



Effects of Legalizing Recreational Cannabis Sales on Cannabis Use and Cannabis-Related Disorder Among Presentations to a Psychiatric Emergency Service

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Introduction: Limited research exists on the impact of changing cannabis policies on psychiatric populations, who are especially vulnerable to the negative effects of substance use. This study examined the changes in cannabis use and cannabis-related disorders across age groups of psychiatric emergency presentations after the start of recreational cannabis sales in Massachusetts.

Methods: Cross-sectional electronic health records from 7,350 unique presentations to a psychiatric emergency service in a tertiary care hospital in Massachusetts were analyzed. Logistic regressions estimated changes in the rates of urine tetrahydrocannabinol positivity and cannabis-related disorder ICD-10 diagnosis codes (F12.X) from precommercialization (January 1, 2017–November 19, 2018) to postcommercialization (November 20, 2018–December 31, 2019) periods across different age groups (12–17, 18–25, 26–49, 50–70 years), controlling for biological sex, race, and ethnicity.

Results: The rates of tetrahydrocannabinol positivity increased significantly from pre to postcommercialization periods (32.4%–36.3%, $p < 0.001$) but not the rates of cannabis-related disorder (10.5%–11.7%). Adolescents (aged 12–17 years) had the largest increase in tetrahydrocannabinol positivity (5%–17.3%, AOR=4.32 [2.15, 8.68]), whereas adults (aged 26–49 years) experienced a modest increase (37.7%–42.5%, AOR=1.24 [1.08, 1.42]). Only the adolescent group had a significant increase in cannabis-related disorders (3.2%–12.1%, AOR=4.63 [1.97, 10.87]).

Conclusions: Commercialization of recreational cannabis sales may disproportionately affect adolescents with psychiatric illnesses or vulnerabilities, resulting in an increased need for psychiatric emergency care. Further research is needed to examine the impact of cannabis policies on this population to inform targeted prevention efforts.

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INTRODUCTION

Cannabis is one of the world's most widely used psychoactive substances,¹ with mounting evidence that early initiation and heavy use, particularly of high tetrahydrocannabinol (THC) potency cannabis, are linked to harmful physical and mental health outcomes.² In the U.S., 24 states and the District of Columbia have legalized adult-use recreational cannabis. The subsequent expansion of the commercial cannabis markets, accompanied by widespread advertising and product engineering, have resulted in greater access to affordable cannabis products,³ higher

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potency products,^{4–6} and reduced public perception of harm.⁷

These trends raise questions about the impact of commercialization on cannabis use and public health, with most research conducted thus far in general population samples. U.S. household surveys of self-reported substance use consistently find increased prevalence and frequency of use and cannabis use disorder diagnoses among adults after recreational cannabis legalization.^{8,9} The effects of legalization on adolescents are more mixed, indicating no appreciable change in self-reported use but small increases in cannabis use disorder⁸ and a rise in cannabis-related emergency department visits based on electronic health record (EHR) data.^{10,11}

Recreational cannabis commercialization may have more pronounced effects on people with a psychiatric illness, given that this population has higher rates of comorbid substance use disorders than the general population.^{12–14} Both cannabis use and cannabis use disorder are associated with more severe depression¹⁵ and psychotic symptoms¹⁶ and increased risk of suicidal behavior among those with a psychiatric condition.^{15,17} Early initiation and heavy use of high THC-potency cannabis is associated with earlier onset of psychosis¹⁸ and higher risk of developing schizophrenia,¹⁹ depression, and suicidal behavior²⁰ even in the absence of a pre-existing mental health condition. Cannabis use may therefore worsen psychiatric symptoms in those with psychiatric illness and hasten or precipitate psychiatric disorder onset in vulnerable others.

Few studies have examined the effects of cannabis policy changes on cannabis use in people with psychiatric illnesses or vulnerabilities.²¹ On the basis of U.S. inpatient claims data, states that legalized both medical and recreational cannabis had higher prevalence of hospital discharges with diagnosis codes for psychosis with cannabis use than states with less liberal laws.²² EHR data from Colorado with urine drug test results and diagnosis codes suggest that cannabis-related emergency department visits increased after recreational cannabis legalization for both adults^{23,24} and adolescents,¹⁰ with high prevalence of co-occurring psychiatric diagnosis in cannabis-related visits (71% in adolescents aged 13–20 years,¹⁰ 31% in adults aged 26–79 years²⁴). Although these studies show high comorbidity between cannabis use and psychiatric illness in patients presenting in acute settings for all-cause medical issues (e.g., cannabis-related poisoning, hyperemesis, injury), the authors are unaware of any published study that has examined the impact of cannabis commercialization in a defined population of people with psychiatric symptoms or illnesses without reliance on self-report.

This study examined changes in rates of cannabis use (objectively measured by a positive urine drug screen

[UDS] for THC) and cannabis-related disorders (determined by diagnosis codes) among individuals presenting to a large, urban psychiatric emergency service before and after commercialization of retail cannabis. This study sought to explore trends across age groups considering the abundant evidence that early and long-term cannabis use can disrupt brain development and neurocognitive function across the lifespan^{25–27} and increase the likelihood of developing cannabis use disorder²⁸ and serious psychiatric symptoms.^{18,20,29}

METHODS

Study Sample

This study analyzed cross-sectional EHR data (Epic Healthcare Systems, Verona, WI) from first visits of unique individuals (aged 12–70 years) presenting to a psychiatric emergency service within the emergency department of a tertiary care hospital in Boston, MA, after recreational cannabis was legalized between January 1, 2017, and December 31, 2019, predating the coronavirus disease 2019 (COVID-19) pandemic. Pre versus postcommercialization period was coded dichotomously, demarcated by the first day of licensed retail sales of recreational cannabis for adults aged ≥ 21 years in Massachusetts (November 20, 2018). Trends in the rates of urine THC positivity and ICD-10³⁰ diagnosis codes for nonremitted cannabis-related disorders given during the encounter were the primary outcomes. The study was deemed exempt by the Mass General Brigham IRB. STROBE reporting guidelines were followed.³¹

All psychiatric emergency service presentations with a UDS immunoassay panel ordered during evaluation were included in the analysis. Per protocol, a toxicology panel was ordered on people presenting with serious trauma, held on a Section 12(a) (involuntary psychiatric evaluation), or presenting with a suspected primary substance use–related complaint. Testing was otherwise ordered at providers' discretion (e.g., to confirm substance use for making a differential diagnosis).

Measures

The panel tested for amphetamines, barbiturates, benzodiazepines, cannabinoids, cocaine metabolite, and opiates. In vitro qualitative urine THC immunoassay was performed in house on a Roche Cobas chemistry analyzer (Roche Diagnostics, Indianapolis, IN) using Roche reagents. Urinary delta-9 carboxy THC concentration ≥ 20 ng/mL was considered a positive test result for approximately past-month cannabis exposure.³² ICD-10 discharge diagnosis codes encompassed the spectrum of nonremitted cannabis-related disorders, including cannabis abuse (F12.1X); cannabis dependence (F12.2X);

and significant cannabis use with intoxication, psychosis, or other cannabis-induced disorders (F12.9X). A F12.9X diagnosis would be given when the psychiatric provider determined that cannabis was clinically significant and/or significantly contributing to presenting psychiatric symptoms. This diagnosis would not be given for casual use not meeting diagnostic criteria for cannabis use disorder or use that was not clinically relevant. Demographics (biological sex, age, race, ethnicity, insurance type, and psychiatric diagnosis) were obtained from the EHR. Age was recoded into a categorical variable with 4 levels, following the age ranges used in the National Survey on Drug Use and Health for adolescents (aged 12–17 years), young adults (aged 18–25 years), adults (aged 26–49 years), and older adults (aged 50–70 years). [Appendix 1](#) (available online) provides details on the immunoassay panel and ICD-10 code categorizations.

Statistical Analysis

THC positivity and cannabis-related disorder rates were calculated for pre and postcommercialization periods. Sample demographics were compared between commercialization periods using chi-square tests. Logistic regression models were used to compute ORs for the likelihood of each outcome in postcommercialization compared with those in the precommercialization periods across age groups, with age categories as a moderating variable and commercialization period as a predictor. Planned contrasts assessed differences in rates before versus after commercialization within each age group, with *p*-values adjusted for multiple comparisons using the Benjamini–Hochberg correction.

To inform the extent to which changes in substance use rates after commercialization were unique to cannabis, age-varying effects before versus after commercialization for other UDS panel substances were examined with logistic regression models. Amphetamine and cocaine metabolites were combined under the class of stimulant drugs, and barbiturates were excluded owing to low positivity rates across age groups (<1%).

Low base rates can result in unstable estimates for ORs. Thus, for each outcome, commercialization effect was nullified by randomly assigning commercialization period across data, and a nonparametric bootstrap analysis³³ was applied to check (1) whether the false-positive rate was well calibrated (alpha of 5%), (2) the power to detect a main effect of commercialization and its interaction with age, and (3) whether OR estimates were unbiased.

To control for changes in cannabis use outcomes that could be attributed to changes in the demographics of psychiatric emergency visits from pre to

postcommercialization periods, sensitivity analysis was performed using propensity score matching on sex, race, insurance type, and diagnosis ([Appendix 2](#), available online). Weighted logistic regression was performed on balanced data to assess changes in THC positivity and cannabis-related disorders due to commercialization within each age group. Sensitivity analyses of the age by commercialization interaction effect on cannabis use outcomes and other substance positivity rates were also conducted on the basis of age groups with and without legal access (12–20 years and 21–70 years).

All logistic regression analyses were adjusted for sex, race, and ethnicity. All statistical tests and 95% CIs were 2 sided, with statistical significance defined as *p*<0.05. Analyses were conducted using R, Version 4.4.0 (R Core Team).

RESULTS

A total of 7,350 psychiatric emergency service visits by unique individuals with a completed UDS comprised the analyzed sample (mean age=36.9 years; 3,372 [45.9%] female; 5,004 [68.1%] White; 898 [12.2%] Black/African American; 316 [4.3%] Hispanic/Latine; 4,009 [54.5%] with public insurance). A total of 1,026 (18.5%) and 672 (19.2%) records had missing UDS data (i.e., not ordered or discharged before drug screen) in pre and postcommercialization periods, respectively. All had a psychiatric disorder diagnosis coded for the psychiatric emergency service encounter, and 2,632 (35.8%) had a co-occurring SUD diagnosis. UDS data were missing at random, with no demographic variable predicting missingness.

[Table 1](#) shows sample demographics and substance positivity rates of visits by commercialization period. The number of adolescent and young adult presentations significantly increased from pre to postcommercialization periods (12–17 years: 4.9%–8.2%; 18–25 years: 19.7%–22.6%), whereas adult and older adult presentations decreased (26–49 years: 51.2%–48.8%; 50–70 years: 24.5%–21.4%). There were significantly more presentations of people with public insurance, anxiety disorders, or nicotine-related disorders and less presentations of people of Hispanic/Latine ethnicity and people with alcohol-, opioid-, sedative-, or cocaine-related disorders during the postcommercialization period than during the precommercialization period.

In the overall sample, there was a significant increase in the THC positivity rate from pre to postcommercialization periods (32.4% vs 36.3%, chi-square (1)=11.91, *p*<0.001), whereas the prevalence of cannabis-related disorder trended nonsignificantly upward (10.5% vs 11.7%, chi-square (1)=2.30, *p*=0.129). Across both time periods, among those with a cannabis-related disorder

Table 1. Sample Characteristics of Psychiatric Emergency Service Presentations by Commercialization Period (N=7,350)

Variable	Overall	Before commercialization (January 1, 2017 –December 19, 2018)	After commercialization (November 20, 2018 –December 31, 2019)
Sample size	7,350	4,531	2,819
Sex			
Male	3,978 (54.1%)	2,492 (55%)	1,486 (52.7%)
Female	3,372 (45.9%)	2,039 (45%)	1,333 (47.3%)
Race/ethnicity			
American Indian/Alaska Native	15 (0.2%)	8 (0.2%)	7 (0.2%)
Asian	338 (4.6%)	202 (4.5%)	136 (4.8%)
Black/African American	898 (12.2%)	565 (12.5%)	333 (11.8%)
Native Hawaiian/other Pacific Islander	9 (0.1%)	6 (0.1%)	3 (0.1%)
White Caucasian	5,004 (68.1%)	3,079 (68%)	1,925 (68.3%)
Hispanic/Latine	316 (4.3%)	226 (5%)	90 (3.2%)
Other	603 (8.2%)	356 (7.9%)	247 (8.8%)
Not recorded/declined	167 (2.3%)	89 (2%)	78 (2.8%)
Age (years)			
Mean age in years (SD)	36.9 (14.6)	37.6 (14.5)	35.6 (14.6)
12–17	452 (6.1%)	221 (4.9%)	231 (8.2%)
18–25	1,529 (20.8%)	893 (19.7%)	636 (22.6%)
26–49	3,654 (49.7%)	2,350 (51.2%)	1,349 (48.8%)
50–70	1,715 (23.3%)	1,112 (24.5%)	603 (21.4%)
Public primary insurance	4,009 (54.5%)	2,327 (51.4%)	1,682 (59.7%)
ICD-10 psychiatric diagnoses at discharge			
Schizophrenia spectrum and nonaffective psychotic disorders	1,594 (21.7%)	992 (21.9%)	602 (21.4%)
Mood disorders	4,672 (63.6%)	2,906 (64.1%)	1,766 (62.6%)
Anxiety disorders	1,808 (24.6%)	1,064 (23.5%)	744 (26.4%)
Obsessive–compulsive disorders	171 (2.3%)	102 (2.3%)	69 (2.4%)
Stress and adjustment disorders	1,180 (16.1%)	726 (16%)	454 (16.1%)
Eating disorders	94 (1.3%)	56 (1.2%)	38 (1.3%)
Personality disorders	220 (3%)	151 (3.3%)	69 (2.4%)
Behavioral and emotional disorders with childhood/adolescent onset	647 (8.8%)	409 (9%)	238 (8.4%)
Substance use disorders (any)	3,027 (41.2%)	1,869 (41.2%)	1,158 (41.1%)
Alcohol-related disorder	1,247 (17%)	817 (18%)	430 (15.3%)
Opioid-related disorder	650 (8.8%)	461 (10.2%)	189 (6.7%)
Cannabis-related disorder	805 (11%) ^a	476 (10.5%)	329 (11.7%)
Sedative, hypnotic, or anxiolytic-related disorder	184 (2.5%)	134 (3%)	50 (1.8%)
Cocaine-related disorder	594 (8.1%)	407 (9%)	187 (6.6%)
Other stimulant-related disorder	247 (3.4%)	160 (3.5%)	87 (3.1%)
Hallucinogen-related disorder	10 (0.1%)	8 (0.2%)	2 (0.1%)
Nicotine-related disorder	809 (11%)	438 (9.7%)	371 (13.2%)
Other psychoactive substance-related disorder	521 (7.1%)	340 (7.5%)	181 (6.4%)

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Table 1. Sample Characteristics of Psychiatric Emergency Service Presentations by Commercialization Period (N=7,350) (continued)

Variable	Overall	Before commercialization (January 1, 2017 –December 19, 2018)	After commercialization (November 20, 2018 –December 31, 2019)
Co-occurring substance use and psychiatric disorder	2,632 (35.8%)	1,619 (35.7%)	1,013 (35.9%)
Urine drug screen immunoassay positivity			
THC	2,491 (33.9%)	1,467 (32.4%)	1,024 (36.3%)
Amphetamine	633 (8.6%)	381 (8.4%)	252 (8.9%)
Benzodiazepine	978 (13.3%)	663 (14.6%)	315 (11.2%)
Cocaine metabolite	974 (13.3%)	643 (14.2%)	331 (11.7%)
Opiate	280 (3.8%)	214 (4.7%)	66 (2.3%)

Note: Boldface indicates statistical significance ($p < 0.05$) for contrast of proportions between pre and postcommercialization periods of recreational cannabis.

^aICD-10 diagnostic codes of cannabis-related disorder included cannabis abuse or dependence (679 [9.3%]) and cannabis use, unspecified with a physical, mental, or behavioral disorder (132 [1.8%]). A minority had cannabis abuse or dependence with psychotic symptoms (5 [0.1%]); cannabis abuse or dependence with other cannabis-induced disorder (6 [0.1%]); cannabis use, unspecified, with psychotic symptoms (4 [0.1%]); and cannabis use, unspecified with other cannabis-induced disorder (8 [0.1%]).

THC, tetrahydrocannabinol.

diagnosis ($n=805$), 85.7% had a diagnosis of cannabis abuse or cannabis dependence (Appendix 1 and Appendix Table 1, available online). Among those who tested positive for THC ($n=2,491$), 28.0% had a cannabis-related disorder diagnosis, with rates of cannabis-related disorder highest among adolescent users (45.1%) and decreasing as age groups increase (18–25 years: 36.5%; 26–49 years: 25.8%; 50–70 years: 20%).

Table 2 shows THC positivity and cannabis-related disorders rates across demographic and clinical variables for both time periods. After commercialization, THC positivity rates significantly increased for both sexes; adolescents and adults; people of Hispanic/Latine ethnicity; those with commercial insurance; and those with a schizophrenia spectrum, mood, anxiety, or child/adolescent-onset developmental disorder diagnosis. THC positivity rates also increased among those without a substance-related disorder diagnosis (not limited to cannabis-related disorder) and those not co-using other substances detected by UDSs.

Postcommercialization cannabis-related disorder rates across demographic/clinical groups did not significantly differ from precommercialization rates, except for adolescents, whose rates increased significantly (3.2%–12.1%, $p=0.05$).

Age was the only demographic variable that moderated the effects of cannabis commercialization on cannabis use outcomes, with significant interaction effects for both changes in the rates of THC positivity and cannabis-related disorder (chi-square (3)=16.25 and 9.08, $ps=0.001$ and .003, respectively). After controlling for

sex, race, and ethnicity, there were significant main effects from age group (chi-square (3)=337.97, $p < 0.001$) and commercialization period (chi-square (1)=16.62, $p < 0.001$) on THC positivity. For cannabis-related disorder, there were significant main effects from age group (chi-square (3)=149.51, $p < 0.001$) but not from commercialization period (chi-square (1)=2.14, $p=0.143$).

As shown in Figure 1 and Table 3, although THC positivity and cannabis-related disorder rates tended to rise across all age groups after cannabis commercialization, the increase was significantly greater for adolescents than for the other age groups. Specifically, the THC positivity rate in adolescents increased from 5% before commercialization to 17.3% after commercialization (AOR=4.32; 95% CI=2.15, 8.68; $p < 0.001$) (Figure 1A), with corresponding rates of cannabis-related disorder increasing from 3.2% to 12.1% (AOR=4.63; 95% CI=1.97, 10.87; $p < 0.001$) (Figure 1B).

Bootstrapped results over 2,000 iterations indicated that OR estimates can be considered reliable because false-positive rates were well calibrated (<5%), power was sufficient (>90%), and bias in log-odd estimates were small (–0.02 to 0.02).

Analyses of changes in positivity rates for other substances indicated significant reductions in opiate and benzodiazepine use after cannabis commercialization but no change in stimulant use (Table 1). There was a significant interaction effect for age and change in opiate positivity (chi-square=9.19, $p=0.01$), with greater decreases in opiate positivity rates after cannabis commercialization among adults (26–49 years) (6.7% vs

Table 2. Urine THC Positivity and Cannabis-Related Disorder Rates as a Function of Patient Characteristics

Demographic	THC positivity rates		Cannabis-related disorder rates	
	Before commercialization % (n/valid n)	After commercialization % (n/valid n)	Before commercialization % (n/valid n)	After commercialization % (n/valid n)
Sex				
Male	37.4% (933/2,492)	41% (609/1,486)	12.7% (316/2,492)	14.1% (209/1,486)
Female	26.2% (534/2,039)	31.1% (415/1,333)	7.8% (160/2,039)	9% (120/1,333)
Race				
American Indian/ Alaska Native ^a	37.5% (3/8)	57.1% (4/7)	0% (0/8)	28.6% (2/7)
Asian	18.8% (38/202)	16.9% (23/136)	9.9% (20/202)	6.6% (9/136)
Native Hawaiian/other Pacific Islander ^a	50% (3/6)	0% (0/3)	0% (0/6)	0% (0/3)
Black/African American	39.1% (221/565)	45.6% (152/333)	12.7% (72/565)	15.3% (51/333)
White	33.2% (1022/3,079)	35.7% (687/1,925)	10.3% (316/3,079)	11.4% (219/1,925)
Hispanic/Latine	27.9% (63/226)	42.2% (38/90)	11.1% (25/226)	15.6% (14/90)
Age (years)				
12–17	5% (11/221)	17.3% (40/231)	3.2% (7/221)	12.1% (28/231)
18–25	39.2% (350/893)	43.1% (274/636)	16.2% (145/893)	18.2% (116/636)
26–49	37.7% (868/2,305)	42.5% (573/1,349)	12% (276/2,305)	11.1% (150/1,349)
50–70	21.4% (238/1,112)	22.7% (137/603)	4.3% (48/1,112)	5.8% (35/603)
Primary insurance				
Public	33.1% (771/2,327)	35.9% (603/1,682)	10.3% (239/2,327)	12.5% (211/1,682)
Commercial	31.6% (696/2,204)	37% (421/1,137)	10.8% (237/2,204)	10.4% (118/1,137)
Schizophrenia/psychotic disorders	30% (298/992)	35.5% (214/602)	12.4% (123/992)	10.5% (63/602)
Mood disorders	33.2% (966/2,906)	36.9% (651/1,766)	11% (319/2,906)	12.5% (221/1,766)
Anxiety disorders	27.9% (297/1,064)	33.9% (252/744)	12.2% (130/1,064)	13.3% (99/744)
Obsessive–compulsive disorders	8.8% (9/102)	18.8% (13/69)	6.9% (7/102)	10.1% (7/69)
Stress and adjustment disorders	34.7% (252/726)	39.2% (178/454)	11.3% (82/726)	12.8% (58/454)
Eating disorders ^a	12.5% (7/56)	21.1% (8/38)	10.7% (6/56)	0% (0/38)
Personality disorders	33.8% (51/151)	34.8% (24/69)	11.3% (17/151)	14.5% (10/69)
Disorders with childhood/adolescent onset	23.7% (97/409)	34.9% (83/238)	11.5% (47/409)	12.6% (30/238)
Alcohol-related disorders				
Yes	35.3% (288/817)	37.2% (160/430)	14.1% (115/817)	15.6% (67/430)
No	31.7% (1,179/3,714)	36.2% (864/2,389)	9.7% (361/3,714)	11% (262/2,389)
Opioid-related disorders				
Yes	45.1% (208/461)	49.7% (94/189)	12.6% (58/461)	14.8% (28/189)
No	30.9% (1,259/4,070)	35.4% (930/2,630)	10.3% (418/4,070)	11.4% (301/2,630)
Cannabis-related disorders				
Yes ^a	86.1% (410/476)	87.5% (288/329)	100% (476/476)	100% (329/329)
No ^a	26.1% (1,057/4,055)	29.6% (736/2,490)	0% (0/4,055)	0% (0/2,490)
Sedative-related disorders				
Yes	56% (75/134)	48% (24/50)	32.1% (43/134)	20% (10/50)
No	31.7% (1,392/4,397)	36.1% (1,000/2,769)	9.8% (433/4,397)	11.5% (319/2,769)

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Table 2. Urine THC Positivity and Cannabis-Related Disorder Rates as a Function of Patient Characteristics (*continued*)

Demographic	THC positivity rates		Cannabis-related disorder rates	
	Before commercialization % (n/valid n)	After commercialization % (n/valid n)	Before commercialization % (n/valid n)	After commercialization % (n/valid n)
Cocaine-related disorders				
Yes	49.6% (202/407)	52.4% (98/187)	27.8% (113/407)	21.9% (41/187)
No	30.7% (1265/4,124)	35.2% (926/2,632)	8.8% (363/4,124)	10.9% (288/2,632)
Stimulant-related disorders				
Yes	48.8% (78/160)	57.5% (50/87)	24.4% (39/160)	28.7% (25/87)
No	31.8% (1389/4,371)	35.7% (974/2,732)	10% (437/4,371)	11.1% (304/2,732)
Hallucinogen-related disorders				
Yes	50% (4/8)	50% (1/2)	50% (4/8)	0% (0/2)
No	32.3% (1,463/4,523)	36.3% (1,023/2,817)	10.4% (472/4,523)	11.7% (329/2,817)
Nicotine-related disorders				
Yes	45.7% (200/438)	49.9% (185/371)	17.8% (78/438)	18.1% (67/371)
No	31% (1,267/4,093)	34.3% (839/2,448)	9.7% (398/4,093)	10.7% (262/2,448)
Psychoactive substance-related disorders				
Yes	52.1% (177/340)	55.2% (100/181)	10% (34/340)	12.2% (22/181)
No	30.8% (1,290/4,191)	35% (924/2,638)	10.5% (442/4,191)	11.6% (307/2,638)
Amphetamine positivity				
Yes	48.3% (184/381)	45.2% (114/252)	14.7% (56/381)	11.9% (30/252)
No	30.8% (1,272/4,130)	35.4% (906/2,558)	10.1% (416/4,130)	11.6% (298/2,558)
Benzodiazepine positivity				
Yes	44% (292/663)	48.3% (152/315)	13.4% (89/663)	11.1% (35/315)
No	30.3% (1,165/3,849)	34.8% (867/2,494)	10% (383/3,849)	11.7% (293/2,494)
Cocaine metabolite positivity				
Yes	52.1% (335/643)	60.4% (200/331)	15.4% (99/643)	14.2% (47/331)
No	29% (1,122/3,871)	33% (819/2,479)	9.6% (373/3,871)	11.3% (281/2,479)
Opiate positivity				
Yes	48.3% (184/381)	45.2% (114/252)	14.7% (56/381)	11.9% (30/252)
No	30.8% (1,272/4,130)	35.4% (906/2,558)	10.1% (416/4,130)	11.6% (298/2,558)

Note: Boldface indicates statistical significance ($p < 0.05$) for contrast of proportions between pre and postcommercialization periods of recreational cannabis.

*Comparisons were not performed for cannabis-related disorder rates owing to low cell count.

THC, tetrahydrocannabinol.

2.7%; AOR=0.38; 95% CI=0.26, 0.54; $p < 0.001$). There was no significant age by commercialization interaction effects for stimulant or benzodiazepine positivity rates (Appendix 3, 4 and Appendix Figure 1, available online).

Sensitivity analysis based on propensity score confirmed the same pattern (Appendix 2 and Appendix Table 2, available online). Similar to the differential impact of commercialization found across the 4 age groups, significantly greater increases in THC positivity and cannabis-related disorder rates after commercialization were found for those under the legal age to buy cannabis (12–20 years) than among those of legal age (21

–70 years) (pre versus postcommercialization THC positivity in 12–20 years: 17.9% vs 29.5%, AOR=1.95, 95% CI=1.43, 2.65; $p < 0.001$; cannabis-related disorder: 7.8% vs 14.8%, AOR=2.07, 95% CI=1.36, 3.15; $p < 0.001$) (Appendix Table 5 and Appendix Figure 2, available online).

DISCUSSION

THC positivity rates increased significantly among people presenting to an urban psychiatric emergency service after the commercialization of recreational cannabis in Massachusetts, whereas the increase in the rates of

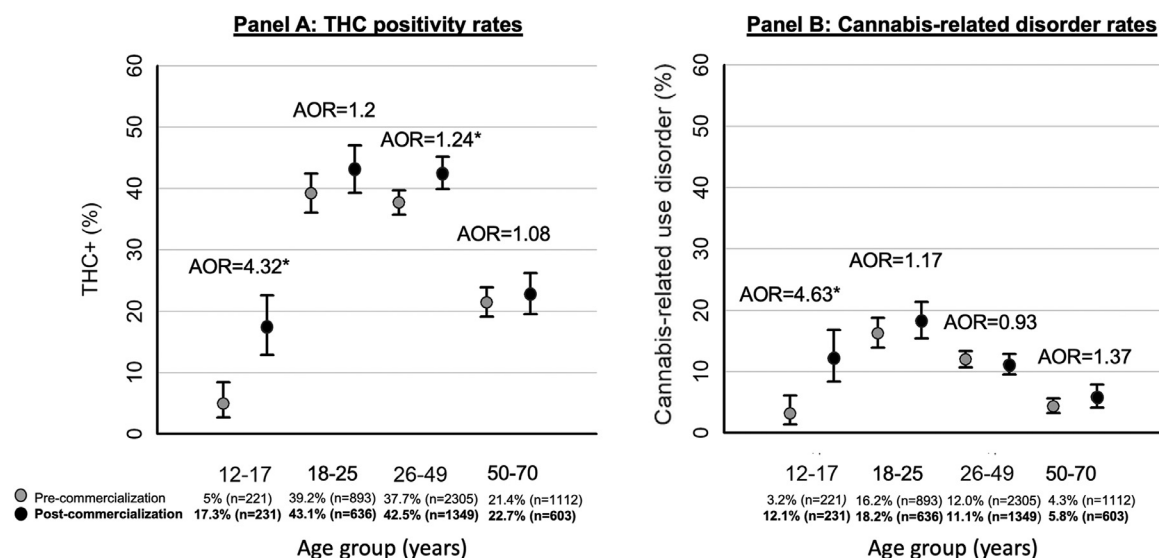


Figure 1. Rates of THC positivity and cannabis-related disorder before versus after cannabis commercialization within each age group.

Note: Figure compares rates of cannabinoid immunoassay positivity (THC+) and cannabis-related disorder from before to after commercialization within each age group. Precommercialization and postcommercialization rates and sample size are indicated in regular font and boldface, respectively. AOR indicate the OR of having a positive cannabis use outcome after commercialization compared with that before commercialization within each age group, adjusted for sex, race, and ethnicity. * indicates statistical significance of $p < 0.01$ for test of age by commercialization simple effect. THC, tetrahydrocannabinol.

cannabis-related disorders was nonsignificant. However, changes in the rates of both THC positivity and diagnoses of cannabis-related disorders after cannabis commercialization differed by age group, with adolescents (aged 12–17 years) showing significantly greater increases in both measures than the other age groups. In fact, other than the adolescent group, only adults (aged 26–49 years) had a significant increase in THC positivity rates after commercialization, and no other age group increased significantly in cannabis-related disorders. In addition, there were no other age-related increases in any other substances detected by UDS or substance-related disorders, suggesting that trends observed were specific to cannabis and not due to broader trends in substance use.

The findings underscore the adverse impacts of cannabis commercialization in a psychiatric population that may be missed in existing population-level analyses. Prior U.S.-based household surveys have reported modest increases in self-reported, past-month cannabis use for adults^{8,34} but not adolescents.^{35–37} However, a large analysis of 2008–2016 National Survey on Drug Use and Health data ($n=505,796$) reported a small increase in self-reported past-year cannabis use disorder among adolescents who use cannabis after commercialization, although there was no change in self-reported cannabis use or frequent past-month use, suggesting that a vulnerable subgroup may be more prone to developing

cannabis-related disorders after legalization.⁸ Building on this evidence, this study found large increases in both cannabis measures among adolescents presenting for treatment to a psychiatric emergency service, which were significantly greater than those in any other age group. These results suggest that cannabis commercialization may have a more prominent negative effect on adolescents with psychiatric illnesses than either the general adolescent population or adults with psychiatric disorders.

Consistent with general population findings,^{8,9} the modest postcommercialization increase in adult cannabis use in this sample may be partly due to greater social acceptability of recreational use among existing cannabis users.³⁸ The comparatively greater effects of commercialization seen in adolescents may be due in part to the increase in new cannabis users among psychiatrically vulnerable individuals, considering that the peak age of cannabis initiation is around the age of 16 years.³⁹ Adolescents with psychiatric symptoms or vulnerability to mental health and substance use conditions may face heightened sensitivity to environmental cues and social influences, making them more responsive to the increased accessibility, societal acceptance,⁷ and youth-oriented marketing exposure accompanying cannabis commercialization.⁴⁰ Similarly, their psychiatric conditions or vulnerabilities may make them susceptible to the negative effects of cannabis use, including psychiatric

Table 3. Pairwise Comparisons and Simple Effects in Fully Adjusted Model Examining Effects on Cannabis Use Outcomes

Type	Contrast	THC positivity rates			Cannabis-related disorder rates		
		OR	95% CI	p-value	OR	95% CI	p-value
Main effects							
Pairwise: age (years)							
	(18–25)–(12–17)	6.90	4.79, 9.94	<0.001	3.08	1.97, 4.82	0.001
	(26–49)–(12–17)	6.04	4.23, 8.63	<0.001	1.80	1.16, 2.80	0.052
	(50–70)–(12–17)	2.48	1.71, 3.59	<0.001	0.72	0.44, 1.17	0.545
	(26–49)–(18–25)	0.88	0.77, 0.99	0.166	0.59	0.49, 0.70	0.001
	(50–70)–(18–25)	0.36	0.31, 0.42	<0.001	0.23	0.18, 0.30	0.001
	(50–70)–(26–49)	0.41	0.36, 0.47	<0.001	0.40	0.31, 0.51	0.001
Interaction effects							
Simple: Commercialization							
12-17	Post - Pre	4.32	2.15, 8.68	<0.001	4.63	1.97, 10.87	0.002
18-25	Post - Pre	1.20	0.97, 1.48	0.120	1.17	0.89, 1.54	0.334
26-49	Post - Pre	1.24	1.08, 1.42	0.006	0.93	0.75, 1.15	0.526
50-70	Post - Pre	1.08	0.85, 1.38	0.507	1.37	0.87, 2.14	0.334
Interaction contrasts							
	Post–Pre/(12–17)–(18–25)	3.60	1.74, 7.47	0.001	3.95	1.61, 9.67	0.008
	Post–Pre/(12–17)–(26–49)	3.49	1.71, 7.12	0.001	4.96	2.06, 11.94	0.002
	Post–Pre/(12–17)–(50–70)	3.98	1.90, 8.33	0.001	3.38	1.29, 8.87	0.026
	Post–Pre/(18–25)–(26–49)	0.97	0.75, 1.25	0.815	1.26	0.89, 1.77	0.234
	Post–Pre/(18–25)–(50–70)	1.11	0.80, 1.52	0.645	0.86	0.51, 1.45	0.562
	Post–Pre/(26–49)– (50–70)	1.14	0.86, 1.50	0.535	0.68	0.42, 1.12	0.197
Covariates							
Sex	Female–male	0.79	0.75, 0.83	<0.001	0.76	0.7, 0.82	<0.001
Race ^a	Asian–White	0.63	0.55, 0.72	<0.001	0.82	0.68, 1	0.071
Race	Black–White	1.38	1.25, 1.53	<0.001	1.26	1.09, 1.46	0.004
Ethnicity	Hispanic/Latine–non-Hispanic/ Latine	1.05	0.93, 1.19	0.530	1.12	0.94, 1.33	0.276

Note: Boldface indicates statistical significance (* $p < 0.01$).

p-values were adjusted for multiple comparisons using the Benjamini–Hochberg correction.

^aComparisons with other racial groups (American Indian/Alaska Native, Native Hawaiian/other Pacific Islander) were not performed owing to low cell count.

THC, tetrahydrocannabinol.

consequences and the development of substance use disorders, as suggested by the supersensitivity hypothesis.⁴¹

The magnified impact of cannabis on the developing brain^{25,42} may also explain more pronounced commercialization effects on cannabis-related disorder rates in adolescents than adults. Although the rate of cannabis-related disorders among users was consistent with epidemiologic studies (20%–33%),^{43,44} there were notable differences between age groups, with rates decreasing by age. Older cannabis users had lower rates of cannabis-related disorders likely because experiencing negative consequences early on will subsequently limit problematic use. Substance use disorders are also associated with premature mortality and, hence, were less represented in older age groups. Furthermore, this pattern is consistent with what has been referred to as telescoping or the accelerated progression from initial substance use to substance use disorder development, observed in

adolescents, partially owing to the neurobiology of the developing brain.⁴⁵ This vulnerability may be compounded by rising THC potency in commercial products,⁴ which has an established dose effect on precipitating and worsening psychiatric symptoms,^{14,46} consistent with the increase in adolescent and young adult presentations to the psychiatric emergency service after commercialization.

These findings raise important public health concerns about the impact of commercial cannabis on youth with psychiatric illnesses, a group more vulnerable to experiencing adverse health, economic, and social consequences of early cannabis use⁴⁷ compared than adults^{48,49} and those without psychiatric conditions.^{12–14} With poorly regulated online dispensaries and no regulation of potency in commercial products,^{50,51} the study's data suggest that people aged <21 years could access cannabis and are not

protected from the harms of early use. These findings highlight the need to enforce youth-oriented protections in the legal market⁵² and enhance prevention efforts. Pediatricians, psychiatrists, and mental health providers must play an important role in educating about cannabis-related risks, assessing substance use, and providing targeted early interventions for people with psychiatric conditions and co-occurring cannabis use.

Limitations

This study minimized measurement biases using objective toxicologic tests and ICD-10 diagnoses by psychiatric providers. Given the rare occurrence of cannabis-induced psychosis/mood disorder cases (0.3%), results suggest that increased psychiatric emergency visits after commercialization was more likely due to increased cannabis use and related psychiatric effects among those with existing psychiatric rather than cannabis-precipitated acute presentations.

Generalizability is limited given single-site data; replication across other psychiatric populations and states is needed. The study period restricted disentangling medical marijuana legalization effects (since 2013 in Massachusetts) from commercialization; however, the significant increases in use that occurred in an already liberalized cannabis environment suggest that greater availability introduced additional risk. Massachusetts only had 74 dispensaries during the study's postcommercialization period versus $\geq 1,500$ today, suggesting even greater present-day effects.⁵³ Longitudinal studies examining polysubstance use patterns^{54,55} and long-term psychiatric outcomes are needed.⁵⁶

CONCLUSIONS

Increased cannabis exposure and cannabis-related disorders among adolescents presenting with psychiatric emergencies in Massachusetts is concerning as cannabis retail availability expands. Although absolute rates remained relatively low, the increases signal emergence of a potential public health challenge in particular for youth with psychiatric illnesses, who are disproportionately vulnerable to the neuropsychiatric effects of cannabis exposure. This study underscores the need for more research on the impact of cannabis policy on vulnerable youth and the development of targeted interventions for this high-risk population.

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SUPPLEMENTAL MATERIAL

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