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The Impact of Adolescent Exposure to Medical Marijuana Laws on High School Completion, College Enrollment and College Degree Completion*

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Abstract

Background—There is concern that medical marijuana laws (MMLs) could negatively affect adolescents. To better understand these policies, we assess how adolescent exposure to MMLs is related to educational attainment.

Methods—Data from the 2000 Census and 2001–2014 American Community Surveys were restricted to individuals who were of high school age (14–18) between 1990 to 2012 (n = 5,483,715). MML exposure was coded as: (i) a dichotomous "any MML" indicator, and (ii) number of years of high school age exposure. We used logistic regression to model whether MMLs affected: (a) completing high school by age 19; (b) beginning college, irrespective of completion; and (c) obtaining any degree after beginning college. A similar dataset based on the Youth Risk Behavior Survey (YRBS) was also constructed for confirmatory analyses assessing marijuana use.

Results—MMLs were associated with a 0.40 percentage point increase in the probability of not earning a high school diploma or GED after completing the 12th grade (from 3.99% to 4.39%). High school MML exposure was also associated with a 1.84 and 0.85 percentage point increase in the probability of college non-enrollment and degree non-completion, respectively (from 31.12% to 32.96% and 45.30% to 46.15%, respectively). Years of MML exposure exhibited a consistent

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dose response relationship for all outcomes. MMLs were also associated with 0.85 percentage point increase in daily marijuana use among 12th graders (up from 1.26%).

Conclusions—Medical marijuana law exposure between age 14 to 18 likely has a delayed effect on use and education that persists over time.

Keywords

medical marijuana laws; educational attainment; adolescence

1. INTRODUCTION

Medical marijuana laws (MMLs) and marijuana decriminalization are becoming increasingly popular, but we know relatively little about their effects. The most direct concern with MMLs is that they promote non-medical marijuana use, especially among adolescents. This possibility is troubling since the developing brain is more sensitive to adverse effects (Cha et al., 2007; Fergusson et al., 2002; Moore et al., 2010; Solowij and Grenyer, 2002; Spear, 2007) and heavy marijuana use is suspected to affect brain development (Tortoriello et al., 2014; Volkow et al., 1996), memory and cognition (Volkow et al., 1996; Yücel et al., 2008; Zalesky et al., 2012), motivational and reward systems (Albrecht et al., 2013; Gilman et al., 2014), and pain regulation (Cooper et al., 2013; Wallace et al., 2007; Wilsey et al., 2013, 2008).

There is strong evidence that regular marijuana use is negatively associated with educational attainment and related outcomes (Hall, 2014; Silins et al., 2014; Stiby et al., 2014), including decreased IQ (Meier et al., 2012), lower grades (Novins and Mitchell, 1998; Resnick et al., 1997), decreased satisfaction with school (Brook et al., 1998), higher absenteeism (SAMHSA, 2012), and high school dropout rates (Marti et al., 2010; Silins et al., 2015). Some studies suggest that the relationship between adolescent use and education is mediated or confounded by various factors, including externalizing behaviors and the adoption of an “unconventional lifestyle” that includes devaluing education and affiliation with substance-using and delinquent peers (Grant et al., 2012; Horwood et al., 2010; Lynskey et al., 2003; Lynskey and Hall, 2000; Verweij et al., 2013). It is also possible that mental health is a mediator of the relationship between marijuana use and education (Hall, 2014). Other researchers suggest a direct, albeit complicated, link between marijuana and educational attainment (Volkow et al., 2014).

MMLs have been linked to increases in adult use (Wen et al., 2015) and other outcomes related to marijuana use, such as price of marijuana, heavy alcohol use, and reductions in alcohol-related traffic fatalities (Anderson et al., 2013). But there is a growing consensus that MMLs likely do not promote increased adolescent use in the relative short term. Hasin and colleagues have produced the most rigorous study to date. They found that states with MMLs did have higher rates of past-month adolescent use, but concluded that MMLs are a marker for “state-level risk factors” (e.g., permissive social norms regarding marijuana use) characterized by increased adolescent use. However, as the authors note, adolescent MML exposure could potentially affect *later* use (Hasin et al., 2015).

In the present study, we investigate the longer-term impact of MMLs by examining the relationship between MMLs and educational attainment using data from the U.S. Census and American Community Survey (ACS). We assume that any potential changes in educational attainment in response to MMLs are due to changes in marijuana use, either at the individual level or in aggregate, but we do not propose that the impact of MMLs on either adolescent use or education are immediate—this process could take years to develop. While MML implementation is associated with changes in the demographic makeup of a state (Grucza et al., 2015), which we explicitly control for by including individual-level sex and race/ethnicity in our models, changes in marijuana policy likely occur independently of many other individual-level correlates of marijuana use. To the degree that this is true, any decreases in educational attainment resulting after MML adoption also provide indirect support for a link between marijuana use and lower educational attainment. Specifically, we examine the effects of MMLs on three educational attainment outcomes: (a) completing high school; (b) beginning college, but not necessarily completing a degree; and (c) obtaining any college degree after having begun college. We additionally conduct several supplementary analyses, including an analysis of heavy marijuana use among high school students.

2. METHODS

2.1. Source data

The repeated cross-sectional dataset used in the main analyses was constructed from the 5% microsample of the 2000 Census and the 2001–2014 waves of the American Community Survey, obtained from the Integrated Public Use Microdata Series website (Ruggles et al., 2010). These data were combined and then restricted to those with an average age of graduation (age 18) between 1994–2013, which allows us to assign high school age policy exposure before and after MML implementation in each state through 2012 (Table S11). We further restricted the sample to—individuals who were born in the United States and who had at least completed the 8th grade. See Table 1 for demographic characteristics of this sample.

2.2. Main outcome measures and covariates

We constructed three outcomes from the educational attainment item in the Census/ACS. The first, “failure to complete high school,” was based on whether an individual reported having a high school diploma or GED. We assessed several thresholds based on highest grade completed: (i) failure to complete high school after completing 12th grade (i.e., attending classes throughout 12th grade without receiving a diploma or GED), (ii) failure to complete high school after completing 11th grade, (iii) failure to complete high school after completing 10th grade, (iv) failure to complete high school after completing 9th grade, and (v) any failure to complete high school, conditioned on completing 8th grade. The second, “college non-enrollment,” was based on reporting that no college coursework had been taken, conditioned on high school completion. The third outcome, “college degree non-completion,” was based on failing to complete an associate’s or higher degree, restricted to those aged 25 and over who had at least begun college. See the Supplemental Material2 and

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Table S23 for a detailed description of the outcomes, samples and comparison groups for each of these analyses.

Several state-level variables were based on the year each respondent was 18. Since individual-level income at time of census/survey would be directly related to earlier education, we included state-level poverty rate to address socioeconomic factors that might affect education during high school. We also included several education-related variables known to affect our outcomes. High school analyses included math and science course graduation requirements and mandated high school exit exams; the average cost of a 4-year public college and the amount of state-funded need-based aid were included in college-level analyses. We created these variables as described in our previous work (Plunk et al., 2015, 2014). We coded race/ethnicity as non-Hispanic White, non-Hispanic Black, Hispanic and other; individuals from the other category were excluded from our final analyses due to high within-group heterogeneity. Additional covariates included dummy variables for state of residence, birth year, Census/ACS wave and sex; a state-specific linear time trend to control for state-level factors that change at a constant rate was also included.

2.3. Medical marijuana law exposure coding

We based our MML exposure coding on effective year of implementation (Table S14; Wen et al., 2015). Policy exposure was operationalized two ways. First, we created a dichotomous dummy variable denoting any exposure to generic MMLs (i.e., irrespective of specific features of MML policy, such as provisions for home cultivation) while of high school age (14–18). Second, we assigned policy exposure to each individual based on the number of years they were exposed to generic MMLs between the ages of 14 and 18, with possible values of 0–5 truncated to 0–4 to reflect years of average high school age exposure (i.e., exposure beginning at age 18 equaled one year, age 17 equaled two years, age 16 equaled three years and ages 14–15 equaled four years).

2.4. Statistical methods

Our approach models exposure to policy change by comparing pre- and post-implementation differences in outcomes for exposed groups to those from unexposed comparison groups (Allison, 2009; Wooldridge, 2010). We used logistic regression to estimate the likelihood of each outcome based on age 14–18 MML exposure. The basic structure of the model follows:

$$Y_{ist}=A_s+B_t+A_st+\beta_1X_{1ist}+\ldots+\beta_nX_{nist}+\beta MML_{st}+\varepsilon_{ist}$$

where Y_{ist} is the educational attainment outcome for i individual for each s state and t year (year of birth). A_s and B_t control for stable unobserved factors and A_st is a state-specific linear time trend. X_1 through X_n are the additional covariates. MML_{st} represents MML exposure for each state and year. This model controls for linearly changing state effects and

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invariant state and time effects provided that *MML* and *Y* are not both correlated with unobserved factors contained in the error term .

Version 3.2.3 of R was used for all analyses (R Development Core Team, 2015). Two-way cluster- robust standard errors were used to address possible correlation of observations both within state and time (Petersen, 2009). These were obtained using R code based on the work of Arai (Arai, 2009). For ease of interpretation, predicted baseline and changes in predicted probabilities (a measure of absolute risk), in addition to standard measures of relative effect (e.g., odds ratios), are reported for all analyses.

2.5 Supplemental Analyses

We performed several supplemental analyses: (1) based on a subset of our sample that was less likely to have migrated between states ("likely non-movers"); (2) analysis of leading and lagged policy exposure; (3) assessing alternate thresholds of age of exposure; (4) models assessing whether early or late adoption affected apparent MML effects; (5) analysis of the college outcomes while controlling for MML exposure during college for those who had not been exposed during high school; (6) assessing the contemporaneous impact of MMLs on high school and college enrollment using the CPS; (7) recreating the main analyses using a second dataset constructed from the Current Population Survey (CPS), which also allowed us to account for GED status (the Census/ACS did not track GED recipients separately until 2008); (8) stratified by race/ethnicity and sex; (9) stratified by residence in an early vs. later MML adopting state; (10) exploring state-level tobacco policies as potential confounders; (11) predicting how MMLs affect an alternate educational outcome: years of education; and (12) whether controlling for additional state-specific time trends affected our results. Finally, we also analyzed Youth Risk Behavior Survey (YRBS) data to determine whether there were consistent associations between MMLs and a marijuana use outcome that could plausibly account for at least a portion of our education findings: daily marijuana use (which we determined based on reporting use of "40 or more times," which is the highest threshold assessed by the YRBS and the only threshold that only includes daily use, as the next lowest threshold falls below 30). We examined 12th graders separately in these analyses since findings based on education outcomes suggested that MMLs would likely only influence later use. See the Supplemental Material for a detailed description of all these supplemental analyses and their methods.

3. RESULTS

3.1. High school non-completion predicted from high school age MML exposure

We did not observe an association between age 14–18 MML exposure and high school non-completion overall. However, we noted significant relationships once we assessed the impact of MMLs on later high school educational attainment. Specifically, MML exposure was associated with increased odds of failing to complete high school after 12th grade (i.e., completing 12th grade without receiving a diploma or GED) and after completing 11th grade, but not with other thresholds of non-completion (e.g., after completing 10th grade; Table 2). Only failure to complete high school after grade 12 remained statistically significant after applying a Bonferroni correction to control for testing multiple high school level outcomes;

as such, we focus on this outcome for the remainder of our analyses (see Table S35 for full models).

Age 14–18 MML exposure was associated with a 0.40 percentage point increase in the probability of failing to complete high school after completing the 12th grade (from 3.99% to 4.39%; *OR* = 1.11, 95% CI [1.05, 1.17]; Table 2). We also estimated the impact of each year of MML exposure, noting significant increases of 0.13 and 0.57 for three and four years of exposure, respectively (from 3.24% to 3.37% and 3.81%, respectively; *OR* = 1.04, 95% CI [1.01, 1.08]; *OR* = 1.18, 95% CI [1.11, 1.26]; Table 3).

3.2. College non-enrollment predicted from high school age MML exposure

Any age 14–18 exposure to MMLs was associated with a 1.84 percentage point increase in the probability of college non-enrollment, conditioned on high school completion (from 31.12% to 32.96%; *OR* = 1.09, 95% CI [1.04, 1.14]; Table 2). Predicting college non-enrollment from years of MML exposure produced consistent results. Two years of exposure was associated with a significant 1.43 percentage point increase in the probability of college non-enrollment, three years with 1.58 and four years with 2.63 (from 30.67% to 32.10%, 32.25% and 33.30%, respectively; *OR* = 1.06, 95% CI [1.03, 1.11]; *OR* = 1.08, 95% CI [1.03, 1.12]; *OR* = 1.12, 95% CI [1.06, 1.19]; Table 3).

3.3. College degree non-completion predicted from high school age MML exposure

Any age 14–18 exposure to MMLs was associated with a 0.85 percentage point increase in the probability of college degree non-completion, conditioned on starting college (from 45.30% to 46.15%; *OR* = 1.03, 95% CI [1.01, 1.06]; Table 2). Analyses based on years of exposure continued to produce consistent results, although only four years of exposure produced a significant effect (from 45.14% to 46.73%; *OR* = 1.06, 95% CI [1.02, 1.11]; Table 3).

3.4. Current high school age monthly and daily marijuana use predicted from any high school age MML

Exposure to MMLs was not associated with past-month marijuana use, which is consistent with findings from other MML studies based on YRBS data (e.g., Choo et al., 2014). However, we did note significant increases in daily marijuana use associated with MML exposure for 12th graders when analyzed separately. For this group, MMLs were associated with a 0.26 percentage point increase in the probability of being a daily marijuana user (from 0.42% to 0.68%; *OR* = 1.62, 95% CI [1.04, 2.54]; Table 4) and a 0.85 percentage point increase when further conditioned on marijuana ever-use (from 1.26% to 2.11%; *OR* = 1.69, 95% CI [1.31, 2.16]).

3.5. Likely non-mover, leading and lagged cohort analyses

Conditioning on likely non-movers individuals who were born in their current state of residence—suggested that there were no differences based on residential migration (Table S46). Leading cohort analyses did not provide evidence that earlier unmeasured disturbances

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or preexisting state characteristics were driving any apparent MML effects. Lagged cohort analyses suggested that MMLs could have a persistent impact on both high school and college non-enrollment, but failed to reach significance for college non-completion (*OR* = 1.04, 95% CI [0.99, 1.01]; Table S47). We also noted similar leading and lagged MML exposure findings for daily marijuana use among 12th graders in our YRBS-based analyses (Table S58). Taken together, point estimates for the leading and lagged cohort analyses are consistent with an effect that does not begin to have a measureable impact until MMLs were implemented in each state and which becomes slightly stronger after the initial period of implementation is over, although evidence a persistent impact on college non-completion and daily marijuana use among 12 graders was weaker.

3.6. Other supplemental analyses

First, we assessed different thresholds of age of exposure (e.g., age 14–17 exposure). Consistent with results reported in Table 3, larger effect sizes were seen for thresholds with earlier ages of exposure at the high school level (Table S69) and were similar across the age thresholds at the college level (Table S710).

Age 14–18 exposure continued to significantly affect college non-enrollment and college degree non-completion after controlling for college-age MML exposure without earlier exposure. Further, we used the CPS to assess the *contemporaneous* impact of MMLs on current high school and college enrollment. Contemporaneous MML exposure was not significantly associated with current high school enrollment between the ages of 14–18. Nor was it associated with the likelihood of having attended college without currently being enrolled or having finished a degree between the ages of 18–25.

We also recreated our main analyses using CPS data. MML exposure was consistently associated with higher odds of failure to complete high school after completing 12th grade (Table S811). This dataset also allowed us to designate which respondents received a GED. After recoding GED recipients as high school non-completers, MML exposure was still significantly associated with higher odds of failure to complete high school. The CPS college-level analyses produced similar effect sizes compared to those based on the Census/ACS, but did not reach statistical significance.

We ran several series of stratified analyses to ascertain differences in response to MML changes based on race/ethnicity, sex and whether an individual lived in an early or later MML adopting state (Tables S9 and S1012). We did not observe any meaningful differences based on these factors. We also assessed whether state-level tobacco policies confounded the relationship MML and education; there was no evidence that this occurred.

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Finally, we estimated how age 14–18 MML exposure affected years of education. There was a statistically significant reduction, but a small effect size suggests that the outcomes used in our main analyses, which represent important educational milestones, are likely a better fit for measuring the impact of MMLs on education (see the Supplemental Material for more detailed results from all the supplemental analyses).

4. DISCUSSION

4.1. Summary of findings

We observed consistent associations between MML implementation and longer-term, but not contemporaneous, educational attainment at both the high school and college level across two nationally representative datasets. Further, we also noted a significant relationship between MML exposure and a marijuana use outcome that could plausibly be linked to a delayed effect of MMLs on educational attainment. Lagged cohort analyses suggest these relationships are likely persistent. Our leading cohort analyses did not provide any evidence that preexisting state-level factors accounted for the apparent relationship between MMLs and education or marijuana use.

The most consistent explanation for all our education findings taken together is that high school age exposure to MMLs promotes heavier marijuana use during later adolescence or young adulthood. Our finding that MMLs are linked to increased daily marijuana use among 12^{th} graders provides plausible evidence that this occurred. Additionally, this is also consistent with the work of Wen and colleagues, who noted that MML exposure led to significant increases in adolescent marijuana use initiation (2015), which could then lead to heavier later use. It is also possible that MML implementation could promote more permissive norms toward marijuana use, which could in turn lead to heavier use later, regardless of the exact age of initiation.

The majority of our findings only measure the indirect impact of MMLs. However, studies assessing other outcomes—such as marijuana prices or heavy drinking behavior—also provide indirect evidence that marijuana use changes in some way when MMLs change (Anderson et al., 2013). This suggests that MML change can have a measureable impact on outcomes that are a consequence of increased marijuana use, similar to our educational attainment findings.

There are several ways marijuana could affect educational attainment if MML exposure does promote later heavier use, as our findings suggest. First, marijuana use could have a cognitive effect that makes school more difficult or reduces academic motivation (Solowij, 1998). Marijuana use could also be related to various externalizing behaviors and delinquent peer group affiliation, which promote social roles that place less value on completing high school (Lynskey and Hall, 2000) or college attendance. Increased marijuana use in aggregate could also promote school environments that are not conducive to learning, especially in the presence of other school-based risk factors, such as already high rates of truancy, low academic achievement and an environment where students do not feel safe (Balfanz and Legters, 2004). Note that these potential mechanisms need not have an immediate impact on educational attainment and are likely more developmental in nature. For example, to the degree that increased marijuana use in response to MML exposure promotes absenteeism during high school, the impact on a more capable student might be a decrease in college readiness, rather than an increase in the probability of dropping out of high school. It is also important to note that some education-related effects are likely missed by our analyses—for example, a small increase in absenteeism might not have a noticeable impact on the educational attainment of the most capable and best prepared students.

However, our findings do suggest it is unlikely that factors related to unconventional lifestyles or a preference for norm-violating behaviors fully explain the relationship between marijuana use and education. We observed decreases in educational attainment related to MML implementation during a time when marijuana use became *more* socially acceptable. Further, our findings are likely most consistent with a persistent developmental effect. Decreases in student motivation and academic expectations could plausibly explain how MML exposure has a delayed effect on educational attainment at both the later high school and college levels. However, failure to complete high school after attending 12th grade is not a well-understood phenomenon; further research on these potential mechanisms of effect is warranted.

Our finding that college non-completion can be influenced by marijuana policy exposure during high school is also consistent with past research. Arria and colleagues found that students who initiated marijuana use before beginning college did worse academically than those who began using marijuana after they arrived on campus (2015). Their conclusion that baseline marijuana use when starting college was a better predictor of academic problems is consistent with our finding that high school MML exposure had an impact on college-level outcomes even after controlling for college-age MML exposure (see Supplemental Material13). Further, recognized differences in marijuana use by grade level for the observation period of our analyses are also consistent with our findings. Findings based on the 2002 to 2008 National Survey of Drug Use and Health, which includes high school dropouts in its sampling universe, demonstrated that the proportion of dropouts who were current marijuana users changed from grade-to-grade. Dropouts comprised 3% of current marijuana users in the 9th grade and increased to 30% of current marijuana users by the 12th grade (SAMHSA, 2012).

4.2. Policy implications

We have shown that MML implementation is consistently linked to lower educational attainment, an unintended consequence for older adolescents and young adults with a lifelong impact on a range of health and socioeconomic outcomes. Our results imply that MMLs were associated with a 10% increase in failing to earn a high school diploma or GED after completing the 12th grade, a 5.9% increase in college non-enrollment and a 1.9% increase in college degree non-completion. These large decreases in educational attainment are directly relevant to public health, but that our results were limited to 12th grade and college-level outcomes also suggests that the impact of MMLs are either not immediate or somehow affect younger students differently, making blanket policy guidance more difficult.

[13]Supplementary material can be found by accessing the online version of this paper at http://dx.doi.org and by entering doi:...

At a minimum, our results should serve as an important reminder that marijuana is a drug of potential abuse with strong psychoactive effects and that advocates of more permissive marijuana policy should seriously consider how young people will be affected. Finally, given the changing marijuana policy landscape in the United States, more research is also needed to better understand how youth will interpret evidence of harm related to marijuana use that they do not feel is being overstated to justify marijuana prohibition.

4.3. Limitations and conclusion

We make several assumptions. Most notably, we assume that educational attainment is not affected by MMLs aside from whatever impact MMLs might have on marijuana use, either at the individual level or in aggregate. The plausibility of a relationship between MML and marijuana use is supported by earlier research establishing that MMLs are non-causally related in increased rates of youth marijuana use (Hasin et al., 2015). Our own results suggesting that MMLs are causally related to increased heavy use among 12^{th} graders adds additional plausibility for a pathway from MMLs to marijuana use. Further, the plausibility of a causal relationship between marijuana use and education is supported by a substantial amount of research. However, this is still an important assumption to deconstruct, since educational attainment is affected by a range of complex phenomena and our data do not capture many relevant risk factors. But our methodological approach implies that this assumption would only be violated if MMLs systematically varied alongside unmeasured factors that were also predictive of education (e.g., if states that implemented MMLs also usually decreased school funding at the same time). We do not see any obvious confounders like this and our leading cohort and alternate state-specific time trend analyses did not provide evidence that this occurred. The consistency of our results also implies that a confounder would have to be related to the timing of MML change in high school while also affecting education at both the high school and college level. It is more plausible that MMLs are associated with delayed increases in marijuana use, which in turn accounts for how MMLs are related to educational attainment. If this is correct, then our results reflect the average effect of MML exposure while holding constant other unmeasured factors that might also influence educational attainment.

We also assume that any error introduced by estimating policy exposure based on state of residence at time of census/survey was essentially random. We have established that our policy estimation procedure is reasonable in previous work (Grucza et al., 2012; Norberg et al., 2009). The overlap between the full-sample and likely non-mover analyses also suggests that between-state migration did not bias our results. Relatedly, it could be possible that the impact of MMLs is not limited to traditional geographic boundaries. Our analyses cannot account for many potential biases related to this phenomenon (e.g., we cannot control for individuals living in counties close to neighboring states), but we would only expect this to bias us toward false positive results if this occurred based on either MML exposure or factors that were directly related to educational attainment. It is also possible that we introduced measurement error into our analyses by focusing on generic MML policy, rather than coding specific MML features (e.g., retail dispensaries or allowances for home cultivation). In preliminary analyses we found that these policy features were not very informative when predicting high school non-completion. While these features have been hypothesized to increase access to marijuana following implementation, there is mixed evidence regarding their effects on use in the short term (Hasin et al., 2015; Pacula et al., 2015). Because of this, there did not seem to be a clear theoretical justification for continuing to use them and we focused on generic MMLs in our final analyses.

At first glance, our YRBS-based marijuana use analyses could be seen to contradict other published work. However, we are unaware of another study that has assessed marijuana use specifically among 12th graders at the threshold that we examined (40+ occasions per month). Further, our estimates for past-month use were consistent both with findings presented by Choo and colleagues (2014) and also by Anderson and colleagues' analyses when the survey design variables of the YRBS were accounted for (2014).

Finally, some of our analyses, particularly of the high school education outcomes, should rightly be considered exploratory (e.g., exploring specific policy features vs. generic MML coding, analyzing high school non-completion by grade after we did not see a significant overall effect). However, it should be noted that our supplemental analyses in which the main analyses were recreated using a CPS-derived dataset do not share this limitation—those analyses were not data-driven. Our YRBS-based marijuana use analyses were also driven by a specific hypothesis. This should increase confidence in our results since it suggests that our findings are not conditional on analytic choices made in response to idiosyncrasies of our initial dataset.

Even in light of these limitations, our findings demonstrate that adolescent exposure to MMLs is significantly related to decreased educational attainment, mostly likely by promoting heavier marijuana use during late adolescence. Additionally, adolescent MML exposure could have a persistent effect on education that lasts at least until college. Our results also imply that marijuana use, instead of serving as a marker for other risk factors, is likely independently related to decreased educational attainment.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Highlights

- We measured the impact of high school age exposure to medical marijuana laws (MMLs)
- MMLs were associated with decreased high school and college educational attainment
- Education results suggested that MMLs could have a delayed effect on marijuana use
- We identified a marijuana use outcome that plausibly explains this relationship
- There was no evidence that existing state characteristics explained our findings

Table 1

Demographic characteristics for the Census/ACS sample

	n	%
Full Sample	5,483,715	100
Likely Non-Movers	3,815,012	69.56
Age at Time of Census/Survey		
19–24	2,820,911	51.44
25–29	1,451,905	26.47
30–34	948,440	17.29
35+	262,459	4.78
Highest Education Completed		
8^{th} Grade	20,168	0.37
9^{th} Grade	66,975	1.22
10^{th} Grade	114,636	2.01
11^{th} Grade	147,878	2.70
12^{th} Grade, Without a Diploma	110,112	2.00
High School Diploma/GED	1,534,681	27.99
Some College, No Degree	1,849,821	33.73
Any College Degree	1,639,444	29.90
Race/Ethnicity		
Non-Hispanic White	4,164,636	75.95
Non-Hispanic Black	691,529	12.61
Any Hispanic Ethnicity	627,550	11.44
Sex		
Men	2,757,075	49.72
Women	2,726,640	50.28
State-Level Covariates		
Mandatory High School Exit Exam	2,475,646	45.15
	Mean	SD
Math and Science Graduation Requirement	4.28	1.86
Average 4-year college cost	3,231	1,450.49
State-Funded Need-Based Aid	179,500	242,599.7
Poverty Rate	13.27	3.26

Note: Based on a combined 2000–2014 Census/ACS sample restricted to those who were age 18 from 1994 to 2013. State-funded need-based aid reported in thousands.

Table 2

High school and college-level educational attainment predicted from any age 14–18 MML exposure

		95% CI				Predicted Baseline Probability	Change in Predicted Probability
	OR	**Lower**	**Upper**		**n**		
Any high school non-completion, irrespective of highest grade completed	1.03	0.96	1.10		5,483,715	6.44	0.16
High school non-completion thresholds by highest grade completed							
Grades 9 to 12	1.04	0.96	1.12		5,463,547	7.95	0.28
Grades 10 to 12	1.05	0.98	1.13		5,396,572	6.86	0.32
Grades 11 to 12	1.07	1.01	1.13	*	5,281,936	5.13	0.33
Grade 12 (i.e., failure to earn a diploma or GED after completing grade 12)	1.11	1.05	1.17	***	5,134,058	3.99	0.40
College non-enrollment	1.09	1.04	1.14	***	4,529,911	31.12	1.84
College degree non-completion	1.03	1.01	1.06	**	1,636,716	45.30	0.85

Note. Based on a combined 2000–2014 Census/ACS sample. Race/ethnicity, sex, state poverty rate, state and time fixed effects, and a state-specific linear trend were included in all models. High school completion analyses also included math and science course graduation requirements and an indicator denoting whether individuals were required to pass an exit exam to earn their diploma. College-level analyses included the average cost of a 4-year public college degree in each state and the amount of state-funded need-based financial aid. 95% CI reflects adjustment for two-way clustering by state and time. The samples for these analyses are conditioned on at least entering into each threshold (e.g., the grade 9–12 threshold is conditioned on completing grade 9, college non-enrollment is conditioned on completing high school, and college non-completion is conditioned on beginning college). The listed 95% confidence intervals reflect unadjusted p-values; the "Grades 11 to 12" high school completion analysis did not remain significant after applying aBonferroni correction.

* $p < 0.05$,

** $p < 0.01$,

*** $p < 0.001$

Table 3

High school and college-level educational attainment predicted from years of high school age MML exposure

		95% CI				Predicted Baseline Probability	Change in Predicted Probability
Years of MML Exposure	**OR**	**Lower**	**Upper**		***n***		
Failure to earn a diploma or GED after completing grade 12					5,134,058	3.24	
1 year	1.02	0.98	1.06		78,148		0.06
2 years	1.03	0.97	1.10		74,458		0.11
3 years	1.04	1.01	1.08	*	68,911		0.13
4 years	1.18	1.11	1.26	***	459,214		0.57
College non-enrollment, conditioned on completing high school					4,529,911	30.67	
1 year	1.03	0.99	1.08		75,984		0.70
2 years	1.06	1.03	1.11	*	65,199		1.43
3 years	1.08	1.03	0.12	**	65,604		1.58
4 years	1.12	1.06	1.19	***	210,792		2.63
College degree non-completion, conditioned on beginning college					1,636,716	45.14	
1 year	1.01	0.99	1.02		31,006		0.17
2 years	1.02	0.99	1.05		25,606		0.46
3 years	1.04	0.98	1.01		27,384		0.91
4 years	1.06	1.02	1.11	***	39,158		1.59

Note. Based on a combined 2000–2014 Census/ACS sample. Race/ethnicity, sex, state poverty rate, state and time fixed effects, and a state-specific linear trend were included in all models. High school completion analyses also included math and science course graduation requirements and an indicator denoting whether individuals were required to pass an exit exam to earn their diploma. College-level analyses included the average cost of a 4-year public college degree in each state and the amount of state-funded need-based financial aid. 95% CI reflects adjustment for two-way clustering by state and time. One year of exposure means that an individual was first exposed at age 18 (two years for age 17, three years for age 16, and four years for ages 14–15). The grade 12 analysis is conditioned on completing grade 12, college non-enrollment is conditioned on completing high school, and college non-completion is conditioned on beginning college. The portion of the sample at each exposure level is reported for *n*.

* $p < 0.05$,

** $p < 0.01$,

*** $p < 0.001$

Table 4

Monthly and daily marijuana use predicted from any high school age MML exposure.

		95% CI				Predicted Baseline Probability	Change in Predicted Probability
	OR	Lower	Upper		*n*		
Any past-month marijuana use							
All grades	0.99	0.67	1.45		124,996	7.59	-0.05
12th grade	1.08	0.54	2.17		32,468	15.06	1.10
Daily marijuana use							
All grades	1.20	0.29	4.99		124,996	0.16	0.03
12th grade	1.62	1.04	2.54	*	32,468	0.42	0.26
Daily marijuana use, conditioned on ever-use							
All grades	1.21	0.37	3.91		45,089	0.92	0.18
12th grade	1.69	1.31	2.16	***	14,756	1.26	0.85

Note. Daily use was defined as self-reporting 40+ times of use in the past month. Based on a combined 1991–2013 YRBS sample. Race/ethnicity, sex, state poverty rate, state and time fixed effects, and a state-specific linear trend were included in all models. 95% CI reflects adjustment for survey design variables and clustering by state and time.

[*] $p < 0.05$,

[***] $p < 0.001$