



Using Existing Data to Advance Knowledge About Adolescent and Emerging Adult Marijuana Use in the Context of Changes in Marijuana Policies

Katarina Guttmannova¹ · Abenaa Acheampong Jones² · Julie K. Johnson³ · Sabrina Oesterle⁴ · Renee M. Johnson² · Silvia S. Martins⁵

Published online: 5 February 2019
© Society for Prevention Research 2019

Although marijuana remains an illegal substance under US federal law, there have been substantial and geographically widespread changes in state policy since 1996. As of October 2018, nine states and the District of Columbia had both medical marijuana laws (MMLs) and recreational marijuana laws (RMLs), and an additional 22 states had MMLs only (National Conference on State Legislatures [NCSL] 2018). In the November 2018 election, Utah and Missouri passed MMLs and Michigan—which already had an MML—passed an RML (Hauser 2018). Approximately two-thirds of US residents currently live in states with MMLs or RMLs, or both. Although the loosening of state-level restrictions on marijuana has been framed as beneficial for reducing the human, social, and economic costs associated with a criminal justice approach (Hawken et al. 2013), it has also spurred concerns about possible public health consequences, particularly for young people (Compton et al. 2017; Hasin 2018). These include potential increases in use of marijuana and other substances, substance use disorders, marijuana-related motor vehicle crashes, and educational and occupational underperformance (Hall 2018; Kilmer 2017; Pacula and Sevigny 2014; Volkow et al. 2014). So far, research has

yielded limited evidence for a post-MML increase in marijuana use and related outcomes among adolescents and emerging adults (i.e., those aged 18–25 years; Hasin 2018; Leung et al. 2018; Sarvet et al. 2018a) and, as outlined in the introduction to this special issue, the evaluation of the short-term effects of RMLs is only in its beginning (Johnson and Guttmannova 2019). Many questions still remain about the impact of marijuana policy change on adolescents and emerging adults, including whether findings of studies of RMLs will differ from those of MMLs.

Evaluation of marijuana policy is ongoing, and two national datasets, the National Survey on Drug Use and Health (NSDUH) and the Youth Risk Behavior Surveillance System (YRBS), are widely used for that research (Leung et al. 2018; Sarvet et al. 2018a; Hasin 2018). Both have repeated cross-sectional designs and methodologies and measurements that have been consistent across several decades. In this commentary, we describe the usefulness of NSDUH and YRBS for evaluation of the effects of changes in marijuana policy on adolescent and emerging adult substance use and marijuana-specific risk factors, and use recent examples of trend and quasi-experimental studies to highlight the unique strengths

✉ Katarina Guttmannova
kg27@u.washington.edu

Abenaa Acheampong Jones
aacheam1@jhu.edu

Julie K. Johnson
juliekatherinejohnson2@gmail.com

Sabrina Oesterle
soe@uw.edu

Renee M. Johnson
rjohnson@jhu.edu

Silvia S. Martins
ssm2183@cumc.columbia.edu

¹ Center for the Study of Health and Risk Behaviors, Dept. of Psychiatry and Behavioral Sciences, School of Medicine, University of Washington, Seattle, WA, USA

² Johns Hopkins Bloomberg School of Public Health, Dept. of Mental Health, Baltimore, MD, USA

³ Massachusetts Cannabis Control Commission, Massachusetts Department of Health, Boston, MA, USA

⁴ School of Social Work, University of Washington, Seattle, WA, USA

⁵ Dept. of Epidemiology, Columbia University Mailman School of Public Health, New York, NY, USA

of each. We also identify gaps in existing knowledge and offer recommendations for future data collection and research that uses these data sources.

National Survey on Drug Use and Health (NSDUH)

The National Survey on Drug Use and Health (NSDUH) is an initiative of the Substance Abuse and Mental Health Services Administration (SAMHSA). It is an annual household-based survey addressing substance use, substance use disorders, mental health problems, and use of treatment and services among civilian, non-institutionalized US household residents aged 12 and older. NSDUH uses a stratified multistage area probability sample to ensure that results are representative at the state and national levels. The survey has been ongoing since 1971 (originally under the name National Household Survey on Drug Abuse, NHSDA) and has included all 50 states and the District of Columbia since 1999 (Center for Behavioral Health Statistics and Quality [CBHSQ] 2017a, b). Both the original NHSDA and its contemporary successor, NSDUH, have undergone several major redesigns (CBHSQ 2014), so careful attention must be paid to analyses of drug use trends over time.

NSDUH has many design strengths and is the most frequently used dataset for research efforts that examine the impact of marijuana policy on change in behavior, norms, attitudes, and related risk factors among adolescents and emerging adults (Hasin 2018; Leung et al. 2018). In addition to being representative at the state and national levels, NSDUH includes several marijuana-related questions that have been assessed consistently over time. The survey includes questions on marijuana use, including lifetime use, age of first use, recency of use, frequency of use in the past 30 days and past 12 months, and symptoms of cannabis use disorder (CBHSQ 2017a, b; SAMHSA 2017). Annual samples include nearly 70,000 participants, and adolescents and emerging adults are oversampled. About 25% of respondents are 12 to 17 years old and another 25% are 18 to 25 years old; therefore, there is a sufficiently large number of youth to conduct stratified analyses to examine the differential impact of changes in marijuana use in association with MMLs and RMLs in specific states and for population subgroups, e.g., age, race/ethnicity, sex/gender, and rural vs. urban status. In the 2016 NSDUH, the prevalence of past-30-day marijuana use was 6.5% for 12- to 17-year-olds, 20.7% for 18- to 25-year-olds, and 7.2% for those aged 26 and older (SAMHSA 2017).

Recent studies using NSDUH data have examined changes in marijuana use among adolescents, emerging adults, and adults aged 26 or older in states with MMLs (e.g., Martins et al. 2016; Mauro et al. 2019; Wen et al. 2019; Wen et al. 2015). Martins et al. (2016) found post-MML increases in

marijuana use among those aged 26 and older, but not among 18- to 25-year-olds. Building on that study, Mauro et al.' (2019) article in this issue examined gender differences in the impact of MMLs on the prevalence of past-month use, daily use, and cannabis use disorder from 2004 to 2013. Although there were no post-MML differences in any of the outcomes among adolescents or emerging adults of either gender, there were statistically significant increases in the prevalence of past-month use and in daily use among those who reported past-year use for men and women past the developmental transition stage of emerging adulthood (i.e., age 26+). The field would benefit from additional studies that examine the impact of MMLs for other demographic subpopulations.

Because all RMLs allow for legal use only among those aged 21 and older (NCSSL 2018), the impact of these policies on use and marijuana-related perceptions may differ for youth below age 21 versus adults over age 21. Research by Wen et al. (2015) provides evidence of such a difference. They used NSDUH data and demonstrated post-MML increases in past-month marijuana use, daily or almost daily marijuana use, and marijuana abuse or dependence among those aged 21 or above, but not among 12- to 20-year-olds. Their conclusions about the relevance of legal age are strengthened as they estimated several age cut points—at ages 18, 25, and 30—but only the age 21 cut point produced statistically significant results. More work needs to investigate differential effects among emerging adults who can and cannot legally access marijuana, or studies should conduct sensitivity and robustness checks to evaluate different age cutoffs. This work is particularly important as evaluations of RMLs begin in earnest once more years of data post-RML are available.

NSDUH is particularly useful for prevention science research because it includes measures of several marijuana-specific risk factors, which are strong predictors of future drug use (e.g., Catalano et al. 2018). These include marijuana-related perceptions, including injunctive norms such as perceived wrongfulness of use and peer and parental disapproval, as well as the perceived harmfulness associated with use. Better understanding of trends in the prevalence of these risk factors before and after the changes in marijuana policy would offer important clues about the mechanisms involved in health risk behaviors (CBHSQ 2017a, b; SAMHSA 2017). In this special issue, Wen et al. (2019) compared several pre- and post-MML marijuana-related perceptions (i.e., perceptions about availability of marijuana, parental approval of marijuana use, wrongfulness of recreational marijuana use, and harmfulness of marijuana use) among adolescents (12- to 17-year-olds) and emerging adults (18- to 25-year-olds) but found only two statistically significant changes: an increase in low perceived harmfulness among emerging adults and a decrease in perceived parental approval among adolescents. Other perceptions did not change in either age group. We need to continue to monitor trends in marijuana-related perceptions, as well as

their association with changes in marijuana use, but should also expand examinations to a greater range of marijuana-related risk factors in multiple ecological domains, i.e., not only individuals' attitudes and norms, but also attitudes and norms in the family, among peers, and in the local community. Moreover, Schmidt et al. (2016) using NSDUH data demonstrated that there is a national trend of increasingly permissive views about marijuana among young people. This trend is independent of state-specific influences and has accelerated in the past decade, perhaps due to the growing number of states adopting MML and the potential digital media spillover of legalization debate across states. Therefore, future studies should examine the association between the secular trends and marijuana-related norms and perceptions of harm and the role of these factors as both predictors and consequences of state-level marijuana policies.

As highlighted in the introduction of this special issue (Johnson and Guttmanova 2019), it would also be important to examine changes in other substance use (especially alcohol, tobacco, and opioids) among adolescents and young adults as well as changes in alcohol-, tobacco-, and opioid-specific risk factors. NSDUH is a suitable data source for this work as it covers the use of all commonly used drugs and diverse margins of use, including substance use disorders, and also assesses a number of other substance-use-specific risk factors (Lipari et al. 2017). Because use of one substance is often associated with use of other drugs, marijuana legalization may have unanticipated consequences for alcohol, tobacco, and opioid use. On the other hand, trends in alcohol, tobacco, and opioid use may also impact marijuana use, interacting with marijuana policy changes. For example, a seemingly paradoxical discrepancy has been observed in recent years between a population-level rise in the prevalence of low perceived harm from marijuana use and a lack of a corresponding increase in the prevalence of marijuana use among adolescents (e.g., Fleming et al. 2016; Lipari et al. 2015; Miech et al. 2015; Sarvet et al. 2018b). Using eight waves of statewide survey data collected from high school students in Washington State between 2000 and 2014, Fleming et al. (2016) found no evidence that this divergence in trends was attributable to a weakening in the individual-level association between marijuana-specific risk factors (e.g., perceptions of harm) and marijuana use. Rather, substantial decreases in alcohol and cigarette use may have had spillover effects on marijuana use, dampening increases in marijuana use that might have otherwise occurred due to increases in marijuana-specific risk factors. Better understanding of the trends in risk factors for different substance use (e.g., perception of harm from using alcohol and tobacco vs. marijuana) and their associations with use of different substances could inform cannabis policy evaluation by making it possible to better account for

other sources of variation in substance use. It would also provide information about the potential counter-effects of substance use-related prevention and intervention efforts planned for or already on the ground.

National YRBS

The National Youth Risk Behavior Survey (YRBS) is a biennial, school-based survey that monitors health-related behaviors among high school students in the USA. It is an initiative of the Centers for Disease Control and Prevention (CDC) and has been ongoing since 1991; the primary purpose is to provide data for public health planning and evaluation (Brener et al. 2013; Kann et al. 2018). The National YRBS uses a three-stage, cluster sample design to obtain a nationally representative sample of 9th through 12th graders. It is designed to produce prevalence estimates that are nationally representative by sex, grade, race/ethnicity, grade by sex, and race/ethnicity by sex.

Survey administration and sampling are conducted at the state level through cooperative agreements with CDC. Although all 50 states are eligible to receive funding and support to conduct the YRBS, not all participate. Additionally, states that do not achieve a response rate of 60% are excluded from the national dataset; their data are not weighted but are available for state-specific analysis (Brener et al. 2013). In 2017, 39 states and the District of Columbia had weighted data and were included in the national data set; seven states had unweighted data; and four states did not participate (i.e., Minnesota, Oregon, Washington, and Wyoming; CDC 2018a). Although YRBS data have been used more frequently for trend studies (e.g., Johnson et al. 2015), the data are increasingly used in quasi-experimental studies evaluating the effect of marijuana policy (e.g., Johnson et al. 2018; Johnson et al. 2017).

Marijuana-related questions include frequency of lifetime and past-30-day marijuana use and age of first use (Kann et al. 2018). Unlike the NSDUH, the national YRBS survey does not include measures of marijuana-specific risk factors, such as perceived harmfulness. However, it does include questions related to unintentional injury, violence, sexual risk behaviors, substance use, unhealthy dietary behaviors, and physical activity. The fact that there are items on multiple health and risk behaviors positions YRBS data to be used to investigate marijuana use in association with other risk behaviors (e.g., sexual risk behaviors, El-Menshawi et al. 2018) and as part of a constellation of adolescent risk behaviors (e.g., Alexander et al. 2018).

Two of the primary strengths of YRBS data are large sample sizes and consistency of assessment across survey years (Brener et al. 2013; CDC 2016). The 2017 sample sizes in states with weighted data ranged from 1147 to 13,201, with a median of 2170 (Kann et al. 2018). These design factors

facilitate assessment of variation in changes in marijuana use over time, across population subgroups (e.g., race/ethnicity), and by grade level, for which there are well-established differences in marijuana use (CDC 2018b). In 2017, about one fourth of 9th graders (23.8%) reported any lifetime marijuana use, whereas 45.8% of 12th graders did (CDC 2018b). Thus, changes in the age of initiation and prevalence of lifetime use may be more relevant outcomes to monitor for 9th and 10th graders, whereas changes in the prevalence of past-month use and increases in the frequency of use may be more relevant for 11th and 12th graders, who—as indicated above—are more likely to have initiated use. Therefore, YRBS may be particularly useful for examining how marijuana-related policies affect adolescents at different stages of development, when different outcomes may be salient.

Although most questions on the national YRBS questionnaire remained the same across years, new questions are introduced based on emerging trends and public health priorities. For example, questions about driving after having used marijuana or riding in a car with someone who had recently used marijuana were added to the 2017 survey. These questions were modeled after similar questions on driving under the influence of alcohol (Kann et al. 2018). Adolescents have high crash rates in general, and increases in marijuana-related impaired driving represent a serious public health threat (Insurance Institute for Highway Safety 2017). Along with motor vehicle crash data from other sources, information about marijuana-related driving behaviors will enable public health professionals to respond to impaired driving among adolescents.

Participating YRBS states are permitted to include additional items on their questionnaires, in consultation with CDC. This enables states to examine topics important for their population, but that have not been selected for inclusion on the national survey. For example, as part of YRBS data collection in Colorado (known as the Healthy Kids Colorado Survey), questions on routes of marijuana administration such as vaping and edibles have been included since 2013 (Johnson et al. 2016). These supplemental items have been used to examine changes in modes of marijuana consumption over time (Tormohlen et al. *in press*).

The fact that data are not available for all states or for all years is an important limitation to using YRBS data for policy evaluation and is exacerbated by the fact that some states with no data or incomplete data are early adopters of MMLs or RMLs and would have been ideal for inclusion in evaluations of the long-term effects of marijuana policy change. Washington State and Oregon passed RMLs in 2012 and 2014, respectively, and unfortunately neither participates in the YRBS. However, both states have adolescent health surveillance programs that are similar to YRBS. The Oregon Health Authority (2018) conducts the Oregon Healthy Teens survey, which is administered every other year to Oregon

students in 8th and 11th grades. In addition to marijuana, alcohol, and tobacco use data and related risk factors (e.g., descriptive and injunctive norms about each substance, perception of harm but also exposure to marijuana product advertising, and peer-related susceptibility to marijuana use), Oregon Healthy Teens survey collects information on diverse topics related to adolescent health such as school climate, mental and emotional health, physical activity and nutrition, and health risk behaviors. Similarly, Washington State conducts the Healthy Youth Survey administered biennially to representative samples of public school students in grades 6, 8, 10, and 12 (e.g., Washington State Department of Health 2016; Johnson et al. 2019). Like Oregon Healthy Teens Survey, the Washington State Healthy Youth Survey contains a diverse range of marijuana use questions, related risk behaviors, and an extensive list of marijuana-specific risk factors (e.g., Fleming et al. 2016).

Strengths of the Oregon and Washington surveillance data are that they include questions that are comparable to items from the YRBS, but they also measure more prevention science-oriented topics (including marijuana-specific risk factors, which are not available in the national YRBS survey) and have larger state samples than YRBS or NSDUH. Although data from the Oregon Healthy Teens and the Washington State Healthy Youth Survey cannot be directly included into the YRBS or other datasets to conduct cross-state analyses, other options are available. These include data harmonization via techniques such as Integrative Data Analysis which was described in the introduction to this special issue (Johnson and Guttmannova 2019). Integrative Data Analysis would allow for simultaneous analysis of trends across multiple states, including early adopters of MMLs or RMLs, and their comparison to counterfactuals that have not experienced policy change or experienced it at different time points. Another option involves a meta-analytic summary of findings from individual studies or states; for an illustration of this technique involving multiple states, see Sarvet et al. (2018a). A meta-analytic approach might be useful in cases where the state-level MML or RML differs from other states, as is the case with Washington State (e.g., Cambron et al. 2017).

Data from state YRBS surveys and from state adolescent health surveillance programs not affiliated with YRBS were used in the first generation of studies evaluating changes in substance use during the period of implementation of RML separately in each state. Brooks-Russell et al. (2019) in Colorado using the Healthy Kids Colorado Survey and Johnson et al. (2019) in Washington State using the Washington State Healthy Youth Survey, both in this special issue, reported no significant increases in substance use among adolescents in these states. These findings were not entirely consistent with those from a study by Cerdá and colleagues (2017), which was based on data from the Monitoring the Future study of 8th, 10th, and 12th grade

students and relied on quasi-experimental methods. The study by Cerda used difference-in-difference models to compare the prevalence of past 30-day marijuana use before versus after RML passage among youth from WA and CO to states that had not passed RML and concluded that there were increases in prevalence of use among 8th and 10th graders in WA, but not among CO youth in any of the three grades. Subsequently, using the WA State Healthy Youth Survey, Dilley et al. (2018) employed models analogous to those used by Cerda and colleagues (2017) to re-assess changes in the prevalence of use in a state-based sample of Washington students. Findings offered no evidence of statistically significant increase in marijuana use for WA State youth and showed that Cerda and colleagues' (2017) conclusions were probably an artifact of the data source, which was not designed to be representative of WA State youth specifically but is usually employed in national or larger regional estimates. These studies highlight the utility of state adolescent health data and the potential importance of using such data for evaluating state-level marijuana policies and examining state-wide trends in substance use.

Limitations of NSDUH and YRBS Data

Both NSDUH and YRBS have a repeated cross-sectional design, which precludes examination of within-individual developmental change in substance use and teasing apart the dynamics of the causal relationship between risk factors and use. These associations are likely reciprocal, as has been demonstrated by Guttmanova and colleagues (Guttmanova et al. 2019), a study included in this special issue. A study of longitudinal data on a cohort of youth followed across adolescence showed that, although marijuana-specific risk factors predicted increases in marijuana use, particularly during the time of developmental transitions, more frequent marijuana use also predicted increases in marijuana-specific risk factors. Longitudinal work is important for the evaluation of marijuana policy impact because it allows for examination of the long-term effects of policy change. Studies that follow individuals over time can capture changes in normative developmental trajectories of marijuana and other substance use (e.g., Epstein et al. 2015; Terry-McElrath et al. 2017), such as whether there are changes in the timing of onset, escalation, and desistance from substance use; what factors predict these patterns; and whether their salience changes over the course of development. Such questions are crucial to address in the changing legal, normative, and social marijuana context.

The fact that YRBS is administered in the school setting has advantages and disadvantages. Youth may be more willing to disclose substance use in the school setting vs. home setting, which may in part explain why reports of substance use are slightly higher for YRBS relative to NSDUH

(SAMHSA 2012). However, YRBS excludes youth who are chronically truant and those who have dropped out of school; these youth are particularly vulnerable to substance use and related harms (Tice et al. 2017). Nevertheless, most adolescents (~95%) do attend school (McFarland et al. 2018), and YRBS data accurately represent school-attending youth populations. A related limitation of the NSDUH data is that it also does not include some marginalized populations, including persons who are homeless and not in shelters and those who are incarcerated.

Directions for Future Research

In addition to the suggestions for extensions of the cited studies that utilized NSDUH or YRBS data we have made throughout this commentary, we include several additional directions for future new research. The increased permissiveness of the social, normative, and legal context related to marijuana comes with dramatic changes in the availability and diversity of marijuana products and their advertising. The potency of marijuana has increased considerably over the course of the last two decades (ElSohly et al. 2016; Mehmedic et al. 2010), and new routes or modes of administration have become more commonplace (Johnson et al. 2016; Tormohlen et al. *in press*). These include dabbing, a new and dangerous method of extracting and inhaling a highly concentrated THC (e.g., Stogner and Miller 2015) and the proliferation of availability and popularity of mass-produced (vs. homemade) and highly potent edibles (e.g., Borodovsky and Budney 2017; Borodovsky et al. 2016, 2017). For example, studies should consider assessing the use of marijuana edibles, which may appeal to adolescents because they are easy to hide from parents and teachers, and they are packaged to mimic popular candies and sweets (Johnson et al. 2016; MacCoun and Mello 2015). Also, packaging of edibles often contains more than one serving size, which can lead to unintentional overdoses (e.g., Monte et al. 2015; Wang et al. 2016).

Future data collection efforts and studies should address unresolved measurement issues related to the quantity and frequency of marijuana use, potency of the product, and typical route of administration in general and specifically in contexts where marijuana is legal vs. where it is not. Unlike for alcohol, a standard unit of marijuana use has not yet been established, making it difficult to compare results across studies or even within a single study across individuals or within the same individuals over time. Also, more psychometric work is needed to assess reliability and validity of measures as well as their measurement invariance across diverse populations and policy settings. Because the potency of cannabis has increased considerably in the RML context, the addictive potential of marijuana has increased (e.g., Budney and Borodovsky 2017), and future studies should consider

measuring potency and examining closely related health consequences including cannabis use disorder (Kimmel and Lopez 2018) and driving while intoxicated (e.g., Hall 2015; Kleiman et al. 2018). Additionally, routes of administration shared with other addictive substances need to be considered. For example, because of the relatively recent emergence and proliferation of electronic nicotine delivery systems (ENDS; Lee et al. 2015), future studies should examine how ENDS use may affect marijuana use (e.g., by asking participants about vaping both nicotine and marijuana but also by analyzing the patterns and sequencing of initiation, escalation, and potentially desistance from use between ENDS and other substances). Related issues that need more research attention, and that have been highlighted in the introduction to this special issue (Johnson and Guttmannova 2019), include complementarity (e.g., co-use or simultaneous use of marijuana and other substances such as alcohol or nicotine) and substitution (e.g., use of marijuana instead of opioids or alcohol).

Researchers have also called for more sophistication in data analysis and measurement to account for heterogeneity in marijuana policy across states and within states over time as well as their interactions with signals from the federal government (Chen 2016; Hunt and Miles 2017; Pacula et al. 2014; Pacula et al. 2015; Johnson et al. 2017; Cambron et al. 2017). This includes, for example, distinguishing between various provisions under different marijuana regimes such as whether dispensaries and home cultivation are allowed under MML; distinguishing between passage of the law and its implementation (Anderson and Rees 2014; Hunt and Miles 2017; Johnson et al. 2018; Pacula et al. 2014); and careful attention to how signals from the federal government, such as the Ogden memo (Cambron et al. 2017), may have interacted with existing state-level marijuana regulations. Because there is such variability in the provisions and implementation of marijuana laws, measuring policy context simply by whether a law has been passed has not yielded clear pattern of findings in marijuana policy evaluation studies (e.g., Pacula et al. 2014; Sarvet et al. 2018a). As more states adopt RMLs, it will be important that they can make evidence-based decisions on the complex regulatory issues concerning supply, taxation, price, and the pace of legalization implementation; all of which have an impact on the availability of marijuana and may also impact public health and safety (for review, see, e.g., Caulkins et al. 2015; Kilmer 2017; Pacula and Sevigny 2014). This requires that evaluation studies consider heterogeneity in MMLs and RMLs across states and within states over time (such as when a sunset clause might be in place). Such heterogeneity is often difficult to operationalize and model in quasi-experimental designs utilizing difference-in-difference modeling. This is where single-case studies might be useful. For example, YRBS data are well suited for synthetic control modeling (e.g., Abadie et al. 2010; Abadie and Gardeazabal 2003; Amjad et al. 2018), which allows for a comparison of a single

“treated” case (e.g., MML or RML passage or implementation in a given state) against a weighted counterfactual of “untreated” cases to derive an estimate of what the marijuana (or other substance) use or related outcomes would have been had the policy change not taken place.

Conclusions

Secondary analysis of existing public health and behavioral data, such as NSDUH and YRBS, has great potential to advance our understanding of marijuana use among adolescents and emerging adults in new marijuana contexts in order to inform policy and preventive intervention development. Because NSDUH and YRBS data are federally funded and free to use, research to enhance our understanding of the effect of changes in marijuana policy can be conducted at relatively low cost. Both datasets share and differ in their strengths and limitations that need to be taken into account when considering their use (such as sampling design, frequency, mode and setting of survey administration, and how data are reported). Each is poised to address a wide range of research questions about the changing legal, social, and normative context related to marijuana and contribute to prevention efforts aimed at curbing substance use among youth.

Acknowledgements The authors thank the contributors to the special issue, the reviewers, and the staff at *Prevention Science*.

Funding This work was supported by the National Institutes of Health grants (R21DA037341, Guttmannova, and R01DA015183, R56DA004452, and R01DA044522, Guttmannova & Oesterle; K01DA031738, RM Johnson; T32DA007292, Jones, JK Johnson; and R01DA037866, Martins). The content is solely the responsibility of the authors and does not necessarily reflect the official views of the NIH.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Ethical Approval This article did not include human subjects.

Informed Consent This article did not include human subjects.

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

References

- Abadie, A., & Gardeazabal, J. (2003). The economic costs of conflict: A case study of the Basque Country. *American Economic Review*, *93*, 113–132. <https://doi.org/10.1257/000282803321455188>.
- Abadie, A., Diamond, A., & Hainmueller, J. (2010). Synthetic control methods for comparative case studies: Estimating the effect of

- California's tobacco control program. *Journal of the American Statistical Association*, 105, 493–505. <https://doi.org/10.1198/jasa.2009.ap08746>.
- Alexander, A. C., Obong'o, C. O., Chavan, P., Vander Weg, M. W., & Ward, K. D. (2018). Applying the problem behavior theory to adolescent drug use among a cross-sectional sample of boys participating in a community-based youth organization. *Substance Use & Misuse*, 53, 610–621. <https://doi.org/10.1080/10826084.2017.1349802>.
- Amjad, M., Shah, D., & Shen, D. (2018). Robust synthetic control. *Journal of Machine Learning Research: JMLR*, 19, 802–852. <http://www.jmlr.org/papers/volume19/17-777/17-777.pdf>.
- Anderson, D. M., & Rees, D. I. (2014). The role of dispensaries: The devil is in the details. *Journal of Policy Analysis and Management*, 33, 235–240. <https://doi.org/10.1002/pam.21733>.
- Borodovsky, J. T., & Budney, A. J. (2017). Legal cannabis laws, home cultivation, and use of edible cannabis products: A growing relationship? *The International Journal on Drug Policy*, 50, 102–110. <https://doi.org/10.1016/j.drugpo.2017.09.014>.
- Borodovsky, J. T., Crosier, B. S., Lee, D. C., Sargent, J. D., & Budney, A. J. (2016). Smoking, vaping, eating: Is legalization impacting the way people use cannabis? *The International Journal on Drug Policy*, 36, 141–147. <https://doi.org/10.1016/j.drugpo.2016.02.022>.
- Borodovsky, J. T., Lee, D. C., Crosier, B. S., Gabrielli, J. L., Sargent, J. D., & Budney, A. J. (2017). U.S. cannabis legalization and use of vaping and edible products among youth. *Drug and Alcohol Dependence*, 177, 299–306. <https://doi.org/10.1016/j.drugalcdep.2017.02.017>.
- Brener, N. D., Kann, L., Shanklin, S., Kinchen, S., Eaton, D. K., Hawkins, J., & Flint, K. H. (2013). Methodology of the Youth Risk Behavior Surveillance System—2013. *Morbidity and Mortality Weekly Report – Recommendations and Reports*, 62, 1–20. <https://www.cdc.gov/mmwr/preview/mmwrhtml/rr6201a1.htm>.
- Brooks-Russell, A., Ma, M., Levinson, A. H., Kattari, L., Kirchner, T., Anderson Goodell, E. M., & Johnson, R. M. (2019). Adolescent marijuana use, marijuana-related perceptions, and use of other substances before and after initiation of retail marijuana sales in Colorado (2013–2015). *Prevention Science*. Advance online publication. doi: <https://doi.org/10.1007/s1121-018-0933-2>.
- Budney, A. J., & Borodovsky, J. T. (2017). The potential impact of cannabis legalization on the development of cannabis use disorders. *Preventive Medicine*, 104, 31–36. <https://doi.org/10.1016/j.ypmed.2017.06.034>.
- 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, 74–90. <https://doi.org/10.1177/0022042616678607>.
- Catalano, R. F., Speaker, E. C., Skinner, M. L., Bailey, J. A., Hong, G., Haggerty, K. P., et al. (2018). Risk and protective factors for adolescent marijuana use. In K. C. Winters & K. A. Sabet (Eds.), *Contemporary health issues on marijuana* (pp. 219–235). New York: Oxford University Press.
- Caulkins, J. P., Kilmer, B., Kleiman, M. A. R., MacCoun, R. J., Midgette, G., Oglesby, P., ... Reuter, P. H. (2015). *Considering marijuana legalization: Insights for Vermont and other jurisdictions* (research report RR-864). Santa Monica, CA: RAND Corporation. Accessed 11 Nov 2018. Available online: https://www.rand.org/pubs/research_reports/RR864.html
- Center for Behavioral Health Statistics and Quality [CBHSQ]. (2017a). *2016 National Survey on Drug Use and Health: Methodological Summary and Definitions*. Accessed 30 Oct 2018. Available online: <https://www.samhsa.gov/data/>.
- Center for Behavioral Health Statistics and Quality. (2017b). *2016 National Survey on Drug Use and Health: Methodological Resource Book* (Section 10, Editing and Imputation Report). Accessed 30 Oct 2018. Available online: <https://www.samhsa.gov/data/report/2016-editing-and-imputation-report>.
- Center for Behavioral Health Statistics and Quality [CBHSQ]. (2014). *National Survey on Drug Use and Health (NSDUH): Summary of Methodological Studies, 1971–2014*. Rockville, MD: Substance Abuse and Mental Health Services Administration [SAMHSA]. Accessed 11 Nov 2018. Available online: <https://www.samhsa.gov/data/sites/default/files/NSDUHmethodsSummary2013/NSDUHmethodsSummary2013.pdf>.
- Centers for Disease Control and Prevention [CDC]. (2016). YRBS Questionnaire Content—1991–2017. Accessed 11 Nov 2018. Available online: https://www.cdc.gov/healthyyouth/data/yrbs/pdf/2017/YRBS_questionnaire_content_1991-2017.pdf.
- Centers for Disease Control and Prevention [CDC]. (2018a). YRBS participation history, data quality and availability. Accessed 11 Nov 2018. Available online: https://www.cdc.gov/healthyyouth/data/yrbs/pdf/2017/2017_hs_participation_history.pdf
- Centers for Disease Control and Prevention [CDC]. (2018b). *1991–2017 High School Youth Risk Behavior Survey Data*. Accessed 9 Nov 2018. Available online: <http://nccd.cdc.gov/youthonline>.
- Cerdá, M., Wall, M., Feng, T., Keyes, K. M., Sarvet, A., Schulenberg, J., et al. (2017). Association of state recreational marijuana laws with adolescent marijuana use. *JAMA Pediatrics*, 171, 142–149. <https://doi.org/10.1001/jamapediatrics.2016.3624>.
- Chen, X. J. (2016). Information diffusion in the evaluation of medical marijuana laws' impact on risk perception and use. *American Journal of Public Health*, 106, e8. <https://doi.org/10.2105/AJPH.2016.303443>.
- Compton, W. M., Volkow, N. D., & Lopez, M. F. (2017). Medical marijuana laws and cannabis use: Intersections of health and policy. *JAMA Psychiatry*, 74, 559–560. <https://doi.org/10.1001/jamapsychiatry.2017.0723>.
- Dille, J. A., Richardson, S. M., Kilmer, B., Pacula R. L., Segawa, M. B., & Cerdá, M. (2018). Prevalence of cannabis use in youths after legalization in Washington State. *JAMA Pediatrics*. Advance online publication. <https://doi.org/10.1001/jamapediatrics.2018.4458>.
- El-Menshaw, M., Castro, G., Rodríguez de la Vega, P., Peláez, J. G. R., & Barengo, N. C. (2018). First time cannabis use and sexual debut in U.S. high school adolescents. *Journal of Adolescent Health*. Advance online publication. doi: <https://doi.org/10.1016/j.jadohealth.2018.08.018>.
- EiSohly, M. A., Mehmedic, Z., Foster, S., Gon, C., Chandra, S., & Church, J. C. (2016). Changes in cannabis potency over the last 2 decades (1995–2014): Analysis of current data in the United States. *Biological Psychiatry*, 79, 613–619. <https://doi.org/10.1016/j.biopsych.2016.01.004>.
- Epstein, M., Hill, K. G., Nevell, A. M., Guttmanova, K., Bailey, J. A., Abbott, R. D., et al. (2015). Trajectories of marijuana use from adolescence into adulthood: Environmental and individual correlates. *Developmental Psychology*, 51, 1650–1663. <https://doi.org/10.1037/dev0000054>.
- Fleming, C. B., Guttmanova, K., Cambron, C., Rhew, I. C., & Oesterle, S. (2016). Examination of the divergence in trends for adolescent marijuana use and marijuana-specific risk factors in Washington State. *Journal of Adolescent Health*, 59, 269–275. <https://doi.org/10.1016/j.jadohealth.2016.05.008>.
- Guttmanova, K., Skinner, M. L., Oesterle, S., White, H. R., Catalano, R. F., Hawkins, J. D. (2019). The interplay between marijuana-specific risk factors and marijuana use over the course of adolescence. *Prevention Science*, X, XX–XX. <https://doi.org/10.1007/s1121-018-0882-9>.
- Hall, W. (2015). What has research over the past two decades revealed about the adverse health effects of recreational cannabis use? *Addiction*, 110, 19–35.

- Hall, W. (2018). Minimizing the adverse public health effects of cannabis legalization. *CMAJ: Canadian Medical Association Journal*, *190*, E1031–E1032. <https://doi.org/10.1503/cmaj.181035>.
- Hasin, D. S. (2018). US epidemiology of cannabis use and associated problems. *Neuropsychopharmacology*, *43*, 195–212. <https://doi.org/10.1038/npp.2017.198>.
- Hauser, C. (2018). Marijuana embraced in Michigan, Utah and Missouri, but rejected in North Dakota. *The New York Times*. Accessed 8 Nov 2018. Available online: <https://www.nytimes.com/2018/11/07/us/politics/michigan-marijuana-legalization.html>.
- Hawken, A., Caulkins, J., Kilmer, B., & Kleiman, M. (2013). Quasi-legal cannabis in Colorado and Washington: Local and national implications. *Addiction*, *108*, 837–838. <https://doi.org/10.1111/add.12156>.
- Hunt, P. E., & Miles, J. (2017). The impact of legalizing and regulating weed: Issues with study design and emerging findings in the USA. *Current Topics in Behavioral Neurosciences*, *34*, 173–198. https://doi.org/10.1007/7854_2015_423.
- Insurance Institute for Highway Safety [IIHS]. (2017). *Fatality Facts: Teenagers 2016*. Arlington (VA): The Institute; 2017. Accessed 9 Nov 2018. Available: <http://www.iihs.org/iihs/topics/t/teenagers/fatalityfacts/teenagers>.
- Johnson, R. M., & Guttmanova, K. (2019). Marijuana use among adolescents and emerging adults in the midst of policy change: Introduction to the special issue. *Prevention Science*, *X*, XX–XX.
- Johnson, R. M., Fairman, B., Gilreath, T., Xuan, Z., Rothman, E. F., Pamham, T., & Furr-Holden, C. D. M. (2015). Past 15-year trends in adolescent marijuana use: Differences by race/ethnicity and sex. *Drug and Alcohol Dependence*, *155*, 8–15. <https://doi.org/10.1016/j.drugalcdep.2015.08.025>.
- Johnson, R. M., Brooks-Russell, A., Ma, M., Fairman, B. J., Tolliver, R., Jr., & Levinson, A. H. (2016). Usual modes of marijuana consumption among high school students in Colorado. *Journal of Studies on Alcohol and Drugs*, *77*, 580–588. <https://doi.org/10.15288/jsad.2016.77.580>.
- 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. K., 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*, 247–254. <https://doi.org/10.1080/08897077.2017.1389801>.
- Johnson, R. M., Fleming, C. B., Cambron, C., Dean, L. T., Brighthaupt, S-C, Guttmanova, K. (2019). Race/ethnicity differences in trends of marijuana, cigarette, and alcohol use among 8th, 10th, and 12th graders in Washington State, 2004–2016. *Prevention Science*, *X*, XX–XX. doi:<https://doi.org/10.1007/s11121-018-0899-0>.
- Kann, L., McManus, T., Harris, W. A., Shanklin, S. L., Flint, K. H., Queen, B., et al. (2018). Youth Risk Behavior Surveillance—United States, 2017. *Morbidity and Mortality Weekly Report. Surveillance Summaries*, *67*, 1–114. <https://doi.org/10.15585/mmwr.ss6708a1>.
- Kilmer, B. (2017). Recreational cannabis—minimizing the health risks from legalization. *New England Journal of Medicine*, *376*, 705–707. <https://doi.org/10.1056/NEJMp1614783>.
- Kimmel, H. L. & Lopez, M. F. (2018). Cannabis use disorder: Recent findings and future directions. *Current Addiction Reports*. Advance online publication. doi:<https://doi.org/10.1007/s40429-018-0223-x>.
- Kleiman, M. A. R., Jones, T., Miller, C. J., & Halperin, R. (2018). Driving while stoned: Issues and policy options. *Journal of Drug Policy Analysis*, *4*, 1–12. <https://doi.org/10.1515/jdpa-2018-0004>.
- Lee, Y. O., Hebert, C. J., Nonnemaker, J. M., & Kim, A. E. (2015). Youth tobacco product use in the United States. *Pediatrics*, *135*, 409–415. <https://doi.org/10.1542/peds.2014-3202>.
- 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*. Advance online publication. doi:<https://doi.org/10.1007/s40429-018-0224-9>.
- Lipari, R., Kroutil, L. A., & Pemberton, M. R. (2015). Risk and protective factors and initiation of substance use: Results from the 2014 National Survey on Drug Use and Health. Accessed 12 Nov 2018. Available online: <https://www.samhsa.gov/data/sites/default/files/NSDUH-DR-FRR4-2014%20%281%29/NSDUH-DR-FRR4-2014.pdf>.
- Lipari, R. N., Ahmsbrak, R. D., Pemberton, M. R., & Porter, J. D. (2017). Risk and protective factors and estimates of substance use initiation: Results from the 2016 National Survey on Drug Use and Health. *NSDUH Data Review*. Accessed 12 Nov 2018. Available online: <https://www.samhsa.gov/data/report/risk-and-protective-factors-and-estimates-substance-use-initiation-results-2016-national>.
- MacCoun, R. J., & Mello, M. M. (2015). Half-baked—the retail promotion of marijuana edibles. *New England Journal of Medicine*, *372*, 989–991. <https://doi.org/10.1056/NEJMp1416014>.
- Martins, S. S., Mauro, C. M., Santaella-Tenorio, J., Kim, J. H., Cerdá, M., Keyes, K. M., et al. (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>.
- 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*, *X*, XX–XX. doi:<https://doi.org/10.1007/s11121-017-0848-3>.
- McFarland, J., Cui, J., & Stark, P. (2018). *Trends in high school dropout and completion rates in the United States: 2014* (NCES 2018-117). U.S. Department of Education. Washington, DC: National Center for Education Statistics. Accessed 12 Nov 2018. Available online: <https://nces.ed.gov/pubs2018/2018117.pdf>.
- Mehmedic, Z., Chandra, S., Slade, D., Denham, H., Foster, S., Patel, A. S., et al. (2010). Potency trends of Δ^9 -THC and other cannabinoids in confiscated cannabis preparations from 1993 to 2008. *Journal of Forensic Sciences*, *55*, 1209–1217. <https://doi.org/10.1111/j.1556-4029.2010.01441.x>.
- Miech, R. A., Johnston, L. D., O'Malley, P. M., Bachman, J. G., & Schulenberg, J. E. (2015). *Monitoring the Future National Survey Results on Drug Use, 1975–2014: Volume I, Secondary School Students*. Ann Arbor, MI: Institute for Social Research, The University of Michigan. Accessed 12 Nov 2018. Available online: http://www.monitoringthefuture.org/pubs/monographs/mtf-vol1_2014.pdf.
- Monte, A. A., Zane, R. D., & Heard, K. J. (2015). The implications of marijuana legalization in Colorado. *JAMA*, *313*, 241–242. <https://doi.org/10.1001/jama.2014.17057>.
- National Conference of State Legislatures [NCSL]. (2018). State medical marijuana laws. Accessed 18 Oct 2018. Available online: <http://www.ncsl.org/research/health/state-medical-marijuana-laws.aspx>.
- Oregon Health Authority. (2018). 2017 *Oregon Healthy Teens Survey*. Accessed 9 Nov 2018. Available online: https://www.oregon.gov/oha/PH/BIRTHDEATHCERTIFICATES/SURVEYS/OREGONHEALTHYTEENS/Documents/2017/2017_OHT_State_Report.pdf.
- Pacula, R. L., & Sevigny, E. L. (2014). Marijuana liberalization policies: Why we can't learn much from policy still in motion. *Journal of Policy Analysis and Management*, *33*, 212–221. <https://doi.org/10.1515/jdpa-2014-0001>.
- Pacula, R. L., Boustead, A. E., & Hunt, P. (2014). Words can be deceiving: A review of variation among legally effective medical marijuana laws in the United States. *Journal of Drug Policy Analysis*, *7*, 1–19. <https://doi.org/10.1515/jdpa-2014-0001>.

- 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*, 7–31. <https://doi.org/10.1002/pam.21804>.
- Sarvet, A. L., Wall, M. M., Fink, D. S., Greene, E., Le, A., Boustead, A. E., et al. (2018a). Medical marijuana laws and adolescent marijuana use in the United States: A systematic review and meta-analysis. *Addiction*, *113*, 1003–1016. <https://doi.org/10.1111/add.14136>.
- Sarvet, A. L., Wall, M. M., Keyes, K. M., Cerdá, M., Schulenberg, J. E., O'Malley, P. M., et al. (2018b). Recent rapid decrease in adolescents' perception that marijuana is harmful, but no concurrent increase in use. *Drug and Alcohol Dependence*, *186*, 68–74. <https://doi.org/10.1016/j.drugalcdep.2017.12.041>.
- Schmidt, L. A., Jacobs, L. M., & Spetz, J. (2016). Young People's more permissive views about marijuana: Local impact of state laws or national trend? *American Journal of Public Health*, *106*(8), 1498–1503. <https://doi.org/10.2105/AJPH.2016.303153>.
- Stogner, J. M., & Miller, B. L. (2015). Assessing the dangers of “dabbing”: Mere marijuana or harmful new trend? *Pediatrics*, *136*, 1–3.
- Substance Abuse and Mental Health Services Administration [SAMHSA]. (2012). *Comparing and evaluating youth substance use estimates from the National Survey on Drug Use and Health and other surveys*. Rockville, MD: Substance Abuse and Mental Health Services Administration. Accessed 31 Oct 2018. Available online: <https://www.samhsa.gov/data/sites/default/files/NSDUH-M9-Youth-2012/NSDUH-M9-Youth-2012.pdf>.
- Substance Abuse and Mental Health Services Administration [SAMHSA]. (2017). *Key substance use and mental health indicators in the United States: Results from the 2016 National Survey on Drug Use and Health* (HHS Publication No. SMA 17–5044, NSDUH Series H-52). Rockville, MD: Center for Behavioral Health Statistics and Quality, Substance Abuse and Mental Health Services Administration. Accessed 30 Oct 2018. Available online: <https://www.samhsa.gov/data/>.
- Terry-McElrath, Y. M., O'Malley, P. M., Johnston, L. D., Bray, B. C., Patrick, M. E., & Schulenberg, J. E. (2017). Longitudinal patterns of marijuana use across ages 18–50 in a US national sample: A descriptive examination of predictors and health correlates of repeated measures latent class membership. *Drug and Alcohol Dependence*, *171*, 70–83. <https://doi.org/10.1016/j.drugalcdep.2016.11.021>.
- Tice, P., Lipari, R. N., & Van Horn, S. L. (2017). Substance use among 12th grade aged youths, by dropout status. In *The CBHSQ Report*. Rockville (MD): Substance Abuse and Mental Health Services Administration (US). Accessed 12 Nov 2018. Available online: <https://www.ncbi.nlm.nih.gov/pubmed/29035491>.
- Tormohlen, K. N., Brooks-Russell, A., Ma, M., Schneider, K. E., Levinson, A., & Johnson, R. M. (in press). Modes of marijuana consumption among Colorado high school students before and after the initiation of retail marijuana sales for adults. *Journal of Studies on Alcohol and Drugs*.
- Volkow, N. D., Baler, R. D., Compton, W. M., & Weiss, S. R. B. (2014). Adverse health effects of marijuana use. *New England Journal of Medicine*, *370*, 2219–2227. <https://doi.org/10.1056/NEJMr1402309>.
- Wang, G. S., Le Lait, M., Deakyn, S. J., Bronstein, A. C., Bajaj, L., & Roosevelt, G. (2016). Unintentional pediatric exposures to marijuana in Colorado, 2009–2015. *JAMA Pediatrics*, *170*, e160971. <https://doi.org/10.1001/jamapediatrics.2016.0971>.
- Washington State Department of Health, Office of the Superintendent of Public Instruction, Department of Social and Health Services, and Liquor and Cannabis Board. (2016). *Healthy Youth Survey Technical Notes*. Accessed 8 Nov 2018. Available online: <https://www.doh.wa.gov/DataandStatisticalReports/DataSystems/HealthyYouthSurvey>.
- 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>.
- Wen, H., Hockenberry, J. M., & Druss, B. G. (2019). The effect of medical marijuana laws on marijuana-related attitude and perception among U.S. adolescents and young adults. *Prevention Science*, *X*, XX–XX. doi:<https://doi.org/10.1007/s11121-018-0903-8>.