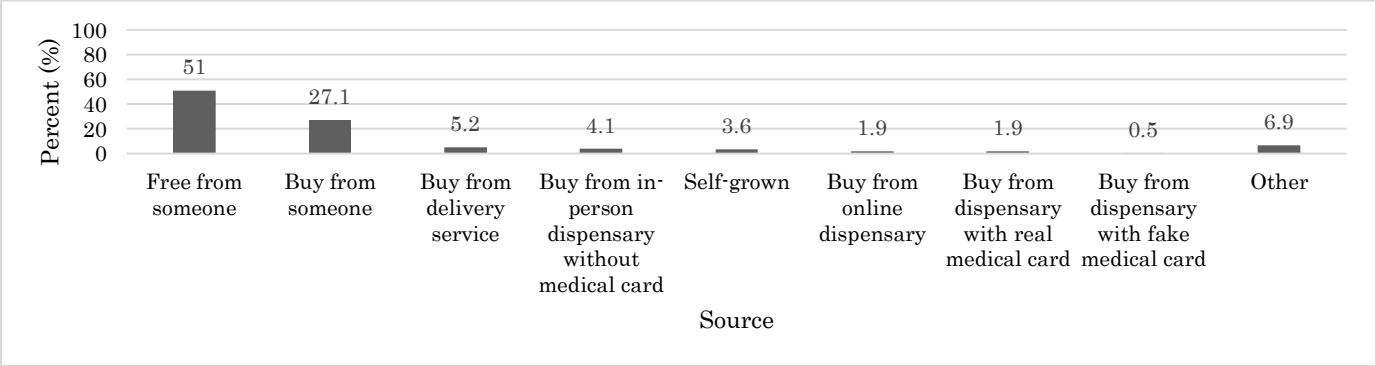


[a]Response options are not mutually exclusive

Among those who used cannabis in the past 30 days, 42.6% reported infrequent past 30-day use (1-2 days), 27.0% moderate use (3-9 days), and 30.5% frequent use (10+ days). Of those who smoked plant material/flower in the past 30 days, most participants (61.0%) smoked one joint/bowl per an average use day. Of those who vaped in the past 30 days, half (49.7%) used their vape device once per use day on average, while another 50.3% used their vape device >1 time per day. Additionally, a quarter (24.5%) of participants who vaped in the past 30 days took one hit per use session on average; the other three-quarters took multiple hits per use session.

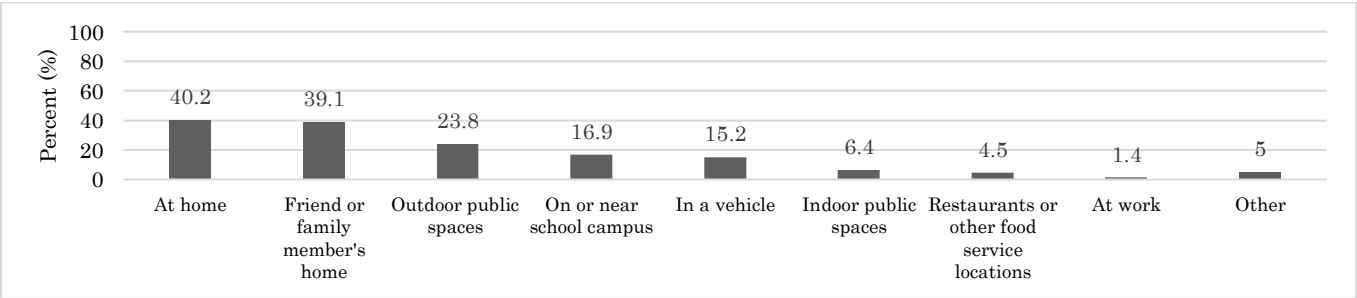
Most youth obtained cannabis products for free from someone they know (51%), followed by purchasing from someone directly (27%) or purchasing from an online delivery service (5%) (Figure 1). Youth most commonly used cannabis either at home (40%) or at a friend or family members home (39%; Figure 2a). Among those who used cannabis at school (n = 71), restrooms (77%) or immediately outside of school buildings (41%) were the most common use locations (Figure 2b). Participants typically used cannabis either with friends (56%) or alone (27%; Figure 3).

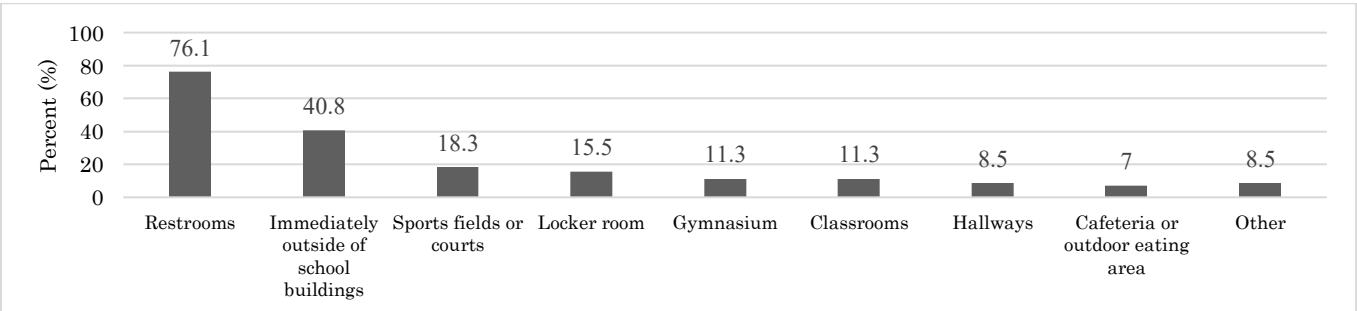
Figure 1. *Locations Where Youth Obtain Cannabis*[a] *(N = 420)*



[a]Response options are not mutually exclusive.

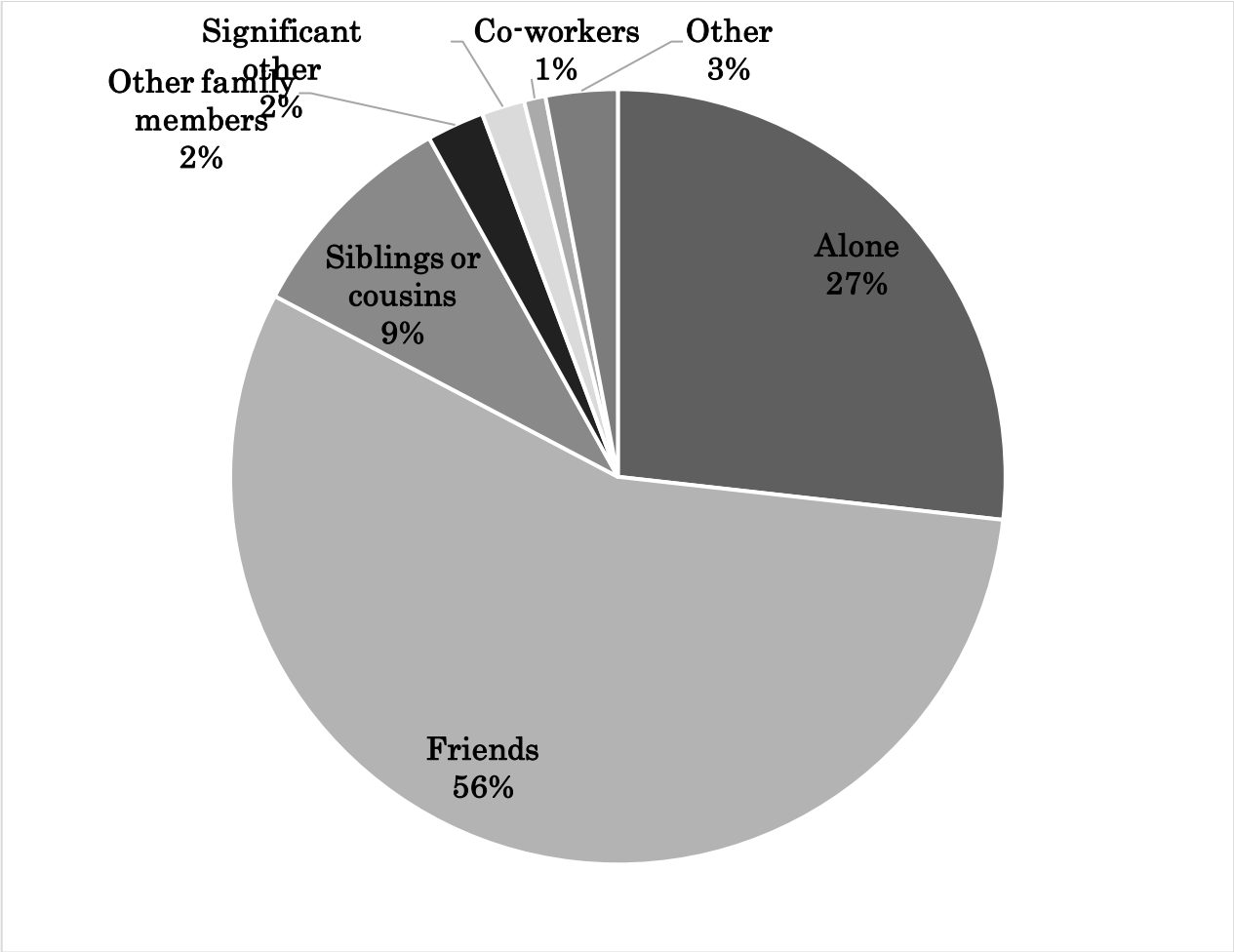
Figures 2A & 2B. *Locations where youth use cannabis*[a] *(a) overall (N=420) and (b) among those who use on campus, specific on-campus location (N = 71)*





[a]Response options are not mutually exclusive.

Figure 3. *Who Youth Are Usually With When Using Cannabis (N = 420; %)*



Associations of Cannabis Use Behaviors with CUD

Using multiple modes of cannabis (vs. only one) was associated with increased odds of probable CUD at follow-up, with greater odds observed with increasing numbers of modes of use (two modes [vs. one] aOR = 2.67, 95% CI = [1.13, 6.28]; three modes [vs. one] aOR = 3.41, 95% CI = [1.41, 8.27]; four modes [vs. one] aOR = 4.37, 95% CI = [1.82, 10.5]; Table 2). Use of cannabis on 10 or more days (vs. 1-5 days) was also associated with greater odds of probable CUD in adjusted models (aOR = 2.87, 95% CI = [1.31, 6.27]). Several other cannabis use behaviors were associated with higher odds of probable CUD in unadjusted, but not adjusted models; these included using mostly THC (vs. mostly CBD), higher frequency of smoking combustible cannabis (e.g., 2–3 times per day), vaping THC three times per day (vs. once), and taking 2–3 puffs per use (vs. one puff). Type of product used first was not significantly associated with probable CUD at follow-up, nor was product type used most often.

Sensitivity Analysis

The associations between baseline cannabis behaviors and individual CAST items at follow-up were largely non-significant, with a few exceptions (e-Table 1). Using multiple modes of cannabis in the past six months (vs. one) was associated with an increased likelihood of using cannabis while alone or experiencing problems with work/school from cannabis use. Higher past 30-day use frequency (10+ days vs. 1-2) was associated with unsuccessful attempts to quit or reduce use and experiencing problems with friends/work/school due to use.

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DISCUSSION

This study describes cannabis use behaviors among Southern California youth, and the relationship between various cannabis use behaviors and the odds of probable CUD six months later. Our findings indicate that greater number of modes of use and frequent (10+ days) past 30-day use were associated with greater odds of probable CUD, while other behaviors (type of product used, quantity of use) were not associated with later problematic use after accounting for baseline CUD.

Using more than one mode of cannabis within the past six months at baseline was a strong predictor of probable CUD at follow-up and of specific CUD symptoms (using while alone and experiencing problems due to using cannabis), with increased risk with an increase in the number of modes of use. This finding is especially concerning, considering that over two thirds of youth who used cannabis within the past six months in this sample endorsed using multiple modes. Because type of product used most often was not associated with probable CUD, we conclude that use of multiple products concurrently may be a stronger indicator of cannabis-related consequences among youth than specific product preference. Previous studies have similarly found that most adolescents who use cannabis engage in poly-product use (Leal & Moscrop-Blake, 2024). While research on the health outcomes of poly-product use is still limited, such patterns may compound risks, as different modes of use carry unique consequences (Russell et al., 2018; Schauer et al., 2020). Therefore, it is important to monitor these trends among adolescents and provide education on the distinct risks associated with each mode of use.

Consistent with our hypotheses, we observed an association between cannabis use frequency and the likelihood of developing probable CUD. This association remained significant even after accounting for baseline CUD, suggesting that frequency of cannabis use may play a unique role in increasing the risk of developing cannabis-related problems beyond the influence of pre-existing CUD symptoms. These findings are in line with prior research identifying cannabis use frequency as having a strong association with mental health problems among adolescents (Leadbeater et al., 2019; Shanahan et al., 2021), and highlights that frequency may be an important marker or identifier for youth at increased risk of developing new CUD. The associations of cannabis use frequency with CUD are important, given that over a fifth of our sample who used any cannabis within the past six months reported frequent past-month cannabis use, and that daily cannabis use is rising among adolescents in the U.S (Miech et al., 2023). Additionally, because our findings on quantity were not significant after adjusting for baseline probable CUD, this relationship might be largely explained by pre-existing CUD symptoms. Therefore, the observed associations for quantity in the unadjusted models may not reflect an effect of increased cannabis use on developing CUD, but rather a continuation of already present symptoms.

Our finding that most-used product type was not associated with probable CUD contrasts with our hypothesis that concentrate use would be associated with a higher risk of probable CUD compared to other product types. This also differs from research on adult cannabis use, which indicates that high-potency products (such as concentrates) are linked to a quicker progression to CUD (Arterberry et al., 2019), and that frequent concentrate use is associated with more severe CUD symptoms compared to non-concentrate users (Bidwell et al., 2018). Additionally, prior research has shown that even within a single product category, modes of administration (e.g., vaping vs. smoking flower) can result in differing pharmacokinetics and subjective effects (Cooper et al., 2009; Spindle et al., 2018). In contrast, our findings suggest that adolescents may be particularly vulnerable to developing CUD when experimenting with multiple modes of administration within a short period. Nonetheless, given the risks associated with high potency products among adults, it remains crucial to monitor their impact among youth, as these patterns may adversely impact the developing adolescent brain over time. Continued monitoring of high potency product use among youth is especially important, since in our sample, concentrates were both the product type most adolescents used first and the most-used product type overall. This popularity reflects a change in product use, which for many years reflected combustible cannabis products were the most popular (Hammond et al., 2020). This preference may be partially driven by the fact that some

adolescents reported using cannabis on school grounds, particularly in school restrooms, likely due to the concealability and rapid effects of concentrate products such as vape pens.

While our findings regarding associations between cannabinoid formulation and CUD symptoms were not statistically significant, the high proportion of adolescents who responded "don't know" when asked about the cannabinoid content of the cannabis product they used most often highlights a meaningful concern. A lack of awareness about cannabinoid formulations may stem from several factors, including shared product use among peers (over half of participants in this sample endorsed using with friends), discarded product packaging containing cannabinoid content, or unclear or inconsistent labeling. This issue reflects a broader challenge in adolescent, and even adult, cannabis use, where individuals frequently lack accurate knowledge of the potency or cannabinoid composition of the products they consume. Because both dose and cannabinoid profile play important roles in determining acute and long-term effects of cannabis, including the risk of developing CUD, this knowledge gap may increase vulnerability to adverse outcomes. Improved product labeling standards, especially those that make cannabinoid content more visible and understandable to consumers, could help young people make more informed decisions and potentially reduce risk.

This study has several limitations. First, all measures are self-reported, which may lead to misclassification of variables, particularly underreporting of cannabis. Second, while the CAST was used as a proxy for probable CUD, it is not a direct measure of DSM-defined CUD. The CAST is designed to assess cannabis-related problems and disorders (Legleye, 2018), with a cutoff indicating probable CUD (Legleye et al., 2011) rather than a definitive diagnosis. Also, despite examining a range of cannabis use behaviors, our study did not include specific measures of product potency, which could influence cannabis-related outcomes and is an important future direction for subsequent studies. We controlled for baseline probable CUD to account for pre-existing cannabis-related problems at the study's outset with the assumption that it preceded the cannabis use behaviors we assessed as predictors and therefore served as a confounder. However, there remains the possibility of residual confounding from cannabis use behaviors initiated prior to the baseline as well as from other unmeasured lifestyle factors that could influence subsequent cannabis use patterns. Additionally, quantity of cannabis use was only assessed for smoking and vaping; data on quantity or dose were not collected for edibles or other non-inhalable products, which limits our ability to evaluate patterns of use across all product types. Finally, our study design utilized Wave 5 of the parent study as the baseline to capture cannabis use during a critical developmental period in late high school, a time when cannabis use becomes significantly more common among youth (Miech et al., 2023). Nevertheless, potential selection bias must be considered due to participants lost to follow-up by this stage and the restriction of analyses to those with complete outcome data at the follow-up wave.

Conclusions

This study demonstrates the importance of understanding specific patterns of cannabis use among adolescents, rather than focusing solely on the general presence of cannabis use. Our findings reveal links between past-month use frequency and number of modes used in the past six-months and the likelihood of developing probable CUD, which was independent of the presence of prior probable CUD. Public health initiatives should emphasize education on the risks associated with using multiple products concurrently and using at higher frequencies, as these behaviors appear to be salient risk factors for adverse cannabis-related outcomes among youth.

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