

Letters

RESEARCH LETTER

Recreational Cannabis Legalization, Retail Sales, and Adolescent Substance Use Through 2021

The past decade has witnessed rapid shifts in cannabis legalization: since 2012, 24 US states and Washington, DC, enacted recreational cannabis legalization (RCL), and 18 implemented recreational cannabis retail sales (RCR). Although studies of early-enacting US states and Canada reported few effects of RCL on adolescent substance use,¹⁻³ experts have highlighted the need to further assess policy outcomes in youth as legalization and retail availability spread and other policies targeting youth substance use shift.⁴ To our knowledge, this study is the first to evaluate associations between RCL and RCR policies and adolescent substance use through 2021, capturing data from youth affected by the COVID-19 pandemic.

Methods | We analyzed repeated cross-sectional biennial Youth Risk Behavior Surveys drawn from 2011 to 2021 state datasets, weighted to be representative of students in 47 participating states. With parent consent, students from ninth to twelfth grade self-reported prior month use of cannabis, alcohol, cigarettes, and e-cigarettes. We coded RCL and RCR dichotomously and as years since effective date or store openings (Table 1). This study was deemed exempt by the Boston College institutional review board from human participation regulations. Statistical significance was set at 2-sided $P < .05$. The STROBE reporting guideline was used.

We estimated separate zero-inflated negative binomial difference-in-differences regressions to evaluate associations among RCL and RCR with substance use, predicting the likelihood of zero use and the frequency of use among

users and calculating total predicted use (eMethods in Supplement 1). Models adjusted for youth demographic characteristics, medical cannabis and decriminalization, other state policies, and state and year fixed effects. Parallel trends analyses on cannabis use using an event study framework were conducted.

Results | Among 898 271 students, RCL was not associated with adolescents' likelihood or frequency of cannabis use, although negative total effect estimates indicated significantly lowered use following RCL (Table 2). Each additional year of RCL exposure was associated with 8% higher odds of zero cannabis use (lower likelihood of any use), with non-significant total effect estimates.

RCR was associated with 28% higher odds of zero cannabis use but also 26% higher frequency of use among users, combining to a nonsignificant total effect estimate. Similarly, each additional year of RCR was associated with 8% higher odds of zero use but also 8% higher frequency of use, with a nonsignificant total effect estimate.

Considering other substances, RCL showed a negative total effect estimate for alcohol use. No significant results emerged for cigarettes. Each additional year of RCL exposure was associated with 16% increased odds of zero e-cigarette use, with a negative total effect estimate. RCR was associated with 42% increased odds of zero e-cigarette use, with each additional year of RCR associated with 20% increased odds of zero use, both showing significant negative total effect estimates.

Discussion | The spread of RCL and RCR has led to lower cannabis prices and increased availability, adult use, and cannabis-related hospitalizations.⁴ Using the most recently available 2011 to 2021 data, we found limited associations between RCL and RCR with adolescent substance use, extending previous findings.¹⁻⁴ RCL was associated with

Table 1. State Data in Youth Risk Behavior Surveys, Prevalence of Substance Use, and Cannabis Policies (N = 1 045 700)

State	Survey years	No.	% Weighted sample	% Use cannabis	Recreational cannabis ^a	Recreational retail sales ^b
AK	2011-2019	7131	0.2	20.4	Feb 2015	Oct 2016
AL	2011-2015, 2019-2021	6919	1.4	16.7	NA	NA
AR	2011-2021	10 936	0.9	16.4	NA	NA
AZ	2011-2021	12 276	2.1	22.3	Nov 2020	Jan 2021
CA	2015-2019	10 060	21.3	20.6	Nov 2016	Jan 2018
CO	2011, 2017-2021	5367	1.5	19.8	Dec 2012	Jan 2014
CT	2011-2021	12 992	1.1	20.7	July 2021	[Jan 2023]
DE	2011-2017, 2021	12 268	0.3	23.5	[Apr 2023]	NA
FL	2011-2021	34 994	5.4	20.3	NA	NA
GA	2011-2013, 2019-2021	9018	3.3	18.9	NA	NA

(continued)

Table 1. State Data in Youth Risk Behavior Surveys, Prevalence of Substance Use, and Cannabis Policies (N = 1 045 700) (continued)

State	Survey years	No.	% Weighted sample	% Use cannabis	Recreational cannabis ^a	Recreational retail sales ^b
HI	2011-2021	32 193	0.3	17.6	NA	NA
IA	2011, 2017-2021	6181	1.0	13.7	NA	NA
ID	2011-2021	9342	0.5	16.4	NA	NA
IL	2011-2021	21 155	3.8	20.5	Jan 2020	Jan 2020
IN	2011, 2015, 2021	10 510	3.3	17.6	NA	NA
KS	2011-2013, 2017-2021	9123	0.9	14.6	NA	NA
KY	2011-2021	12 122	1.3	16.2	NA	NA
LA	2011-2013, 2017-2021	5423	1.2	17.9	NA	NA
MA	2011-2019	13 985	1.9	25.4	Dec 2016	Nov 2018
MD	2011-2021	236 855	1.7	18.6	[July 2023]	NA
ME	2011-2021	52 653	0.4	20.0	Jan 2017	Oct 2020
MI	2011-2021	23 028	2.9	19.3	Dec 2018	Dec 2019
MO	2013-2021	7003	1.8	17.8	[Dec 2022]	[Feb 2023]
MS	2011-2015, 2019-2021	8992	0.9	16.6	NA	NA
MT	2011-2021	26 443	0.3	20.4	Jan 2021	[Jan 2022]
NC	2011-2021	18 085	3.0	21.2	NA	NA
ND	2011-2021	12 173	0.2	14.1	NA	NA
NE	2011-2021	10 765	0.6	12.3	NA	NA
NH	2011-2021	57 138	0.4	23.7	NA	NA
NJ	2011-2013, 2019-2021	5421	2.6	19.8	Feb 2021	[Apr 2022]
NM	2011-2021	37 272	0.7	25.9	June 2021	[Apr 2022]
NV	2013-2021	8343	0.9	18.3	Jan 2017	July 2017
NY	2011-2021	59 796	5.1	18.8	Mar 2021	[Dec 2022]
OH	2011-2013, 2019-2021	4852	2.6	20.3	[Dec 2023]	NA
OK	2011-2021	9546	1.2	16.7	NA	NA
PA	2015-2021	10 581	3.5	18.1	NA	NA
RI	2011-2021	15 699	0.3	22.5	[May 2022]	[Dec 2022]
SC	2011-2021	8684	1.3	18.7	NA	NA
SD	2011-2015, 2019-2021	6547	0.3	15.4	NA	NA
TN	2011-2021	14 825	1.9	18.3	NA	NA
TX	2011-2013, 2017-2021	13 160	9.7	18.3	NA	NA
UT	2011-2013, 2017-2021	8756	1.1	8.5	NA	NA
VA	2011-2021	24 762	2.6	16.5	Jul 2021	[Jan 2024]
VT	2011, 2015-2021	85 987	0.2	23.3	Jul 2018	[Oct 2022]
WI	2011-2013, 2017-2021	11 557	1.7	17.7	NA	NA
WV	2011-2021	8976	0.5	18.1	NA	NA
WY	2011-2015	15 806	0.3	18.1	NA	NA

Abbreviation: NA, not applicable.

data.

^a States adopting recreational cannabis legalization (RCL) with effective dates after April 1, 2021 [in brackets], were coded as nonrecreational cannabis legalization in all models. Sixteen states contributed pre-RCL and post-RCL

^b Date at least 1 recreational cannabis retail (RCR) store open in state, coded as nonretail if the date was after April 1, 2021. Nine states contributed pre-RCR and post-RCR data.

modest decreases in cannabis, alcohol, and e-cigarette use. RCR was associated with lower e-cigarette use, and with lower likelihood but also increased frequency of cannabis use among users, leading to no overall change in cannabis use.

Together, results found no net increases in cannabis or, through spillover effects, alcohol or tobacco use among

adolescents in response to the rapid rise of RCL and RCR. Results suggest that legalization and greater control over cannabis markets have not facilitated adolescents' entry into substance use. Yet, given the negative health consequences associated with early and heavy use of these substances,^{4,5} and results suggesting users of cannabis may be increasing their frequency of use in

Table 2. Difference-in-Differences Zero-Inflated Negative Binomial Models Associating RCL and RCR With Adolescent Substance Use^a

Variable	OR, IRR, or total marginal effect estimates (95% CI)		Alcohol (n = 854 920)		Cigarettes (n = 885 316)		E-cigarettes (n = 578 196)	
	Inflation model, OR	NB model, IRR	Total marginal effect estimates	Inflation model, OR	NB model, IRR	Total marginal effect estimates	Inflation model, OR	NB model, IRR
Model 1: RCL enactment								
RCL	1.10 (0.99 to 1.22)	0.96 (0.90 to 1.02)	-0.29 (-0.50 to -0.07) ^b	1.10 (0.97 to 1.25)	0.94 (0.87 to 1.01)	-0.17 (-0.31 to -0.03) ^b	1.04 (0.89 to 1.22)	0.92 (0.77 to 1.11)
Model 2: years since RCL								
Years since RCL	1.08 (1.02 to 1.14) ^b	1.06 (1.00 to 1.13)	0.01 (-0.20 to 0.23)	1.05 (0.98 to 1.13)	0.99 (0.94 to 1.04)	-0.06 (-0.14 to 0.03)	1.00 (0.96 to 1.04)	1.01 (0.97 to 1.06)
Model 3: RCR enactment								
RCR	1.28 (1.06 to 1.56) ^b	1.26 (1.02 to 1.56) ^b	0.12 (-0.61 to 0.85)	1.19 (0.95 to 1.49)	0.95 (0.79 to 1.14)	-0.22 (-0.52 to 0.07)	1.14 (0.93 to 1.39)	1.04 (0.86 to 1.26)
Model 4: years since RCR								
Years since RCR	1.08 (1.02 to 1.15) ^b	1.08 (1.00 to 1.15) ^b	0.04 (-0.19 to 0.28)	1.04 (0.97 to 1.13)	0.99 (0.94 to 1.05)	-0.04 (-0.14 to 0.05)	1.01 (0.95 to 1.06)	1.04 (0.98 to 1.10)

Abbreviations: IRR, incidence rate ratio; NB, negative binomial; OR, odds ratio; RCL, recreational cannabis legalization; RCR, recreational cannabis retail.

^a All models include adjustments for age, race and ethnicity, sex, year, state, beer taxes, cigarette and e-cigarette taxes, cigarette and e-cigarette smoke-free restaurant laws, state tobacco 21 laws, and unemployment rate. The

^b Indicates significant P value at .05.

Youth Risk Behavior Surveys began asking about e-cigarette use in 2015, leading to a smaller sample size. Further details on study methods are available in eMethods of Supplement 1.

response to retail availability, greater attention is warranted to sources and trajectories among frequent youth users of cannabis.⁶

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