



Published in final edited form as:

Drug Alcohol Depend. 2015 July 1; 152: 68–72. doi:10.1016/j.drugalcdep.2015.04.014.

A Reexamination of Medical Marijuana Policies in Relation to Suicide Risk*

Richard A. Grucza¹, Michael Hur¹, Arpana Agrawal¹, Melissa J. Krauss¹, Andrew D. Plunk², Patricia A. Cavazos-Rehg¹, Frank J. Chaloupka³, and Laura J. Bierut^{1,4}

¹Department of Psychiatry, Washington University School of Medicine, St. Louis, MO, USA

²Department of Pediatrics, Eastern Virginia Medical School, Norfolk, VA

³Department of Economics and Health Policy Center, University of Illinois at Chicago, Chicago, IL, USA

⁴Siteman Cancer Center, Washington University School of Medicine, St. Louis, MO, USA

Abstract

Objectives—Previous research has suggested that medical marijuana policies lead to reductions in suicide rates. In this study, we further investigate the association between these policies and within-state changes in suicide risk.

Methods—Data on suicide deaths (n=662,993) from the National Vital Statistics System Multiple Cause of Death files were combined with living population data. Fixed-effects regression methods were employed to control for state differences in suicide rates and national and state secular trends. Analyses extended prior research that suggested a protective effect of medical marijuana policies by incorporating newer data and additional covariates.

Results—After adjustment for race/ethnicity, tobacco control policies, and other covariates, we found no association between medical marijuana policy and suicide risk in the population ages 15

• Supplementary material can be found by accessing the online version of this paper at <http://dx.doi.org> and by entering doi:...

© 2015 Published by Elsevier Ltd

Address for Correspondence: Richard A Grucza, Department of Psychiatry, Washington University School of Medicine, 660 South Euclid Avenue, Box 8134, St. Louis, Missouri 63110. Phone: 314-362-6535 Fax: 314-362-4247, gruczar@psychiatry.wustl.edu.

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

Conflicts of Interest: LJB is listed as an inventor on Issued U.S. Patent 8,080,371, "Markers for Addiction" covering the use of certain genetic polymorphisms in determining the diagnosis, prognosis, and treatment of addiction.

Contributors:

Richard A Grucza. Conceived and designed study, conducted analyses, led writing of manuscript.

Michael Hur. Conducted analyses, critically reviewed of manuscript.

Arpana Agrawal. Drafted portions of manuscript, critically reviewed of manuscript.

Melissa J Krauss. Conducted analyses, critically reviewed of manuscript.

Patricia A Cavazos-Rehg, Ph. D. Critically reviewed manuscript.

Andrew D Plunk, Ph. D. Drafted portions of manuscript. Critically reviewed manuscript.

Frank J Chaloupka, Ph. D. Advised on analyses, critically reviewed manuscript

Laura J Bierut, M.D. Advised on interpretation of data, critically reviewed manuscript.

All authors reviewed and approved the final manuscript.

and older (OR=1.000; 95% CI: 0.956, 1.045; $p=.98$), among men overall (OR=0.996; 95% CI: 0.951, 1.043; $p=.87$) or for any other age-by-sex groups.

Conclusion—We find no statistically significant association between medical marijuana policy and suicide risk. These results contradict prior analyses which did not control for race/ethnicity and certain state characteristics such as tobacco control policies. Failure to control for these factors in future analyses would likely bias estimates of the associations between medical marijuana policy and health outcomes.

Keywords

marijuana; medical marijuana; policy; suicide; epidemiology

1. INTRODUCTION

Over the past two decades, 23 states and the District of Columbia have legalized marijuana for medical use in the U.S. (Anderson et al., 2014; Pacula et al., 2013). These policies were adopted at different times, allowing researchers to analyze the effects of policy changes as a natural experiment: differences in medical marijuana policies between states over time allow investigators to draw inferences about whether policy that could facilitate access to marijuana are causally associated with key public health outcomes (Anderson et al., 2014, 2013; Cerdá et al., 2012; Choo et al., 2014; Gorman and Charles Huber, 2007; Harper et al., 2012; Lynne-Landsman et al., 2013; Pacula et al., 2013; Rylander et al., 2014; Schuermeier et al., 2014; Wall et al., 2011). In one of the more intriguing examples of such a study, Anderson and colleagues examined the association between legalization of medical marijuana and changes in state suicide rates over the period 1990–2007 (Anderson et al., 2014). Their results suggested that legalization of medical marijuana led to a *decrease* in suicide rates. Specifically, they reported that legalization was associated with a 5% decrease in the suicide rate for men overall, about a 10% decrease in the suicide rate of men aged 20 through 29, and a nearly 14% decrease in men aged 30 through 39.

If the legalization of marijuana for medical purposes truly leads to reductions in suicide rates, this would have important implications for public health and policy. Suicide is among the ten leading causes of death in the United States and the 4th leading contributor to years of potential life lost among people under 65 (Centers for Disease Control and Prevention, 2014; Murphy et al., 2013). Any true effect on suicide rates should be seriously considered in the policy debates surrounding both medical and recreational marijuana. However, a *protective* effect against suicide is surprising given that neurodevelopmental and psychiatric effects—including suicide risk—are among the primary health concerns associated with regular marijuana use (Batalla et al., 2013; Hall and Degenhardt, 2009; Meier et al., 2012; Moore et al., 2007; Price et al., 2009; van Ours et al., 2013; Volkow et al., 2014). Given the relevance of such a finding to policy, the suggestion that medical marijuana policies might lead to *lower* rates of suicide warrants closer scrutiny.

In the present study, we sought to extend the work exploring the association between medical marijuana policy and reduced suicide risk (Anderson et al., 2014). We utilized data from individual death records, which allowed us to adjust for demographic variables at an

individual level. This was not possible in the prior study, which analyzed state suicide rates instead of individual death records. Yet adjusting for demographic variables could be important because they may be associated with suicide rates, and, as key characteristics of state electorates, could influence state policy change. For example, race and educational attainment, which were not addressed in the prior study, are well known to be associated with suicide rates (Centers for Disease Control and Prevention, 2013; Crosby et al., 2013, 2011). We also adjusted for several additional state policies and characteristics that past research suggests could be relevant. For example, we have recently shown that state tobacco control policies may influence suicide risk (Grucza et al., 2014). Tobacco control policies also likely influence the prevalence of marijuana use (Chaloupka et al., 1999; Farrelly et al., 2001; Williams et al., 2004), and may influence alcohol use which could be an important determinant of suicide risk (Kaplan et al., 2014; Krauss et al., 2014; Young-Wolff et al., 2013a, 2013b). We also included measures of state political orientation, per-capita mental health spending, and health insurance coverage, all of which may be associated with suicide risk (Kposowa, 2013; Tondo et al., 2006; Yoon and Bruckner, 2009) and are plausibly related to state policy environments. If these factors changed concurrently with adoption of medical marijuana policy, lack of explicit control for them could lead to biased estimates of the association between medical marijuana policy and suicide. Finally, we incorporated more recent data into our analyses, reflecting newly adopted state medical marijuana policies.

2. METHODS

2.1 Overview

As an initial step, we conducted analyses comparable to those used in the prior report on medical marijuana policy and suicide, employing data from the same time period and including the same set of covariates (Anderson et al., 2014). However, our analyses utilized individual-level data modeled via logistic regression, whereas the previous report described the association between log-transformed state-level suicides rates modeled from aggregated data using linear regression. Because of these differences, we refer to our initial analyses as “comparison analyses” rather than “replication analyses.” In these comparison analyses, we used the same medical marijuana policy coding and the same set of covariates as the previous report: average annual unemployment rate, per-capita income, beer excise taxes, zero-tolerance policies for youth driving under the influence, blood-alcohol content limits of 0.08 for drivers (vs. 0.10), and marijuana decriminalization policy indicators. In the main set of analyses, we extended the observation period from 1990–2007 to 1990–2010; four additional states (Arizona, Michigan, New Jersey, and New Mexico) and the District of Columbia passed medical marijuana policies during this time (Lynne-Landsman et al., 2013). Initial models were based on the same covariates as the comparison analyses, while subsequent models included individual-level demographic covariates (age, sex, race/ethnicity and educational attainment) and several additional state-level covariates (citizen political orientation, per-capita mental health spending, percentage of uninsured adults, cigarette excise taxes and a smoke-free air policy score).

2.2 Data

Individual-level data on suicide deaths were obtained from the Multiple Cause of Death files for 1990–2010, collected by the National Center for Health Statistics. Customized files including geographic data were obtained through the National Association for Public Health Statistics and Information Systems (NAPHSIS). From the complete set of death records, we selected observations for which suicide was either the underlying cause or among the contributing causes of death, using codes from the International Classification of Disease, versions 9 and 10 (codes E950-E959 and X60-X84, Y87, respectively). These records were combined with data on the living population obtained from the annual American Community Survey (ACS) for the years 2001–2010. For living population data prior to 2001 (when the ACS was initiated), we used data from 1% samples of the 1990 and 2000 Census. In order to estimate data for years 1991 through 1999, we used a linear interpolation procedure described elsewhere (Grucza et al., 2014, 2012). Briefly, this was done by determining the weights for records representing each possible combination of covariate parameters in each Census data set (i.e., each combination of year, state, race/ethnicity, sex, age group and education). Weights for intracensal years were estimated as: $[(2000\text{-year}) \times (1990\text{ weight}) + (\text{year} - 1990) \times (2000\text{ weight})] / 10$. These data sets were obtained from the Integrated Public Use Microdata Series maintained by the Minnesota Population Center (Ruggles et al., 2010). This process is described in more detail in Part II of the Supplemental Material. Analyses to support the validity of this approach are described there as well.

2.3 Variables

Medical marijuana policy was coded as “1” for years when use of marijuana for medical purposes was legally sanctioned and “0” for years when it was not. When the policy was in place for only part of the year, we coded the value for the fraction of the year during which the policy was in place; for example, if the policy in a state was implemented on July 1, we coded a value of 0.5 for that year. Sources for policy data included Anderson and colleagues (2014) for the years 1990–2007 and Lynne-Landsman and colleagues (2013) for subsequent years. Individual-level covariates extracted from mortality and living population records included state of residence, age, race/ethnicity, and education. Race/ethnicity was coded as non-Hispanic white, non-Hispanic black, Hispanic, and other. Age was grouped into the categories used by Anderson et al (2014): 15–19, 20–29, 30–39, 40–49, 50–59, 60 and above. Education was dichotomized, with individuals classified as having a high-school diploma or less *versus* having had some post-secondary education.

The unemployment, per-capita income and insurance coverage variables were obtained from the United Health Foundation (n.d.). Alcohol policy variables (excise taxes, zero-tolerance laws and BAC limit policies) were obtained from the Alcohol Policy Information System for years 1998-present and from the Statewide Data Availability System for earlier years (National Institute on Alcohol Abuse and Alcoholism, n.d.; Ponicki, 2004). Indicators for marijuana decriminalization policy were coded from Pacula et al (2003) with updated data provided by a coauthor of that report (Chriqui, 2013). Data on smoke-free air policies were obtained from the State Cancer Legislative Database (n.d.). Cigarette excise taxes were obtained from “The Tax Burden on Tobacco” (Orzechowski and Walker, 2012). Development of the state political orientation measure was described by Berry and

colleagues (1998) and updated data was obtained from Fording (2014). State per-capita mental health spending was obtained from the National Association of State Mental Health Directors Research Institute (n.d.). State unemployment rate and health insurance coverage were coded as percentages. BAC limit policies, marijuana decriminalization policy, and zero-tolerance policies were coded using dichotomous indicators. Beer and cigarette excise taxes, percapita income and per-capita mental health spending were coded as dollar amounts. Mental health spending data were available only for years 1990, 1997 and 2001–2010; missing years were estimated via linear interpolation. The smoke-free air policy measure was obtained by summing scores for policies covering private worksites, restaurants, and bars and ranged from 0 to 6, representing the sum of a two point scale for each domain (0 for no policy, 1 for restrictions with less than a complete ban, and 2 for a complete ban; International Agency for Research on Cancer, 2009). The political orientation measure was coded as described in (Berry et al., 1998).

2.4 Statistical Analysis

All models used logistic regression in which individual suicide outcomes were modeled from medical marijuana legalization policy within all 50 states and Washington, D.C. Parameter estimates and standard errors were calculated using the SAS statistical package “surveylogistic” procedure, treating states as sampling clusters to account for intra-correlation of outcomes within states when estimating standard errors (Angrist and Pischke, 2008).

The comparison analyses paralleled those described in the prior report analyzing suicide rates in relation to medical marijuana policy (Anderson et al., 2014). Data from years 1990–2007 were analyzed; the most basic model included medical marijuana policy and categorical indicators for state and year. State covariates were added in the second model, and state-specific linear time trends were added in the third model. State-specific linear time-trends are modeled as state by year interactions, with year specified as a continuous, rather than a categorical variable.

Model development is summarized in Table 1. The main analyses incorporated data on state suicides and medical marijuana policy through 2010. Model 1 of the main analyses included state and year indicators, state time-trends, and the six state covariates that were included in the comparison analyses. Model 2 included individual-level demographic covariates. The full model (Model 3) included the additional state covariates and a refined model (Model 4) removed covariates that were not significantly associated with suicide risk. Several post-hoc analyses were conducted to examine the association of these additional variables with state medical marijuana policy. These are described and summarized in the Supplemental Material.

3. RESULTS

Initial analyses examined the association between medical marijuana policies and suicide risk over the period 1990–2007 to allow for comparison with results obtained by Anderson and colleagues (2014). Model development is described in Table S1¹; results are shown in Tables S2 and S3². Similar to the prior results, medical marijuana policies exhibited a

significant protective association among men overall, and among the 20–29 and 30–39 year age groups. However, these results do not adjust for the full set of covariates that we included in our main analyses.

Models for the main analyses are described in Table 1; Tables 2 and 3 summarize these results. These analyses cover the extended time period of 1990–2010, and the fully adjusted models include additional covariates (demographic factors, and additional state covariates). In the first partially adjusted model (Model 1), similar to the prior report (Anderson et al., 2014), the overall association between medical marijuana policy and suicide risk suggested a statistically significant protective effect (OR=0.956; 95% CI: 0.923, 0.992; $p=.02$), particularly among men (OR=0.956; 95% CI: 0.929, 0.984; $p=.002$). However, after addition of demographic covariates (Model 2), the magnitudes of the estimates were slightly reduced and no longer nominally significant. In the fully adjusted Model 3, which included the additional state characteristics, the odds ratio was exactly 1 (OR=1.000; 95% CI: 0.956, 1.045; $p=.98$). Likewise, the association was not statistically significant in the sex-stratified analyses after adjusting for demographic variables, and odds ratios were very close to 1 in the fully adjusted models (OR=0.996; 95% CI: 0.951, 1.043; $p=.87$ for men; OR=1.011; 95% CI: 0.948, 1.078; $p=.74$ for women; Table S4³). Odds ratios describing covariate associations for Model 3 are listed in Table S4⁴. We estimated an additional model in which all covariates that were not significantly associated with suicide at $p<.05$ in either the overall or sex-specific models were excluded (zero-tolerance policy, BAC .08 policy, marijuana decriminalization, citizen political orientation, percapita mental health spending and percentage of uninsured adults). In this refined model (Model 4), the ORs of interest were identical to the previous model and the confidence intervals were only slightly larger (Table 2).

The report by Anderson and colleagues (2014) highlighted several age and sex-specific associations between medical marijuana policies and suicide rates and we also sought to examine whether these would remain significant in our more comprehensive results. Thus, Table 3 reports the results of our analyses stratified by sex and age group. These stratified analyses utilized the fully adjusted Model 3 and the refined Model 4. For comparison, we also show the results of the partially adjusted Model 1, which was most similar to that employed in the report from Anderson and colleagues (2014). In the fully adjusted Model 3, the associations between medical marijuana policy and suicide risk among the twelve age-by-sex groups were non-significant with only one exception: men over 60 (OR=1.04; 95% CI: 1.005, 1.105; $p=.04$). This association would suggest that medical marijuana policy *increases* risk for suicide; however, it would not meet nominal significance criteria after adjustment for multiple testing and therefore will not be considered further. In the refined model (Model 4), the ORs were again very similar to the previous model, with slightly larger confidence intervals (Table 2).

Post-hoc analyses examined which variables might have contributed to the initially observed association between medical marijuana policy and suicide in models that were not fully adjusted. These results are shown in Table S5⁵. Briefly, adoption of medical marijuana

• Supplementary material can be found by accessing the online version of this paper at <http://dx.doi.org> and by entering doi:...

policy was associated with shifts toward populations that were older, less white, and higher in percentage of women. Trends in medical marijuana states also favored stronger tobacco control policies and higher per-capita mental health spending.

4. DISCUSSION

In this report, we show that the association between state medical marijuana policy and suicide risk was not statistically significant, nor even suggestive of a protective effect, after adjustment for key covariates. Though an earlier report demonstrated an apparent correspondence between the legalization of medical marijuana and a decrease in suicide rates among men (Anderson et al., 2014), incorporation of demographic variables and additional state characteristics into the regression models reduced the magnitude of this association such that it was no longer consistent with even a modest protective effect.

The analytical design used both here and in the former study corresponds to a quasi-experiment that controls for state differences in suicide rates, as well as both national and state-specific secular trends (Angrist and Pischke, 2008). This approach can be very powerful in that it analyzes within-state changes in an outcome in relation to policy change. However, confounding can be an issue when state characteristics that change over time and are correlated with both policy and outcome. We showed that adoption of medical marijuana policy was associated with shifts toward populations that were older and higher in percentages of minorities and women (Table S5⁶), which is problematic because minorities and women have much lower suicide rates than whites and men, respectively (Centers for Disease Control and Prevention, 2013; Crosby et al., 2011). Medical marijuana states also trended toward stronger tobacco control policies and higher per-capita mental health spending. Our own recent work suggests that implementation of strong tobacco control policies is associated with reductions in suicide risk (Grucza et al., 2014). These findings are corroborated by analyses presented here (Table S4⁷). It is likely that these factors, if not explicitly controlled, could bias estimates toward a protective effect of medical marijuana policy on suicide risk.

In summary, this study finds no association between medical marijuana policy and suicide risk, contradicting an earlier report suggesting that legalization of medical marijuana might protect against suicide (Anderson et al., 2014). That earlier work did not control for individual-level demographics or for state tobacco control policies, both of which are associated with medical marijuana policy and with suicide risk (Centers for Disease Control and Prevention, 2013; Crosby et al., 2011; Grucza et al., 2014; Tables S4, S5⁸). The primary limitation of this report is that we did not account for the various dimensions of medical marijuana policy (e.g., provisions for dispensaries, home growth, etc.). This was intentional so that our methods would match those of the earlier report as closely as possible, but future research should examine the roles of these various policy components (Pacula et al., 2013). Meanwhile, we conclude that medical marijuana legalization does not appear to lead to changes in suicide rates. Instead, it appears that medical marijuana legalization is correlated with changes in other factors that contribute to suicide risk, such as the demographic makeup of states and tobacco control policies. Medical marijuana legalization also corresponded with changes in age of state populations and per-capita mental health

spending. These variables were not associated with suicide risk in our study, but may be relevant to other public health outcomes. Thus, extant studies of medical marijuana policy and public health outcomes that have not accounted for these differences should be interpreted cautiously, and future studies should take these factors into account.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

Author Disclosures

Role of Funding Source: The authors are responsible for the content; the NIH played no role in the development of this content aside from funding.

REFERENCES

- Anderson DM, Hansen B, Rees DI. Medical marijuana laws, traffic fatalities, and alcohol consumption. *J. Law Econ.* 2013; 56:333–369.
- Anderson DM, Rees DI, Sabia JJ. Medical marijuana laws and suicides by gender and age. *Am. J. Public Health.* 2014; 104:2369–2376. [PubMed: 24432945]
- Angrist, JD.; Pischke, JS. *Mostly Harmless Econometrics: An Empiricist’s Companion.* Princeton University Press; 2008.
- Batalla A, Bhattacharyya S, Yücel M, Fusar-Poli P, Crippa JA, Nogué S, Torrens M, Pujol J, Farré M, Martin-Santos R. Structural and functional imaging studies in chronic cannabis users: a systematic review of adolescent and adult findings. *PLoS One.* 2013; 8:e55821. [PubMed: 23390554]
- Berry WD, Ringquist EJ, Fording RC, Hanson RL. Measuring citizen and government ideology in the American states, 1960–93. *Am. J. Pol. Sci.* 1998; 42:327–348.
- Centers for Disease Control and Prevention (CDC). Suicide among adults aged 35–64 years—United States, 1999–2010. *MMWR Rep.* 2013; 62:321–325.
- Centers for Disease Control and Prevention, National Center for Injury Prevention and Control. *WISQARS System.* Atlanta: 2014.
- Cerdá M, Wall M, Keyes KM, Galea S, Hasin D. Medical marijuana laws in 50 states: investigating the relationship between state legalization of medical marijuana and marijuana use, abuse and dependence. *Drug Alcohol Depend.* 2012; 120:22–27. [PubMed: 22099393]
- Chaloupka, FJ.; Pacula, RL.; Farrelly, MC.; Johnston, LD.; O’Malley, PM. Working Paper No. 6939. Washington, DC: National Bureau of Economic Research; 1999. Do Higher Cigarette Prices Encourage Youth to Use Marijuana?.
- Choo EK, Benz M, Zaller N, Warren O, Rising KL, McConnell KJ. The impact of state medical marijuana legislation on adolescent marijuana use. *J. Adolesc. Health Off. Publ. Soc. Adolesc. Med.* 2014; 55:160–166.
- Chriqui, JF. [February, 2013] Personal Communication. 2013.
- Crosby AE, Ortega L, Stevens MR. Suicides - United States, 1999–2007. *MMWR Surveill. Summ.* Wash. DC 2002. 2011; 60(Suppl):56–59.
- Crosby AE, Ortega L, Stevens MR. Centers for Disease Control and Prevention (CDC). Suicides—United States, 2005–2009. *MMWR.* 2013; 62:179–183. [PubMed: 24264512]
- Farrelly MC, Bray JW, Zarkin GA, Wendling BW. The joint demand for cigarettes and marijuana: evidence from the National Household Surveys on Drug Abuse. *J. Health Econ.* 2001; 20:51–68. [PubMed: 11148871]
- Fording RC. State Ideology Data [WWW Document]. 2014 URL <https://rcfording.wordpress.com/state-ideology-data/>.

- Gorman DM, Charles Huber J. Do medical cannabis laws encourage cannabis use? *Int. J. Drug Policy*. 2007; 18:160–167. [PubMed: 17689362]
- Grucza RA, Hipp PR, Norberg KE, Rundell L, Evanoff A, Cavazos-Rehg P, Bierut LJ. The legacy of minimum legal drinking age law changes: long-term effects on suicide and homicide deaths among women. *Alcohol. Clin. Exp. Res.* 2012; 36:377–384. [PubMed: 22085045]
- Grucza RA, Plunk AD, Krauss MJ, Cavazos-Rehg PA, Deak J, Gebhardt K, Chaloupka FJ, Bierut LJ. Probing the smoking-suicide association: do smoking policy interventions affect suicide risk? *Nicotine Tob. Res.* 2014; 16:1487–1494. [PubMed: 25031313]
- Hall W, Degenhardt L. Adverse health effects of non-medical cannabis use. *Lancet*. 2009; 374:1383–1391. [PubMed: 19837255]
- Harper S, Strumpf EC, Kaufman JS. Do medical marijuana laws increase marijuana use? Replication study and extension. *Ann. Epidemiol.* 2012; 22:207–212. [PubMed: 22285867]
- IARC Handbooks of Cancer Prevention. Tobacco Control, Vol. 13: Evaluating The Effectiveness Of Smoke-Free Policies. Lyon, France: 2009.
- Kaplan MS, Huguet N, McFarland BH, Caetano R, Conner KR, Giesbrecht N, Nolte KB. Use of alcohol before suicide in the United States. *Ann. Epidemiol.* 2014; 24:588.e1–2–592.e1–2. [PubMed: 24953567]
- Kposowa AJ. Association of suicide rates, gun ownership, conservatism and individual suicide risk. *Soc. Psychiatry Psychiatr. Epidemiol.* 2013; 48:1467–1479. [PubMed: 23456258]
- Krauss MJ, Cavazos-Rehg PA, Plunk AD, Bierut LJ, Grucza RA. Effects of state cigarette excise taxes and smoke-free air policies on state per capita alcohol consumption in the United States, 1980 to 2009. *Alcohol. Clin. Exp. Res.* 2014; 38:2630–2638. [PubMed: 25257814]
- Lynne-Landsman SD, Livingston MD, Wagenaar AC. Effects of state medical marijuana laws on adolescent marijuana use. *Am. J. Public Health*. 2013; 103:1500–1506. [PubMed: 23763418]
- Meier MH, Caspi A, Ambler A, Harrington H, Houts R, Keefe RSE, McDonald K, Ward A, Poulton R, Moffitt TE. Persistent cannabis users show neuropsychological decline from childhood to midlife. *Proc. Natl. Acad. Sci. U. S. A.* 2012; 109:E2657–E2664. [PubMed: 22927402]
- Moore THM, Zammit S, Lingford-Hughes A, Barnes TRE, Jones PB, Burke M, Lewis G. Cannabis use and risk of psychotic or affective mental health outcomes: a systematic review. *Lancet*. 2007; 370:319–328. [PubMed: 17662880]
- Murphy SL, Xu J, Kochanek KD. Deaths: final data for 2010. *Natl. Vital Stat. Rep.* 2013; 61:1–118. [PubMed: 24979972]
- National Association of State Mental Health Directors Research Institute. State Mental Health Agency Profiles System (Profiles) and Revenue Expenditures Studies. n.d. : Retrieved from <http://www.nri-incdata.org>.
- National Institute on Alcohol Abuse and Alcoholism. [accessed 10.11.13] APIS - Alcohol Policy Information System [WWW Document]. n.d. URL <http://alcoholpolicy.niaaa.nih.gov/>
- Orzechowski W, Walker R. The Tax Burden on Tobacco: Historical Compilation 2012, vol. 47. Arlingt. Va Orzechowski Walk. Consult. 2012
- Pacula RL, Chiqui JF, King J. Marijuana Decriminalization: What does it mean in the United States? National Bureau of Economic Research. NBER Working Paper No. 9690. 2003
- Pacula RL, Powell D, Heaton P, Sevigny EL. Assessing The Effects Of Medical Marijuana Laws On Marijuana And Alcohol Use: The Devil Is In The Details. National Bureau of Economic Research. NBER Working Paper No. 19302. 2013
- Ponicki, W. Pac. Inst. Res. Eval. Prev. Res. Cent. Berkeley CA: 2004. Statewide Availability Data System II, 1933–2003. National Institute on Alcohol Abuse and Alcoholism Research Center Grant P60-AA006282-23.
- Price C, Hemmingsson T, Lewis G, Zammit S, Allebeck P. Cannabis and suicide: longitudinal study. *Br. J. Psychiatry J. Ment. Sci.* 2009; 195:492–497.
- Ruggles S, Alexander JT, Genadek K, Ronald Goeken, Schroeder MB, Sobek M. Integrated Public Use Microdata Series: Version 5.0 [Machine-readable database]. [WWW Document]. 2010
- Rylander M, Valdez C, Nussbaum AM. Does the legalization of medical marijuana increase completed suicide? *Am. J. Drug Alcohol Abuse*. 2014; 40:269–273. [PubMed: 24949839]

- Schuermeyer J, Salomonsen-Sautel S, Price RK, Balan S, Thurstone C, Min S-J, Sakai JT. Temporal trends in marijuana attitudes, availability and use in Colorado compared to non-medical marijuana states: 2003–11. *Drug Alcohol Depend.* 2014; 140:145–155. [PubMed: 24837585]
- State Cancer Legislative Database. Database Search [WWW Document]. n.d. URL http://www.sclid-nci.net/db_search/index.cfm.
- Tondo L, Albert MJ, Baldessarini RJ. Suicide rates in relation to health care access in the United States: an ecological study. *J. Clin. Psychiatry.* 2006; 67:517–523. [PubMed: 16669716]
- United Health Foundation. America's Health Rankings (Custom Report). n.d. Retrieved from <http://statehealthstats.americashealthrankings.org/>.
- Van Ours JC, Williams J, Fergusson D, Horwood LJ. Cannabis use and suicidal ideation. *J. Health Econ.* 2013; 32:524–537. [PubMed: 23518573]
- Volkow ND, Baler RD, Compton WM, Weiss SRB. Adverse Health Effects of Marijuana Use. *N. Engl. J. Med.* 2014; 370:2219–2227. [PubMed: 24897085]
- Wall MM, Poh E, Cerdá M, Keyes KM, Galea S, Hasin DS. Adolescent marijuana use from 2002 to 2008: higher in states with medical marijuana laws, cause still unclear. *Ann. Epidemiol.* 2011; 21:714–716. [PubMed: 21820632]
- Williams J, Liccardo Pacula R, Chaloupka FJ, Wechsler H. Alcohol and marijuana use among college students: economic complements or substitutes? *Health Econ.* 2004; 13:825–843. [PubMed: 15362176]
- Yoon J, Bruckner TA. Does deinstitutionalization increase suicide? *Health Serv. Res.* 2009; 44:1385–1405. [PubMed: 19500164]
- Young-Wolff KC, Hyland AJ, Desai R, Sindelar J, Pilver CE, McKee SA. Smoke-free policies in drinking venues predict transitions in alcohol use disorders in a longitudinal U.S. sample. *Drug Alcohol Depend.* 2013a; 128:214–221. [PubMed: 22999418]
- Young-Wolff KC, Kasza KA, Hyland AJ, McKee SA. Increased cigarette tax is associated with reductions in alcohol consumption in a longitudinal U.S. sample. *Alcohol. Clin. Exp. Res.* 2013b; 38:241–248. [PubMed: 23930623]

Highlights

- Prior research suggested that medical marijuana policies lead to reduced suicide risk
- We attempted to update, replicate and extend this research.
- We found no association between medical marijuana policies and suicide risk.
- The difference is likely explained by additional covariates in the newer analyses.
- It is unlikely that medical marijuana policies reduce suicide risk.

Table 1

Covariates included in main analysis models, data years 1990–2010

	Model I	Model II	Model III	Model IV
Policy Determinants				
State Indicators	X	X	X	X
Year Indicators	X	X	X	X
State Linear Trends (State×Year)	X	X	X	X
State Covariates (Set 1)^a				
Average Annual Unemployment Rate	X	X	X	X
Per Capita Income	X	X	X	
Beer Excise Taxes	X	X	X	X
Zero-tolerance Law	X	X	X	
BAC 0.08 Policy	X	X	X	
Marijuana Decriminalization	X	X	X	
Individual Demographics				
Age		X	X	X
Sex		X	X	X
Race		X	X	X
Education		X	X	X
State Covariates (Set 2)^b				
Citizen Political Orientation			X	
Per Capita Mental Health Spending			X	
Percent of Uninsured Adults			X	
Cigarette Excise Taxes			X	X
Smoke-free Air Policy			X	X

^a Covariates utilized in Anderson et al (2014).^b Covariates introduced in this report.

Table 2

Odds ratios describing the association between medical marijuana policy and suicide risk, 1990–2010.

	Suicides Total		Suicides, Men		Suicides, Women	
	OR (95% CI)	P	OR (95% CI)	P	OR (95% CI)	P
I. Partially adjusted model ^a	0.956 (0.923, 0.992)	.02	0.956 (0.929, 0.984)	.002	0.968 (0.892, 1.051)	.44
II. Same as I, but also adjusted for demographic covariates	0.974 (0.939, 1.010)	.15	0.972 (0.941, 1.004)	.09	0.979 (0.903, 1.062)	.61
III. Same as II, but also adjusted for additional state covariates	1.000 (0.956, 1.045)	.98	0.996 (0.951, 1.043)	.87	1.011 (0.948, 1.078)	.74
IV. Same as III but removing covariates not significantly associated with suicide	1.000 (0.949, 1.053)	.99	0.996 (0.944, 1.051)	.89	1.011 (0.946, 1.080)	.74

Notes:

^a See Table 1 for model development. Each odds ratio describes the policy-suicide association from a model in which suicide risk was modeled from medical marijuana policy and listed covariates. Full covariate coefficients for the fully adjusted model (III) are listed in Table S4

Table 3

Odds ratios describing the association between medical marijuana policy and suicide risk, by age and sex, 1990–2010.

Men	Partially Adjusted (Model 1) ^a		Fully Adjusted (Model 3)		Refined (Model 4)	
	OR (95% CI)	P	OR (95% CI)	P	OR (95% CI)	P
Age <20 Years	0.965 (0.827, 1.126)	.65	1.026 (0.928, 1.135)	.62	1.023 (0.923, 1.134)	.66
Age 20–29 Years	0.937 (0.889, 0.988)	.02	0.965 (0.889, 1.047)	.39	0.964 (0.884, 1.051)	.40
Age 30–39 Years	0.907 (0.861, 0.956)	.002	0.944 (0.876, 1.018)	.14	0.947 (0.871, 1.030)	.21
Age 40–49 Years	0.928 (0.877, 0.983)	.01	0.967 (0.898, 1.041)	.37	0.962 (0.895, 1.034)	.30
Age 50–59 Years	1.005 (0.947, 1.067)	.87	1.039 (0.958, 1.127)	.36	1.048 (0.965, 1.138)	.27
Age ≥60 Years	1.014 (0.974, 1.055)	.49	1.054 (1.005, 1.105)	.03	1.053 (0.995, 1.114)	.07
Women						
Age <20 Years	1.062 (0.788, 1.433)	.69	1.114 (0.851, 1.458)	.43	1.126 (0.857, 1.480)	.39
Age 20–29 Years	0.952 (0.838, 1.081)	.45	0.988 (0.850, 1.148)	.87	0.982 (0.844, 1.143)	.81
Age 30–39 Years	0.986 (0.866, 1.122)	.83	1.025 (0.916, 1.146)	.67	1.017 (0.906, 1.142)	.77
Age 40–49 Years	0.935 (0.867, 1.009)	.08	0.939 (0.856, 1.031)	.19	0.950 (0.864, 1.045)	.29
Age 50–59 Years	1.004 (0.903, 1.116)	.94	1.034 (0.932, 1.148)	.53	1.043 (0.943, 1.153)	.41
Age ≥60 Years	0.971 (0.846, 1.113)	.67	1.069 (0.980, 1.166)	.13	1.058 (0.979, 1.143)	.16

Notes:

^aSee Table 1 for model development. Each odds ratio describes the policy-suicide association from a model in which suicide risk was modeled from medical marijuana policy and listed covariates.