Changes in Cannabis Use From 2014 to 2019 Among Young Adults in Washington State

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Introduction: Understanding changes in cannabis use in the legalized nonmedical cannabis context is critical. Washington State, one the earliest states to implement legalization, presents a unique opportunity to examine how cannabis use and its consequences changed after the implementation of legalization for adults. With a focus on Washington State young adults, this study conducted in 2022−2023 examined changes in (1) cannabis use by sex and age, (2) preferred mode of use, and (3) cannabis use disorder symptoms.

Methods: Using repeated cross-sectional data on young adults aged 18−25 years in Washington State from 2014 (premarket opening) to 2019 (N=12,945), logistic regression models assessed trends over time in the prevalence of any and frequent (20+ days) past-month cannabis use. Among individuals reporting use, multinomial logistic regressions estimated trends over time in the preferred mode of use and negative binomial regressions examined trends in the count of cannabis use disorder symptoms.

Results: From 2014 to 2019, the prevalence of cannabis use converged by sex, with females being equally likely as males to report both any and frequent use by 2019. Among young adults reporting past-month use, smoking as the preferred mode of use decreased relative to other modes. Number of cannabis use disorder symptoms reported increased, which was not accounted for by changes in preferred mode of use.

Conclusions: During the 5-year period following the implementation of legalization, patterns of young adult cannabis use shifted, including particularly sharp increases among females and increases in cannabis use disorder symptoms. Future studies should investigate underlying causes for these important changes.
Am J Prev Med 2023;000(000):1−8. © 2023 American Journal of Preventive Medicine. Published by Elsevier Inc. All rights reserved.

INTRODUCTION

As of June 2023, a total of 23 U.S. states had legalized nonmedical cannabis for adults aged ≥21 years.[1] Washington State (WA) was one of the first 2 states to legislate and implement legalization of cannabis for nonmedical use, with its first nonmedical cannabis stores opening on July 1, 2014. Since then, the number of stores has multiplied, the price of cannabis declined, and the potency and variety of products increased.[2−4] Thus, data from WA constitute a salient source of information on patterns and consequences of cannabis use in a legalized context. This study focused on WA's young adults, an age group susceptible to substance misuse associated with disruptions in the transition to adulthood[5,6] and adverse health consequences.[7−9]

Data indicate prevalence of cannabis use among young adults has increased in recent years for both any and frequent use. Nationwide data from the Monitoring

the Future study (MTF) indicate prevalence of past-month cannabis use and daily or almost daily cannabis use (20+ occasions in the previous month) recently reached their highest levels in the 3 decades during which MTF has gathered this information.[10] In WA, using the same data source as this study, Kilmer et al.[11] found that the use of nonmedical cannabis among young adults aged 18−25 years increased between 2014 and 2019 across various frequency thresholds, particularly for those aged ≥21 years who had access to the legal market. Importantly, there has been some indication of changes in the population of young adults who use cannabis in recent years. Other studies, although not focusing specifically on the legalized cannabis context, have found increases in cannabis use among females compared with males, particularly among younger birth cohorts.[12]

Increases in cannabis use raise public health concern because they may be accompanied by adverse health consequences, such as addiction. Although some individuals use cannabis without experiencing significant harm, others experience acute or chronic adverse health consequences.[5,8,9] Increasing potency of cannabis products[4] and a shift toward modes of use such as dabbing[13] (inhaling heated and vaporized dabs containing butane hash oil) that facilitate rapid intake of higher amounts of tetrahydrocannabinol (THC) fuel concern that consequences of cannabis use may have worsened in recent years. However, greater familiarity with cannabis and its effects, well-defined regulations associated with legalization (e.g., clear labeling of cannabis products),[14] and modes of use that allow for more precise titration could help consumers make more informed decisions about harm reduction.[15]

The objective of this study was to examine changes in past 30-day use with an emphasis on frequent cannabis use (i.e., use on ≥20 days in the past 30 days[16,17]) from 2014 (before cannabis stores opened in WA) to 2019 and whether these changes differed by sex or for those under/of legal age to purchase cannabis. The study also assessed trends over time in preferred mode of use and in cannabis use disorder (CUD) symptoms. Finally, the study examined whether changes in the demographic composition and preferred mode of use accounted for changes in CUD symptoms.

METHODS

Study Sample

Annual cross-sectional surveys conducted as part of the Young Adult Health Survey provided data for this analysis. Each year, the study surveyed a new group of approximately 2,000 young adults who met the eligibility criteria of being (1) aged 18−25 years and (2) residents of WA. Participants were recruited from across WA through direct mail or online advertising. Annually, a randomly selected list of licensed drivers aged 18−25 years, provided by the WA Department of Licensing, were mailed a letter inviting their participation. The study also used Facebook, Craigslist, Instagram, and other social media for online recruitment. In 2014, data were collected between late April and early August, with the majority (69%) collected before the first cannabis retail outlets opened in July 2014 and the remainder collected within a few weeks of stores opening.[11] Data collection spanned June−November in 2015−2018 and August−December in 2019. The web-based survey had questions on substance use, risk factors, and related health risk behaviors. Additional details are provided elsewhere.[11] The University of Washington Institutional Review Board approved all measures and procedures.

Measures

Participants were asked how many days they had used cannabis in the past 30 days. Dichotomous measures for any and frequent past-month use were created. Following International Cannabis Toolkit guidelines,[16] frequent use was defined as ≥20 days in the past 30 days.

Participants who reported cannabis use in the prior 30 days were asked about their usual preferred method of use. Thus, this measure provides information on changes in preferred mode of use, not the prevalence of each mode. In 2015−2019, response options were: *smoked it* (in a joint, bong, pipe, blunt); *ate it* (in brownies, cakes, cookies, candy); *drank it* (tea, cola, alcohol); *vaporized it with an electronic device like a vape pen or e-cig; used it by dabbing*; and *used it some other way* (please describe). *Drinking* was endorsed by few respondents (<1%) and was coded to be included in the edibles category. In 2014, dabbing was not offered as a response option given that this method of use was only emerging at that time; however, respondents who answered *other way* were asked to specify, with an open-ended response option, and anyone in that year who mentioned dabbing was coded into the dabbing category.

Based on items adapted from the National Survey of Drug Use and Health,[18] respondents indicated the presence of 5 CUD symptoms in the past year[11] including: (1) setting limits on use but failing to keep to those limits (2 items); (2) wanting or trying to stop or cut down on use but failing to do so (2 items); (3) spending considerable time obtaining, using, or getting over the effects of cannabis (1 item); (4) physical or psychological/emotional problems resulting from cannabis use and continuing to use despite these impacts (3 items); and

(5) increased tolerance such that the same amount had less effect than it used to (1 item). A count measure was based on the number of CUD symptoms endorsed. Supplemental analyses examined each symptom individually.

Regarding demographic variables, dichotomous coding was used for sex assigned at birth (0=male and 1=female) and age (0=18−20 years and 1=21−25 years). Race and ethnicity were coded into 4 categories (Non-Hispanic/Latinx [NH] White, NH Asian, Hispanic/Latinx any race, and NH Other race [including Black, Native American, Pacific Islander, Native Hawaiian, and multiracial]) that were indicator coded in regression models, with NH White as the reference category. Region of the state was indicator coded into 3 categories (East, Northwest, and Southwest), with East as the reference category.

Statistical Analysis

Logistic regression models assessed trends in the prevalence of any and frequent cannabis use. Using likelihood-ratio tests (LRTs) on unweighted data, linear change (year coded from 0 to 5), quadratic change (a year-squared term added), and free-form change (year indicator coded with 2014 as the referent) were compared with respect to model fit. Because of their inclusion in the post-stratification weights, other model covariates included sex, age, race/ethnicity, and region. After assessing the specification of year effects, the first main effect model assessed overall trends for the full sample. Follow-up models included 2-way interactions between calendar year and both sex and age.

Changes in preferred mode of use among individuals who reported past-month use (N=3,860) were examined with multinomial logistic regression models, using smoking as the reference category. Again, LRTs compared fit for different codings of time (i.e., linear, quadratic, and free-form change). In addition to covariates for sex, age, race/ethnicity, and region, this model also included a covariate for whether an individual reported frequent cannabis use.

Finally, negative binomial regression models assessed predictors of CUD symptom count among those reporting past-month cannabis use (*n*=3,785; 75 [2%] of those who reported past-month use were excluded from analyses owing to skipping items needed to score CUD symptoms). After conducting LRTs to determine the form of change with respect to time, the first model specification regressed symptom count on year and demographic covariates, the second added mode of use as a predictor, and the third added whether respondents reported frequent use as a predictor.

To aid in interpretation of results, figures depict trends in outcomes across years. For these figures, the best fitting representation of time (i.e., linear or quadratic trends lines) was plotted against estimates from models with year indicator coded. Stata, version 17.0,[19] and the survey commands for post-stratification weights were used.

RESULTS

For this study, analytic sample comprised 12,945 individuals who provided data on past-month cannabis use and demographic covariates used in sample weighting. Based on 2010 U.S. Census, the study sample had higher proportions of individuals assigned female at birth, of White or Asian race, and residing in the Northwest region of the state than the young adult population in WA. Separately for each year/cohort, post-stratification weights were created based on sex, geographic region, and race/ethnicity and data from the 2010 U.S. Census. Weights were applied to analyses so that model estimates more closely represented the statewide population. Table 1 shows the demographic composition of the sample with and without weighting (shown by year/cohort in Appendix Table 1, available online). For the full sample, prevalence of any cannabis use increased from 27% in 2014 to 32% in 2019 and prevalence of frequent use (20+ days) increased from 10% to 12%. For prevalence of any and frequent use by year for the full sample and subsamples defined by sex and age see Appendix Table 2 (available online). LRTs (Appendix Table 3, available online) indicated quadratic change models did not fit significantly better than linear change models for either any or frequent use, although some misfit was indicated for the linear change specification compared with free-form change. As shown in Appendix Table 4 (available online), main effects models indicate that linear trends across years were positive for both any use (OR=1.06; 95% CI=1.03,1.08) and frequent use (OR=1.06; 95% CI=1.02,1.11). For both any and frequent use, year-by-sex interactions were statistically significant (any use: OR=1.08; 95% CI=1.03,1.14; frequent use: OR=1.10; 95% CI=1.02,1.19). As shown in Figure 1, prevalence of any and frequent cannabis use increased more for females than for males; marginal estimates for linear change models indicated any and frequent use increased by 40% and 69%, respectively, for females compared with 7% and 10% for males (models stratified by sex shown in Appendix Table 5, available online).

Preferred mode of use changed markedly during the study period. In 2014, a total of 88% of those who used cannabis in the prior month reported smoking as their preferred mode compared with 52% in 2019 (Appendix Table 6, available online). Quadratic and free-form change specifications fit better than a linear change

**Table 1.** Sample Size by Year and Unweighted and Weighted Distribution of Study Participant Characteristics

Survey year/characteristics	n	n[a]	Unweighted % or Mean (SD)	Weighted % or Mean (SD)
2014	2,101	545	—	—
2015	1,675	493	—	—
2016	2,490	671	—	—
2017	2,337	745	—	—
2018	2,406	772	—	—
2019	1,936	634	—	—
Total	12,945	3,860	—	—
Female sex	—	—	67	49
Race/ethnicity	—	—		
NH White	—	—	65	66
NH Asian	—	—	11	8
NH other race	—	—	9	7
Hispanic/Latinx, any race	—	—	15	19
Geographic region				
East	—	—	21	25
Northwest	—	—	52	45
Southwest	—	—	27	30
Age 21 years or older	—	—	63	63
Any past-month cannabis use	—	—	30	30
Frequent (20+ days) past-month cannabis use	—	—	10	11
Preferred mode of use (N = 3,860)				
Smoking	—	—	68	69
Edibles	—	—	14	12
Vaping	—	—	11	11
Dabbing	—	—	6	6
Other	—	—	2	2
CUD symptoms (N = 3,785)	—	—	0.81 (1.12)	0.85 (1.14)

[a]*n* of individuals who reported past-month cannabis use.
CUD, Cannabis use disorder; NH, Non-Hispanic/Latinx; WA, Washington State.

model (Appendix Table 3, available online), reflecting a change in dabbing between 2014 and 2015 likely partially tied to the change in item response options. Estimates for the quadratic model indicated edibles, vaping, and dabbing all increased relative to smoking (Table 2). There was also a notable difference in the preferred mode of use by sex, with females being more likely than males to prefer edibles compared with smoking (models
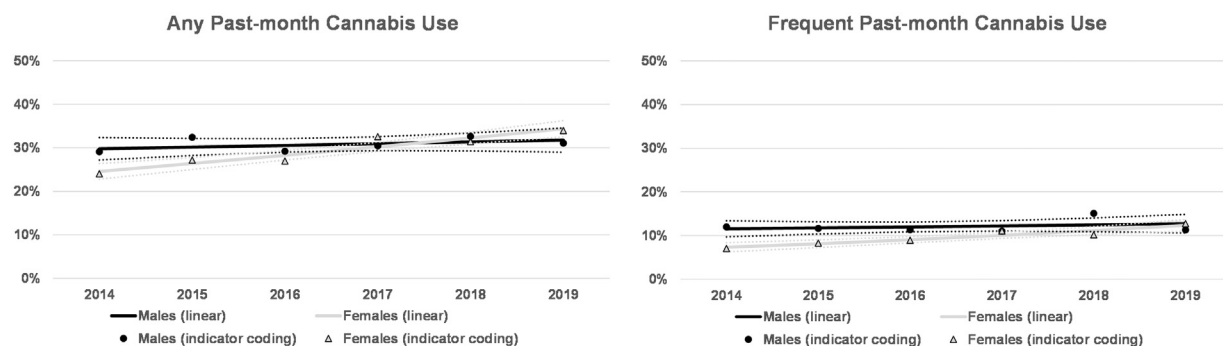
Figure 1. Trends in any and frequent cannabis use by sex based on logistic model that includes interactions between year and both age and sex. Marginal estimates derived from models that include age, race/ethnicity, and region of the state as covariates. Lines and 95% confidence intervals based on marginal estimates from model with linear coding of year. Estimates based on models using indicator coding of year are shown as markers that correspond in color to the given trend line.

Table 2. Multinomial Regression Model Predicting Preferred Mode of Cannabis Use (ref=Smoking)

Covariate	Edibles			Vaping			Dabbing			Other		
	OR	95% CI		OR	95% CI		OR	95% CI		OR	95% CI	
Year	**1.55**	**1.18**	**2.03**	1.22	0.93	1.61	**2.04**	**1.47**	**2.83**	1.38	0.74	2.57
Year squared	1.00	0.95	1.05	1.03	0.98	1.08	**0.93**	**0.88**	**0.99**	0.95	0.84	1.07
Frequent cannabis use	**0.11**	**0.08**	**0.16**	0.88	0.68	1.16	**5.02**	**3.50**	**7.19**	1.59	0.88	2.87
Female	**1.64**	**1.29**	**2.09**	0.83	0.66	1.05	0.85	0.63	1.14	0.63	0.36	1.09
Age 21+ years	**2.04**	**1.60**	**2.60**	**1.60**	**1.22**	**2.10**	0.73	0.52	1.01	0.64	0.35	1.15
Race/ethnicity (ref=NH White)												
NH Asian	0.91	0.61	1.37	1.04	0.68	1.60	0.76	0.31	1.85	0.53	0.16	1.78
Hispanic/Latinx	0.96	0.71	1.30	**0.65**	**0.43**	**0.98**	0.79	0.50	1.24	0.90	0.43	1.90
NH other	0.75	0.52	1.07	0.72	0.47	1.09	1.02	0.61	1.71	1.24	0.49	3.11
Region of state (ref=East)												
Northwest	1.09	0.81	1.46	**2.05**	**1.43**	**2.93**	**0.64**	**0.43**	**0.95**	0.55	0.27	1.10
Southwest	1.07	0.77	1.49	1.08	0.71	1.63	0.72	0.47	1.08	0.77	0.36	1.64

Note: Boldface indicates statistical significance ($p < 0.05$). Total sample size was N=3,860.
NH, Non-Hispanic/Latinx.

stratified by sex shown in Appendix Table 7, available online). Frequent use was associated with greater odds of reporting dabbing as the preferred mode relative to smoking and also lower odds of edibles relative to smoking. Trends in preferred mode of use are shown separately for those who used 1−19 days and 20+ days in the past month in Appendix Figure 1 (available online).

Linear change fit well for CUD symptoms against other specifications (Appendix Table 3, available online). As shown in Table 3, the first model predicting CUD symptom count showed a positive and statistically

significant increase in symptoms over time among those who used cannabis in the past 30 days. Number of symptoms was 17% lower among females than males. The second model indicated symptom count differed by the preferred mode of use, with the count being 27% higher among those who preferred dabbing than smoking, whereas edibles and vaping were associated with 48% and 21% fewer symptoms than smoking, respectively. Model 3 indicated the positive association with dabbing was small and no longer statistically significant after frequent use was added as a covariate. The positive

Table 3. Negative Binomial Regression Models Predicting Number of CUD Symptoms

Covariate	Model 1			Model 2			Model 3		
	CR	95% CI		CR	95% CI		CR	95% CI	
Year	**1.04**	**1.01**	**1.07**	**1.05**	**1.02**	**1.09**	**1.05**	**1.02**	**1.08**
Female	**0.83**	**0.75**	**0.91**	**0.85**	**0.78**	**0.94**	**0.87**	**0.79**	**0.96**
Age 21 years	0.98	0.89	1.08	1.02	0.92	1.12	0.94	0.85	1.04
Race/ethnicity (ref=NH White)									
NH Asian	0.89	0.73	1.07	0.90	0.75	1.08	0.99	0.83	1.19
Hispanic/Latinx	1.03	0.90	1.18	1.04	0.91	1.19	1.03	0.90	1.17
NH other	**1.28**	**1.07**	**1.54**	**1.24**	**1.04**	**1.48**	1.20	0.97	1.48
Region of state (ref=East)									
Northwest	1.03	0.90	1.18	1.06	0.93	1.21	1.07	0.94	1.21
Southwest	1.05	0.91	1.21	1.05	0.91	1.22	1.00	0.87	1.16
Preferred mode (ref=Smoking)									
Edibles	—	—	—	**0.52**	**0.43**	**0.63**	**0.68**	**0.56**	**0.83**
Vaping	—	—	—	**0.79**	**0.67**	**0.92**	**0.81**	**0.69**	**0.95**
Dabbing	—	—	—	**1.27**	**1.05**	**1.54**	0.99	0.82	1.20
Other	—	—	—	0.78	0.55	1.11	0.73	0.51	1.05
Frequent use	—	—	—	—	—	—	**2.12**	**1.90**	**2.37**

Note: Boldface indicates statistical significance ($p < 0.05$). Sample size n=3,785.
CR, count ratio; CUD, cannabis use disorder; NH, Non-Hispanic/Latinx.

effect of year was statistically significant in all 3 models, indicating that increases in CUD symptoms across years were not fully accounted for by any of the variables added as model covariates. The 5% yearly increase indicated in Model 3 translates to a 28% increase in symptom count between 2014 and 2019. Mean symptoms by year and models stratified by sex and nonfrequent versus frequent use are shown in Appendix Tables 8, 9, and 10 (available online). Supplemental analyses examining the 5 CUD symptoms individually (Appendix Table 11, available online) showed positive linear effects of year for each symptom, which were statistically significant for spending considerable time on and having physical or psychological/emotional problems because of cannabis use.

DISCUSSION

Using data from a statewide sample of young adults, this study found that between 2014 and 2019 the prevalence of any and frequent past-month cannabis use among young adults in WA increased, and these increases occurred primarily among females. The increases in cannabis use by females resulted in sex parity in the prevalence of any and frequent use by 2019. There were also substantial changes in the way young adults used cannabis, with a shift to modes other than smoking. Importantly, results also indicated an increase over time in CUD symptoms reported by those who used cannabis in the past month. Moreover, these increases were not accounted for by increases in prevalence of modes of use that deliver high amounts of THC, such as dabbing. Although dabbing was associated with more CUD symptoms, it did not account for their positive time trend.

One potential explanation for the increase in CUD symptoms among those who used cannabis includes increases in cannabis potency.[4] The study included the first 5 years after cannabis stores opened, when the number of cannabis retailers, variety of products, and potency of cannabis products increased and the price of cannabis decreased.[2−4,20] Although the study did not find mode of use had an association with CUD symptoms after accounting for frequent use, there was evidence that frequent use predicted both higher likelihood of dabbing than smoking and higher CUD symptom count. These findings are consistent with other studies documenting a strong positive association between frequency of cannabis use and development of CUD (for review, see[21]).

Results are consistent with other reports of a narrowing sex gap in the prevalence of cannabis use in recent years nationally (for review, see[12]), as well as in studies focusing explicitly on legalized nonmedical cannabis states, particularly for female college students[22] and female nondaily cigarette smokers[23] (for review, see[24]). This study indicates that, by 2019, females made up more than half of young adults who reported past-month cannabis use in WA. Almost 1 in 6 females (15%) reported using daily or almost daily in 2019, up from 7% in 2014. Although males reported more CUD symptoms than females, it is possible that with additional time there will also be a narrowing of the sex gap in CUD symptoms.

The findings related to changes in the preferred mode of use are consistent with increases in cannabis vaping nationally among young adults[25] and older adults (aged ≥50 years) in WA between 2014 and 2016.[26] Furthermore, the finding that females were more likely than males to prefer edibles (versus smoking) is consistent with other studies[27−29] and suggests that, in addition to sex assigned at birth, gender identity and related norms about substance use may be important variables to examine in future studies. One of the oft-cited reasons[28] for preferring edibles is discreteness, which has been hypothesized to reflect gendered norms about substance use.[30]

Future research on changes in cannabis use will be helped by better measures of THC dosage.[16] Studies, particularly those with adequate representation of participants reporting racial/ethnic minoritized identities, should assess trends in use and related patterns by race and ethnicity to elucidate whether implementation of cannabis legalization impacts health disparities. Furthermore, future studies should incorporate specific focus on gender identity to explore the role of social and cultural factors on substance use.[30] Finally, researchers should explore whether population-wide changes in mental health and socioeconomic circumstances account for changes in cannabis use and its consequences.

Limitations

This study was based on data from WA, an early adopter of nonmedical cannabis legalization. Examining effects of different regulatory regimes in other states[31,32] could identify factors that help curb negative consequences of legalization. Although recruitment efforts were statewide and aimed at yielding a representative sample of young adults, the sample over-represented some demographic groups. The authors applied post-stratification weights to increase the generalizability of these findings. The assessment of CUD symptomatology used in this study has been criticized as subjective and susceptible to under-reporting[33]; however, the study also examined a widely used measure of frequent use, concordant with

the diagnostic criteria for CUD and less sensitive to reporting bias.[18,33]

CONCLUSIONS

The findings from this study of young adults in WA after legalization of cannabis point to increases in cannabis use by females, decreases in smoking as the preferred mode of cannabis use, and an increase in CUD symptoms among those using cannabis. Results suggest specific focus on prevention, screening, and intervention efforts for females is warranted. Furthermore, patterns of cannabis use have changed dramatically since non-medical cannabis was legalized with respect to modes of use. Regulation and prevention messaging addressing use in modes other than smoking may be needed. Screening efforts need to cast a wide net to capture multiple methods or modes of use and their frequency. Although legalization may hold the harm reduction promise of better regulated markets and more informed consumers of cannabis, results of this study indicate young adult cannabis use in WA did not become more benign in the 5 years after the stores opened. CUD symptom counts increased, pointing to the need for continued prevention and treatment efforts in the context of legalized cannabis.

ACKNOWLEDGMENTS

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SUPPLEMENTAL MATERIAL

Supplemental materials associated with this article can be found in the online version at https://doi.org/10.1016/j.amepre.2023.09.027.

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