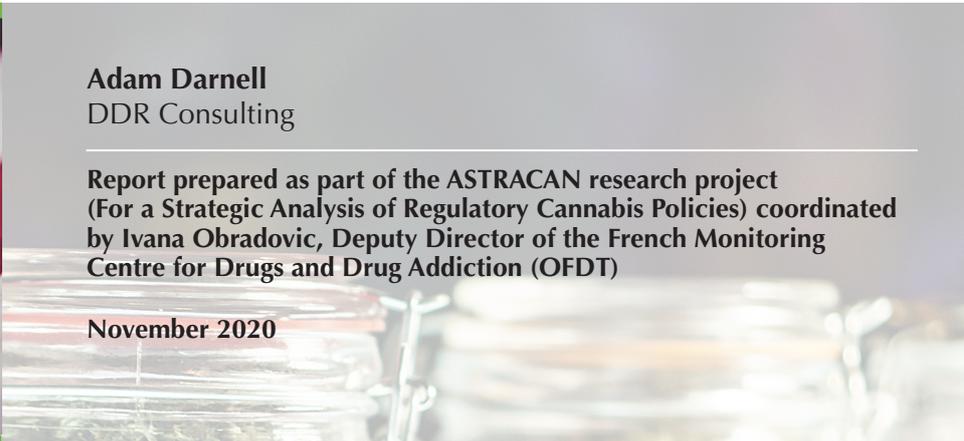


# REVIEW OF SCIENTIFIC EVIDENCE ON EFFECTS OF MEDICAL AND NON-MEDICAL MARIJUANA LEGALIZATION ON PUBLIC HEALTH IN THE UNITED STATES

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Report prepared as part of the ASTRACAN research project  
(For a Strategic Analysis of Regulatory Cannabis Policies) coordinated  
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November 2020



This report was produced on behalf of the French Monitoring Centre for Drugs and Drug Addiction (OFDT) as part of the ASTRACAN research project (For a Strategic Analysis of Cannabis Regulation Policies). The report was written in English by Adam Darnell, an independent consultant specialising in public policy evaluation. This work was coordinated by Ivana Obradovic, Deputy Director of OFDT.

**The content of this document reflects the opinions of the author concerned and not necessarily those of the French Monitoring Centre for Drugs and Drug Addiction (OFDT).**

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## **Introduction**

This is a review and synthesis of the scientific literature on public health effects of liberalization of marijuana prohibition in the United States. The review is focused on studies designed to identify causal effects of medical and non-medical marijuana legalization on public health outcomes<sup>1</sup>. I searched existing reviews<sup>2</sup>, library databases, and the internet for studies addressing marijuana policy effects, whether peer-reviewed or not, and screened them using the following criteria:

- the type of policy examined,
- the outcomes examined, and
- methodological quality.

I describe each criterion in more detail below.

### ***Type of Policy***

The review is limited to studies examining effects of medical marijuana laws (MML) and non-medical marijuana laws (NMML) in the United States. There is considerable variability in the specific features of MMLs and NMMLs, and this variability is discussed in more detail below as it pertains to conclusions that can be drawn from the extant literature.

### ***Outcomes***

The review is limited to studies examining outcomes broadly related to public health. The specific outcomes examined in the final pool of selected studies is largely determined by the availability of data sources that are suitable for state-level policy evaluation – that is, multi-year, multi-state data sources. The final pool of studies examined outcomes including:

- youth and adult use of marijuana,
- disordered cannabis use,
- use of other substances including alcohol, tobacco, and opioids,
- health outcomes including overall health, obesity, mental health, suicide, poison control contacts, and emergency department visits,
- traffic safety, and
- workplace safety.

### ***Methodological Quality***

The review is limited to studies that had strong internal validity, which supports interpretation of an observed association between policy and outcome as a causal effect of the policy. Precluding a randomized experimental design, the typical characteristics of a study that supports causal inference are the observation of change in an outcome before and after intervention, for units exposed to the intervention and comparison units that are not. The most common design in the literature on effects of legalization is the difference-in-

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<sup>1</sup> The term “non-medical” refers to legalization for general adult use, commonly referred to as “recreational” in the United States.

<sup>2</sup> Existing reviews included: (Bahji & Stephenson, 2019; Carliner et al., 2017; Chihuri & Li, 2019; D’Amico et al., 2017; Guttmanova et al., 2016; Hall et al., 2019; Hall & Lynskey, 2020; Hammond et al., 2020; Ladegard et al., 2020; J. Leung et al., 2018, 2019; Melchior et al., 2019; Sarvet et al., 2018; Smart & Pacula, 2019; Unlu et al., 2020; Vyas et al., 2018; Wendelboe et al., 2019; Zvonarev et al., 2019)

differences (DiD) design or related analytic approaches that specify fixed effects for state and year. These designs examine the difference in outcomes before and after legalization among legalizing states and compare it to the difference in outcomes among non-legalizing states over the same time period. Synthetic Control Method (SCM) studies were also included in the review. SCM designs create a weighted composite of non-legalizing states for comparison to a single legalizing state. In formulating the weighted composite of comparison states, greater weight is given to non-legalizing states that are most similar to the legalizing state, which maximizes the validity of the comparison. All of these designs provide the basic conditions for causal inference—comparison of change in outcomes before and after intervention for legalization and comparison states. The review also included interrupted time series analyses (compared to DiD, these studies typically have fewer cases and more timepoints) if they examined multiple time series—either considering differential effects on alternate outcomes, or effects on the same outcome in more than one state with varying time of intervention. Time series analyses examining the effect of a single policy on a single outcome were excluded.

With these criteria in place, the scope for this review excludes studies that examine effects of decriminalization and studies that examine effects of MMLs or NMMLs outside of the United States. The review also excludes studies examining effects of legalization on other outcomes such as crime and achievement. A total of 84 studies are included. It is also important to note that this review does not directly address effects of cannabis use. Studies addressing the harms or benefits of cannabis use would treat cannabis use as the independent variable, whereas this review is focused on studies examining cannabis policy as the independent variable<sup>3</sup>.

### ***Variation in Specific Features of Legalization***

The question of whether enactment of an MML or an NMML leads to harms or benefits in the population is a natural question, and many early studies of marijuana legalization addressed this sort of question using binary indicators of enactment of the law. Since the first MML passed in California in 1996, 32 other states plus the District of Columbia have passed MMLs. As more states have passed these laws, variability in their specific provisions has become more apparent. The first states to adopt MMLs did so by voter initiative, and these laws tended to be relatively limited in their provisions, but as more states passed MMLs and the federal stance grew more tolerant, MMLs began to be passed by legislation and grew more detailed in their provisions (Pacula & Smart, 2017). At present, differences between MMLs are numerous, including requirements regarding the doctor-patient relationship, qualifying conditions, registration, legal protection for retail dispensaries, allowance for home and collective cultivation, possession limits, and a variety of limits on product types, among many other differences (Klieger et al., 2017; Network for Public Health Law, 2019). It is now widely recognized in the research literature that there is substantial variability between states in the specific features of both medical and non-medical legalization that needs to be accounted for in outcome studies (Cambron et al., 2017; Kamin, 2017; Klieger et al., 2017; Pacula et al., 2002; Pacula & Smart, 2017)<sup>4</sup>.

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<sup>3</sup> For a review of the harms and benefits of cannabis use see (National Academies of Sciences, Engineering, and Medicine, Committee on the Health Effects of Marijuana, 2017).

<sup>4</sup> For the sake of simplicity I focus on state as the jurisdiction of interest, but policy heterogeneity exists within national, city, and county jurisdictions as well [see for example Dilley et al., (2017)]. There is also important variability in policy effects over time and between specific portions of the population (Pacula & Smart, 2017).

It is now common for outcome studies of legalization to account for specific features of MMLs in one way or another, but there is a lot of variety and inconsistency in how this is done—the particular features examined, how they are defined, and how they are specified in analyses—making it difficult to draw conclusions. The earliest outcome study in our review to differentiate specific features of MMLs focused on binary indicators of provisions for legal protection of dispensaries, required patient registration, and allowance for personal cultivation (Pacula et al., 2015). Since then, outcome studies have examined effects of these and other MML provisions, which are reviewed below. First, I will discuss a line of research that has focused on measuring and describing variation in MML provisions. This type of research has the potential to promote consistency in how MMLs are differentiated in outcome studies. It also provides an introduction to the variety of ways policies are differentiated in the review that follows.

Bestrashniy and Winters (2015) and Klieger et al. (2017) coded state MMLs on an array of different binary features, establishing agreement between multiple coders on the provisions in each state law. There are at least as many differences between MMLs as there are MMLs, so there is a need to identify a small number of meaningful categories of MML types for outcome analysis, or to identify one or more quantitative dimensions on which to rate MMLs. Several studies have attempted to condense the large array of specific provisions. The Bestrashniy study combined sets of binary indicators into three indices concerning restrictions on cultivation, possession, and overall restrictiveness. Chapman et al. (2016) took a similar approach, differentiating MMLs on four dimensions—restrictions on patient entry into the system, possession limits, restrictions on supply, and overall restrictiveness. One notable difference between these studies is that the Bestrashniy study established consensus on the ratings of multiple experts for each binary indicator, and then combined binary items into composite scales. In contrast, in the Chapman study raters provided scores for the overall dimensions only. The former approach is favorable inasmuch as the specific provisions are simpler pieces of information and are more likely to be rated reliably. In addition, establishing agreement on the specific provisions can serve as a foundation for the subsequent *empirical* definition of composite dimensions – how many dimensions there are and which items comprise them. The *a priori* determination of how specific provisions should be combined, with no evidence of the internal consistency of overall dimensions is a limitation of both studies. One study did use an empirical approach to defining categories. Hunt et al. (2013) used latent class analysis of specific provisions across MML states to identify three types of MMLs: states that allow doctor prescribing but no legal form of supply, those that allow home cultivation, and a third group with more diverse forms of supply. These studies have made important progress towards the goal of identifying a small number of meaningfully different types of MMLs, or the key dimensions of difference between MMLs (e.g., restrictiveness of supply).

One particularly promising approach for establishing consistent treatment of marijuana policies in outcome studies is the public availability of policy databases that contain up-to-date information on essential MML and NMML features for every state. Typically, a panel of experts defines a coding scheme that determines which policy features are collected and how they are coded, and multiple raters code policies for each state, updating them as they change over time. Two such databases are the Alcohol Policy Information System ([APIS](#); (Klitzner et al., 2017) and the Prescription Drug Abuse Policy System ([PDAPS](#); (Klieger et al., 2017).

Several other studies are notable because they have examined state differences in the level of participation in MML programs, and some of them have considered how specific provisions affect participation rates. Fairman (2016) explored state differences in MML participation rates and demographics. Williams et al. (2016) differentiated “medicalized” and “non-medicalized” MML systems using expert ratings of seven features common to medical practice and found that states with one or no medical features had higher participation rates. Smart (2016) examined the relationship between specific policy provisions and registration rates, and found higher rates of MML participation in states with less restriction on qualifying conditions, lower costs for registration, less restriction on supply, and higher possession limits. The expectation is that larger systems (systems with a larger number of patients relative to population) are expected to produce more “spillover” from legitimate medical use to non-medical use. Registration rates have been used as a proxy for restrictiveness of regulations in MML outcome studies (Abouk & Adams, 2018; Smart, 2016), but one disadvantage of this approach is that effects of registration rates do not directly inform specific policy choices. Registration rates ideally would be treated as a criterion for specific policy provisions, as in the above studies. That type of research could lead to more precise consideration of optimal registration rates. To the extent that there are medical benefits of cannabis, access is desirable, but too much access is not. Theoretically, registration rates should roughly follow the prevalence of conditions for which marijuana is a treatment. It should also be noted that registration rates are not the only pathway for MML effects. People may access medical marijuana without registering, another pathway for harms and benefits to result, which is also subject to policy provisions but would not be reflected in registration rates.

NMML is a newer phenomenon than MML, and there are fewer instances of it, so the research on specific provisions is in an earlier stage of development. A number of authors have recommended NMML policy options in the interest of public health (Carnevale et al., 2017; Caulkins, 2019; Orenstein & Glantz, 2018; Pacula et al., 2014; Shover & Humphreys, 2019; Transform Drug Policy Foundation, 2016). Other studies have inventoried policy differences between state NMMLs (Barry & Glantz, 2018; Darnell et al., 2019; Lancione et al., 2020). Several discussions of NMML policy features have recognized the multiple interests pursued in legalization (e.g., reducing illicit drug markets, generating public revenue, protecting public health) and noted that policies serving one interest may negatively affect others (Auriol et al., 2019; Kilmer, 2019; Rogeberg, 2018) pointing to the importance of comprehensive evaluations of outcomes.

It is now widely recognized that there are many differences in the specific provisions of both MML and NMML across states, and these specific provisions can affect outcomes. Is there so much heterogeneity that the overall category of MML (or NMML) has no meaning? Although policy heterogeneity is important, studies of the effect of MML or NMML as a general category can still provide meaningful information. Studies typically produce average effects, and any average has the potential to conceal important differences for subsets of the sample.<sup>5</sup> A null overall effect for a heterogeneous class of MMLs or NMMLs could contain positive and negative effects that cancel each other out. Identifying the characteristics that are associated with those different effects would be ideal. Such findings would transform the

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<sup>5</sup> This issue is particularly applicable to legalization outcome studies, many of which use individual-level data from states with widely different sample sizes, making more populous states more influential on average effects (Chu, 2018).

yes or no question of legalization to a question of how best to legalize. The literature is moving in that direction, but it is early – findings on effects of legalization are still developing, and effects of specific provisions are even more developmental. In the meantime, average effects of MML or NMML as a general category of policies typically reflect the overall effect of those types of laws in the nation, which is meaningful, and can be complemented by findings on variation in effects for different states.

Next, I review the evidence for effects of legalization by outcome category. For each outcome I discuss evidence for effects of legalization as represented by coarse indicators of enactment as well as effects of specific provisions when available. For each outcome I describe findings for effects of MMLs first, followed by NMMLs. At times I refer to the two types of policies together as “legalization,” and I use the terms cannabis and marijuana interchangeably. Any non-null effects discussed (e.g., increases, reductions) are statistically significant ( $p < .05$ ).

### **Youth Cannabis Use**

Youth cannabis use has been one of the most frequently studied public health impacts of marijuana policy. Early studies of MML typically examined effects of coarse indicators of MML enactment and consistently indicated that youth cannabis use has not increased as a result of MML, after controlling for pre-law levels of use, which tended to be higher in MML states (Anderson et al., 2015; Choo et al., 2014; Harper et al., 2012; Khatapoush & Hallfors, 2004; Lynne-Landsman et al., 2013; Martins et al., 2016; Schuermeyer et al., 2014; Stolzenberg et al., 2016; Wall et al., 2011, 2016)<sup>6</sup>. These findings have been generated from school-aged samples (most commonly, 12-17 years old or grades 8-12) and apply to various representations of marijuana use including lifetime, current, and frequent use. Two more recent studies used coarse MML indicators and produced similar results (Cerdá et al., 2018; Mauro et al., 2019). The more recent data provide longer post-MML observation periods and new entrants to the MML group as more states have enacted MMLs, and these studies have continued to produce evidence that youth cannabis use has not increased as a result of MML. One exception to this trend is the study by Wen et al. (2015) which found that a coarse indicator of MML enactment was associated with a higher likelihood of past-year first-time cannabis use, but not current use, among 12-20-year olds. The slightly older age cutoff and the outcome (past-year initiation) are possible explanations for the difference in findings between this study and the others that produced null effects.

In the past five years it has become more common to account for specific features of MML. Pacula et al. (2015) used data from the National Longitudinal Study of Youth which follows a sample of 12-17-year olds from 1997 through 2011 (so the results pertain to young adulthood to some extent). They examined effects of a coarse indicator of MML along with distinctions for MMLs that require patient registration, offer legal protection for dispensaries, and allow home cultivation. They found null effects of the coarse indicator of MML, but increases in prevalence of current cannabis use associated with MMLs that provide legal protection for dispensaries and those that allow home cultivation. When their

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<sup>6</sup> These citations include two sets of studies wherein an original study produced evidence that MML increased youth cannabis use and a replication study indicated a null effect – the study by Wall et al. (2011) was refuted by Harper et al. (2012), and the study by Stolzenberg et al. (2016) was refuted by Wall et al. (2016). In both cases the refutations cited inadequate statistical control for pre-MML differences due to the use of random as opposed to fixed effects for state.

sample was limited to youth under 18, the effect was null, but this adjustment also changed the states included in MML and comparison groups due to the longitudinal nature of the sample (omitting observations from older participants resulted in omitting more recent MML enactments). In another study, Wen et al. (2015) used data from the National Survey on Drug Use and Health (NSDUH) current through 2012. They differentiated a similar set of MML provisions as Pacula et al. and found that enacting an MML with legal protection for dispensaries was associated with an increase in current marijuana use among 12-20 year olds.

Hasin et al. (2015) used data from the Monitoring the Future Study (MTF), a national survey of students in grades 8 through 12, current through 2014. They examined effects of a coarse MML indicator along with an indicator distinguishing MMLs that allow for legal dispensaries. Findings indicated declines in the prevalence of current marijuana use among 8<sup>th</sup> graders, null effects among 10<sup>th</sup> and 12<sup>th</sup> graders, and similar effects when distinguishing MMLs with legal dispensaries.<sup>7</sup>

Coley et al. (2019) used data from the Youth Risk Behavior Surveys (YRBS), a national survey of students in grades 9 through 12, current through 2015. They found that MMLs were associated with lower current use, and that MMLs with 2.5 oz possession limits were as well. For the latter finding, states with MMLs without possession limits were grouped with states without MMLs in the comparison group.

Several other studies have used more detailed schemes to differentiate MMLs. Williams et al. (2017) distinguished “medicalized” MMLs based on 7 criteria established in earlier work [e.g., non-smoked consumption, supply limits; (Williams et al., 2016)]. Using NSDUH data current through 2013, they found non-significant changes in youth cannabis use and heavy use for both medicalized and non-medicalized states, as compared to non-MML states.

Schmidt (2019) used NSDUH data current through 2013 and examined effects of a coarse indicator of MML and also a continuous scale of the extent to which distribution is controlled in the medical system (Chapman et al., 2016). Findings indicated that neither MML enactment nor the extent of controls on medical marijuana distribution were associated with cannabis use among youth aged 12-14 and 15-17.

Johnson et al. (2017) used YRBS data through 2011. Their treatment of specific MML provisions was guided by work describing variation in provisions across MMLs (Bestrashniy & Winters, 2015; Chapman et al., 2016) and differentiated possession limits, mandatory/voluntary registration, dispensaries, for-profit dispensaries, home cultivation, plant limits, caregiver dispensing, and limits on the number of patients per caregiver. This study found that a coarse indicator of MML enactment was associated with decreases in youth current use, and it found null effects for heavy use. Among specific MML provisions, higher possession limits were associated with increases in 30-day use, and voluntary as opposed to mandatory registration was associated with increases in 30-day use and heavy

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<sup>7</sup> Subsequent studies have drawn the validity of the MTF sample into question. Dilley et al. (2019) and Midgette & Reuter (2020) compared the MTF sample for a single state to that state’s own school survey which had a similar sampling frame but captured a much larger probability sample than MTF. The authors found markedly different changes in cannabis use pre- and post- recreational marijuana legalization between the two data sources. The authors noted that the MTF is designed for the purpose of producing national and regional, but not state, estimates. In this review, studies that use MTF data are Cerda et al. (2017, 2018) and Hasin et al. (2015).

use. On the contrary, when using a composite index of specific provisions that was designed to reflect the degree of liberalization of MMLs, more liberalized MMLs were associated with decreases in current youth use.

Smart (2016) used NSDUH data current through 2013 and found that current use among 12-17 year olds was not affected by MML enactment as represented by a coarse MML indicator, but that higher rates of registration in medical marijuana programs were associated with increases in current use. This study is unique in its measurement of MML -- whereas other studies have attempted to account for policy features that presumably influence who participates in the medical marijuana system, this study directly measured participation on a per capita basis<sup>8</sup>.

Several studies have examined the effect of NMMLs on youth cannabis use. Cerda et al. (2017) examined effects of NMMLs in the first two states to enact them (Washington & Colorado) using MTF data current through 2015, and found NMML in WA was associated with increased cannabis use among 10<sup>th</sup> graders. This finding was later refuted by studies that compared the relatively small MTF sample in Washington to the much larger sample from the state's own school survey, the latter indicating that cannabis use decreased after legalization (Dilley et al., 2019; Midgette & Reuter, 2020). In a later study of NSDUH data current through 2016, which included the next two states to enact NMML (Oregon & Alaska), Cerda et al. (2020) found that youth cannabis use was unaffected by NMML enactment. Both of these studies used a coarse indicator of NMML enactment. In contrast, Darnell et al. (2017) examined the effect of the amount of legal non-medical marijuana sold within each school district in Washington and found that legal sales amounts over the first year and a half were unrelated to youth cannabis use.

One study is unique among the studies in this section in that outcomes were not measured with a survey (Wang et al., 2019). The authors used web search data to measure interest in cannabis among youth and adults through 2017. The study examined effects of NMML enactment by the first nine states to legalize and found that enactment was associated with increased cannabis-related searches among adults age 20 or older but not younger web users.

Overall, findings for effects of MML on youth cannabis use consistently indicate null effects of a coarse indicator of MML enactment. The one exception was the finding that first-time use in the past year, but not current use, was associated with MML enactment among 12-20 year olds. On the other hand, studies examining effects of specific provisions of MMLs have produced mixed results. Three studies have produced evidence that youth use increased under certain types of MMLs—those with higher rates of participation, legal protection for dispensaries, higher possession limits, and voluntary as opposed to mandatory registration. Another study found evidence of increased cannabis use after enactment of MMLs with legal protection for dispensaries and home cultivation, but this effect was based on a longitudinal sample of youth that were followed into young adulthood. Several other studies produced findings in the opposite direction—more liberal MML provisions were associated with decreased youth use. Thus, no clear pattern has emerged yet for the relationship between

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<sup>8</sup> Several studies have examined the relationship between specific features of MMLs and participation finding that less strictly regulated medical marijuana systems have more participants (Smart, 2016; Williams et al., 2016).

specific provisions of MMLs and youth use. There are far fewer studies examining effects of NMML to date, but findings thus far have indicated null effects of NMMLs on youth use.

### **Adult Cannabis Use**

Studies on effects of legalization on adult cannabis use have produced more consistent results. Studies using coarse MML indicators have consistently indicated that current adult cannabis use increased following MML enactment, as compared to states without MMLs and accounting for pre-MML differences between states (Choi et al., 2019; Hasin et al., 2017; Martins et al., 2016; Mauro et al., 2019; Schmidt et al., 2019; Wen et al., 2015). This group of studies also includes several findings indicating increases in the prevalence of daily use (Mauro et al., 2019; Wen et al., 2015). It should be noted that all but one of these studies (Hasin et al.) used the same data source (NSDUH), with some variations between studies in the recency of data, states included in the MML group, and analytic methods. In addition, there are two studies that used NSDUH data and found null effects (Harper et al., 2012; Schuermeyer et al., 2014). The Schuermeyer study focused on Colorado as its only MML state, and both are relatively early studies, so the composition of MML and non-MML states and the length of follow-up data may explain the discrepant findings.

Several studies have examined effects of specific MML policy features on adult use. Wen et al. (2015) analyzed NSDUH data through 2012 and found that MMLs with non-specific pain as a qualifying condition were associated with increased past month use and heavy use among adults 21 and older. Williams et al. (2017) distinguished “medicalized” MMLs based on seven criteria established in earlier work [e.g., non-smoked consumption, supply limits; (Williams et al., 2016)]. They found that enactment of non-medicalized MMLs was associated with increased current use by adults. Schmidt et al. (2019) used a scale measuring controls on distribution of medical marijuana (Chapman et al., 2016) and found no differences in adult use between MMLs with tighter controls. Smart (2016) measured per capita participation in state MML registries and found that adult past month use increased as a result of growth in medical registries. All three of the latter studies analyzed NSDUH data current through 2013.

One pattern that emerges from findings for adult cannabis use is that studies have typically found that effects of MML are larger among adults 26 and older than for the 18-25 age group. In some cases, null effects were found for younger adults (Martins et al., 2016; Mauro et al., 2019; Williams et al., 2017), and in other cases significant effects were found for everyone over 18 with larger effects for adults 26 and older (Smart, 2016).

Several studies have examined effects of NMML on adult use. Cerda et al. (2020) analyzed NSDUH data through 2016 and found NMML enactment was associated with increases in current use and heavy use among adults 26 and older, but not 18-25-year olds. Bae & Kerr (2020) used a national survey of college students aged 18-26 and found increases in current use and heavy use associated with NMML enactment through 2018, with larger effects among students 21 and older, the age group with legal access. In another non-NSDUH study, Wang et al. (2019) examined internet search content through 2017, and found increases in cannabis-related search by adults 20 and older associated with NMML enactment.

Overall, findings for adult cannabis use consistently indicate that the prevalence of current cannabis use has increased among adults as a result of MML enactment. Effects tend to be larger for older adults and less strictly regulated medical marijuana systems. There is also

scattered evidence for increases in daily use by adults. Although findings for NMML are in an earlier stage of development, the available studies confirm the expectation that providing a legal supply of cannabis to adults will lead to more adult cannabis consumption.

### **Cannabis Use Disorder**

Studies examining effects of legalization on disordered cannabis use either examine substance abuse treatment admissions involving cannabis or self-reported symptoms of cannabis use disorder (CUD) from surveys.

Studies examining effects of MML enactment on admissions to substance abuse treatment for cannabis abuse have produced mixed results. All but one of these studies (Shi, 2017) used the Treatment Episodes Data Set (TEDS), a national administrative data set of publicly funded substance abuse treatment admissions. Among the studies examining effects of MML enactment, Chu (2014) analyzed TEDS data through 2008 and found null effects of a coarse MML indicator in his primary model but found increases in cannabis-involved admissions when limiting the data to first-time admissions. Anderson et al. (2015) analyzed TEDS data current through 2009 and found null effects of a coarse MML indicator on cannabis-involved admissions among 15-20 year olds (the study did not examine adults). One other study used hospital admissions data current through 2014 to examine inpatient hospitalizations for marijuana abuse (Shi, 2017). This study found null effects of MML enactment and active MML dispensaries.

Two other studies used TEDS data to examine effects of specific MML features. Pacula et al. (2015) found that a coarse indicator of MML was associated with decreases in cannabis-involved treatment admissions through 2011, but they found increases in states with legal protection for dispensaries, both in the entire sample and when limited to persons under 21. Another study focused on pregnant women in the TEDS data through 2014 (Meinhofer et al., 2019). This study found that a coarse MML indicator was associated with increases in cannabis-involved treatment admissions among pregnant women aged 12-49, with larger effects for MMLs with active dispensaries and when the sample was limited to 18-49 year olds.

Another group of studies examined cannabis abuse through survey data assessing self-reported symptoms that represent the diagnostic criteria for cannabis use disorder. Wen et al. (2015) examined NSDUH data through 2012 and found increases in self-reported CUD after MML enactment among the population aged 21 and older. In another analysis of NSDUH data, current through 2013, Mauro et al. (2019) found null effects of a coarse MML indicator for respondents 12-17, 18-25, and 26 and older. Hasin et al. (2017) used several different national survey data sources that offer a more rigorous assessment of cannabis use disorder than the NSDUH. Data were current through 2013 and indicated increases in CUD that were associated with a coarse indicator of MML enactment. Only one study in this group examined effects of specific policy features. Williams et al. (2017) analyzed NSDUH data through 2013 and found that enactment of MML in states with non-medicalized (i.e., less strict) systems was associated with decreases in self-reported CUD symptoms among 18-25 year olds. For other age groups (12-17 & 26 and older) neither medicalized nor non-medicalized MML enactment was associated with CUD prevalence.

I found two studies that examined the effect of NMML on disordered cannabis use. Darnell et al. (2017) analyzed TEDS data through 2015 and found null effects for NMML enactment

in Washington on treatment admissions for cannabis abuse, both among adults and under 21 year olds. Cerda et al. (2020) analyzed self-reported symptoms from NSDUH data current through 2016 and found that NMML enactment was associated with increases in CUD symptoms among 12-17 year olds, with larger effects among respondents 26 and older, and null effects among 18-25 year olds.

Overall, studies of effects of MMLs on substance abuse treatment admissions involving cannabis have produced mixed results, but they suggest some concerning possible harms emerging from heavy use of cannabis. Coarse indicators of MML enactment have been associated with increases in first-time admissions, and the enactment of MMLs with legal dispensaries has been associated with increased admissions among youth, adults, and pregnant women. However, this collection of studies also includes a number of null findings. Studies of self-reported symptoms of cannabis abuse have more consistently indicated increases in cannabis abuse following MML enactment. There were only two studies of NMML effects, and only one that included multiple states, which indicated that self-reported cannabis use increased among youth and adults after NMML enactment, with larger effects among adults.

### **Other Substance Use**

Marijuana legalization may affect the use of drugs other than marijuana as well. The harms of use of alcohol, tobacco, and opioids are well-documented, making potential effects of legalization on use of these substances central to evaluation of the public health impact of legalization (Caulkins et al., 2015). There are reasonable expectations that legalization may increase or decrease other drug use. If marijuana is used as a substitute for other drugs, legalization would be expected to reduce the use of other drugs. On the other hand, if marijuana tends to be used in combination with other drugs, either concurrently or simultaneously, legalization would be expected to increase other drug use.<sup>9</sup> These alternate possibilities, substitution and complementarity, have been examined in research on effects of legalization on alcohol, tobacco, and opioids.

### ***Alcohol***

Studies addressing legalization effects on alcohol use have generally produced more evidence for substitution than complementarity. Regarding MML, I found only two studies that produced evidence of increased alcohol use, consistent with complementarity. Wen et al. (2015) found that binge drinking increased among NSDUH respondents 21 and older following MML enactment through 2012. They also found increases on items directly addressing concurrent and simultaneous use of alcohol and cannabis—past-month use of both drugs alone or in combination, and use of both drugs on the same occasion—among adults 21 and older. That study also examined effects of specific MML provisions and found

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<sup>9</sup> Use of marijuana “in combination” with other drugs could include use of multiple drugs on separate occasions (i.e., concurrent) or on the same occasion (i.e., simultaneous). Only a small subset of ecological studies are able to address this distinction – for example, because they have survey questions explicitly addressing simultaneous use. Other approaches are less direct, including examining prevalence of use of each drug separately, combining variables to focus on reported use of both drugs, or examining the other drug alone. Many studies simply analyze use of the other substance in relationship to marijuana law and interpret the findings as consistent with substitution or complementarity. Demonstrating corresponding changes in marijuana use strengthens the case, but studies that do not observe changes in both substances happening within the same individual leave open the possibility that the two changes are not actually related.

that non-specific pain as a qualifying condition was associated with complementarity, but that other provisions (dispensaries, registries, & home cultivation) were unrelated to alcohol use.

The bulk of studies concerning alcohol have produced evidence of substitution. Several of these studies used population survey data. Anderson et al. (2013) analyzed BRFSS data through 2010 and found MML enactment was associated with decreases in any alcohol use, frequent use, and binge drinking in the population 18 and older. In another BRFSS study, current through 2012, Sabia et al. (2017) found MML enactment was associated with decreases in binge drinking in the population 18 and older. Among studies focused on youth, Cerda et al. (2018) analyzed MTF data through 2015 and found that MML enactment was associated with decreases in binge drinking among 8<sup>th</sup> graders and no effect among 10<sup>th</sup> and 12<sup>th</sup> graders. Johnson et al. (2018) analyzed YRBS data through 2011 and found that MML enactment was associated with decreases in past-month alcohol use and use of alcohol and marijuana in the past month (concurrently or simultaneously).

Several other studies have examined MML effects on alcohol use using other data sources and produced additional evidence of substitution. Smart (2016) examined alcohol-related poisoning mortality among persons 15 and older through 2013. Findings indicated that poisoning deaths involving alcohol decreased among 45-64 year olds, but not other age groups, in states with greater participation in MML registries. Another group of studies used data on alcohol sales. Anderson et al. (2013) used industry-reported data on sales of beer, wine, and liquor through 2010 and found that MML enactment was associated with declines in sales of beer. Baggio et al. (2020) used a proprietary database of retail UPC (universal product code) scanner records on aggregate alcohol sales and beer and wine sales through 2015. The study identified decreases in alcohol consumption associated with MML enactment for all beverage types. On the contrary, Veligati et al. (2020) analyzed data on alcohol tax receipts through 2016 and found no effect of MML enactment. Potential explanations for the contradictory findings are that the Baggio study was conducted at the county-month level of analysis versus state-year in the Veligati study. Also, the representativeness of the proprietary data source in the Baggio study was not clearly indicated and may differ from the sales data based on tax receipts used in the Veligati study.

Several studies have examined effects of NMML on alcohol use. Darnell et al. (2017) examined the relationship between the amount of legal cannabis sold in Washington counties and binge and heavy drinking and found no evidence of an effect of legal cannabis sales under NMML through 2015. Alley et al. (2020) analyzed data from the National College Health Assessment (NCHA-II) current through 2018 and found that NMML enactment was associated with decreased binge drinking among college students 21 and older (the age of legal access to marijuana) but not among younger students. Veligati et al. (2020) found no effect of NMML on alcohol tax receipts. Leung (2019) analyzed data from the Healthy Minds Study, a probability sample of college students current through 2017. Results indicated a null effect of a coarse indicator of MML enactment on binge drinking. Finally, Wang (2019) examined internet searches for various substances through 2017 and found that NMML enactment was associated with decreases in searches related to alcohol among adults 20 and older, but a null effect among youth.<sup>10</sup>

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<sup>10</sup> Two layers of detail have been omitted from the discussion of findings for alcohol and tobacco. Many of these studies examined effects on cannabis use in addition to alcohol/tobacco. Accompanying changes in cannabis use could strengthen the interpretation of effects as evidence of either substitution or

## **Tobacco**

Studies concerning effects of legalization on tobacco use have generally indicated no effect, or decreases. Among studies of the adult population, Andreyeva and Ukert (2019) analyzed BRFSS data through 2013 and found null effects of MML enactment (and active dispensaries) on cigarette use among the population 18 and older. Leung (2019) found a null effect of a coarse indicator of MML enactment on current cigarette smoking among college students through 2017. In contrast, Choi et al. (2019) found that MML enactment was associated with declines in cigarette smoking prevalence in three different adult (18+) population surveys (NSDUH, BRFSS, and the Current Population Survey) current through 2015. I found only one study examining MML effects on youth smoking. Cerda et al. (2018) analyzed MTF data through 2015 and found MML enactment was associated with decreases in cigarette use among 8<sup>th</sup> graders, null effects among 10<sup>th</sup> graders, but increases in cigarette use among 12<sup>th</sup> graders.

Several studies have examined effects of NMMLs on smoking. Alley et al. (2020) analyzed data from a population survey of college students through 2018 and found that NMML enactment had no effect on consumption of nicotine products including cigarettes, smokeless tobacco, and vaping. Veligati et al. (2020) found null effects of both MML and NMML on tobacco tax receipts through 2016. This study produced important insight into a likely potential confound in analyses linking marijuana laws to cigarette use. Smoke-free air policies proliferated over the same years as marijuana liberalization and likely affect smoking, so they may be a time-varying confound to the extent they coincide with marijuana law enactments. In the Veligati study, effects of marijuana policy were significant until the enactment of smoke-free air policies was accounted for. Another study examined the effect of NMML in Washington State (Darnell et al., 2017) finding that the amount of legal cannabis sold in Washington counties had no effect on the prevalence of cigarette smoking through 2015. One other study (Wang et al., 2019) examined NMML effects on substance-related internet search terms through 2017 and found that tobacco-related search increased among adults (21+) and decreased among youth.

With few exceptions studies examining effects of marijuana legalization on tobacco use have produced null effects. One study did find evidence of decreased smoking following MML enactment across three different population surveys.

## **Opioids**

Marijuana is expected to substitute for opioids, particularly in the management of pain. Studies have examined potential effects of marijuana legalization on opioid overdose deaths, self-reported opioid abuse, treatment admissions, traffic fatalities, and opioid prescribing.

Studies of the effect of MMLs on opioid overdose deaths have produced conflicting results. One study found MMLs were associated with a decrease in opioid overdose mortality (Bachhuber et al., 2014). That study was limited to the period 1999-2010 and examined the effect of a coarse indicator of MML enactment. Subsequent studies using more recent data have found effects in the opposite direction—MML enactment was associated with increased opioid overdose mortality (Phillips & Gazmararian, 2017; Shover et al., 2019).

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complementarity. However, findings for cannabis were reported in a previous section and including them again here complicated an already detailed set of findings. The same can be said of effects of specific MML provisions. That set of findings was very mixed and obscured the conclusions for effects of MML enactment.

Shover et al. suggested that all of these studies may suffer from omitted variable bias, perhaps failing to account for contextual factors surrounding the opioid epidemic that may coincide with MML and affect opioid mortality. Interestingly, the Phillips & Gazmararian study also examined the combination of MML with prescription drug monitoring programs (PDMPs), finding a marginally significant beneficial effect of MMLs when combined with PDMPs. This finding suggests the importance of accounting for combinations of policies given that the effect of a given policy may depend on what other policies are in place.

A number of studies have examined effects of specific features of MMLs on opioid mortality. Powell et al. (2018) found null effects of a coarse MML indicator on mortality through 2013, but reductions in mortality when MMLs with dispensaries were distinguished. Smart (2016) differentiated MML states by their population rates of participation in medical marijuana registries and found lower overdose mortality through 2013 among adults aged 45-64 associated with higher rates of participation. The Shover study cited above included additional analysis with separate categories for MML states with accompanying NMML, and MML states only allowing low THC products; it found that only the 'other' MML states (those without NMML and THC restrictions) had higher opioid deaths<sup>11</sup>.

NMML effects on opioid mortality have also been examined. Livingston et al. (2017) used an interrupted time series analysis of opioid mortality in Colorado through 2015 adjusting for opioid mortality over the same period in two neighboring states. Findings indicated a reduction in mortality associated with the initiation of legal sales. In contrast, Alcocer (2020) examined opioid mortality through 2017 in Colorado compared to a synthetic control group of states with MML but not NMML. Findings indicated a null effect of the initiation of retail sales on opioid overdose mortality. The stronger comparison group in the Alcocer study and the longer follow-up period are possible explanations for the conflicting findings.

One particularly strong study (Chan et al., 2020) analyzed opioid mortality through 2017 testing effects of the enactment of MML and NMML and active dispensaries for each (4 separate intervention estimates). Their preferred model omitted comparison states that experienced the steepest increases in opioid mortality on the reasoning that smaller increases in legalizing states could be mistaken for an effect of legalization. Findings indicated reductions in opioid mortality associated with both MML and NMML dispensaries, and these findings were robust to various alternative specifications.

Another group of studies examined effects of legalization on self-reported opioid misuse. Wen et al. (2015) analyzed NSDUH data through 2012 examining effects of a coarse indicator of MML enactment along with specific provisions for non-specific pain as a qualifying condition, required registration, legal protection for dispensaries, and home cultivation. Findings indicated null effects for all MML variables on opioid misuse among 12-20 year olds and adults. A more recent analysis of NSDUH data current through 2014 examined effects of MML enactment and dispensaries and found null effects on opioid misuse and opioid use disorder (Segura et al., 2019). One study focused on youth—Cerdeira et al. (2018) analyzed MTF data through 2015 and found that a coarse indicator of MML enactment was associated with a decrease in non-medical opioid use among 8<sup>th</sup> graders, a null effect among 10<sup>th</sup> graders, and an increase among 12<sup>th</sup> graders.

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<sup>11</sup> THC is delta-9-tetrahydrocannabinol, the main psychoactive compound in marijuana.

I identified one study that examined the effect of NMML on self-reported opioid misuse. Alley et al. (2020) analyzed data from a national sample of college students (NCHA-II) current through 2018 and found that NMML enactment was not associated with opioid misuse.

Several other studies have examined effects of MML on opioid use as reflected in substance abuse treatment data. Chu (2015) analyzed treatment admissions involving heroin using TEDS data current through 2011 and found that MML enactment was associated with declines in treatment admissions involving heroin, accompanied by increases in marijuana admissions, for people 18 and older. Powell et al. (2018) focused on opioid pain relievers (excluding heroin) in TEDS data through 2013. They found null effects of a coarse MML indicator but reductions in opioid admissions when MMLs with legal protection for dispensaries were distinguished, and even larger effects when legal dispensaries were active. One study to not use TEDS data examined inpatient hospitalizations for opioid abuse and opioid overdose through 2014 and found reductions in both associated with MML enactment but not active dispensaries (Shi, 2017).

One study examined MML effects on opioid abuse using traffic fatalities data. Kim et al. (2016) examined drivers in fatal crashes who tested positive for opioids, using FARS data through 2013. To deal with the large amount of missing data on toxicology in FARS data the study was limited to 18 states with the most complete data. The study produced null effects for MML enactment with a legal supply source (either home cultivation or dispensaries).

A sizeable group of studies has examined legalization effects on opioids using data on opioid prescribing. Because most of these studies have been published within the past several years many examined effects of both MML and NMML. Because all states that have enacted NMML had previously passed MML, effects of NMML represent the additional change in the outcome caused by NMML above and beyond changes produced by MML. This group of studies includes data sources covering prescriptions paid by Medicare or Medicaid, a data source of all prescriptions filled by pharmacies, and a survey measure of prescriptions.

Bradford & Bradford (2016) examined Medicare prescriptions through 2013, focusing on prescriptions for specific health conditions. MML was defined as having an enacted MML and available supply (allowance for home cultivation or legal and operating dispensaries). Findings indicated that MML enactment was followed by reductions in prescriptions for pain management (not necessarily limited to opioids). In a later study, Bradford et al. (2018) analyzed Medicare prescriptions through 2015, examining effects of MML with separate indicators for MML enactment, allowance for home cultivation, and dispensaries. MML enactment produced null effects on opioid prescribing outcomes, but allowance for home cultivation and dispensaries were both associated with reductions in opioid prescribing.

Other authors have used Medicaid prescription data. Wen and Hockenberry (2018) examined effects of MML and NMML on Medicaid prescribing through 2016. Legalization was represented by law enactment and policy heterogeneity was addressed by state-specific estimates for each of 8 MML states and 4 NMML states that changed law status during the study period. The comparison group consisted of all other states, and in an alternate analysis omitted states that did not enact MML prior to the study period. Both MML and NMML enactment indicators were associated with decreased opioid prescribing. State-specific estimates indicated these decreases were found in 4 of 8 MML states and 3 of 4 NMML states. There was no clear identification of policy differences that would explain the difference in state effects. Bradford & Bradford examined Medicaid prescriptions for certain

conditions through 2014 and found that states with enacted MML (regardless of available supply) had reductions in prescriptions for pain management (Bradford & Bradford, 2017). Liang et al. (2018) examined opioid prescriptions among Medicaid recipients through 2014. MML was represented with separate indicators for law enactment and active dispensaries. They found null effects for Schedule II drugs which comprise approximately 95% of opioid prescriptions. However, the study did identify reductions due to enactment but not dispensaries in less-commonly prescribed Schedule III opioids which the authors noted tend to be used for less severe pain management. In the most recent Medicaid study, Shi et al. (2019) examined effects of NMML on Medicaid prescriptions through 2017. Eight states and the District of Columbia were compared to six states with MML but not NMML. Findings indicated null effects for NMML enactment.

In another study, McMichael et al. (2020) used a dataset containing all prescriptions (derived from pharmacies records as opposed to prescribers) current through 2018 to examine effects of MML and NMML. Both MML and NMML enactment were associated with decreases in opioid prescriptions. The study also reported analyzing effects of different types of MMLs and finding results consistent with coarse enactment indicators, but it did not specify which aspects of MMLs were accounted for.

Finally, Ozluk (2017) used data from the Medical Expenditure Panel Survey (MEPS) a representative survey of the US population that includes information on prescription opioid expenditures. Data were limited to respondents 18 or older and were current through 2014. The study examined effects of MML enactment plus provisions for dispensaries, non-specific pain, registry requirement, and home cultivation. The study used a unique approach to examining effects of specific provisions in that it reported effects of combinations of provisions, and identified states that have enacted those combinations. Results indicated that MML enactment was associated with a decrease in the amount of expenditure (but not the likelihood of being an opioid user) among 18-39-year olds (but not older adults). Independent effects for specific provisions indicated that this effect was attributable to MMLs that allowed home cultivation. Regarding combinations of provisions, four types of MMLs were examined. Results indicated that the reduction in expenditures was isolated to the two types of MMLs that placed the least restrictions on access to cannabis.

Overall, studies of effects of legalization on other drug use have produced several noticeable patterns of findings. Studies of effects on alcohol have produced consistent evidence that alcohol consumption decreases following MML and NMML enactment. Studies of effects on tobacco have generally indicated null effects of MML and NMML. Studies examining effects of legalization on opioids are the most numerous in this category. Studies of opioid mortality have produced mixed findings. There are indications from several studies that opioid mortality has been reduced following legalization, although null effects and increases have been identified in other studies. Studies of self-reported opioid misuse have generally produced null effects. And studies of opioid prescribing have consistently indicated reductions in prescription opioid use following legalization. Although these latter findings are consistent with substitution, none of the opioid prescribing studies observed accompanying changes in marijuana use, which would strengthen the case for substitution.

## Health

The health category of outcomes includes studies addressing effects on self-reported general health, obesity, and mental health from population surveys; suicide; calls to poison control; and emergency department visits.

Andreyeva and Ukert (2019) analyzed BRFSS data through 2013 and found that MML enactment was associated with increases in respondents reporting very good or excellent overall health in the population 18 and older. Separate effects for MML enactment and active dispensaries were estimated, indicating active dispensaries produced a reduction in overall health, following the increase associated with enactment, resulting in an overall effect of enactment and dispensaries that was still positive. Nicholas and Maclean (2019) used data from the Health and Retirement Study through 2012, a representative sample of adults 50 and older, and found that ratings of overall health were higher following enactment. The study also examined effects of specific MML provisions (i.e., required registration, active dispensaries, home cultivation, and non-specific pain as a qualifying condition), but findings from these analyses did not produce an interpretable pattern of results.

Sabia et al. (2017) used BRFSS data to examine MML effects on body weight finding that body mass index and obesity were reduced among adults 18 and older following MML enactment. This study examined effects of specific policy provisions and found that non-specific pain as a qualifying condition was associated with decreases, but it found null effects for dispensaries, collective cultivation, or registries.

Dutra et al. (2018) used NSDUH data to analyze the prevalence of serious mental illness (SMI) in the population 18 and older through 2015. SMI was defined as self-reported symptoms of a wide range of psychological disorders that impair daily functioning. The study differentiated liberal and restrictive MMLs on the basis of qualifying conditions.<sup>12</sup> Findings indicated increased prevalence of cannabis use and SMI following enactment of liberal MMLs but not restrictive MMLs. Another study examining mental health outcomes analyzed data from the Healthy Minds Study, a probability sample of college students current through 2017 (G. Leung, 2019). Results indicated a null effect of a coarse indicator of MML enactment on self-reported depression, anxiety, and suicidal ideation.

Effects of MML on completed suicides have been examined in a number of studies, which have produced mixed results. Anderson et al. (2014) examined the effect of MML enactment on state suicide rates through 2007 and found reductions among males. However, a re-analysis of the same data that included additional time-varying covariates (e.g., state demographics, mental health expenditures) found null effects (Grucza et al., 2015). One other study examined suicide rates in California and found that all suicides and suicides by gunshot were reduced following MML enactment relative to a synthetic comparison (Bartos et al., 2019). This study used data current through 2004, examined MML in only one state, and did not explicitly account for the covariates identified by Grucza et al.

Emergency department (ED) visits involving cannabis have also been examined, however data availability has limited the research on this outcome. The only national data system on

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<sup>12</sup> The analysis also included a separate binary indicator of whether the MML allowed patients to petition providers for special approval to use marijuana for conditions beyond the allowed qualifying conditions. The study also used meta-regression which is a unique analytic approach among studies in this review, reported by the authors to treat states independently eliminating the need for fixed effects for state.

ED visits was the Drug Abuse Warning Network (DAWN), a national public health surveillance system that discontinued data collection in 2011. An older study used DAWN data to examine effects of early MMLs, finding no evidence of an effect of enactment in California, Washington, and Colorado on ED visits involving cannabis (Gorman & Huber, 2007). Most studies of ED visits use datasets unique to a given state and often lack comparison data. One exception is a study by Conyers & Ayres (2020) that examined the effect of medical marijuana dispensaries in Arizona by taking advantage of the fact that the location of medical marijuana dispensaries was determined by lottery. They compared postal codes with dispensaries to those without and found that dispensaries were related to increased ED visits involving cannabis.

Contacts to poison control centers provide insight into another aspect of health impacts of legalization. Shi & Liang (2020) examined cannabis poisoning data from the US National Poison Data System which includes calls to all 55 poison centers in the US through 2017. Calls concerning exposure to cannabis were unrelated to enactment of NMML but increased after NMML dispensaries became active.

One other study in this group examined MML effects on mortality due to cardiovascular causes (Abouk & Adams, 2018). MML enactment was associated with increases in cardiovascular deaths for both men and women through 2014. The study also differentiated restrictive and lax MMLs, based on dispensary regulations and the number of registrants. Findings indicated the increased cardiovascular mortality was isolated to enactment of lax MMLs.

Overall, effects of legalization on self-reported health outcomes are mixed, in part due to the variety of outcomes that have been examined. In this category there are very few specific outcomes that have been examined by more than one study. Therefore, findings for the entire category are inconclusive, but more findings than not provide evidence of health harms due to MML enactment and several of these findings are specifically associated with MML dispensaries.

### **Traffic Safety**

Nearly all analyses of legalization effects on traffic safety used national data from the Fatal Accident Reporting System (FARS) which provides a census of motor vehicle accidents involving fatalities. Limitations of FARS data include that only fatal accidents are included, and data on driver fault and involvement of alcohol and drugs are often incomplete. As a result, analyses typically do not account for fault, and many ignore impairment, focusing on total fatalities as a less biased version of the data. Findings for effects of MML and NMML on traffic fatalities are mixed.

One of the earliest studies of MML effects on fatal accidents (Anderson et al., 2013) examined effects of a coarse indicator of MML enactment on fatalities with and without alcohol involvement through 2010. They found MML enactment was associated with reductions in fatalities with alcohol involved, interpreting findings as evidence of substitution. Two other studies found decreases associated with MML. Bartos examined all fatalities regardless of substance involvement in California through 2015 compared to a synthetic comparison group and found decreases following MML enactment. Cook et al. (2020) aggregated all FARS fatalities to the city level and examined effects of city decriminalization and state MML through 2017. Findings indicated reductions following

MML enactment with larger effects among 15-24-year-old victims and alcohol-involved and weekend nighttime crashes.

Two other studies produced null effects. Masten and Guenzberger (2014) analyzed marijuana-involved fatal accidents through 2009 using interrupted time series analysis<sup>13</sup>. The study did identify increases in 3 of 12 states examined, but most states produced null effects. The study did not identify a consistent pattern in indicators of MML restrictiveness between states with increases and those without. Santaella et al. (2017) estimated the effect of MML enactment on traffic fatalities in 19 states through 2014, identifying decreases in seven states, increases in two states, and null effects for the remaining ten. The authors found no clear differences between states in policy features to explain this variation.

In contrast, another group of studies has produced evidence of increased fatal accidents resulting from MML. Smart (2016) examined the effect of medical marijuana registration rates through 2013 and found increases in fatal accidents involving young drivers (15-20 years old). When substance involvement was considered, MML effects were larger among 15-20-year olds with alcohol involvement, among 21-24-year olds with marijuana involvement, and among both age groups when both alcohol and marijuana were involved. Sevigny (2018) examined marijuana-involved fatal accidents through 2014, using multiple imputation to deal with the large amounts of missing data for substance involvement. The study found no evidence of an effect of MML enactment, and allowance for home cultivation, but an increase following the availability of active dispensaries, both legal and quasi-legal. The author reasoned that driving to purchase marijuana and consuming before returning home may be the reason for this finding. Notrica et al. (2020) examined effects of a comprehensive set of traffic safety-related policies, including decriminalization, MML, and NMML. Marijuana policies were represented with a single time-varying ordinal variable (prohibition, MML, decriminalization, NMML) which was associated with traffic fatalities through 2015. Relating this finding to the other studies is more difficult because effects of MML and NMML are typically modeled with separate indicators.

One final study of MML effects is unique in this group because it did not use FARS data. Fink et al. (2020) used three different national surveys to examine effects of MML enactment on self-reported driving under the influence of cannabis and alcohol<sup>14</sup>. The study found increases in self-reported driving under the influence of cannabis associated with MML enactment compared to states that never enacted MML.

There have been several studies to examine effects of NMML on traffic safety. Sevigny (2018) focused on MML effects using FARS data through 2014, but also reported estimates of the effect of NMML on fatalities involving THC-positive drivers. Findings indicated declines following NMML enactment but were based on the first year of enactment in only two states (Colorado & Washington).

Several other studies have identified null effects of NMML. Aydelotte et al. (2017) compared total FARS fatalities through 2015 in Washington and Colorado to eight states with similar traffic safety characteristics that had not enacted NMML or MML. Findings indicated null

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<sup>13</sup> Unlike nearly all of the other studies in this review, this study did not include comparison data, but the study met our standard for internal validity because it examined effects of MML enactment in 12 different states with varying time of intervention.

<sup>14</sup> Datasets were the National Longitudinal Alcohol Epidemiologic Study (NLAES) and the National Epidemiologic Survey on Alcohol and Related Conditions (NESARC & NESARC-III).

effects for NMML enactment. Hansen et al. (2020) examined FARS data through 2016 comparing Washington and Colorado to a synthetic comparison group of non-NMML states. The study produced null effects of NMML enactment and initiation of retail sales on total fatalities and fatalities with or without THC or alcohol involvement.

Two studies produced evidence of increased fatalities due to NMML. Aydelotte et al. (2019) examined total fatalities through 2017 on a monthly basis in Washington and Colorado compared to nine states that didn't change MML or NMML status during the study period (some had adopted MML before the study period and some had neither NMML nor MML). The study considered the effect of NMML enactment and initiation of legal sales, finding increases due to initiation of sales. In one of the few studies to use data other than FARS, Lane and Hall (2019) analyzed a dataset of transportation-related fatalities through 2016 which contained a broader set of fatalities than FARS (including aviation and boating fatalities for example). The study examined effects of NMML sales initiation in Washington, Colorado, and Oregon compared to adjacent states. Findings indicated an increase in fatalities immediately following initiation of legal sales that decreased in later years.

Overall, findings for effects of legalization on traffic safety are inconclusive. Nearly all studies have examined traffic accidents involving fatalities, and almost all of these have used the FARS data set. Findings for effects of MML on fatal accidents are mixed. Multiple studies produced evidence of decreased fatalities due to MMLs, suggesting that MMLs may improve traffic safety by reducing driving under the influence of alcohol or other drugs. Other studies found null effects, and still another group of studies found positive effects of MMLs on traffic fatalities. Furthermore, no clear conclusions can be drawn about effects of specific provisions. Effects of NMMLs on fatalities were also mixed. Only one study in this group examined an outcome other than fatalities, and it found increases in self-reported driving under the influence of marijuana following MML enactment. It is difficult to characterize the direction of findings on traffic fatalities due to the assortment of differences between studies, including which accidents are selected from FARS, which states are analyzed, and how policies are differentiated.

### **Workplace Safety and Wellness**

The review also includes a smaller collection of studies that address legalization effects on health outcomes in the workplace. One study addressed workplace fatalities, considering the possibility that marijuana impairment negatively affects safety, and the competing possibility that substitution for other more impairing drugs may improve safety. Another group of studies examined the ability to work as affected by illness and injury (e.g., employment, hours worked, and illness-related absences). These studies consider the possibility that increased marijuana access through MML reduces work via marijuana misuse, versus the alternate possibility that therapeutic benefits of medical marijuana access allow people to manage injuries and illnesses and work more.

Anderson et al. (2018) analyzed a national dataset of all workplace fatalities for workers 16 and older current through 2015. The study examined effects of MML enactment and also distinguished MMLs with non-specific pain as a qualifying condition and allowance for collective cultivation. Results indicated MML enactment was associated with reductions in fatalities only in the 25-44 age group, and this effect was stronger for MMLs allowing for collective cultivation and non-specific pain as a qualifying condition.

Ullman (2017) examined self-reported work absences due to illness in a nationally representative sample from the Current Population Survey current through 2012. MML enactment was associated with reductions in health-related absenteeism among males and among full-time workers. The study also distinguished lax and restrictive MMLs based on dispensary regulations and registration rates and found that enactment of lax MMLs, but not restrictive ones, was associated with reductions in absenteeism among full-time workers.

Nicholas and Maclean (2019) used data from the Health and Retirement Study through 2012, a nationally representative sample of adults 50 and older, and found that older adults who were employed were able to work more (e.g., more hours, more full-time employment) following MML enactment, and this effect was larger among older adults reporting health conditions that would qualify for medical marijuana treatment. MML enactment was unrelated to the likelihood of employment. The authors interpreted this pattern of results as evidence that MML enactment produced therapeutic benefits enabling respondents to work more, which outweighed possible negative effects of marijuana abuse on employment, such as job loss. The study also examined effects of specific MML provisions (i.e., required registration, active dispensaries, home cultivation, and non-specific pain as a qualifying condition), but findings from these analyses did not produce an interpretable pattern of results.

Ghimire and Maclean (2020) examined MML effects on workers' compensation (WC) claims through 2013. WC claims can be made for on-the-job injuries and could increase if marijuana-related impairment at work increased as a result of MML, or could decrease if therapeutic benefits of medical marijuana allow people to continue work or return to work more quickly. Results indicated that MML enactment was associated with reductions in the likelihood and duration of WC claims. The study also distinguished MMLs with required registration, legal protection for dispensaries, allowance for collective cultivation, non-specific pain as a qualifying condition, and employment protection for medical marijuana users. Among these specific provisions, the employment protection provision was associated with larger reductions in WC claiming.

Overall, the studies in this section suggest that MML reduces workplace fatalities and absences due to injury or illness and increases the ability to work. These findings are consistent with the expectation that access to medical marijuana allows people with health conditions that can be managed by marijuana to work more. The evidence is also consistent with the possibility that medical marijuana may be used instead of other drugs, such as alcohol or opioids, that have stronger negative effects on work. There were no studies of NMML effects on workplace outcomes.

## **Conclusions**

Below I summarize findings for each category of outcomes, leading to a discussion of the limitations of the existing research on effects of legalization.

### ***Youth Cannabis Use***

Findings for effects of MML on youth cannabis use generally indicated that youth use has not been affected by MML enactment on average across the various versions of MML that have been enacted thus far. Studies examining effects of specific MML provisions have produced mixed results—some studies have indicated that less restrictive MMLs are associated with increased youth use, others have indicated decreases, and the majority have indicated null effects of specific provisions. There are far fewer studies examining effects of NMML to date, but findings thus far have indicated null effects of NMML on youth use.

### ***Adult Cannabis Use***

Studies of MML effects on adult marijuana use have consistently indicated that adult use increases as a result of MML enactment. In addition, findings for specific provisions of MMLs have suggested that MMLs with fewer restrictions on access, such as allowing non-specific pain as a qualifying condition, are associated with increased adult cannabis use, although other results of this type have been null. Studies of NMML thus far have indicated that cannabis use increases among adults following NMML enactment. Studies have generally demonstrated that this effect is specific to the portion of their samples age 21 or older which is the age of legal access in all NMMLs. Increased prevalence of use by adults resulting from MML and NMML is to be expected. Change in heavy use specifically is one of the more concerning potential outcomes of legalization (Caulkins, 2019). These studies have not yet produced clear evidence of MML or NMML effects on heavy cannabis use (e.g., daily or near-daily past-month use).

### ***Cannabis Use Disorder***

Studies of effects of MMLs on substance abuse treatment admissions involving cannabis have produced mixed results but suggest some concerning possible harms emerging from heavy use of cannabis. These include a study indicating an increase in first-time admissions, and findings indicating increased treatment admissions among youth, adults, and pregnant women following enactment of MMLs with legal dispensaries. Studies of self-reported symptoms of cannabis abuse have more consistently indicated increases in cannabis abuse following MML enactment, although this group of studies also includes null effects and the rare decrease in disordered use. There were only two studies of NMML effects, and only one that included multiple states, which indicated that self-reported cannabis use increased among youth and adults, with larger effects among adults.

### ***Other Substance Use***

A substantial body of research has considered potential effects of legalization on use of drugs other than marijuana. Increased access to marijuana may allow it to be used instead of other drugs, in which case legalization may lead to reductions in other drug use. On the other hand, if marijuana is used in combination with other drugs, legalization would be expected to increase other drug use. The harms of use of alcohol, tobacco, and opioids are

well-documented, making potential effects of legalization on use of these substances a potentially overriding factor in the public health impact of legalization (Caulkins et al., 2015).

Studies of legalization effects on alcohol have produced consistent evidence that alcohol consumption decreases as a result of both MML and NMML enactment, consistent with substitution (i.e., marijuana being used as a substitute for alcohol, rather than in combination with alcohol). One study did find increases in binge drinking and past month use of marijuana and alcohol in combination among adults following MML enactment. Several other studies produced null effects. But more studies indicated reductions in alcohol use, leading to the conclusion that at present the evidence suggests that legalization reduces alcohol consumption.

Studies of effects of legalization on tobacco use, primarily cigarette smoking, have generally produced null effects for both MML and NMML enactment. One study did produce evidence of declines in smoking in the adult population across three different surveys following MML enactment. Another study found evidence of increased smoking among 12th graders (but decreases among 8th graders). However, more studies produced null effects. Very few studies in this group examined effects of specific provisions limiting conclusions that can be drawn in that regard.

A large number of studies have examined legalization effects on opioid abuse. These studies have examined opioid-related mortality using death records, self-reported opioid misuse in surveys, and opioid prescribing from medical administrative data. The evidence for opioid mortality is distinctly mixed. Early evidence of reductions in opioid mortality due to MML enactment were not replicated in several more recent studies. Effects of MML provisions, specifically dispensary provisions have been associated with reductions in opioid mortality in two studies. Effects of NMML on opioid mortality were also examined in two studies which produced null effects. One recent and particularly well-designed study accounted separately for enactment of MML and NMML and the availability of active dispensaries for both, and it identified reductions in opioid mortality attributable to the presence of active MML dispensaries and NMML dispensaries. In contrast, studies of self-reported opioid misuse have generally indicated null effects for both MML and NMML. Other studies examined MML effects on treatment admissions and traffic fatalities involving opioids and produced mixed results for MML enactment and specific provisions, including increases, decreases, and null effects. On the other hand, studies of prescribing data have produced stronger evidence of reductions in opioid consumption associated with both MML and NMML, consistent with the expectation that marijuana can be used as a substitute for opioids for pain management. This group of studies also included several that produced null effects, and studies examining effects of specific provisions have not produced an interpretable pattern of findings.

### **Health**

Effects of legalization on self-reported health outcomes are mixed, in part due to the variety of outcomes that have been examined—there are very few specific outcomes that have been examined by more than one study. Therefore, findings for the category are inconclusive, but more findings than not provide evidence of health harms due to MML enactment. Several of these findings are specifically associated with MML dispensaries.

Among the assorted findings in this category, MML has been associated with increases in ratings of overall health, decreases in body mass index, and increases in serious mental illness. MMLs with dispensaries had harmful effects in two of those studies. Several studies examined effects of MMLs on suicide and produced contradictory findings. One of these analyses identified reductions in suicide following MML but was later refuted by a study that included additional time-varying covariates and found null effects. A different study focused on California and identified decreases in suicides. Other findings in the health category include a study focused on Arizona that identified an increase in ED visits in areas of the state that had active MML dispensaries. Another national study identified an increase in poison control calls following the enactment of MMLs with active dispensaries. Finally, cardiovascular deaths were found to increase following enactment of MMLs with relatively lax restrictions on access.

### ***Traffic Safety***

Findings for effects of legalization on traffic safety are inconclusive. Nearly all studies of legalization effects on traffic safety have examined traffic accidents involving fatalities, and almost all of these have used the FARS data set. Fatal accidents are an extreme subset of possible traffic safety outcomes. Findings for this group of studies have been mixed. Multiple studies have produced evidence of decreased fatalities due to MMLs, suggesting that MMLs may improve traffic safety by reducing driving under the influence of alcohol or other drugs. Other studies found null effects, and still another group of studies found increased traffic fatalities due to MMLs. Several of these studies examined state-specific effects of MML for multiple states, but there were no clear conclusions that could be drawn about effects of specific provisions. Effects of NMMLs on fatalities were also mixed. Two studies found null effects and two found increased fatalities following NMML. Only one study in this group examined an outcome other than fatalities, and it found increases in self-reported driving under the influence of marijuana following MML enactment. Aside from that study, effects of legalization on less severe impacts on traffic safety are unknown. Overall, it is difficult to characterize the direction of findings on traffic fatalities due to various differences between studies, including which accidents are selected from FARS, which states are analyzed, and how policies are differentiated.

### ***Workplace Safety and Wellness***

This outcome category included only four studies. One addressed workplace fatalities, and the others addressed employment, hours worked, and absenteeism. Findings indicated reduced workplace fatalities and increased amounts worked in terms of hours and reduced absenteeism. These findings are consistent with the expectation that access to medical marijuana allows people to manage illness and injury and work more. They are also consistent with substitution of marijuana for other drugs such as alcohol or opioids which may have greater negative effects on workplace outcomes.

### ***Limitations of Current Research on Marijuana Legalization***

This review applied strict criteria for study quality, including only studies that supported causal inference, and it still included a larger number of studies. This is an impressive body of literature that is rapidly developing, with most studies being published in the past five years. Identifying policy effects on population-level outcomes is a tall order because variation in those outcomes is subject to so many influences, only one of which is the policy change of

interest. Although the studies selected for this review are the strongest available, several of them demonstrated legalization effects that were nullified after accounting for time-varying confounds that are not commonly accounted for in other studies (Grucza et al., 2015; Veligati et al., 2020). The presence of time-varying confounds is a very real possibility that is easy to forget when digesting the many factors that are accounted for by these studies. This possibility admits a degree of uncertainty to all of the conclusions in this review. The challenges are even greater for outcome studies that attempt to identify effects on secondary outcomes—outcomes that are indirectly affected by legalization. Studies of health effects of drug policy for example expect changes in health outcomes to result from intermediate changes in drug use. These secondary outcomes are more multiply-determined than drug use, which itself is subject to manifold determinants.

In light of these difficulties it may be acceptable to infer effects on secondary outcomes by associating policy effects on drug use with findings from other studies demonstrating effects of drug use on those secondary outcomes. Effects of drug use are better understood through individual-level studies focused on drug use as the independent variable. Observed changes in marijuana use resulting from legalization can be assumed to have negative effects on the people reporting greater use of cannabis on the basis of research on health effects of cannabis use, regardless of whether ecological studies have been able to demonstrate policy effects on those health outcomes. Null effects from population studies are particularly ambiguous to interpret. Studies may be underpowered and they may also fail to account for important changes coinciding with policy changes. So there may be harms resulting from legalization that cannot be demonstrated in population-level policy evaluations.

Among the many challenges of this type of research, policy heterogeneity and measurement of cannabis use are particularly important. Studies of legalization effects on public health rely heavily on population surveys which typically provide measures of cannabis use that are limited to age of first use, lifetime prevalence, past-month prevalence, number of days used in the past month, and prevalence of disordered cannabis use (Geissler et al., 2020; Guttmannova et al., 2019). Many harms of cannabis use are dependent on the intensity of THC consumption (National Academies of Sciences, Engineering, and Medicine, Committee on the Health Effects of Marijuana, 2017). A number of authors have recognized the need for national surveys to collect data reflecting the amount of cannabis, and ideally, THC consumed, and they have also made recommendations for how to address the numerous practical difficulties in doing that (Caulkins et al., 2020; Darnell, 2019; Kilmer & Pacula, 2017). In addition, legalization has been accompanied by rapid changes in the potency of marijuana, the diversity of forms it is produced in, and the modes of consumption—such differences in the type of cannabis consumed and how it is consumed also factor into the intensity of cannabis and THC consumption (Choo & Emery, 2017; Darnell, 2019). The bulk of studies of legalization effects on cannabis use to date have examined the prevalence of past-month use, and we remain relatively uninformed about effects of legalization on the amount consumed. Variables reflecting intensity of cannabis consumption would be valuable outcomes in studies of policy effects, would be useful for identifying subpopulations with more harmful versions of use, and would also be useful in individual-level studies examining outcomes of cannabis use. Limitations of the available data also explain why there are no findings discussed in this report concerning vaporized consumption of marijuana (i.e., vaping). Population surveys have typically not included items addressing vaping or have only

recently begun to do so. As a result, we found no studies addressing legalization effects on vaping that met the inclusion criteria.

Another notable limitation of the current research is the diversity of ways marijuana policy has been represented in outcome analyses. As discussed in the introduction, there are many differences in the specific provisions of legalization across states, leading to extensive variation across studies in which features researchers choose to focus on and how they are measured. This makes it difficult to draw conclusions on effects of specific provisions. Publicly available marijuana policy databases are a promising development that should promote consistency in how policies are treated in outcome studies, but these are a recent development and not used in any of the outcome studies identified in this review. The small number of states we have to work with presents the need for the identification of sets of policy features that can be used to divide states into a small number of groups, or the development of key dimensions of variation, such as restrictiveness of supply, that can be used to rate marijuana laws. The identification of policy types representing combinations of policies not only manages division of a smaller number of states, but it also examines effects of combinations of policy features. Several studies in this review raised the possibility of interdependent policy effects – either effects of combinations of marijuana policies, such as combinations of specific provisions, or combinations with other types of laws that may influence outcomes. The Ozluk (2017) study combined marginal effects of binary MML policy provisions to identify the effect of particular combinations that exist across the US. Similarly, the Phillips and Gazmararian (2017) study of opioid mortality found evidence that MML policy effects were dependent on prescription drug monitoring programs being in place. These related policies not only need to be accounted for, but they may also generate interactions with marijuana policies.

Interactions of specific features of marijuana policy have also been discussed by authors who have considered the interdependence of regulations to protect public health and other aspects of the overall marijuana policy regime, such as tax and law enforcement policy (Auriol et al., 2019; Rogeberg, 2018). Regulations to protect public health (and other regulations on cannabis commerce) may restrict the actions of legal cannabis suppliers which could place them at a competitive disadvantage with illicit suppliers, who are unregulated. However, if the illicit market has been suppressed by policies that promote law enforcement and successful competition of legal suppliers, harmful side-effects of public health regulations on illicit market activity may be avoided. Although the two studies cited above are theoretical discussions, they point to the desirability of a comprehensive evaluation of marijuana policy effects that considers the net effect of an overall policy regime on multiple outcomes.

Returning to the problem of inconsistent treatment of marijuana policy features across studies, there is plenty of theory about how to regulate cannabis markets in the interest of public health. This knowledge also provides a solid rationale for how specific policy features can be expected to influence public health outcomes—our expectations about specific policy features are not naive. In addition, policy information is publicly available, making it feasible to obtain the consensus of experts on a fixed classification of states in terms of MML, NMML, or both, or even a time-varying classification, with associated predictions for effects on outcomes. Such a classification would ideally be derived empirically to account for the actual covariation between specific policy features and the group sizes that result from different approaches to classification. Prior commitments to a classification of states could

then be tested for effects on outcomes, and ideally multiple outcomes, for stronger tests of heterogeneous policy effects than are available from the current evidence.

On a related note, there are a number of practical details in the treatment of marijuana policies that differ between studies and that may influence findings. Measurement issues aside, when specific policy features are accounted for, they are often specified in models differently. Variables representing specific policy features may be included with indicators of MML enactment or on their own, they may be estimated as a group or individually, and studies may or may not omit non-MML states from these analyses. These decisions change the nature of contrasts that are drawn, and they are often not clearly articulated. In addition, each approach divides states into groups in a certain way, and variability in the sample and group sizes that result are often not discussed.

A related issue that will become more important with time is how MML and NMML policies are treated with respect to each other in a given study. In MML studies, common strategies include omitting NMML states, or omitting years of outcome data in which NMML has occurred, or including separate indicators of NMML if data are recent enough. Studies of NMML differ in how comparison groups are composed, particularly with regard to whether non-MML states are included in the comparison group, and which MML states are included. All of these variations may affect results and add to the difficulty of drawing conclusions across studies. It is particularly informative when studies consider multiple specifications and relate findings to other studies that have used those specifications.

The diversity in approaches to examining effects of legalization is a by-product of the profusion of research on the topic. This analysis of challenges and limitations of the current research is intended to inform future studies on the topic. The body of literature on effects of both MML and NMML is rapidly evolving and conclusions can be expected to change and clarify with time.

## References

Abouk, R., & Adams, S. (2018). Examining the relationship between medical cannabis laws and cardiovascular deaths in the US. *International Journal of Drug Policy*, *53*, 1–7.

<https://doi.org/10.1016/j.drugpo.2017.11.022>

Alcocer, J. J. (2020). Exploring the effect of Colorado's recreational marijuana policy on opioid overdose rates. *Public Health*, *185*, 8–14. <https://doi.org/10.1016/j.puhe.2020.04.007>

Alley, Z. M., Kerr, D. C. R., & Bae, H. (2020). Trends in college students' alcohol, nicotine, prescription opioid and other drug use after recreational marijuana legalization: 2008–2018. *Addictive Behaviors*, *102*, 106212. <https://doi.org/10.1016/j.addbeh.2019.106212>

Anderson, D. M., Hansen, B., & Rees, D. I. (2013). Medical Marijuana Laws, Traffic Fatalities, and Alcohol Consumption. *The Journal of Law and Economics*, *56*(2), 333–369. <https://doi.org/10.1086/668812>

Anderson, D. M., Hansen, B., & Rees, D. I. (2015). Medical Marijuana Laws and Teen Marijuana Use. *American Law and Economics Review*, *17*(2), 495–528. <https://doi.org/10.1093/aler/ahv002>

- Anderson, D. M., Rees, D. I., & Sabia, J. J. (2014). Medical Marijuana Laws and Suicides by Gender and Age. *American Journal of Public Health*, 104(12), 2369–2376. <https://doi.org/10.2105/AJPH.2013.301612>
- Anderson, D. M., Rees, D. I., & Tekin, E. (2018). Medical marijuana laws and workplace fatalities in the United States. *International Journal of Drug Policy*, 60, 33–39. <https://doi.org/10.1016/j.drugpo.2018.07.008>
- Andreyeva, E., & Ukert, B. (2019). The Impact of Medical Marijuana Laws and Dispensaries on Self-Reported Health. *Forum for Health Economics and Policy*, 22(2). <https://doi.org/10.1515/fhep-2019-0002>
- Auriol, E., Mesnard, A., & Perrault, T. (2019). *Defeating Crime? An Economic Analysis of Cannabis Legalization Policies*. 58.
- Aydelotte, J. D., Brown, L. H., Luftman, K. M., Mardock, A. L., Teixeira, P. G. R., Coopwood, B., & Brown, C. V. R. (2017). Crash Fatality Rates After Recreational Marijuana Legalization in Washington and Colorado. *American Journal of Public Health*, 107(8), 1329–1331. <https://doi.org/10.2105/AJPH.2017.303848>
- Aydelotte, J. D., Mardock, A. L., Mancheski, C. A., Quamar, S. M., Teixeira, P. G., Brown, C. V. R., & Brown, L. H. (2019). Fatal crashes in the 5 years after recreational marijuana legalization in Colorado and Washington. *Accident Analysis & Prevention*, 132, 105284. <https://doi.org/10.1016/j.aap.2019.105284>
- Bachhuber, M. A., Saloner, B., Cunningham, C. O., & Barry, C. L. (2014). Medical Cannabis Laws and Opioid Analgesic Overdose Mortality in the United States, 1999-2010. *JAMA Internal Medicine*, 174(10), 1668. <https://doi.org/10.1001/jamainternmed.2014.4005>
- Bae, H., & Kerr, D. C. R. (2020). Marijuana use trends among college students in states with and without legalization of recreational use: Initial and longer-term changes from 2008 to 2018. *Addiction (Abingdon, England)*, 115(6), 1115–1124. <https://doi.org/10.1111/add.14939>
- Baggio, M., Chong, A., & Kwon, S. (2020). Marijuana and alcohol: Evidence using border analysis and retail sales data. *Canadian Journal of Economics/Revue Canadienne d'économique*, 53(2), 563–591. <https://doi.org/10.1111/caje.12437>
- Bahji, A., & Stephenson, C. (2019). International Perspectives on the Implications of Cannabis Legalization: A Systematic Review & Thematic Analysis. *International Journal of Environmental Research and Public Health*, 16(17), 3095. <https://doi.org/10.3390/ijerph16173095>
- Barry, R. A., & Glantz, S. A. (2018). Marijuana Regulatory Frameworks in Four US States: An Analysis Against a Public Health Standard. *American Journal of Public Health*, 108(7), 914–923. <https://doi.org/10.2105/AJPH.2018.304401>
- Bartos, B. J., Kubrin, C. E., Newark, C., & McCleary, R. (2019). Medical Marijuana Laws and Suicide. *Archives of Suicide Research*, 1–14. <https://doi.org/10.1080/13811118.2019.1612803>
- Bestrashniy, J., & Winters, K. C. (2015). Variability in Medical Marijuana Laws in the United States. *Psychology of Addictive Behaviors : Journal of the Society of Psychologists in Addictive Behaviors*, 29(3), 639–642. <https://doi.org/10.1037/adb0000111>

- Bradford, A. C., & Bradford, W. D. (2016). Medical Marijuana Laws Reduce Prescription Medication Use In Medicare Part D. *Health Affairs*, 35(7), 1230–1236. <https://doi.org/10.1377/hlthaff.2015.1661>
- Bradford, A. C., & Bradford, W. D. (2017). Medical Marijuana Laws May Be Associated With A Decline In The Number Of Prescriptions For Medicaid Enrollees. *Health Affairs*, 36(5), 945–951. <https://doi.org/10.1377/hlthaff.2016.1135>
- Bradford, A. C., Bradford, W. D., Abraham, A., & Adams, G. B. (2018). Association Between US State Medical Cannabis Laws and Opioid Prescribing in the Medicare Part D Population. *JAMA Internal Medicine*, 178(5), 667–672. <https://doi.org/10.1001/jamainternmed.2018.0266>
- Cambron, C., Guttmanova, K., & Fleming, C. B. (2017). State and National Contexts in Evaluating Cannabis Laws: A Case Study of Washington State. *Journal of Drug Issues*, 47(1), 74–90. <https://doi.org/10.1177/0022042616678607>
- Carliner, H., Brown, Q. L., Sarvet, A. L., & Hasin, D. S. (2017). Cannabis use, attitudes, and legal status in the U.S.: A review. *Preventive Medicine*, 104, 13–23. <https://doi.org/10.1016/j.ypmed.2017.07.008>
- Carnevale, J. T., Kagan, R., Murphy, P. J., & Esrick, J. (2017). A practical framework for regulating for-profit recreational marijuana in US States: Lessons from Colorado and Washington. *International Journal of Drug Policy*, 42, 71–85. <https://doi.org/10.1016/j.drugpo.2017.03.001>
- Caulkins, J. P. (2019). Legalising Drugs Prudently: The Importance of Incentives and Values. *Journal of Illicit Economies and Development*, 1(3), 279–287. <https://doi.org/10.31389/jied.44>
- Caulkins, J. P., Kilmer, B., Kleiman, M. A. R., MacCoun, R. J., Midgette, G., Oglesby, P., Pacula, R. L., & Reuter, P. (2015). *Considering Marijuana Legalization: Insights for Vermont and Other Jurisdictions* [Product Page]. RAND Corporation. [https://www.rand.org/pubs/research\\_reports/RR864.html](https://www.rand.org/pubs/research_reports/RR864.html)
- Caulkins, J. P., Pardo, B., & Kilmer, B. (2020). Intensity of cannabis use: Findings from three online surveys. *International Journal of Drug Policy*, 79, 102740. <https://doi.org/10.1016/j.drugpo.2020.102740>
- Cerdá, M., Mauro, C., Hamilton, A., Levy, N. S., Santaella-Tenorio, J., Hasin, D., Wall, M. M., Keyes, K. M., & Martins, S. S. (2020). Association Between Recreational Marijuana Legalization in the United States and Changes in Marijuana Use and Cannabis Use Disorder From 2008 to 2016. *JAMA Psychiatry*, 77(2), 165–171. <https://doi.org/10.1001/jamapsychiatry.2019.3254>
- Cerdá, M., Sarvet, A. L., Wall, M., Feng, T., Keyes, K. M., Galea, S., & Hasin, D. S. (2018). Medical marijuana laws and adolescent use of marijuana and other substances: Alcohol, cigarettes, prescription drugs, and other illicit drugs. *Drug and Alcohol Dependence*, 183, 62–68. <https://doi.org/10.1016/j.drugalcdep.2017.10.021>
- Cerdá, M., Wall, M., Feng, T., Keyes, K. M., Sarvet, A., Schulenberg, J., O'Malley, P. M., Pacula, R. L., Galea, S., & Hasin, D. S. (2017). Association of State Recreational Marijuana Laws With Adolescent Marijuana Use. *JAMA Pediatrics*, 171(2), 142–149. <https://doi.org/10.1001/jamapediatrics.2016.3624>

- Chan, N. W., Burkhardt, J., & Flyr, M. (2020). The effects of recreational marijuana legalization and dispensing on opioid mortality. *Economic Inquiry*, 58(2), 589–606. <https://doi.org/10.1111/ecin.12819>
- Chapman, S. A., Spetz, J., Lin, J., Chan, K., & Schmidt, L. A. (2016). Capturing Heterogeneity in Medical Marijuana Policies: A Taxonomy of Regulatory Regimes Across the United States. *Substance Use & Misuse*, 51(9), 1174–1184. <https://doi.org/10.3109/10826084.2016.1160932>
- Chihuri, S., & Li, G. (2019). State marijuana laws and opioid overdose mortality. *Injury Epidemiology*, 6(1), 38. <https://doi.org/10.1186/s40621-019-0213-z>
- Choi, A., Dave, D., & Sabia, J. J. (2019). Smoke Gets in Your Eyes: Medical Marijuana Laws and Tobacco Cigarette Use. *American Journal of Health Economics*, 5(3), 303–333. [https://doi.org/10.1162/ajhe\\_a\\_00121](https://doi.org/10.1162/ajhe_a_00121)
- Choo, E. K., Benz, M., Zaller, N., Warren, O., Rising, K. L., & McConnell, K. J. (2014). The Impact of State Medical Marijuana Legislation on Adolescent Marijuana Use. *Journal of Adolescent Health*, 55(2), 160–166. <https://doi.org/10.1016/j.jadohealth.2014.02.018>
- Choo, E. K., & Emery, S. L. (2017). Clearing the haze: The complexities and challenges of research on state marijuana laws. *Annals of the New York Academy of Sciences*, 1394(1), 55–73. <https://doi.org/10.1111/nyas.13093>
- Chu, Y.-W. L. (2014). The effects of medical marijuana laws on illegal marijuana use. *Journal of Health Economics*, 38, 43–61. <https://doi.org/10.1016/j.jhealeco.2014.07.003>
- Chu, Y.-W. L. (2015). Do Medical Marijuana Laws Increase Hard-Drug Use? *The Journal of Law and Economics*, 58(2), 481–517. <https://doi.org/10.1086/684043>
- Chu, Y.-W. L. (2018). Commentary on Sarvet et al. (2018): What do we still need to know about the impacts of medical marijuana laws in the United States? *Addiction*, 113(6), 1017–1018. <https://doi.org/10.1111/add.14167>
- Coley, R. L., Hawkins, S. S., Ghiani, M., Kruzik, C., & Baum, C. F. (2019). A quasi-experimental evaluation of marijuana policies and youth marijuana use. *The American Journal of Drug and Alcohol Abuse*, 45(3), 292–303. <https://doi.org/10.1080/00952990.2018.1559847>
- Conyers, G., & Ayres, I. (2020). A lottery test of the effect of dispensaries on emergency room visits in Arizona. *Health Economics*, 29(8), 854–864. <https://doi.org/10.1002/hec.4013>
- Cook, A. C., Leung, G., & Smith, R. A. (2020). Marijuana Decriminalization, Medical Marijuana Laws, and Fatal Traffic Crashes in US Cities, 2010–2017. *American Journal of Public Health*, 110(3), 363–369. <https://doi.org/10.2105/AJPH.2019.305484>
- D’Amico, E. J., Tucker, J. S., Pedersen, E. R., & Shih, R. A. (2017). Understanding Rates of Marijuana Use and Consequences Among Adolescents in a Changing Legal Landscape. *Current Addiction Reports*, 4(4), 343–349. <https://doi.org/10.1007/s40429-017-0170-y>
- Darnell, A. J. (2019). *Measuring Youth Cannabis Use in Washington State*. <http://www.wsipp.wa.gov/Publications?reportId=625>
- Darnell, A. J., Bitney, K., & WSIPP. (2017). I-502 evaluation and benefit-cost analysis: Second required report. *Olympia: Washington State Institute for Public Policy*.

- Darnell, A. J., Hirsch, M., & Wanner, P. (2019). *Suppressing illicit cannabis markets after state marijuana legalization*. [http://www.wsipp.wa.gov/ReportFile/1708/Wsipp\\_Suppressing-Illicit-Cannabis-Markets-After-State-Marijuana-Legalization\\_Report.pdf](http://www.wsipp.wa.gov/ReportFile/1708/Wsipp_Suppressing-Illicit-Cannabis-Markets-After-State-Marijuana-Legalization_Report.pdf)
- Dilley, J. A., Hitchcock, L., McGroder, N., Greto, L. A., & Richardson, S. M. (2017). Community-level policy responses to state marijuana legalization in Washington State. *International Journal of Drug Policy*, 42, 102–108. <https://doi.org/10.1016/j.drugpo.2017.02.010>
- Dilley, J. A., Richardson, S. M., Kilmer, B., Pacula, R. L., Segawa, M. B., & Cerdá, M. (2019). Prevalence of Cannabis Use in Youths After Legalization in Washington State. *JAMA Pediatrics*, 173(2), 192. <https://doi.org/10.1001/jamapediatrics.2018.4458>
- Dutra, L. M., Parish, W. J., Gourdet, C. K., Wylie, S. A., & Wiley, J. L. (2018). Medical cannabis legalization and state-level prevalence of serious mental illness in the National Survey on Drug Use and Health (NSDUH) 2008–2015. *International Review of Psychiatry*, 30(3), 203–215. <https://doi.org/10.1080/09540261.2018.1467385>
- Fairman, B. J. (2016). Trends in registered medical marijuana participation across 13 US states and District of Columbia. *Drug and Alcohol Dependence*, 159, 72–79. <https://doi.org/10.1016/j.drugalcdep.2015.11.015>
- Fink, D. S., Stohl, M., Sarvet, A. L., Cerda, M., Keyes, K. M., & Hasin, D. (2020). Medical Marijuana Laws and Driving Under the Influence of Marijuana and Alcohol. *Addiction*, add.15031. <https://doi.org/10.1111/add.15031>
- Geissler, K. H., Kaizer, K., Johnson, J. K., Doonan, S. M., & Whitehill, J. M. (2020). Evaluation of Availability of Survey Data About Cannabis Use. *JAMA Network Open*, 3(6), e206039–e206039. <https://doi.org/10.1001/jamanetworkopen.2020.6039>
- Ghimire, K. M., & Maclean, J. C. (2020). Medical marijuana and workers' compensation claiming. *Health Economics*, 29(4), 419–434. <https://doi.org/10.1002/hec.3992>
- Gorman, D. M., & Huber, C. J. (2007). Do medical cannabis laws encourage cannabis use? *International Journal of Drug Policy*, 18(3), 160–167. <https://doi.org/10.1016/j.drugpo.2006.10.001>
- Grucza, R. A., Hur, M., Agrawal, A., Krauss, M. J., Plunk, A. D., Cavazos-Rehg, P. A., Chaloupka, F. J., & Bierut, L. J. (2015). A reexamination of medical marijuana policies in relation to suicide risk. *Drug and Alcohol Dependence*, 152, 68–72. <https://doi.org/10.1016/j.drugalcdep.2015.04.014>
- Guttmanova, K., Jones, A. A., Johnson, J. K., Oesterle, S., Johnson, R. M., & Martins, S. S. (2019). Using Existing Data to Advance Knowledge About Adolescent and Emerging Adult Marijuana Use in the Context of Changes in Marijuana Policies. *Prevention Science*, 20(2), 291–299. <https://doi.org/10.1007/s11121-019-00991-w>
- Guttmanova, K., Lee, C. M., Kilmer, J. R., Fleming, C. B., Rhew, I. C., Kosterman, R., & Larimer, M. E. (2016). Impacts of Changing Marijuana Policies on Alcohol Use in the United States. *Alcoholism: Clinical and Experimental Research*, 40(1), 33–46. <https://doi.org/10.1111/acer.12942>
- Hall, W., & Lynskey, M. (2020). Assessing the public health impacts of legalizing recreational cannabis use: The US experience. *World Psychiatry*, 19(2), 179–186. <https://doi.org/10.1002/wps.20735>

- Hall, W., Stjepanović, D., Caulkins, J. P., Lynskey, M., Leung, J., Campbell, G., & Degenhardt, L. (2019). Public health implications of legalising the production and sale of cannabis for medicinal and recreational use. *The Lancet*, 394(10208), 1580–1590. [https://doi.org/10.1016/S0140-6736\(19\)31789-1](https://doi.org/10.1016/S0140-6736(19)31789-1)
- Hammond, C. J., Chaney, A., Hendrickson, B., & Sharma, P. (2020). Cannabis use among U.S. adolescents in the era of marijuana legalization: A review of changing use patterns, comorbidity, and health correlates. *International Review of Psychiatry*, 32(3), 221–234. <https://doi.org/10.1080/09540261.2020.1713056>
- Hansen, B., Miller, K., & Weber, C. (2020). Early Evidence on Recreational Marijuana Legalization and Traffic Fatalities. *Economic Inquiry*, 58(2), 547–568. <https://doi.org/10.1111/ecin.12751>
- Harper, S., Strumpf, E. C., & Kaufman, J. S. (2012). Do Medical Marijuana Laws Increase Marijuana Use? Replication Study and Extension. *Annals of Epidemiology*, 22(3), 207–212. <https://doi.org/10.1016/j.annepidem.2011.12.002>
- Hasin, D. S., Sarvet, A. L., Cerdá, M., Keyes, K. M., Stohl, M., Galea, S., & Wall, M. M. (2017). US Adult Illicit Cannabis Use, Cannabis Use Disorder, and Medical Marijuana Laws: 1991–1992 to 2012–2013. *JAMA Psychiatry*, 74(6), 579–588. <https://doi.org/10.1001/jamapsychiatry.2017.0724>
- Hasin, D. S., Wall, M., Keyes, K. M., Cerdá, M., Schulenberg, J., O’Malley, P. M., Galea, S., Pacula, R. L., & Feng, T. (2015). Medical marijuana laws and adolescent marijuana use in the USA from 1991 to 2014: Results from annual, repeated cross-sectional surveys. *The Lancet Psychiatry*, 2(7), 601–608. [https://doi.org/10.1016/S2215-0366\(15\)00217-5](https://doi.org/10.1016/S2215-0366(15)00217-5)
- Hunt, P., Miles, J. N. V., & Boustead, A. (2013). *Understanding Patterns in Medical Marijuana Laws: A Latent Class and Transition Analysis*. 23.
- Johnson, J., Hodgkin, D., & Harris, S. K. (2017). The design of medical marijuana laws and adolescent use and heavy use of marijuana: Analysis of 45 states from 1991 to 2011. *Drug and Alcohol Dependence*, 170, 1–8. <https://doi.org/10.1016/j.drugalcdep.2016.10.028>
- Johnson, J., Johnson, R. M., Hodgkin, D., Jones, A. A., Matteucci, A. M., & Harris, S. K. (2018). Heterogeneity of state medical marijuana laws and adolescent recent use of alcohol and marijuana: Analysis of 45 states, 1991–2011. *Substance Abuse*, 39(2), 247–254. <https://doi.org/10.1080/08897077.2017.1389801>
- Kamin, S. (2017). Marijuana Regulation in the United States. In E. U. Savona, M. A. R. Kleiman, & F. Calderoni (Eds.), *Dual Markets* (pp. 105–119). Springer International Publishing. [https://doi.org/10.1007/978-3-319-65361-7\\_7](https://doi.org/10.1007/978-3-319-65361-7_7)
- Khatapoush, S., & Hallfors, D. (2004). “Sending the Wrong Message”: Did Medical Marijuana Legalization in California Change Attitudes about and use of Marijuana? *Journal of Drug Issues*, 34(4), 751–770. <https://doi.org/10.1177/002204260403400402>
- Kilmer, B. (2019). How will cannabis legalization affect health, safety, and social equity outcomes? It largely depends on the 14 Ps. *The American Journal of Drug and Alcohol Abuse*, 45(6), 664–672. <https://doi.org/10.1080/00952990.2019.1611841>

- Kilmer, B., & Pacula, R. L. (2017). Understanding and learning from the diversification of cannabis supply laws: Learning from diversification of cannabis laws. *Addiction*, *112*(7), 1128–1135. <https://doi.org/10.1111/add.13623>
- Kim, J. H., Santaella-Tenorio, J., Mauro, C., Wrobel, J., Cerdà, M., Keyes, K. M., Hasin, D., Martins, S. S., & Li, G. (2016). State Medical Marijuana Laws and the Prevalence of Opioids Detected Among Fatally Injured Drivers. *American Journal of Public Health*, *106*(11), 2032–2037. <https://doi.org/10.2105/AJPH.2016.303426>
- Klieger, S. B., Gutman, A., Allen, L., Pacula, R. L., Ibrahim, J. K., & Burris, S. (2017). Mapping medical marijuana: State laws regulating patients, product safety, supply chains and dispensaries, 2017: State medical marijuana laws. *Addiction*, *112*(12), 2206–2216. <https://doi.org/10.1111/add.13910>
- Klitzner, M. D., Thomas, S., Schuler, J., Hilton, M., & Mosher, J. (2017). The New Cannabis Policy Taxonomy on APIS: Making Sense of the Cannabis Policy Universe. *The Journal of Primary Prevention*, *38*(3), 295–314. <https://doi.org/10.1007/s10935-017-0475-6>
- Ladegard, K., Thurstone, C., & Rylander, M. (2020). Marijuana Legalization and Youth. *Pediatrics*, *145*(Supplement 2), S165–S174. <https://doi.org/10.1542/peds.2019-2056D>
- Lancione, S., Wade, K., Windle, S. B., Filion, K. B., Thombs, B. D., & Eisenberg, M. J. (2020). Non-medical cannabis in North America: An overview of regulatory approaches. *Public Health*, *178*, 7–14. <https://doi.org/10.1016/j.puhe.2019.08.018>
- Lane, T. J., & Hall, W. (2019). Traffic fatalities within US states that have legalized recreational cannabis sales and their neighbours. *Addiction*, *114*(5), 847–856. <https://doi.org/10.1111/add.14536>
- Leung, G. (2019). *The Impact of Medical Marijuana Laws on College Students' Mental Health, Drugs Substitutability, and Academic Outcomes*. 71.
- Leung, J., Chiu, C. Y. V., Stjepanović, D., & Hall, W. (2018). Has the Legalisation of Medical and Recreational Cannabis Use in the USA Affected the Prevalence of Cannabis Use and Cannabis Use Disorders? *Current Addiction Reports*, *5*(4), 403–417. <https://doi.org/10.1007/s40429-018-0224-9>
- Leung, J., Chiu, V., Chan, G. C. K., Stjepanović, D., & Hall, W. D. (2019). What Have Been the Public Health Impacts of Cannabis Legalisation in the USA? A Review of Evidence on Adverse and Beneficial Effects. *Current Addiction Reports*, *6*(4), 418–428. <https://doi.org/10.1007/s40429-019-00291-x>
- Liang, D., Bao, Y., Wallace, M., Grant, I., & Shi, Y. (2018). Medical cannabis legalization and opioid prescriptions: Evidence on US Medicaid enrollees during 1993–2014. *Addiction*, *113*(11), 2060–2070. <https://doi.org/10.1111/add.14382>
- Livingston, M. D., Barnett, T. E., Delcher, C., & Wagenaar, A. C. (2017). Recreational Cannabis Legalization and Opioid-Related Deaths in Colorado, 2000–2015. *American Journal of Public Health*, *107*(11), 1827–1829. <https://doi.org/10.2105/AJPH.2017.304059>
- Lynne-Landsman, S. D., Livingston, M. D., & Wagenaar, A. C. (2013). Effects of State Medical Marijuana Laws on Adolescent Marijuana Use. *American Journal of Public Health*, *103*(8), 1500–1506. <https://doi.org/10.2105/AJPH.2012.301117>

- Martins, S. S., Mauro, C. M., Santaella-Tenorio, J., Kim, J. H., Cerda, M., Keyes, K. M., Hasin, D. S., Galea, S., & Wall, M. (2016). State-level medical marijuana laws, marijuana use and perceived availability of marijuana among the general U.S. population. *Drug and Alcohol Dependence, 169*, 26–32. <https://doi.org/10.1016/j.drugalcdep.2016.10.004>
- Masten, S. V., & Guenzburger, G. V. (2014). Changes in driver cannabinoid prevalence in 12 U.S. states after implementing medical marijuana laws. *Journal of Safety Research, 50*, 35–52. <https://doi.org/10.1016/j.jsr.2014.03.009>
- Mauro, C. M., Newswanger, P., Santaella-Tenorio, J., Mauro, P. M., Carliner, H., & Martins, S. S. (2019). Impact of Medical Marijuana Laws on State-Level Marijuana Use by Age and Gender, 2004–2013. *Prevention Science, 20*(2), 205–214. <https://doi.org/10.1007/s11121-017-0848-3>
- McMichael, B. J., Van Horn, R. L., & Viscusi, W. K. (2020). The impact of cannabis access laws on opioid prescribing. *Journal of Health Economics, 69*, 102273. <https://doi.org/10.1016/j.jhealeco.2019.102273>
- Meinhofer, A., Witman, A., Murphy, S. M., & Bao, Y. (2019). Medical marijuana laws are associated with increases in substance use treatment admissions by pregnant women. *Addiction, 114*(9), 1593–1601. <https://doi.org/10.1111/add.14661>
- Melchior, M., Nakamura, A., Bolze, C., Hausfater, F., Khoury, F. E., Mary-Krause, M., & Silva, M. A. D. (2019). Does liberalisation of cannabis policy influence levels of use in adolescents and young adults? A systematic review and meta-analysis. *BMJ Open, 9*(7), e025880. <https://doi.org/10.1136/bmjopen-2018-025880>
- Midgette, G., & Reuter, P. (2020). Has Cannabis Use Among Youth Increased After Changes in Its Legal Status? A Commentary on Use of Monitoring the Future for Analyses of Changes in State Cannabis Laws. *Prevention Science, 21*(1), 137–145. <https://doi.org/10.1007/s11121-019-01068-4>
- National Academies of Sciences, Engineering, and Medicine, Committee on the Health Effects of Marijuana. (2017). *The Health Effects of Cannabis and Cannabinoids: The Current State of Evidence and Recommendations for Research*. National Academies Press. <https://doi.org/10.17226/24625>
- Network for Public Health Law. (2019). *Medical Marijuana Programs*. Network for Public Health Law. <https://www.networkforphl.org/resources/medical-marijuana-programs/>
- Nicholas, L. H., & Maclean, J. C. (2019). The Effect of Medical Marijuana Laws on the Health and Labor Supply of Older Adults: Evidence from the Health and Retirement Study. *Journal of Policy Analysis and Management, 38*(2), 455–480. <https://doi.org/10.1002/pam.22122>
- Notrica, D. M., Sayrs, L. W., Krishna, N., Rowe, D., Jaroszewski, D. E., & McMahon, L. E. (2020). The impact of state laws on motor vehicle fatality rates, 1999–2015: *Journal of Trauma and Acute Care Surgery, 88*(6), 760–769. <https://doi.org/10.1097/TA.0000000000002686>
- Orenstein, D. G., & Glantz, S. A. (2018). Regulating Cannabis Manufacturing: Applying Public Health Best Practices from Tobacco Control. *Journal of Psychoactive Drugs, 50*(1), 19–32. <https://doi.org/10.1080/02791072.2017.1422816>

- Ozlu, P. (2017). The effects of medical marijuana laws on utilization of prescribed opioids and other prescription drugs. *Available at SSRN 3056791*.
- Pacula, R. L., Chriqui, J. F., Reichmann, D. A., & Terry-McElrath, Y. M. (2002). State Medical Marijuana Laws: Understanding the Laws and Their Limitations. *Journal of Public Health Policy, 23*(4), 413. <https://doi.org/10.2307/3343240>
- Pacula, R. L., Kilmer, B., Wagenaar, A. C., Chaloupka, F. J., & Caulkins, J. P. (2014). Developing Public Health Regulations for Marijuana: Lessons From Alcohol and Tobacco. *American Journal of Public Health, 104*(6), 1021–1028. <https://doi.org/10.2105/AJPH.2013.301766>
- Pacula, R. L., Powell, D., Heaton, P., & Sevigny, E. L. (2015). Assessing the Effects of Medical Marijuana Laws on Marijuana Use: The Devil is in the Details. *Journal of Policy Analysis and Management, 34*(1), 7–31. <https://doi.org/10.1002/pam.21804>
- Pacula, R. L., & Smart, R. (2017). Medical Marijuana and Marijuana Legalization. *Annual Review of Clinical Psychology, 13*(1), 397–419. <https://doi.org/10.1146/annurev-clinpsy-032816-045128>
- Phillips, E., & Gazmararian, J. (2017). Implications of prescription drug monitoring and medical cannabis legislation on opioid overdose mortality. *Journal of Opioid Management, 13*(4), 229–239. <https://doi.org/10.5055/jom.2017.0391>
- Powell, D., Pacula, R. L., & Jacobson, M. (2018). Do medical marijuana laws reduce addictions and deaths related to pain killers? *Journal of Health Economics, 58*, 29–42. <https://doi.org/10.1016/j.jhealeco.2017.12.007>
- Rogeberg, O. (2018). Prohibition, regulation or laissez faire: The policy trade-offs of cannabis policy. *International Journal of Drug Policy, 56*, 153–161. <https://doi.org/10.1016/j.drugpo.2018.03.024>
- Sabia, J. J., Swigert, J., & Young, T. (2017). The Effect of Medical Marijuana Laws on Body Weight. *Health Economics, 26*(1), 6–34. <https://doi.org/10.1002/hec.3267>
- Santaella-Tenorio, J., Mauro, C. M., Wall, M. M., Kim, J. H., Cerdá, M., Keyes, K. M., Hasin, D. S., Galea, S., & Martins, S. S. (2017). US Traffic Fatalities, 1985-2014, and Their Relationship to Medical Marijuana Laws. *American Journal of Public Health, 107*(2), 336–342. <https://doi.org/10.2105/AJPH.2016.303577>
- Sarvet, A. L., Wall, M. M., Fink, D. S., Greene, E., Le, A., Boustead, A. E., Pacula, R. L., Keyes, K. M., Cerdá, M., Galea, S., & Hasin, D. S. (2018). Medical marijuana laws and adolescent marijuana use in the United States: A systematic review and meta-analysis. *Addiction, 113*(6), 1003–1016. <https://doi.org/10.1111/add.14136>
- Schmidt, L. A., Jacobs, L. M., Vlahov, D., & Spetz, J. (2019). Impacts of Medical Marijuana Laws on Young Americans Across the Developmental Spectrum. *Maternal and Child Health Journal, 23*(4), 486–495. <https://doi.org/10.1007/s10995-018-2656-1>
- Schuermeyer, J., Salomonsen-Sautel, S., Price, R. K., Balan, S., Thurstone, C., Min, S.-J., & Sakai, J. T. (2014). Temporal trends in marijuana attitudes, availability and use in Colorado compared to non-medical marijuana states: 2003–11. *Drug and Alcohol Dependence, 140*, 145–155. <https://doi.org/10.1016/j.drugalcdep.2014.04.016>

- Segura, L. E., Mauro, C. M., Levy, N. S., Khaulil, N., Philbin, M. M., Mauro, P. M., & Martins, S. S. (2019). Association of US Medical Marijuana Laws With Nonmedical Prescription Opioid Use and Prescription Opioid Use Disorder. *JAMA Network Open*, 2(7), e197216–e197216. <https://doi.org/10.1001/jamanetworkopen.2019.7216>
- Sevigny, E. L. (2018). The effects of medical marijuana laws on cannabis-involved driving. *Accident Analysis & Prevention*, 118, 57–65. <https://doi.org/10.1016/j.aap.2018.05.023>
- Shi, Y. (2017). Medical marijuana policies and hospitalizations related to marijuana and opioid pain reliever. *Drug and Alcohol Dependence*, 173, 144–150. <https://doi.org/10.1016/j.drugalcdep.2017.01.006>
- Shi, Y., & Liang, D. (2020). The association between recreational cannabis commercialization and cannabis exposures reported to the US National Poison Data System. *Addiction*, add.15019. <https://doi.org/10.1111/add.15019>
- Shi, Y., Liang, D., Bao, Y., An, R., Wallace, M. S., & Grant, I. (2019). Recreational marijuana legalization and prescription opioids received by Medicaid enrollees. *Drug and Alcohol Dependence*, 194, 13–19. <https://doi.org/10.1016/j.drugalcdep.2018.09.016>
- Shover, C. L., Davis, C. S., Gordon, S. C., & Humphreys, K. (2019). Association between medical cannabis laws and opioid overdose mortality has reversed over time. *Proceedings of the National Academy of Sciences*, 116(26), 12624–12626. <https://doi.org/10.1073/pnas.1903434116>
- Shover, C. L., & Humphreys, K. (2019). Six policy lessons relevant to cannabis legalization. *The American Journal of Drug and Alcohol Abuse*, 45(6), 698–706. <https://doi.org/10.1080/00952990.2019.1569669>
- Smart, R. (2016). *Essays on the Effects of Medical Marijuana Laws* [UCLA]. <https://escholarship.org/uc/item/7842d9b4>
- Smart, R., & Pacula, R. L. (2019). Early evidence of the impact of cannabis legalization on cannabis use, cannabis use disorder, and the use of other substances: Findings from state policy evaluations. *The American Journal of Drug and Alcohol Abuse*, 45(6), 644–663. <https://doi.org/10.1080/00952990.2019.1669626>
- Stolzenberg, L., D'Alessio, S. J., & Dariano, D. (2016). The effect of medical cannabis laws on juvenile cannabis use. *International Journal of Drug Policy*, 27, 82–88. <https://doi.org/10.1016/j.drugpo.2015.05.018>
- Transform Drug Policy Foundation. (2016). *How to Regulate Cannabis: A Practical Guide*. <https://transformdrugs.org/product/how-to-regulate-cannabis-a-practical-guide/>
- Ullman, D. F. (2017). The Effect of Medical Marijuana on Sickness Absence. *Health Economics*, 26(10), 1322–1327. <https://doi.org/10.1002/hec.3390>
- Unlu, A., Tammi, T., & Hakkarainen, P. (2020). *Drug Decriminalization Policy: Literature Review: Models, Implementation and Outcomes*. THL. <http://www.julkari.fi/handle/10024/140116>

- Veligati, S., Howdeshell, S., Beeler-Stinn, S., Lingam, D., Allen, P. C., Chen, L.-S., & Grucza, R. A. (2020). Changes in alcohol and cigarette consumption in response to medical and recreational cannabis legalization: Evidence from U.S. state tax receipt data. *International Journal of Drug Policy*, 75, 102585. <https://doi.org/10.1016/j.drugpo.2019.10.011>
- Vyas, M. B., LeBaron, V. T., & Gilson, A. M. (2018). The use of cannabis in response to the opioid crisis: A review of the literature. *Nursing Outlook*, 66(1), 56–65. <https://doi.org/10.1016/j.outlook.2017.08.012>
- Wall, M. M., Mauro, C., Hasin, D. S., Keyes, K. M., Cerda, M., Martins, S. S., & Feng, T. (2016). Prevalence of marijuana use does not differentially increase among youth after states pass medical marijuana laws: Commentary on Stolzenberg et al. (2015) and reanalysis of US National Survey on Drug Use in Households data 2002–2011. *International Journal of Drug Policy*, 29, 9–13. <https://doi.org/10.1016/j.drugpo.2016.01.015>
- Wall, M. M., Poh, E., Cerdá, M., Keyes, K. M., Galea, S., & Hasin, D. S. (2011). Adolescent Marijuana Use from 2002 to 2008: Higher in States with Medical Marijuana Laws, Cause Still Unclear. *Annals of Epidemiology*, 21(9), 714–716. <https://doi.org/10.1016/j.annepidem.2011.06.001>
- Wang, P., Xiong, G., & Yang, J. (2019). Frontiers: Asymmetric Effects of Recreational Cannabis Legalization. *Marketing Science*, 38(6), 927–936. <https://doi.org/10.1287/mksc.2019.1176>
- Wen, H., & Hockenberry, J. M. (2018). Association of Medical and Adult-Use Marijuana Laws With Opioid Prescribing for Medicaid Enrollees. *JAMA Internal Medicine*, 178(5), 673–679. <https://doi.org/10.1001/jamainternmed.2018.1007>
- Wen, H., Hockenberry, J. M., & Cummings, J. R. (2015). The effect of medical marijuana laws on adolescent and adult use of marijuana, alcohol, and other substances. *Journal of Health Economics*, 42, 64–80. <https://doi.org/10.1016/j.jhealeco.2015.03.007>
- Wendelboe, A. M., Mathew, R., Chongsuwat, T., Rainwater, E., Wendelboe, M. A., Wickersham, E., & Chou, A. F. (2019). Is There Less Opioid Abuse in States Where Marijuana Has Been Decriminalized, Either for Medicinal or Recreational Use? A Clin-IQ. *Journal of Patient-Centered Research and Reviews*, 6(4), 267–273. <https://doi.org/10.17294/2330-0698.1704>
- Williams, A. R., Olfson, M., Kim, J. H., Martins, S. S., & Kleber, H. D. (2016). Older, Less Regulated Medical Marijuana Programs Have Much Greater Enrollment Rates Than Newer ‘Medicalized’ Programs. *Health Affairs (Project Hope)*, 35(3), 480–488. <https://doi.org/10.1377/hlthaff.2015.0528>
- Williams, A. R., Santaella-Tenorio, J., Mauro, C. M., Levin, F. R., & Martins, S. S. (2017). Loose regulation of medical marijuana programs associated with higher rates of adult marijuana use but not cannabis use disorder. *Addiction*, 112(11), 1985–1991. <https://doi.org/10.1111/add.13904>
- Zvonarev, V., Fatuki, T. A., & Tregubenko, P. (2019). The Public Health Concerns of Marijuana Legalization: An Overview of Current Trends. *Cureus*, 11(9). <https://doi.org/10.7759/cureus.5806>