Drug and Alcohol Dependence 199 (2019) 1–9

Contents lists available at ScienceDirect

Drug and Alcohol Dependence

journal homepage: www.elsevier.com/locate/drugalcdep

Full length article

Effects of mandatory prescription drug monitoring program (PDMP) use laws on prescriber registration and use and on risky prescribing

Gail K. Strickler[a,*], Kun Zhang[b], John F. Halpin[b], Amy S.B. Bohnert[c], Grant T. Baldwin[b], Peter W. Kreiner[a]

[a] Institute for Behavioral Health, Brandeis University, Waltham, MA, USA
[b] Division of Unintentional Injury Prevention, National Center for Injury Prevention and Control, Centers for Disease Control and Prevention, Atlanta, GA, USA
[c] Department of Psychiatry, University of Michigan and VA Center for Clinical Management Research, University of Michigan North Campus Research Complex, 2800 Rd., Bldg. 16, Room 227W, Ann Arbor, MI, 48109, USA

ARTICLE INFO

Keywords:
Opioids
Prescriber mandates
Prescription drug monitoring programs

ABSTRACT

Background: Comprehensive mandatory use laws for prescription drug monitoring programs (PDMPs) have been implemented in a number of states to help address the opioid overdose epidemic. These laws may reduce opioid-related overdose deaths by increasing prescribers' use of PDMPs and reducing high-risk prescribing behaviors.
Methods: We used state PDMP data to examine the effect of these mandates on prescriber registration, use of the PDMP, and on prescription-based measures of patient risk in three states—Kentucky, Ohio, and West Virginia—that implemented mandates between 2010 and 2015. We conducted comparative interrupted time series analyses to examine changes in outcome measures after the implementation of mandates in the mandate states compared to control states.
Results: Mandatory use laws increased prescriber registration and utilization of the PDMP in the mandate states compared to controls. The multiple provider episode rate, rate of opioid prescribing, rate of overlapping opioid prescriptions, and rate of overlapping opioid/benzodiazepine prescriptions decreased in Kentucky and Ohio. Nevertheless, the magnitude of changes in these measures varied among mandates states.
Conclusions: These findings indicate that PDMP mandates have the potential to reduce risky opioid prescribing practices. Variation in the laws may explain why the effectiveness varied between states.

1. Introduction

Between 1999 and 2016, the number of opioids prescribed in the United States has tripled, and this increase has occurred in parallel with a quintupling of opioid overdose deaths (Guy et al., 2017; Hedegaard et al., 2017). The ongoing opioid overdose epidemic has been multifactorial in its origin and development, and will require a variety of measures to bring under control, including efforts to reduce excessive prescribing. Mandatory use laws for prescription drug monitoring programs (PDMPs) – state laws that require prescribers to review patient prescription history of controlled substances prior to prescribing opioids in particular – have emerged as promising strategies to address the epidemic. As of December 2017, 40 of the 49 states with PDMPs had enacted mandatory use laws, though they vary in comprehensiveness with regard to the types of prescribers to which they apply, classes of prescription drugs included, and conditions under which the law applies (Brandeis University, 2017). Comprehensive mandatory use laws, compared with less-than-comprehensive ones, require all prescribers with a DEA license to enroll in the PDMP and review patient prescription histories prior to prescribing all initial opioid prescriptions or all opioid prescriptions. Among the early states that have enacted legislation for comprehensive mandatory use laws are Kentucky (2012), Tennessee (2013), New York (2013), West Virginia (2013), and Ohio (2015) (Centers for Disease Control and Prevention (CDC, 2016).

Research is beginning to document the effects of these laws, although findings have been mixed. The three earliest states to enact comprehensive mandates – Kentucky, New York, and Tennessee – reported subsequent increases in prescriber PDMP use, ranging from 3- to 8-fold, and decreases in rates of multiple provider episodes by as much as two-thirds (Hopkins et al., 2014). In an initial, rigorous study of 38 states' PDMPs from 2006 to 2013, CDC researchers found statistically significant decreases in total opioid-related overdose death rates, prescription opioid-related death rates, and opioid prescribing in states with comprehensive mandatory use laws versus those without such

* Corresponding author at: Institute for Behavioral Health, Brandeis University, 415 South Street, Waltham, MA, 02454-9110, USA.
E-mail addresses: strickler@brandeis.edu, gks@brandeis.edu (G.K. Strickler).

https://doi.org/10.1016/j.drugalcdep.2019.02.010
Received 10 August 2018; Received in revised form 30 January 2019; Accepted 3 February 2019
Available online 22 March 2019
0376-8716/

Table 1
Key Elements of Kentucky, Ohio and West Virginia Mandatory PDMP Use Laws.
Source: Prescription Drug Monitoring Programs: Evidence-based practices to optimize prescriber use. A Report of the PEW Charitable Trusts, December 2016. Accessed 6/12/2017 at: http://www.pewtrusts.org/en/research-and-analysis/reports/2016/12/prescription-drug-monitoring-programs.

State	Effective date	Policy	Drugs Included	Timing triggers	Exceptions
Kentucky	7/20/12	Mandatory checks of PDMP required prior to prescribing any DEA Scheduled II-IV controlled substance	DEA Schedules II-IV	Initial prescription, every 90 days	Terminally ill patient; inpatient at hospital or long-term care facility; PDMP inaccessible; during an emergency or following surgery; single-dose treatments to relieve symptoms from a procedure; cancer pain
Ohio	5/20/11	State law enacted mandating health care licensing agencies adopt rules requiring use of PDMP	N/A	N/A	N/A
	12/1/11	OH Medical Board adopts rules requiring use of PDMP by physicians and physician assistants	DEA Schedules II-IV	Initial prescription, if prescriber believes treatment is likely to last more than 90 days; annually thereafter	7 days supply exempt; terminally ill patient, Inpatient at hospital or long-term care facility, PDMP inaccessible
	4/1/15	Mandatory checks of PDMP required prior to prescribing opioids and benzodiazepines	Opioids and benzodiazepines	Initial prescription, every 90 days	7 days supply exempt; terminally ill patient, Inpatient at hospital or long-term care facility, PDMP inaccessible
West Virginia	6/8/12	State law enacted mandating that health care licensing agencies adopt rules requiring use of PDMP	N/A	N/A	N/A
	5/6/13	WV Medical Board adopts rules requiring use of PDMP by physicians and physician assistants	Pain-relieving controlled substances for chronic, non-malignant pain	Initial prescription, at least annually thereafter	Terminally ill patient, PDMP inaccessible

Note: Pain clinic regulation laws were enacted in Kentucky in Q3 of 2012, in Ohio in Q3 of 2011, and in West Virginia in Q2 of 2012. (see http://pdaps.org/datasets/pain-management-clinic-laws, Accessed 12-05-2018.

laws (Dowell et al., 2016b). Pardo (2017) reported an effect of more robust PDMPs on reducing opioid overdose death rates, where mandatory use laws were weighted heavily in his index of PDMP robustness (Pardo, 2017). However, two other recent studies of mandatory use laws failed to find significant effects on opioid-related overdose death rates. In a study of 34 states from 1999 to 2013, Patrick et al. (2016) found no effect of mandatory use laws in general on overdose death rates, over and above the effects of PDMPs without mandatory use laws (Patrick et al., 2016). Using Medicare Part D claims data for all states, 2007–2013, Buchmueller and Carey (2018) found no effect of comprehensive mandatory use laws on fatal and non-fatal opioid overdoses among the Medicare population (Buchmueller and Carey, 2018). Using administrative claims data representative of the privately insured, Pauly et al. (2018) found no effect of mandatory use laws on rates of prescription opioid-related poisonings (Pauly et al., 2018). An extensive review of the effects of PDMPs and PDMP features on fatal and nonfatal drug overdoses, including a careful assessment of methods used in prior studies, concluded that insufficient evidence exists of an effect of mandatory use laws (as well as for other PDMP features) on fatal and nonfatal drug overdoses (Fink et al., 2018).

Several studies have addressed the effects of mandatory use laws on opioid prescriptions and measures of patient risk. Buchmueller and Carey (2018) found significant effects of these laws on decreasing rates of prescriber and pharmacy shopping behavior, overlapping opioid prescriptions, and continuous opioid supply of at least seven months (Buchmueller and Carey, 2018). In a study of the effects of Ohio's 2015 mandatory use law, Winstanley et al. (2018) found that the law's implementation was associated with significant decreases in opioid and benzodiazepine prescriptions and decreases in multiple provider episodes for opioids and for benzodiazepines (Winstanley et al., 2018). Using administrative claims data for commercially insured people, Haffajee et al. (2018) found reductions in opioid dosage associated with "robust" or comprehensive mandatory use laws in four states, relative to comparison states; one state, Kentucky, also showed decreases in the percentage of people filling opioid prescriptions, in persons receiving high opioid dosage, and in persons using multiple prescribers or pharmacies (Haffajee et al., 2018). However, two studies of opioid prescribing to selected populations in relation to mandatory use laws, one of patients with non-cancer chronic pain, and one of patients undergoing elective surgery, found no effect of these laws on opioid prescribing (Lin et al., 2018; Stucke et al., 2018).

These mandate studies share several limitations. An inherent limitation in examining the effects of mandatory use laws across many states together is that heterogeneity of effects of these laws in different states can be obscured, a limitation avoided in only two of the previous studies (Haffajee et al., 2018; Winstanley et al., 2018). Second, only two of the studies cited above (Pauly et al., 2018; Winstanley et al., 2018) go beyond 2014, limiting examination of longer-term effects of mandates and recent laws. Third, although mandatory use laws are built upon the premise that increasing use of the PDMP will improve opioid-related health outcomes, the effects on prescriber registration and utilization of the PDMP have not typically been examined (for an exception, see Delcher et al., 2015). Finally, these studies have focused primarily on comprehensive mandates (compared to less-than-comprehensive mandates or no mandate) and their impact on opioid-related overdose deaths. Thus, they shed little light on the possible intermediate mechanisms underlying this effect, such as the reduction of high-risk opioid prescribing behaviors. Of the exceptions noted above (Buchmueller and Carey, 2018; Haffajee et al., 2018; Lin et al., 2018; Stucke et al., 2018; Winstanley et al., 2018), all but one used administrative claims data, which omitted out-of-system claims and claims paid by cash.

To address many of these limitations, we report on a detailed time-series analyses using PDMP all-payer prescription data in three mandatory use states: Kentucky, Ohio, and West Virginia examined individually in relation to control states, over the period 2010 – 2016. All

three states examined encompass "comprehensive" mandatory use laws (Pew Charitable Trusts, 2016). In addition, Ohio enacted a less-than-comprehensive mandate prior to its comprehensive mandate. We examine the effects of these laws on prescriber registration and utilization of the PDMP, as well as on a range of prescribing behavior measures and prescription-based measures of patient risk.

2. Methods

2.1. Selection of mandate and non-mandate states

The three "mandate" states in this study, Kentucky, Ohio, and West Virginia were among the first in the nation to enact and implement comprehensive mandatory use laws. Selection criteria for mandate states included having 1) a PDMP use mandate enacted in the state as of December 31, 2016; and 2) PDMP prescription data and prescriber usage data available to the study by December 31, 2016. Table 1 presents the key elements of each state's mandate. In 2012, Kentucky passed a comprehensive mandate use law. The Kentucky mandate required all prescribers to check the PDMP, with some exceptions, prior to any initial prescription of Schedule II, III, or IV controlled substances, and at least every 90 days for treatment lasting more than three months (Pew Charitable Trusts, 2016).

In contrast to Kentucky, Ohio's mandate use legislation was implemented in two stages between 2011 and 2015. The initial legislation, enacted in June 2011, required health care licensing boards state-wide to adopt rules requiring prescriber enrollment and use of the PDMP. In December 2011, the Ohio Medical Board first adopted rules requiring physicians and physician assistants to query the PDMP. In addition, Ohio's 2011 mandate required prescribers to check the PDMP prior to prescribing an initial Schedule II, III, or IV controlled substance to a given patient if they believed that treatment was likely to last more than 90 days, and at least once annually thereafter. Thus, we defined the first stage as less-than-comprehensive. In April 2015, more comprehensive requirements were implemented in Ohio, which strengthened the earlier mandate. The 2015 implementation specifically mandated state-wide all prescriber queries of the PDMP before initial prescriptions for opioids and benzodiazepines, and every 90 days thereafter, with limited exceptions (State of Ohio, 2017).

West Virginia passed its initial mandate legislation in 2012 requiring prescribers to query the PDMP when prescribing or dispensing controlled substances for patients under certain circumstances (West Virginia Board of Medicine, 2012). Subsequently, the West Virginia medical board adopted comprehensive regulations effective in 2013 mandating that all physicians and physician assistants query the PDMP for any initial "pain-relieving controlled substance" prescriptions, prescribed or dispensed in the course of treatment for chronic, non-malignant pain. Prescribers are required to check at least annually thereafter if the course of treatment continues. Pain-relieving controlled substance refers to any Schedule II-V controlled substance, including, but not limited to, opioids that are considered effective for pain-relief (West Virginia Board of Medicine, 2012).

Two states served as controls in the analysis: California and Virginia. Criteria for selection as a control state included having 1) no PDMP use mandate enacted in the state as of December 31, 2016; and 2) PDMP data and prescriber usage data available to the study by December 31, 2016. California and Virginia were the only PBSS states that met control state selection criteria.

We obtained permission from each state's PDMP Manager for use of their data in this analysis. The study protocol was reviewed and approved by the Brandeis University Institutional Review Board.

2.2. Data

2.2.1. PDMP prescription data

Our primary data source was PDMP data from the Prescription Behavior Surveillance System (PBSS); data for all five states in the study were made available to the authors via data use agreements with the states. Methodological details of PBSS have already been published (Paulozzi et al., 2015). The PBSS is a public health surveillance and evaluation tool using de-identified, longitudinal prescription data from state PDMPs; the tool is designed to measure trends in controlled substance prescribing and dispensing, including trends in indicators of medical use and possible misuse, abuse, and diversion. In contrast to claims data, PDMP data are comprehensive, all-payer data (i.e., all types of insurers as well as cash payments) that allow for analysis of prescription-level measures and a focus on in-state prescribers. PBSS includes data from 2010 to 2017. The current study utilized PDMP data from PBSS between Q3 of 2010 and Q3 of 2016; this study period corresponded to the available PDMP data for the five states in the study. For all five states, we included Schedule II through Schedule IV controlled substances prescribed only to in-state residents by in-state prescribers. Prescriptions from all pharmacies licensed to dispense in the state were included. Buprenorphine products indicated for conditions other than pain were excluded from our analysis.

2.2.2. Prescriber usage of PDMP data

State PDMPs track the number of prescribers who enrolled in the PDMP and the number of queries to the PDMP by registered prescribers; these data represent a unique and not easily accessible source of information. We requested and obtained quarterly data on prescriber usage of the PDMP for the study period via email from the PDMP administrator of each state in our analysis. The usage data included: 1) count of active prescribers enrolled in the PDMP by quarter; 2) count of prescribers who queried the PDMP by quarter; and 3) count of queries/reports requested by quarter. West Virginia, however, was not able to provide us with data on the count of prescribers who queried its PDMP.

2.3. Measures

2.3.1. PDMP use mandate

The key independent variable was implementation of (i.e., exposure to) a PDMP use mandate, measured as a dichotomous (0, 1) variable for each state and in each quarter from 2010 to 2016. We used the effective date of each PDMP use mandate to define the quarter in which the use mandate was implemented and set the value of the variable to 0 for all quarters up to that point. For each quarter after the implementation of the PDMP use mandate, the variable was coded as 1. For Kentucky, we used the July 2012 (Q3) as PDMP use mandate date; For Ohio, two PDMP use mandate variables were created, corresponding to the December 2011 (Q4) and the April 2015 (Q2) mandate implementations; For West Virginia, we used May 2013 (Q2) as PDMP use mandate date.

2.3.2. Outcomes

Three PDMP usage measures were examined in this study. These measures are derived from indicators required by the Bureau of Justice Assistance as part of its performance measures for PDMPs (Kreiner et al., 2013).

1 The percent of active, state-licensed prescribers enrolled in the PDMP by quarter was defined as the number of prescribers who, as of the last date of the quarter, were 1) licensed to practice in the state; 2) had at least one controlled substance prescription dispensed in the state in the quarter; and 3) were enrolled in the PDMP, divided by the total number of active, state-licensed prescribers.
2 The percent of active state-licensed prescribers enrolled in the PDMP who had accessed the PDMP by quarter was defined as the number of prescribers who, as of the last date of the quarter, were 1) licensed to practice in the state; 2) had at least one controlled substance prescription dispensed in the state in the quarter; 3) were enrolled in the PDMP; and 4) had used the PDMP at least once in the

Table 2
Estimated Impact of Mandatory PDMP Use Laws on PDMP Measures by State: Results of Comparative Interrupted Time Series Analysis (ITSA).
Source: Authors' analysis of data from the Prescription Behavior Surveillance System, Q3 2010-Q3 2016.

Measures	Kentucky Mandate		Ohio Mandate (1)		Ohio Mandate (2)		West Virginia Mandate	
	Level change immediately following mandate	Trend change	Level change immediately following mandate	Trend change	Level change immediately following mandate	Trend change	Level change immediately following mandate	Trend change
Rate of solicited reports per 1000 state residents	157.2***	3.47***	35.0*	12.7***	−3.16	1.33	41.8**	−5.14**
% of prescribers enrolled	22.5***	−1.40*	0.46	3.20***	14.1***	−4.93***	0.36	−2.43***
% of prescribers accessing	25.6***	−1.52***	−1.08	1.96***	2.36	−1.71	N/A	N/A
High MME rate per 1000 state residents	0.63	−0.11	0.01	−0.01	0.12	−0.42	−0.28	0.05
MPE rate per 100,000 state residents	−4.85***	0.25	−0.05	−0.23	0.72	−0.53	0.49	0.16
Overlapping opioid Rx rate per 1000 state residents	−1.79	−0.49***	−3.04*	−0.10	0.46	−0.61	−0.25	−0.15
Overlapping opioid-benzo Rx rate per 1000 state residents	−1.95	−0.46***	−2.19	−0.12	1.02	−0.78*	−0.05	−0.25
Opioid prescribing rate per 1000 state residents	−24.0*	−3.00**	3.74	−2.55*	1.51	−7.86**	1.75	0.29

Notes: * = p < .05, ** = p < .01, *** = p < .001. N/A = data not available. Ohio mandate (1) refers to the state's first mandatory PDMP use law. Ohio mandate (2) refers to Ohio's second mandatory PDMP use law.

quarter, divided by the total number of active, state-licensed prescribers. This measure refers to the number of *prescribers* who accessed the PDMP.

3 The rate of reports requested/solicited by quarter was defined as the total number of PDMP reports requested in the quarter by active, state-licensed prescribers, per 1000 state residents. This measure refers to the number of *reports requested* by prescribers. A given prescriber may have requested more than one report in a quarter.

Five prescription-based measures of patient risk were examined. Measures of patient risk are based on their association with overdose or clinical diagnosis of drug abuse (Dowell et al., 2016a; Liu et al., 2013; Paulozzi et al., 2012, 2015). We categorized controlled prescription drugs into pharmacologic categories (e.g., opioid analgesics, benzodiazepines) using the Truven Health Analytics quarterly RED BOOK Select Database. We used the number of state residents as the denominator for these measures rather than the number of individuals who received an opioid prescription. Our rationale was that mandates might result in a decrease in number of people who received an opioid prescription, so using that as the denominator could mask any effects of the mandate on the measures of interest. This choice facilitated comparisons over time within a state as well as comparisons across states.

1 Rate of patients with multiple provider episodes (MPEs) for opioids, defined as the total number of unique patients who obtained opioid prescriptions dispensed in the quarter in the state from 5 or more pharmacies and written by 5 or more prescribers within a 3 month period, per 100,000 state residents. MPE rates are presented per 100,000 (rather than per 1000) state residents due to the small number of MPEs per quarter.
2 Rate of prescriptions for all opioids, defined as the total number of Schedule II, III or IV opioid prescriptions dispensed in the quarter in the state per 1000 state residents.
3 Rate of patients who had overlapping opioid prescriptions, defined as the total number of unique patients in the quarter with at least two opioid prescriptions, (regardless of opioid type) that overlapped for at least 7 days based on fill dates and days supplied, per 1000 state residents.
4 Rate of unique patients who had overlapping opioid and benzodiazepine prescriptions, defined as the total number of unique patients in the quarter with at least one opioid prescription and one benzodiazepine prescription, regardless of their specific drug names, that overlap for at least 7 days per 1000 state residents. Concurrent use of prescription opioids and benzodiazepines is associated with an increased risk for opioid overdose (Dowell et al., 2016a).
5 Rate of unique patients with a high daily dosage, defined as the total number of unique patients in the quarter whoever received > = 90 cumulative Morphine Milligram Equivalents (MMEs) of opioids daily, per 1000 state residents.

2.4. Analytic approach

The measures were compiled quarterly from 2010 quarter 3 through 2016 quarter 3. We then conducted comparative interrupted time series analyses (ITSA) for the outcome measures. The comparative ITSA enabled us to assess and control for differences in baseline levels and trends between mandate and control states, as well as estimate degree of changes (i.e., level change and slope change) in outcome measures associated with the mandates (Bernal et al., 2017; Soumerai et al., 2015). The study assumed both level change and slope change in outcomes. The use of control states allowed us to account for secular trends, for example, due to increased national awareness of inappropriate use and prescribing of opioids. One important condition of applying comparative ITSA is that pre-intervention trends between treatment and control states have to be similar. Thus, we explored pre-intervention trends in our analysis. We approached the ITSA analysis

separately for the three mandate states because the implementation and specific policy provisions vary among the states. This approach would also allow us to show any potentially heterogeneous impact of the three mandates.

California and Virginia were used as the control states for prescription-based measures of patient risk. Only California was used as the control state for PDMP usage measures as data for these measures from Virginia were only available for a small portion of the study period.

We used generalized least-squares method for all comparative ITSA regression analyses. Autocorrelation of error terms was assumed to follow a first-order autoregressive process for our time series data. All analyses were conducted in Stata Version 14.2. We adjusted for autocorrelation under the Prais-Winsten procedure in the Stata ITSA routine. See additional details on ITSA specifications and results in the Appendix A.

3. Results

We presented comparative ITSA results of both level change and slope (trend) change in Table 2 as the estimated effects of the mandate law on our PDMP usage measures and prescription-based measures. The level change and slope change were akin to difference-in-differences estimations (Linden, 2015). Figs. 1 and 2 were graphic representations of the core ITSA results. We present graphical results for the remaining measures in Figs. 3 and 4 as Supplementary materials in the Appendix A. Pre-intervention trends were not significantly different for the majority of our outcome measures between the mandate states and control states except for the percent of prescribers enrolled in the PDMP in Kentucky. We presented results of the pre-intervention trends in the Appendix A.

3.1. PDMP usage measures

Fig. 1 showed levels and trends based on comparative ITSA results for PDMP usage measures. Columns A, B, and C represented three intervention states, i.e., Kentucky, Ohio, and West Virginia. The vertical dashed line represented the quarter when the mandate law was implemented. Figures in column A showed potential positive impacts of the mandate in Kentucky on increasing PDMP usage. For instance, the rate of solicited PDMP reports was 34.5 per 1000 residents in Q3 of 2010 and 277.7 per 1000 residents in Q3 of 2016; the percent of prescribers enrolled in the PDMP was 29.5% in Q3 of 2010 and 88.3% in Q3 of 2016. Figures in column B also indicated potential positive impacts of the mandate in Ohio on increasing PDMP usage. For instance, the rate of solicited PDMP reports was 18.6 per 1000 residents in Q3 of 2010 and 283.6 per 1000 residents in Q3 of 2016; the percent of prescribers enrolled in the PDMP was 20.1% in Q3 of 2010 and 97.3% in Q3 of 2016. Nevertheless, it was unclear based on figures in column C if there was any impact of the mandate in West Virginia on PDMP usage.

The first three rows of measures in Table 2 showed these estimated results from the ITSA for PDMP usage measures. The Kentucky mandate was associated with a statistically significant level change (difference-in-differences of levels) immediately following the mandate implementation for all three PDMP usage measures. Specifically, in Kentucky, the rate of solicited PDMP reports increased by 157.2 per 1000 residents; the percent of prescribers enrolled in the PDMP increased by 22.5 percentage points, and the percent of prescribers accessing the PDMP increased by 25.6 percentage points. However, the Kentucky mandate was only associated with a statistically significant increase (3.47 per 1000 residents per quarter) in trend (difference-in-differences of slopes) for the rate of solicited PDMP reports. The trend difference between Kentucky and the control state in the percent of prescribers enrolled and the percent of prescribers accessing the PDMP decreased (indicated by the significant negative trend change in Table 2) due to declining trend in Kentucky over time after mandate implementation.

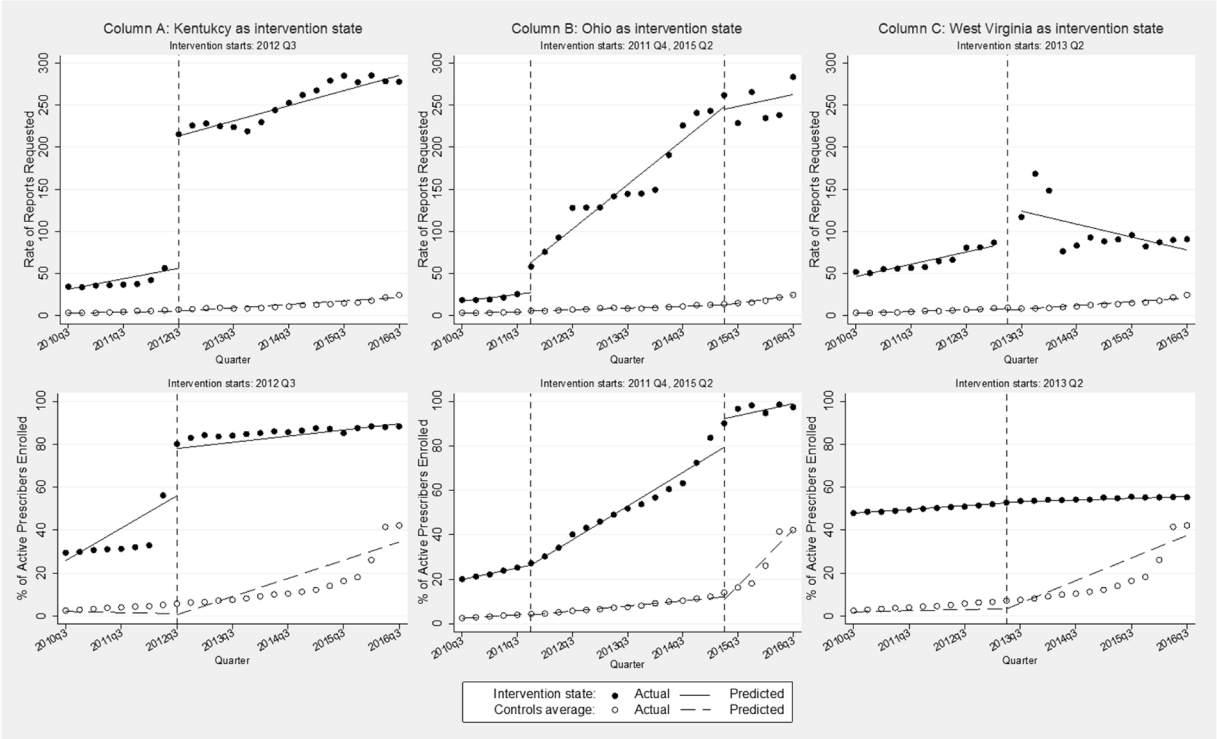

Fig. 1. PDMP Usage Measures I, Pre- and Post-Mandatory PDMP Use Law, by Intervention State.
Notes: Data on reports requested in West Virginia were not available for Q2 2013.
Source: Authors' analysis of PDMP usage data requested from state PDMP administrators, Q3 2010-Q3 2016.

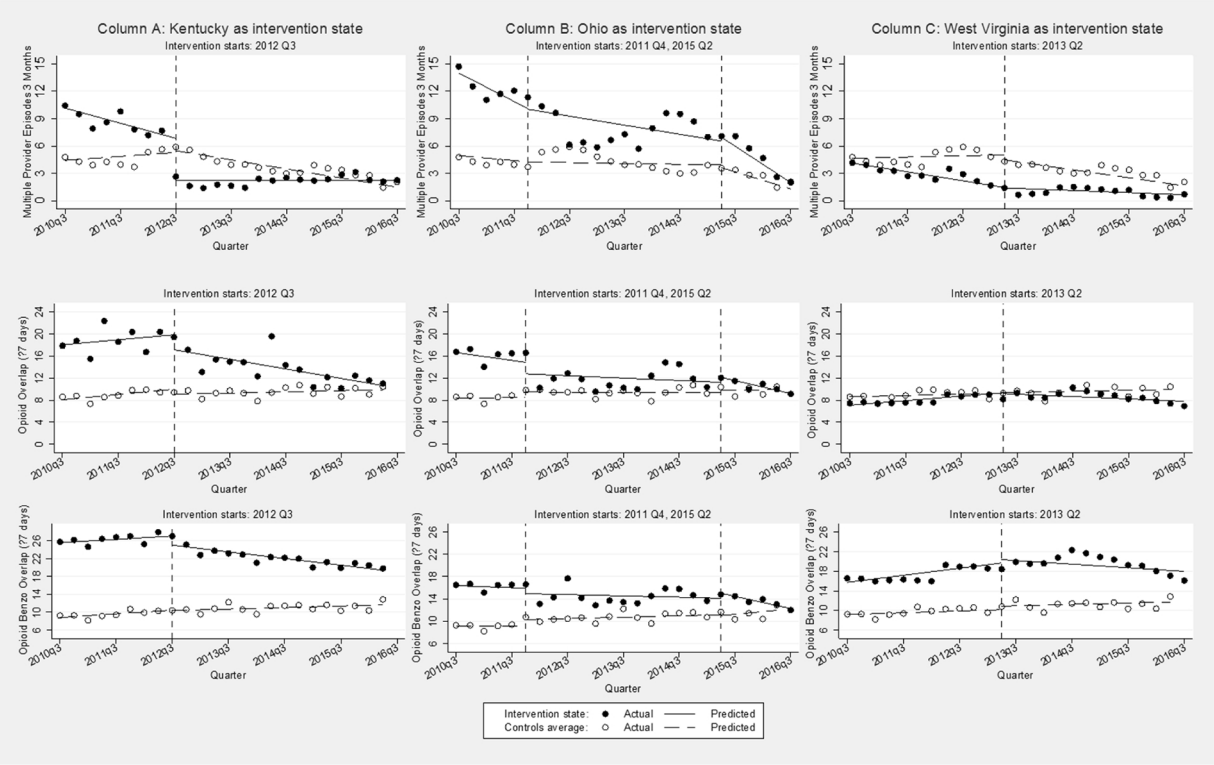

Fig. 2. Prescription Based Outcome Measures I, Pre- and Post-Mandatory PDMP Use Law, by Intervention State.
Source: Authors' analysis of data from the Prescription Behavior Surveillance System, Q3 2010-Q3 2016.

Ohio's first and second mandates had differing effects on the three PDMP usage measures. Its first mandate was associated with both a statistically significant level increase (35.0 per 1000 residents) immediately following the mandate implementation and a significant trend increase (12.7 per 1000 residents per quarter) in the rate of solicited PDMP reports. Unlike Kentucky, the percent of prescribers enrolled and accessing the PDMP did not experience a level change immediately following the first mandate implementation in Ohio; however, its first mandate was associated with a significant trend increase in these two PDMP usage measures (3.20 and 1.96 percentage points per quarter respectively). In contrast, Ohio's second mandate was only associated with a significant impact on the percent of prescribers enrolled in the PDMP. This measure experienced a significant level increase by 14.1 percentage points, but with a decreased trend (indicated by the significant negative trend change of 4.93 in Table 2) due to plateauing of the trend in Ohio and rising of the trend in the control states over time after the second mandate implementation.

Similar to Kentucky and Ohio (first mandate only), the mandate in West Virginia was associated with statistically significant level increase in the rate of solicited PDMP reports immediately following the mandate implementation. However, the magnitude of increases in West Virginia was smaller than Kentucky but slightly larger than Ohio (first mandate). For instance, the rate of solicited PDMP reports in West Virginia increased by 41.8 per 1000 residents. Unlike Kentucky and Ohio, despite a level increase, the mandate in West Virginia was associated with a significant trend decrease in the rate of solicited reports (indicated by the significant negative trend change in Table 2). No data were available from West Virginia on the percent of prescribers accessing the PDMP.

3.2. Prescription-based outcome measures

Fig. 2 showed levels and trends based on comparative ITSA results for our three core prescription-based outcome measures. Similar to Fig. 1, columns A–C represented three intervention states, and the vertical dashed line represented the quarter when the mandate law was implemented. Figures in all three columns showed potential positive impacts of the mandate in three intervention states on decreasing prescription-based measures for either level or trend or both. For instance, MPE rates in Kentucky, Ohio, and West Virginia were 10.4, 14.7, and 4.2 per 100,000 residents respectively in Q3 of 2010 and 2.2, 2.0 and 0.7 per 100,000 residents respectively in Q3 of 2016. Rates of overlapping opioid and benzodiazepine prescriptions in the three states were 25.7, 16.5 and 16.6 per 1000 residents respectively in Q3 of 2010 and 19.7, 11.9, and 16.1 per 1000 residents respectively in Q3 of 2016.

Row four to row eight of measures in Table 2 presented estimated results from comparative ITSA for prescription-based outcome measures. The Kentucky mandate was associated with a statistically significant level decrease in the 3-month MPE rate immediately following the mandate implementation (4.85 per 100,000 residents), but it was not associated with a significant trend decrease in this measure. On the contrary, the rate of overlapping opioid prescriptions and overlapping opioid and benzodiazepine prescriptions did not experience a significant level decrease immediately following the mandate implementation, but the mandate was associated with a significant trend decrease for these two measures (−0.49 per 1000 residents per quarter and −0.46 per 1000 residents per quarter respectively). The overall opioid prescribing rate in Kentucky experienced both a significant level decrease (24.0 per 1000 residents) immediately following the mandate implementation as well as a trend decrease (−3.0 per 1000 residents per quarter). The first Ohio mandate was associated with a level decrease in the rate of overlapping opioid prescriptions and overlapping opioid and benzodiazepine prescriptions (−3.04 and −2.19 per 1000 resident per quarter, respectively) immediately following the mandate implementation; however, only the level decrease in overlapping opioid prescriptions was significant. As indicated by the figures in Column B (Fig. 2), the first Ohio mandate was associated with trend decrease as well for the two overlapping measures (−0.1 and −0.12 respectively);

nevertheless, neither was statistically significant. Additionally, the first mandate in Ohio was only associated with a significant trend decrease (−2.55 per 1000 residents per quarter) for the overall opioid prescribing rate, but no significant effect on its level change. With regard to Ohio's second mandate law, it was associated with larger trend decrease compared to the first mandate for all prescription-based outcome measures (indicated by the negative trend change under post-mandate 2: −0.53, −0.61, −0.78, and −7.86), but the larger trend decrease was only statistically significant for the rate of overlapping opioid and benzodiazepine prescriptions and rate of overall opioid prescribing.

Unlike either Kentucky or Ohio, the West Virginia mandate was not associated with statistically significant changes in any of the prescription-based outcome measures.

4. Discussion

Mandatory use laws are predicated on the assumption that (1) requiring prescribers to access patient prescription histories in the PDMP will, in fact, lead to their doing so, and that (2) increased prescriber access to this information will lead to more appropriate opioid prescribing and improved health outcomes. This study provides evidence of the efficacy of mandates on increasing prescriber registration and utilization of the PDMP immediately after the enactment of the law. Although the efficacy sustained over time, estimates of slope changes indicated that the efficacy attenuated. One potential explanation is the improvement of these outcomes among control states in the post mandate period, which could be due to increasing national visibility of the opioid overdose epidemic, PDMPs, and PDMP-related policies such as the mandate, over the study period. In addition, by studying different mandatory use states separately, we found differential effects of comprehensive mandatory use laws in the study states. In particular, while we found evidence in all three states that comprehensive mandates increased levels of prescriber registration (except for West Virginia's insignificant estimate) and utilization of the PDMP, we found no effects on the patient risk measures examined in West Virginia. In contrast, we found decreases in level and/or trend associated with the mandates in Kentucky and Ohio with regard to multiple provider episode rate, rate of overlapping opioid prescriptions, and rate of overlapping opioid/benzodiazepine prescriptions. We found decreases in both level and trend of overall opioid prescribing rate associated with Kentucky's mandate. As the three mandate states have mandatory enrollment laws in addition to mandatory use laws, and legal provisions regarding consequences for failure to comply with PDMP rules, these factors are unlikely to explain the modest results found in West Virginia.

Several differences between the states may help to explain these varying findings. Because PDMP data typically do not include a unique patient identifier, most PDMPs employ probabilistic record-matching algorithms to determine which prescriptions belong to the same patient. Such algorithms account for variations in patient name and address if other patient-identifying information matches. Some PDMPs, however, including West Virginia's, use exact matching of patient information to determine which prescription records to assign to a given patient. Therefore, in states such as West Virginia, it is likely that not all prescriptions obtained by some patients are correctly identified in the PDMP as belonging to those patients. This may be especially true for patients who exhibit multiple provider episode behaviors and may actively seek to avoid detection. Exact matching of prescription records may have two consequences with respect to our study. First, the risk measures examined (i.e., high MME rate, MPE rate, overlapping opioid rate, overlapping opioid-benzodiazepine rate) all depend on correctly aggregating prescriptions by patient. If some prescriptions belonging to a single patient are mistakenly assigned to other patients, these measures are likely to be less sensitive to change. If West Virginia's mandatory use law has had an effect on these measures, we may be unable to detect it with PDMP data due to the inherent weakness of exact matching methodology. Second, when a West Virginia prescriber queries the PDMP, not all of his or her patient's prescriptions may appear, giving the prescriber an incomplete picture of that patient's prescription history, and perhaps leading them to write an opioid prescription where they might not have done so with more complete information. This second consequence of exact matching may also help explain the finding that West Virginia's mandate was associated with an increased level of prescriber registration and utilization of the PDMP, as well as with a decreasing trend in registration and use. Once prescribers begin to use the PDMP and then find that the information available therein is incomplete, for example by not including prescriptions the prescriber him- or herself has written, they may be disinclined to continue using the PDMP to the same degree.

The varying effects of Ohio's two separate mandate laws provide further insight on the importance of examining the specific content of PDMP policies. While Kentucky and West Virginia enacted comprehensive mandates only, Ohio initially enacted a less than comprehensive mandate, followed four years later by a more comprehensive mandate. Consistent with Buchmueller and Carey (2018), we found that both mandates had effects in reducing selected risk measures – the 2011 mandate on rates of overlapping opioid and overlapping opioid and benzodiazepine prescriptions and the 2015 mandate on trend in the MPE rate. The mandates had differing effects on prescriber registration with and use of the PDMP, however. The 2011 mandate was associated with an increase in level of solicited reports (i.e., prescriber queries) and increasing trends of solicited reports, percent of prescribers registered with the PDMP, and percent accessing the PDMP. In contrast, the 2015 mandate was associated with increases in the percent of prescribers registered and percent accessing the PDMP, and with decreasing trends in all three measures of prescriber registration and use. The latter finding appears to reflect a leveling off of the previously increasing trends in these three measures.

Also consistent with Buchmueller and Carey (2018), we found differential effects of the mandates on different risk measures. While Kentucky's mandate was associated with decreases in all of the risk measures and in the opioid prescribing rate, and Ohio's mandates were associated with decreases in MPE rate and rates of overlapping opioids and overlapping opioids and benzodiazepines, none of the mandates were associated with decreases in the rate of high daily dosage (high MME rate). There are at least two factors which may have influenced this lack of impact on high daily dosage. First, the prescription history contained in PDMP reports may have limited influence on a prescriber's clinical decision-making regarding appropriate dosage. This might be particularly true among those patients who have been on long term high dose opioid therapy for a substantial period of time prior to introduction of the mandates, versus patients with newly initiated high daily dosage. Our high daily dosage measure did not differentiate these two types of opioid users. More importantly, the two available national-level opioid prescribing guidelines (Chou et al., 2009; Department of Veterans Affairs and Department of Defense, 2010) during our study period used 200 daily MME as the threshold for high daily dosage, which is different from the measure assessed in this current study. Second, although a more common feature currently on PDMP reports, daily dosage of prescriptions and/or patients, computed across all prescriptions, were not always available on PDMP reports in our study period which would limit prescribers' ability to monitor and reduce high dosage.

Our study was able to separate immediate effects of the mandates from slower-to-develop effects manifested in changes in trends or slopes. By examining changes in trends, we were able to identify mandate effects that previous studies were not designed to detect. Such effects can give rise to hypotheses about mechanisms by which the mandates can change behaviors. For example, while Kentucky's comprehensive mandate resulted in an immediate increase in the percent of prescribers enrolled in the PDMP, the percent of prescribers accessing the PDMP, and the number of reports requested, Ohio's initial, less-comprehensive mandate resulted in a slower but steady increasing

trend in these measures, arriving after several years at levels comparable to those achieved in Kentucky. This finding suggests that it may hold promise for a state to take incremental steps that build toward implementation of a comprehensive mandatory use law.

Our study had several limitations. In some states, mandatory use laws have been enacted concurrently with other laws, such as those directed at pill mills (pain clinic regulation laws) or to enact PDMP enhancements. A limitation of all studies of mandatory use laws, including ours, is that the effects of these laws are not possible to fully separate from the possible effects of other concurrent measures. For example, pill mill laws are unlikely to have had more than a negligible effect on PDMP usage measures. They may have affected prescribing behaviors, however, due to fear of greater oversight from law enforcement. The three states with comprehensive mandates that we examined all enacted pill mill laws concurrently with their comprehensive mandatory use laws. However, Ohio's initial, less-than-comprehensive mandate, did not have a concurrent pill mill law, yet still effected changes in certain prescribing measures. Second, we were able to measure PDMP use, but not to monitor compliance with each state's mandatory use law. Because each mandate has exceptions, it is to be expected that prescribers will not always check the PDMP prior to prescribing an opioid; however, the extent to which not checking is legitimate is currently not knowable. Third, because PDMP data do not include clinical information, we were not able to assess the appropriateness of opioid prescribing in each state, pre- or post-mandate. We were also not able to assess patient health outcomes apart from their expected association with the risk measures examined. Fourth, we were not able to examine whether or not the mandate law had any unintended consequences, particularly on the transition from prescription opioids to illicit opioids. However, previous studies show that illicit opioid-related deaths are going up regardless of whether states implemented laws to curb inappropriate prescribing (Dowell et al., 2016b; Rudd et al., 2014; Seth et al., 2018). Fifth, the ITSA revealed that baseline levels in the mandate states were often different than those in the control states, and such baseline level differences may reflect other differences between the mandate and control states that we could not control for. However, our results showed that pre-mandate trends were similar (indicated by the pre-mandate trend difference), which is an important condition for the validity of comparative ITSA, for all our outcome measures except for rate of solicited PDMP reports in West Virginia and percent of prescribers enrolled in Kentucky. ITSA analyses of the effects of each state's mandate(s) without control states resulted in findings similar to those reported here. Nevertheless, future research should consider examination of varying groups of control states in relation to state mandatory use laws.

4.1. Conclusions

Mandatory checking of the PDMP by prescribers is a promising approach for states to address the opioid overdose epidemic. Mandates appear to be consistently effective across states in increasing PDMP registration and utilization, though they exhibit varying effects on prescribing measures of risky opioid use in different state contexts. Thus, analysis shows that a state's efforts to customize its mandate law to suit its own unique circumstances can maximize its effectiveness. Comprehensive mandates can more rapidly improve PDMP registration and usage in comparison to less comprehensively designed mandates, though it appears that both approaches can be equally effective in the long term. In order to translate increased usage of PDMPs into improved prescribing behaviors, it is also important for states to improve the accessibility and ease of use of PDMPs, for example by integration of PDMP data into electronic health record systems.

Role of funding source

This project was supported by Grant No. 2011-D6-BX-K052 awarded by the Bureau of Justice Assistance, with funding from the Centers for Disease Control and Prevention (CDC) and the Food and Drug Administration (FDA). The Bureau of Justice Assistance is a component of the U.S. Department of Justice's Office of Justice Programs, which also includes the Bureau of Justice Statistics, the National Institute of Justice, the Office of Juvenile Justice and Delinquency Prevention, the Office for Victims of Crime, and the SMART Office. Points of view or opinions in this document are those of the authors and do not necessarily represent the official position or policies of the U.S. Department of Justice, the FDA, or the CDC.

Contributors

Drs. Kun, Kreiner and Strickler were lead investigators for study design, analysis and manuscript development. Drs. Baldwin, Bohnert and Halpin were involved with study design and manuscript development. All authors have contributed to and approved the final manuscript.

Conflict of interest

No conflict declared.

Acknowledgments

This project was supported by Grant No. 2011-D6-BX-K052 awarded by the Bureau of Justice Assistance. The Bureau of Justice Assistance is a component of the U.S. Department of Justice's Office of Justice Programs, which also includes the Bureau of Justice Statistics, the National Institute of Justice, the Office of Juvenile Justice and Delinquency Prevention, the Office for Victims of Crime, and the SMART Office. Points of view or opinions in this document are those of the authors and do not necessarily represent the official position or policies of the U.S. Department of Justice or the Centers for Disease Control and Prevention.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.drugalcdep.2019.02.010.

References

Bernal, J.L., Cummins, S., Gasparrini, A., 2017. Interrupted time series regression for the evaluation of public health interventions: a tutorial. Int. J. Epidemiol. 46, 348–355.

Brandeis University Prescription Drug Monitoring Program (PDMP) Training and Technical Assistance Center (TTAC), 2017. Mandatory PDMP Use. Brandeis PDMP TTAC, Waltham, MA (Accessed 2 January 2018). http://www.pdmpassist.org/pdf/Mandatory_Query_Conditions_20171114.pdf.

Buchmueller, T.C., Carey, C., 2018. The effect of prescription drug monitoring programs on opioid utilization in Medicare. Am. Econ. J. Appl. Econ. 10, 77–112. https://doi.org/10.1257/pol.2016009477.

Centers for Disease Control and Prevention (CDC), 2016. Prevention Status Reports, National Summary: Prescription Drug Overdose. Department of Health and Human Services, Atlanta, GA (Accessed 31 March 2016). https://www.cdc.gov/psr/NationalSummary/NSPDO.aspx.

Chou, R., Fanciullo, G.J., Fine, P.G., Adler, J.A., Ballantyne, J.C., Davies, P., Donovan, M.I., Fishbain, D.A., Foley, K.M., Fudin, J., Gilson, A.M., Kelter, A., Mauskop, A., O'Connor, P.G., Passik, S.D., Pasternak, G.W., Portenoy, R.K., Rich, B.A., Roberts, R.G., Todd, K.H., Miaskowski, C., American Pain Society-American Academy of Pain Medicine Opioids Guidelines Panel, 2009. Clinical guidelines for the use of chronic opioid therapy in chronic noncancer pain. J. Pain 10, 113–130.

Delcher, C., Wagenaar, A.C., Goldberger, B.A., Cook, R.L., Maldonado-Molina, M.M., 2015. Abrupt decline in oxycodone-caused mortality after implementation of Florida's prescription drug monitoring program. Drug Alcohol Depend. 150, 63–68. https://doi.org/10.1016/j.drugalcdep.2015.02.010.

Department of Veterans Affairs (VA) and The Department of Defense (DoD), 2010. VA/DoD Clinical Practice Guideline for Management of Opioid Therapy for Chronic Pain. The Management of Opioid Therapy for Chronic Pain Working Group. The Office of Quality and Performance, VA, Washington, D.C (Accessed 12 March 2018). https://www.va.gov/painmanagement/docs/cpg_opioidtherapy_fulltext.pdf.

Dowell, D., Haegerich, T., Chou, R., 2016a. CDC guideline for prescribing opioids for chronic pain—United States, 2016. JAMA 315, 1624–1645. https://doi.org/10.1001/jama.2016.1464.

Dowell, D., Zhang, K., Noonan, R.K., Hockenberry, J.M., 2016b. Mandatory provider review and pain clinic laws reduce the amounts of opioids prescribed and overdose death rates. Health Aff. (Millwood) 35, 1876–1883. https://doi.org/10.1377/hlthaff.2016.0448.

Fink, D.S., Schleimer, J.P., Sarvet, A., Grover, K.K., Delcher, C., Castillo-Carniglia, A., Kim, J.H., Rivera-Aguirre, A.E., Henry, S.G., Martins, S.S., Cerdá, M., 2018. Association between prescription drug monitoring programs and nonfatal and fatal drug overdoses: a systematic review. Ann. Intern. Med. 168, 783–790.

Guy Jr., G.P., Zhang, K., Bohm, M.K., Losby, J., Lewis, B., Young, R., Murphy, L.B., Dowell, D., 2017. Vital signs: changes in opioid prescribing in the United States, 2006-2015. MMWR Morb. Mortal. Wkly. Rep. 66, 697–704. https://doi.org/10.15585/mmwr.mm16626a15584.

Haffajee, R.L., Mello, M.M., Zhang, F., Zaslavsky, A.M., Larochelle, M.R., Wharam, J.F., 2018. Four states with robust prescription drug monitoring programs reduced opioid dosages. Health Aff. (Millwood) 37, 964–974. https://doi.org/10.1377/hlthaff.2017.1321.

Hedegaard, H., Warner, M., Minino, A.M., 2017. Drug overdose deaths in the United States, 1999–2016. NCHS Data Brief 294, 1–8.

Hopkins, D., Dreyzehner, J.J., O'Leary, T., 2014. Lessons Learned from Mandating Prescriber Compliance. National RX Drug Abuse Summit, Atlanta, GA (Accessed 30 April 2017). https://www.slideshare.net/OPUNITE/pdmp-5-hopkins-dreyzehneroleary.

Kreiner, P., Nikitin, R., Shields, T.P., 2013. Bureau of Justice Assistance Prescription Drug Monitoring Program Performance Measures Report: January 2009 Through June 2012. Brandeis University Prescription Drug Monitoring Program Center of Excellence. Prepared for U.S. Department of Justice, Bureau of Justice Assistance, Waltham, MA.

Lin, H.C., Wang, Z., Boyd, C., Simoni-Wastila, L., Buu, A., 2018. Associations between statewide prescription drug monitoring program (PDMP) requirement and physician patterns of prescribing opioid analgesics for patients with non-cancer chronic pain. Addict. Behav. 76, 348–354.

Linden, A., 2015. Conducting interrupted time-series analysis for single- and multiple-group comparisons. Stata J. 15, 480–500.

Liu, Y., Logan, J.E., Paulozzi, L.J., Zhang, K., Jones, C.M., 2013. Potential misuse and inappropriate prescription practices involving opioid analgesics. Am. J. Manag. Care 19, 648–665.

Pardo, B., 2017. Do more robust prescription drug monitoring programs reduce prescription opioid overdose? Addiction 112, 1773–1783.

Patrick, S.W., Fry, C.E., Jones, T.F., Buntin, M.B., 2016. Implementation of prescription drug monitoring programs associated with reductions in opioid-related death rates. Health Aff. (Millwood) 35, 1324–1332.

Paulozzi, L.J., Kilbourne, E.M., Shah, N.G., Nolte, K.B., Desai, H.A., Landen, M.G., Harvey, W., Loring, L.D., 2012. A history of being prescribed controlled substances and risk of drug overdose death. Pain Med. 13, 87–95.

Paulozzi, L.J., Strickler, G.K., Kreiner, P.W., Koris, C.M., 2015. Controlled substance prescribing patterns—Prescription Behavior Surveillance System, eight states, 2013. MMWR Surveill. Summ. 64, 1–14. https://doi.org/10.15585/mmwr.ss16409a15581.

Pauly, N.J., Slavova, S., Delcher, C., Freeman, P.R., Talbert, J., 2018. Features of prescription drug monitoring programs associated with reduced rates of prescription opioid-related poisonings. Drug Alcohol Depend. 184, 26–32.

Pew Charitable Trusts, 2016. Prescription Drug Monitoring Programs: Evidence-Based Practices to Optimize Prescriber Use. A Report Prepared by the Pew Charitable Trusts and the Institute for Behavioral Health. Brandeis University (Accessed 18 March 2018). http://www.pewtrusts.org/~/media/assets/2016/12/prescription_drug_monitoring_programs.pdf.

Rudd, R.A., Paulozzi, L.J., Bauer, M.J., Burleson, R.W., Carlson, R.E., Dao, D., Davis, J.W., Dudek, J., Eichler, B.A., Fernandes, J.C., Fondario, A., Gabella, B., Hume, B., Huntamer, T., Kariisa, M., Largo, T.W., Miles, J., Newmyer, A., Nitcheva, D., Perez, B.E., Proescholdbell, S.K., Sabel, J.C., Skiba, J., Slavova, S., Stone, K., Tharp, J.M., 2014. Increases in heroin overdose deaths – 28 states, 2010–2012. MMWR Morb. Mortal. Wkly. Rep. 63, 849–854.

Seth, P., Scholl, L., Rudd, R., Bacon, S., 2018. Overdose deaths involving opioids, cocaine, and psychostimulants—United States, 2015–2016. Am. J. Transplant. 18, 1556–1568.

Soumerai, S.B., Starr, D., Majumdar, S.R., 2015. How do you know which health care effectiveness research you can trust? A guide to study design for the perplexed. Prev. Chronic Dis. 12, E101.

State of Ohio Board of Pharmacy, 2017. 2016 Ohio Automated Rx Reporting System (OARRS) Annual Report. (Accessed 2 February 2017). https://www.ohiopmp.gov/portal/default.aspx.

Stucke, R.S., Kelly, J.L., Mathis, K.A., Hill, M., Barth, R., 2018. Association of the use of a mandatory prescription drug monitoring program with prescribing practices for patients undergoing elective surgery. JAMA Surg. 153 (12), 1105–1110 [E-pub ahead of print].

West Virginia Board of Medicine, 2012. Practitioner Requirements for Accessing the West Virginia Controlled Substances Monitoring Program Database, in Title Number 11 West Virginia Code § 60A.9-Sa(b). Legislative Rule-Making Review Committee (Accessed 9 June 2017). http://regs.cqstatetrack.com/info/get_text?action_id=287732&text_id=289398&type=action_text.

Winstanley, E.L., Zhang, Y., Mashni, R., Schnee, S., Penm, J., Boone, J., McNamee, C., MacKinnon, N.J., 2018. Mandatory review of a prescription drug monitoring program and impact on opioid and benzodiazepine dispensing. Drug Alcohol Depend. 188, 169–174.