



Association of Marijuana Legalization With Marijuana Use Among US High School Students, 1993-2019

D. Mark Anderson, PhD; Daniel I. Rees, PhD; Joseph J. Sabia, PhD; Samuel Safford, MA

Introduction

Thirty-six states have legalized medical marijuana, and 18 states have passed recreational marijuana laws (RMLs). Organizations such as the American Academy of Pediatrics are concerned that legalization will encourage youth marijuana use.¹ Marijuana use during adolescence may adversely affect areas of the prefrontal cortex that control important cognitive processes.¹

Using data from the Youth Risk Behavior Survey (YRBS) for the period 1993 to 2017, in a previous study with 3 of us as authors (D.M.A., D.I.R., and J.J.S.),² we reported that RML adoption was associated with an 8% decrease in the odds of marijuana use among high school students. However, that study had prelegalization and postlegalization data from only 7 states and pre- and post-recreational sales data from only 3 states, limiting generalizability of the results. In addition, we had also reported unweighted estimates based on pooled national and state YRBS data, which we had subsequently been advised was not appropriate for the following reasons: (1) "Pooling national and state YRBS data is inappropriate because underlying person-level weights are different, and there is some overlap between national and state YRBS data; thus, a student could be represented more than once. The YRBS codebook explicitly warns against combining these data." and (2) "YRBS data are designed to be weighted to capture representative populations."³ To address this concern, we provided weighted estimates of the association between RMLs and marijuana use among teenagers and linked to these estimates in a Letter in reply.⁴

Using data from the YRBS for the period 1993 to 2019, this study provides updated and weighted, unpooled national and state YRBS-based estimates of the association between legalization and adolescent marijuana use.

Methods

National and state YRBS data from 1993 to 2019 were analyzed separately. Data pre- and post-RML enactment were available from 10 states; 7 states contributed more than 1 wave of post-RML data, and these same 7 states contributed data to the YRBS before and after the first marijuana dispensary sales began. Data on preenactment and postenactment of medical marijuana laws (MMLs) were available from 29 states. Ethical review was not required because analyses of secondary, deidentified data are considered exempt from requiring institutional review board approval by the San Diego State University Institutional Review Board. This report attempted to follow the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guidelines.

Effective legalization dates come from the report by Anderson and Rees.⁵ Current marijuana use was defined as any use in the past 30 days, and frequent marijuana use was defined as use at least 10 times in the past 30 days.

National and state YRBS data on marijuana use were analyzed separately. Weighted multivariable logistic regression was used to estimate the association between legalization and marijuana use. To control for time-invariant factors at the state level and common trends, all models were adjusted for state and survey wave indicators. Alternative models were further adjusted for individual- and state-level characteristics; event-study estimates were produced by replacing the

This article was retracted and replaced on March 8, 2022. See supplemental content for versions that show errors and corrections.

+ Supplemental content

Author affiliations and article information are listed at the end of this article.

Open Access. This is an open access article distributed under the terms of the CC-BY License.

RML and MML indicators with leads and lags. Two-sided hypothesis tests were used, and estimates were considered significant if $P < .05$. Analyses were conducted with Stata statistical software version 16.1 (StataCorp).

Results

Among 191 923 national YRBS respondents, the mean (SD) age was 16.06 (1.23) years, 49.1% of respondents reported as female, and 61.0% reported as non-Hispanic White individuals. Among 1 418 682 state YRBS respondents, the mean (SD) age was 16.03 (1.23) years, 49.8% of respondents reported as female, and 59.0% reported as non-Hispanic White individuals.

Based on the national YRBS data and in the fully adjusted models RML adoption was not associated with current marijuana use (odds ratio [OR], 1.01; 95% CI, 0.85-1.19) or frequent marijuana

Table. Estimates of the Association of Enactment of Marijuana Legalization Laws With Adolescent Marijuana Use

Variable	OR (95% CI) ^a			
	Model 1 ^b		Model 2 ^c	
	Current use	Frequent use	Current use	Frequent use
National YRBS (n = 191 923)				
RML	1.04 (0.90-1.21)	1.02 (0.80-1.30)	1.01 (0.85-1.19)	0.99 (0.78-1.26)
MML	0.94 (0.85-1.04)	0.91 (0.75-1.10)	0.94 (0.84-1.05)	0.90 (0.74-1.10)
State YRBS (n = 1 418 682)				
RML	0.92 (0.82-1.03)	0.88 (0.77-1.01)	0.93 (0.85-1.02)	0.89 (0.79-1.01)
MML	1.00 (0.95-1.05)	1.00 (0.94-1.06)	0.99 (0.93-1.04)	0.99 (0.92-1.06)
National YRBS, replacing RML with RML sales allowed (n = 191 923)				
RML sales allowed	1.11 (0.82-1.50)	1.13 (0.71-1.81)	1.09 (0.84-1.41)	1.14 (0.73-1.78)
MML	0.94 (0.85-1.05)	0.91 (0.75-1.10)	0.94 (0.84-1.05)	0.90 (0.74-1.10)
State YRBS, replacing RML with RML sales allowed (n = 1 418 682)				
RML sales allowed	0.76 (0.66-0.86) ^d	0.87 (0.78-0.97) ^d	0.78 (0.70-0.87) ^d	0.89 (0.78-1.02)
MML	0.99 (0.94-1.04)	1.00 (0.94-1.06)	0.98 (0.92-1.04)	0.99 (0.91-1.02)

Abbreviations: MML, medical marijuana laws; OR, odds ratio; RML, recreational marijuana laws; YRBS, Youth Risk Behavior Survey.

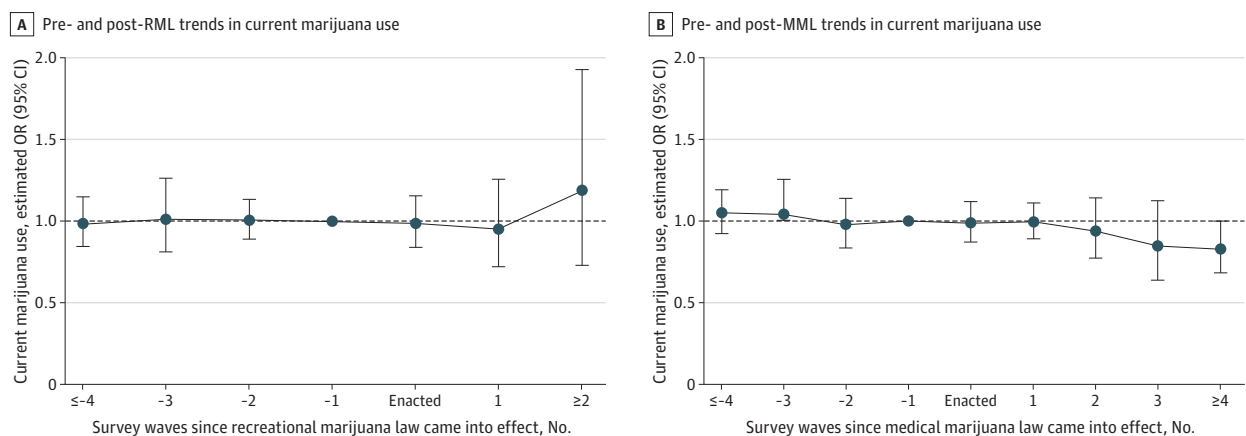
^a SEs, which were used to construct the 95% CIs, were corrected for clustering at the state level.

^b Estimated ORs were adjusted for state and survey wave (ie, year) indicators.

^c Estimated ORs were adjusted for individual-level characteristics (age, sex, grade, and race), whether marijuana use and possession were decriminalized in the respondent's state, the presence of a state-level 0.08 blood alcohol concentration law, the state beer tax, state income per capita, state unemployment rate, and state and survey wave indicators.

^d $P < .01$.

Figure. Event Study Analysis



Each panel reports weighted estimates from a separate logistic regression based on biennial data from the national Youth Risk Behavior Surveys (1993-2019) including 191 923 participants. Estimated odds ratios (ORs) of current marijuana use (and their 95% CIs) are reported. ORs were adjusted for individual-level characteristics (age, sex, grade, and race), whether marijuana use and possession were decriminalized in the

respondent's state, the presence of a state-level 0.08 blood alcohol concentration law, the state beer tax, state income per capita, state unemployment rate, state and survey wave (ie, year) indicators. Values on the horizontal axis reflect survey waves since legalization came into effect. The omitted category was 1 survey wave prior to legalization going into effect.

use (OR, 0.99; 95% CI, 0.78-1.26). In the fully adjusted models, MML adoption also was not associated with current marijuana use (OR, 0.94; 95% CI, 0.84-1.05) or frequent marijuana use (OR, 0.90; 95% CI, 0.74-1.10). Estimates from a separate analysis of the state YRBS data also showed no significant association of RML or MML adoption with current or frequent marijuana use (**Table**).

The **Figure, A**, shows RML event-study estimates based on the national YRBS data. Prior to RML adoption, there was no association with marijuana use, suggesting the parallel-trends assumption held. Similarly, after legalization, there was no association with marijuana use, consistent with the results reported in the **Table**. The **Figure, B**, shows an event study for MML adoption.

Discussion

In this cross-sectional study using weighted national YRBS data and weighted state YRBS data, there were no significant associations between enactment of RMLs or MMLs and marijuana use among high school students. These findings differ from the previous report by Anderson et al² that had reported estimates based on unweighted pooled national and state data based on an analytic approach not recommended by the YRBS.³ This approach could also be inappropriate if legalization had heterogeneous effects across states.^{3,4} Limitations of this study are inclusion of data only through 2019 and only 10 states had data on pre- and post-RML enactment. RMLs are a relatively new phenomenon, and as more recent postlegalization data become available, further research will be needed to better define the associations between RMLs and adolescent marijuana use.

ARTICLE INFORMATION

Accepted for Publication: July 8, 2021.

Published: September 7, 2021. doi:10.1001/jamanetworkopen.2021.24638

Retraction and Replacement: This article was retracted and replaced on March 8, 2022, to fix errors in the analysis methods and results (see [Supplement 1](#) for the retracted article with errors highlighted and [Supplement 2](#) for the replacement article with corrections highlighted).

Open Access: This is an open access article distributed under the terms of the [CC-BY License](#). © 2021 Anderson DM et al. *JAMA Network Open*.

Corresponding Author: D. Mark Anderson, PhD, Department of Agricultural Economics and Economics, Montana State University, PO Box 172920, Bozeman, MT 59717-2920 (dwight.anderson@montana.edu).

Author Affiliations: Department of Agricultural Economics and Economics, Montana State University, Bozeman (Anderson); Department of Economics, Universidad Carlos III de Madrid, Madrid, Spain (Rees); Center for Health Economics and Policy Studies, San Diego State University, San Diego, California (Sabia, Safford).

Author Contributions: Dr Sabia had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Concept and design: All authors.

Acquisition, analysis, or interpretation of data: Anderson, Sabia, Safford.

Drafting of the manuscript: Anderson, Rees, Sabia.

Critical revision of the manuscript for important intellectual content: All authors.

Statistical analysis: Rees, Sabia, Safford.

Obtained funding: Anderson, Sabia.

Supervision: Anderson, Sabia.

Conflict of Interest Disclosures: Dr Sabia reported receiving grants from Troesh Family Foundation and Charles Koch Foundation during the conduct of the study. No other disclosures were reported.

Funding/Support: Dr Anderson acknowledges partial support from the Eunice Kennedy Shriver National Institute of Child Health and Human Development of the National Institutes of Health (NIH) (research infrastructure grant No. R24 HD042828), to the Center for Studies in Demography and Ecology at the University of Washington. Dr Sabia and Mr Safford acknowledge partial support from the Center for Health Economics & Policy Studies at San Diego State University, including grant funding received from the Charles Koch Foundation.

Role of the Funder/Sponsor: The funders had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

Disclaimer: The content is solely the responsibility of the authors and does not necessarily represent the official views of the NIH.

REFERENCES

1. Committee on Substance Abuse, Committee on Adolescence; Committee on Substance Abuse Committee on Adolescence. The impact of marijuana policies on youth: clinical, research, and legal update. *Pediatrics*. 2015;135(3):584-587. doi:10.1542/peds.2014-4146
2. Anderson DM, Hansen B, Rees DI, Sabia JJ. Association of marijuana laws with teen marijuana use: new estimates from the Youth Risk Behavior Surveys. *JAMA Pediatr*. 2019;173(9):879-881. doi:10.1001/jamapediatrics.2019.1720
3. Jones CM, Underwood JM, Volkow ND. Challenging the association of marijuana laws with teen marijuana use. *JAMA Pediatr*. 2020;174(1):99. doi:10.1001/jamapediatrics.2019.4235
4. Anderson DM, Rees DI, Sabia JJ. Challenging the association of marijuana laws with teen marijuana use-reply. *JAMA Pediatr*. 2020;174(1):99-100. doi:10.1001/jamapediatrics.2019.4238
5. Anderson DM, Rees DI. The public health effects of legalizing marijuana. NBER Working Paper No. 28647. Accessed August 13, 2021. <https://www.nber.org/papers/w28647>

SUPPLEMENT 1.

Retracted Article With Errors Highlighted

SUPPLEMENT 2.

Replacement Article With Corrections Highlighted