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Review

Prescription Drug Monitoring Programs and Prescription Opioid–Related Outcomes in the United States

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Prescription drug monitoring programs (PDMPs) are a crucial component of federal and state governments' response to the opioid epidemic. Evidence about the effectiveness of PDMPs in reducing prescription opioid–related adverse outcomes is mixed. We conducted a systematic review to examine whether PDMP implementation within the United States is associated with changes in 4 prescription opioid–related outcome domains: opioid prescribing behaviors, opioid diversion and supply, opioid-related morbidity and substance-use disorders, and opioid-related deaths. We searched for eligible publications in Embase, Google Scholar, MEDLINE, and Web of Science. A total of 29 studies, published between 2009 and 2019, met the inclusion criteria. Of the 16 studies examining PDMPs and prescribing behaviors, 11 found that implementing PDMPs reduced prescribing behaviors. All 3 studies on opioid diversion and supply reported reductions in the examined outcomes. In the opioid-related morbidity and substance-use disorders domain, 7 of 8 studies found associations with prescription opioid–related outcomes. Four of 8 studies in the opioid-related deaths domain reported reduced mortality rates. Despite the mixed findings, emerging evidence supports that the implementation of state PDMPs reduces opioid prescriptions, opioid diversion and supply, and opioid-related morbidity and substance-use disorder outcomes. When PDMP characteristics were examined, mandatory access provisions were associated with reductions in prescribing behaviors, diversion outcomes, hospital admissions, substance-use disorders, and mortality rates. Inconsistencies in the evidence base across outcome domains are due to analytical approaches across studies and, to some extent, heterogeneities in PDMP policies implemented across states and over time.

drug prescriptions; opioid-related disorders; prescription drug diversion; prescription drug monitoring programs; substance-related disorders

Abbreviation: PDMP, prescription drug monitoring program.

INTRODUCTION

The ongoing opioid-overdose epidemic remains unabated. In 2017, opioid-related deaths accounted for 68% of the total drug overdose deaths in the United States (1). From 1999 to 2017, the annual number of overdose deaths related to opioids (including licit and illicit opioids) increased more than 600% (1). Moreover, the types of opioids involved in these deaths have evolved. From 1999 to 2010, commonly prescribed opioids were the leading cause of opioid-related deaths; these leveled off from 2011 to 2016 and were surpassed by synthetic opioids as the leading cause of opioid-related deaths in 2016 (1). Despite the evolution of the opioid epidemic from prescription to synthetic opioids as the leading cause of death, commonly prescribed opioids continue to play a significant role in the epidemic, and interventions to improve opioid prescribing behaviors remain a priority.

Implementing and enhancing state prescription drug monitoring programs (PDMPs) is a widespread policy response to the opioid epidemic (2). Prescription drug monitoring programs are statewide electronic databases that collect data on controlled substances as defined by federal and state

controlled-substances laws. By 2017, all 50 states and the District of Columbia had an operational PDMP or passed legislation to operate a PDMP (3). Enacted and implemented by individual states, PDMPs differ in important aspects such as administrative agencies, funding, consumer-related regulations, data collection intervals, program evaluation, substances monitored, reporting requirements, and authorized user access (4, 5). Moreover, state PDMPs have evolved considerably in recent years (6). A recent analysis revealed that between 1999 and 2016, US states had transitioned their PDMPs to more robust programs by increasing the reporting frequency, expanding the drug schedules monitored, and initiating interstate data sharing (7). As PDMPs evolve and grow into complex tools for identifying illegal prescribing behaviors and informing prescriber decisions, we need a new synthesis of the available literature assessing PDMPs' effectiveness.

Three reviews have advanced our knowledge regarding PDMPs' impact. First, in their scoping review, Finley et al. (8) summarized the PDMPs literature and found inconsistent and mixed evidence to support any impact. In assessing the available evidence, they proposed a conceptual framework to evaluate PDMPs' effectiveness, including opioid prescribing behaviors, opioid diversion and supply, opioid substance-use disorders, and opioid-related morbidity and mortality. We used the conceptual framework to guide this systematic review, expanded our analysis to 4 core search databases, and included bias assessments for each included study.

Second, the systematic review by Fink et al. (9) was focused on nonfatal and fatal drug-overdose outcomes. The search strategy included multiple data sources as well as bias assessments for each study. Although Fink et al. found mixed results between PDMP implementation and nonfatal or fatal overdoses, in their review, they found some evidence that specific operational features may differentially affect fatal drug poisonings. In the present review, we followed the comprehensive search approach used by Fink et al. and expanded the scope of our review to include 3 additional opioid-related domains: prescribing behaviors, opioid diversion and supply, and opioid substance-use disorders.

And third, in their systematic review, Wilson et al. (10) assessed the PDMPs' effectiveness in reducing overall opioid prescribing or dispensing, rates of multiple provider use, rates of inappropriate prescribing or dispensing, and rates of nonmedical prescription opioid use. They found limited evidence linking PDMPs to decreased prescribing outcomes for different types of opioids or multiple provider outcomes. However, the review had a limited list of search terms and omitted any discussion of the different features attached to PDMPs' effectiveness.

In sum, and building on these 3 previous reviews, our review makes the following novel contributions to the literature: We provide an updated appraisal and synthesis of the evolving evidence on PDMPs. We used an expanded and predefined search strategy to increase the recall rate of literature and applied it to 4 core search databases. We increased the number of examined prescription opioid–related outcomes and classified new outcomes into 4 main domains, as described by Finley et al. (8). We also discussed variations in state PDMPs to inform what program features were consistently associated with prescription opioid–related outcomes.

METHODS

We followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Protocols, a 17-item checklist, to perform this systematic review (11). The protocol for this systematic review was registered with the International Prospective Register of Systematic Reviews (identifier: CRD42019122231) (12). Our central question of interest was whether PDMP implementation is associated with improved prescription opioid–related outcomes in 4 domains: opioid prescribing behaviors, opioid diversion and supply, opioid-related morbidity and substance-use disorders, and opioid-related deaths.

Study eligibility

Studies were included if they 1) assessed at least 1 of the 4 prescription opioid–related outcomes associated with PDMP implementation, using observational research designs such as before and after comparison, time-series analysis, or prospective and retrospective cohorts; 2) presented quantitative data or at least 1 measure of association (odds ratio, risk ratio, rate ratio, rate difference) between PDMP implementation and a prescription opioid–related outcome; and 3) were published in the English language and were conducted in the United States. Excluded from this systematic review were studies that did not have a before and after PDMP implementation comparison, those that focused exclusively on illicit opioids such as heroin or the burden of opioids, clinical guidelines, and those that were not published in peer-reviewed journals, such as theses and dissertations, along with commentaries, opinions, testimonials, books, letters, reviews, corrections, editorials, and conference abstracts. Given that PDMPs were designed to identify illegal prescribing behaviors, we decided to focus on the expected direct associations that PDMPs might have on prescription opioids. Despite heroin and other illicit opioids' surge as critical components of the opioid epidemic, we considered that any associations between PDMPs and outcomes related to the use of these illicit opioids are unintended results. Different countries have implemented PDMPs to curb the global burden of substance-use disorders. It is estimated that worldwide, 29.5 million people are affected by a substance-use disorder, with 70% of the burden attributed to opioids (13). For this review, we decided to focus on PDMPs in the United States to minimize the variability in the results that might be attributed to differences in health systems between the United States and other countries.

Search strategy, data sources, data extraction, and quality assessment

The search strategy was first designed and tested on December 13, 2017, and was last updated on January 9,

2019. We carried out a comprehensive search of 4 electronic databases: Embase; Google Scholar; MEDLINE, as a combination of Ovid MEDLINE, Epub Ahead of Print, In-Process & Other Non-Indexed Citations, Daily and Versions, and PubMed; and Web of Science Core Collection. The search was not restricted to a specific period; the review includes any study published up to January 9, 2019. These databases have been identified as the most reliable combination and minimum requirement of search engines for a reliable recall rate of literature (14). Databases were searched using a single-line search strategy (15) with Emtree and Medical Subject Headings terms (Web Appendix 1) (available at https://academic.oup.com/aje). Two authors (V.P.-P. and S.C.) screened titles and abstracts of identified studies on the basis of eligibility criteria and independently extracted data from the studies included in the review. Discrepancies were resolved through discussion. References to identified studies were manually screened. For each selected study, we recorded data on the primary author, publication year, study population, exposures, outcome assessments, and results. Two authors (V.P.-P. and S.C.) also evaluated the quality of all included studies independently (Web Table 1) using the Newcastle-Ottawa Scale (16), a tool for assessing methodological quality or risk of bias in nonrandomized studies. We assessed study quality on the basis of the selection of the study groups, the comparability of the groups, and the ascertainment of the exposure or outcome of interest. Because no explicit guidance exists for the Newcastle-Ottawa Scale scores, we used thresholds for classifying each study as described in the report on the Newcastle-Ottawa Quality Assessment Form for Cohort Studies (17).

Data synthesis and analysis

Information extracted and tabulated from each study included states analyzed, study period, population size, prescription opioid–related outcomes, PDMP characteristics, and main findings. When available, we extracted associations' magnitude and direction for each examined outcome and reported these in the result tables. Each article was then categorized into 1 of the 4 prescription opioid–related outcome domains and sorted by publication date in ascending order. Studies that evaluated multiple outcomes were listed in different domains accordingly. We used EndNote, version 8.2 (Clarivate, Philadelphia, Pennsylvania) as the reference management software for collecting, selecting, and formatting references (18).

RESULTS

The 4-database search identified 1,524 records. After removing 834 duplicates within and between each database, 690 studies were screened. In the first screening and assessment for eligibility, 371 and 290 records were removed, respectively, leaving 29 studies that met the inclusion criteria (Figure 1). All studies included in this systematic review were published between January 1, 2009, and January 9, 2019. We classified the studies according to their outcome of interest (Tables 1–4). Of the 29 studies, 16 addressed opioid prescribing behaviors (19–34), 3 addressed opioid supply or diversion (35–37), 8 addressed opioid-related morbidity and substance-use disorders (22, 35, 36, 38–42), and 8 addressed opioid-related deaths (25, 29, 39, 43–47). Some studies (22, 25, 29, 35, 36, 39) addressed more than 1 domain of opioid-related outcomes.

We described the quality scores for each included study in Web Table 1. The distribution of quality scores was similar between studies reporting associations between PDMPs and opioid-related outcomes and those reporting no associations (χ^2 test, $P = 0.22$; data not shown). No significant time trend was found ($P = 0.35$; data not shown) for the year of publication and whether studies reported any PDMP association. Fifteen studies (52%) received a good-quality score, 9 studies (31%) received a fair-quality score, and 5 (17%) received a poor-quality score.

Prescription opioid–related outcomes

The review revealed mixed findings between PDMPs and each of the 4 prescription opioid–related outcome domains. Of the 16 studies that examined the association between PDMPs and prescribing behaviors, 11 reported a reduction in different prescribing outcomes post-PDMP implementation (Table 1). Prescription drug monitoring programs were associated with reduced odds of receiving an opioid analgesic prescription among patients post-surgical dental extraction in New York (31); decreased total opioid volumes and mean morphine milligram equivalents in Florida (32); reduced rate of schedule II opioid prescriptions among patients from ambulatory care visits (19); lowered the number of patients with opioid prescriptions from high-risk prescribers in Florida (23); reduced rates of morphine milligram equivalents prescribed (25); reduced opioid use among Medicare (28) and Medicaid (33) beneficiaries; decreased the number of overlapping opioid prescriptions, based on nationwide insurance claims data (20); reduced average morphine milligram equivalents per transaction, total opioid volume, and the number of prescriptions among patients identified as high-risk in Florida (24); reduced opioid prescription rates in Iowa's outpatient pharmacies (30); and decreased days' supply of prescription opioids for Medicare beneficiaries (34).

In the opioid supply and diversion domain, all 3 studies reported reductions associated with PDMP implementation (Table 2). Prescription drug monitoring program states were associated with fewer quantities of oxycodone shipments (36), reduced rates of so-called doctor-shopping for prescription opioids (35), and lower diversion rates for oxycodone, morphine, methadone, and hydrocodone in Florida (37).

In the opioid-related morbidity and substance-use disorders domain, 7 of 8 studies reported statistically significant changes in prescription opioid–related outcomes after PDMP implementation (Table 3). These included fewer opioid-related admissions and inpatient drug rehabilitation admissions (36); lower opioid substance-use disorder rates in the general population and the population seeking treatment for specialized opioid centers (41); fewer days

Table 1. Studies of Prescription Drug Monitoring Programs and Opioid Prescribing Behaviors

First Author, Year (Reference No.)	No. of States	Years	Population	Outcome	PDMP Exposure Definitions	Findings	PDMPs Association
Paulozzi, 2011 (29)	50 and D.C.	1999–2005	ARCOS data on 7 prescribed opioids	Total MME per person for each state for each year	19 operational PDMP states, defined as capable of collecting data and distributing data to ≥1 authorized users of the data 13 proactive PDMP states, defined as those generating reports for prescribers, dispensers, or law enforcement authorities without being solicited 4 high-reporting PDMP states with >100 solicited or unsolicited reports per 10,000 population to doctors, dispensers, or other recipients	Mean MME rates each year were not different between states with an operational PDMP (362.43 MME/person/year, mean SE, 15.99) and states without an operational PDMP (341.67 MME/person/year, mean SE, 10.20) Mean MME rates each year were not different between states with a proactive PDMP (365.67 MME/person/year, mean SE, 20.47) vs. states with an operational PDMP (362.43 MME/person/year, mean SE, 15.99) Mean MME rates each year were higher among states with a high-reporting PDMP (540.75 MME/person/year, mean SE, 45.54) than were among states with an operational PDMP (362.43 MME/person/year, mean SE, 15.99)	No
Brady, 2014 (21)	50 and D.C.	1999–2008	ARCOS quarterly data on opioids dispensed	Opioids dispensed converted into MME per capita	PDMP implementation refers to the quarter and year when electronic prescription drug data collection began, and 3 features: type of governing agency, committee oversight, nonaccess requirement	No statistically significant difference was found in MMEs dispensed in state quarters with and without PDMPs (difference of −3%, SE, 0.07; $P = 0.68$). Results of PDMPs by the type of governing agency, committee oversight, or nonaccess requirement were also nonstatistically significant.	No

Table continues

Table 1. Continued

First Author, Year (Reference No.)	No. of States	Years	Population	Outcome	PDMP Exposure Definitions	Findings	PDMPs Association
McAllister, 2015 (27)	1 (Florida)	12/2013–2/2014	E-FORCSE data on 710 patients	Total number of controlled substances prescribed per emergency department visit and the number of opioid analgesics prescribed	E-FORCSE collects and stores prescribing and dispensing data for all controlled substances in schedules II, III, and IV dispensed within the state, uploaded within 7 days of dispensing, and registration is voluntary	The average number of controlled substances prescribed per emergency department visit did not change after providing prescribers with E-FORCSE data, compared with the historical control group (0.28 vs. 0.23; Wilcoxon rank-sum test, $P = 0.13$). The percentage of patients with prescribed opioids was not different between the intervention and control groups (19.5% vs. 23.6%; $P = 0.18$)	No
Rasubala, 2015 (31)	1 (New York)	2013–2014	Dental urgent care center data on drug prescriptions for 6,204 dental visits	Dosages and quantities (number of pills) of opioid prescriptions (schedule II or III) by dentists	I-STOP and mandatory database consultation before prescribing a controlled substance	Statistically significant reduction in the number of opioid prescriptions in post–I-STOP-1 (OR = 0.37, 95% CI: 0.31, 0.45) and post–I-STOP-2 (OR 0.24, 95% CI: 0.20, 0.30) periods compared with the pre–I-STOP period. Adjusted estimates for the frequency of surgical extractions remained statistically significant.	Yes
Rutkow, 2015 (32)	2 (Florida and Georgia)	7/2010–9/2012	IMS Health LifeLink Prescription data on 2.6 million patients, 431,890 prescribers, and 2,829 pharmacies	Total opioid volume prescribed using MME doses, mean MME per transaction, mean days' supply per transaction, and the total number of opioid prescriptions dispensed	Florida's PDMP collects and stores prescribing and dispensing data for all controlled substances in schedules II, III, and IV dispensed within the state, uploaded within 7 days of dispensing; registration is voluntary. Georgia served as a comparison state	The PDMP and pill-mill laws were associated with statistically significant reductions in total opioid volume (−2.5 kg/month, $P < 0.05$) and mean MME (−0.45 mg/transaction, $P = <0.05$), but no significant changes for mean days' supply (0.00 days' supply difference) and the total number of opioid prescriptions dispensed (−0.01 opioid prescriptions)	Yes

Table continues

Table 1. Continued

First Author, Year (Reference No.)	No. of States	Years	Population	Outcome	PDMP Exposure Definitions	Findings	PDMPs Association
Bao, 2016 (19)	24	2001–2010	NAMCS data on 26,275 ambulatory care office visits	Having at least 1 schedule II opioid analgesic prescribed and having at least 1 opioid of any kind prescribed or continued at a pain-related ambulatory care visit	PDMP implementation, defined as the date on which a state opened online access to its database to prescribers and dispensers	The implementation of a PDMP was associated with reductions in the rate of prescribing of schedule II opioids ("marginal effect," −0.017; $P < 0.01$), opioids of any kind (marginal effect, −0.015), and pain medication overall (marginal effect, −0.01). The implementation of a program also slightly increased the prescribing of nonopioid analgesics (marginal effect, 0.02)	Yes
Chang, 2016 (23)	2 (Florida and Georgia)	7/2010–9/2012	IMS LifeLink Longitudinal Prescription data on 12.02 million eligible opioid prescriptions	1) Total number of patients with an opioid prescription; 2) proportion of prescriptions dispensed as opioids among all prescriptions; 3) proportion of patients with at least 1 opioid prescription among all patients; 4) average MME per transaction; 5) total opioid volume prescribed using morphine equivalent doses; 6) average days' supply per transaction; and 7) total number of opioid prescriptions dispensed	Florida's PDMP collects and stores prescribing and dispensing data for all controlled substances in schedules II, III, and IV dispensed within the state, uploaded within 7 days of dispensing; registration is voluntary. Georgia served as a comparison state	Among high-risk prescribers, a PDMP and pill-mill laws produced significant declines in the number of patients with an opioid prescription (536 fewer patients/month; $P < 0.01$); average MME per transaction (0.88 fewer mg/month/transaction; $P < 0.01$); total opioid volume (3.88 fewer kg/month; $P < 0.01$); the number of opioid prescriptions dispensed (847 fewer prescriptions/month; $P < 0.05$). A slight increase in the total number of days' supply (0.02 more days/month/transaction; $P < 0.05$) was found.	Yes

Table continues

Table 1. Continued

First Author, Year (Reference No.)	No. of States	Years	Population	Outcome	PDMP Exposure Definitions	Findings	PDMPs Association
Dowell, 2016 (25)	38 and D.C.	2006–2013	IMS Health's National Prescription Audit on prescribed opioids dispensed	State-specific annual opioid prescribing rates as MME per state resident per year	Mandated provider review of information from PDMPs before prescribing	The implementation of mandating PDMP use and pill-mill laws resulted in declined prescribing rates more sharply (10.60% decrease) than in states not implementing either policy (5.50% decrease)	Yes
Brown, 2017 (22)	1 (New York)	2010–2015	ARCOS quarterly data on opioids distributed and NYSDOH-BNE data	Distribution of the most-used opioids converted into MME and the number of opioid prescriptions filled to the BNE	I-STOP and mandatory database consultation before prescribing a controlled substance	MME distribution increased after I-STOP implementation (+2.73 MME; $P < 0.01$). Trends in the number of prescriptions filled for opioids showed a decrease (inconclusive data)	No
Moyo, 2017 (28)	19	2008–2012	Beneficiary summary files and Part D Prescription Drug Event Medicare claims	Mean daily MME dose per prescription, total opioid volume dispensed as cumulative monthly mean MME dose, number of opioid prescriptions dispensed, and total opioid volume dispensed of schedule II, III, IV, and V opioids	PDMP implementation, defined as the date on which a state initiated online PDMP access to prescribers	PDMP implementation was associated with reductions of opioid use among Medicare beneficiaries, as indicated by significant declines in total opioid volume (−2.36 kg/month, 95% CI: −3.44, −1.28), schedule II total opioid volumes (−1.89 kg/month, 95% CI: −3.38, −0.40), and schedule III total opioid volumes (−0.28 kg/month, 95% CI: −0.54, −0.03). Beneficiaries with disabilities experienced greater reductions in total opioid volume and daily MMEs than those eligible by age.	Yes

Table continues

Table 1. Continued

First Author, Year (Reference No.)	No. of States	Years	Population	Outcome	PDMP Exposure Definitions	Findings	PDMPs Association
Wen, 2017 (33)	46	2011–2014	Medicaid State Drug Utilization Files from the CMS data on the number of prescriptions and spending	Number of filled prescriptions (including new prescriptions and refills) and the amount of postrebate Medicaid spending on prescription opioids in each quarter per 100 Medicaid enrollees	Implementation of mandates for registration, use, any, or both related to PDMP, defined as the effective date of each statutory mandate	Mandates of registration and use (−1.90 fewer opioid prescriptions per quarter per 100 enrollees; $P < 0.05$) or mandates of registration alone (−1.49 fewer opioid prescriptions per quarter per 100 enrollees; $P < 0.05$) reduced schedule II opioid prescriptions. Mandates of registration and use (−83.76 fewer US $ per quarter per 100 enrollees; $P < 0.05$), or mandates of registration alone (−67.24 fewer US $ per quarter per 100 enrollees; $P < 0.05$) reduced schedule II spending	Yes
Bao, 2018 (20)	48	2011–2015	Health Care Cost Institute's insurance claims data	Overlapping opioid prescriptions for ≥7 days, opioid prescriptions from ≥3 prescribers, overlapping opioid and benzodiazepine prescriptions for ≥7 days, and a very high standardized dosage of opioids	PDMP implementation, defined as the effective date of the legislation (for comprehensive use mandates and delegation laws) or the "go-live" date of interstate data sharing in interconnect	Operational PDMPs by the end of 2010 with a comprehensive use mandate reduced the probability of overlapping opioid prescriptions by 9.20%, having ≥3 opioid prescribers by 6.60%, and overlapping opioid and benzodiazepine prescriptions by 8%. PDMPs with delegate laws and with interstate data sharing also reduced the probability of opioid-related outcomes.	Yes
Chang, 2018 (24)	2 (Florida and Georgia)	7/2010–9/2012	Quintiles IMS LifeLink Longitudinal Prescription data on 1.67 million patients and ∼12 million opioid prescriptions	Average MME per transaction, total opioid volume across all prescriptions by using MME, average days supplied per transaction, the total number of opioid prescriptions dispensed	Florida's PDMP collects and stores prescribing and dispensing data for all controlled substances in schedules II, III, and IV dispensed within the state, uploaded within 7 days of dispensing; registration is voluntary. Georgia served as a comparison state	A PDMP and pill-mill laws produced significant declines in average MME per transaction, total opioid volume, and the number of opioid prescriptions for all types of high-risk patients. Chronic users had the largest associations, 1.20 fewer MME per transaction/month (95% CI: −1.46, −0.95), 4.58 fewer kg/month total opioid volume (95% CI: −5.41, −3.76), and 0.71 fewer opioid prescriptions (95% CI: −0.90, −0.52)	Yes

Table continues

Table 1. Continued

First Author, Year (Reference No.)	No. of States	Years	Population	Outcome	PDMP Exposure Definitions	Findings	PDMPs Association
Lin, 2018 (26)	50 and D.C.	2012	NAMCS data on ambulatory visits to nonfederally employed office-based physicians	Prescribing pain medications (opioid and nonopioid agents) and prescribing opioids (including opioids, opioid combinations, and opioid equivalents) when any pain medication is prescribed	PDMP implementation as no requirement of enrollment, mandatory enrollment, and mandatory query of PDMP data before prescribing	State PDMP implementation (OR = 0.73, 95% CI: 0.40, 1.34), PDMPs with mandatory enrollment (OR = 0.69, 95% CI: 0.32, 1.45), or PDMPs with mandatory query (OR = 0.72, 95% CI: 0.38, 1.34) did not reduce the odds of opioid prescribing for patients with noncancer chronic pain	No
Ranapurwala, 2018 (30)	1 (Iowa)	2003–2014	Administrative claims data from a private health insurer	OPR prescription rate, OPR dose per day in MME, OPR dose per fill in MME, days' supply per fill	Iowa's PDMP allows prescriber registration and access to authorized users	OPR prescription rates declined by 34 prescriptions/1,000 (95% CI: −51, −17) per person-years in the year post-PDMP. Similarly, OPR dose per day declined by 2.9 MME/day (95% CI: −3.7, −2.0) 2 years post-PDMP, and OPR dose per fill declined 42 MME per fill (95% CI: −63, −21) 2 years post-PDMP. The OPR days' supply kept increasing post-PDMP implementation, albeit at a slightly slower rate than pre-PDMP implementation	Yes
Yarbrough, 2018 (34)	21	2010–2013	Medicare Part D data on physician-level prescribing	Total days' supply prescribed per physician for all opioids, nonopioid analgesics, oxycodone-containing products, hydrocodone-containing products, and opioids categorized in DEA schedules II-IV	PDMP implementation, defined as prescriber and dispenser access, online access, and required reporting of all prescriptions dispensed by the pharmacy	Total days' supply prescribed declined 2.0% for opioids ($P < 0.01$), 5.2% for oxycodone ($P < 0.01$), and 2.8% for hydrocodone ($P < 0.01$) in the presence of a PDMP. Statutes that enforce nonuse requirement undermine PDMP's findings.	Yes

Abbreviations: ARCOS, Automation of Reports and Consolidated Orders System; BNE, Bureau of Narcotics Enforcement; CI, confidence interval; CMS, Centers for Medicare and Medicaid Services; D.C., District of Columbia; DEA, Drug Enforcement Administration; E-FORCSE, Electronic-Florida Online Reporting of Controlled Substances Evaluation program; IMS, Intercontinental Marketing Services; I-STOP, Internet System for Tracking Over-Prescribing; MME, morphine milligram equivalent; NAMCS, National Ambulatory Medical Care Survey; NYSDOH, New York State Department of Health; OPR, opioid pain reliever; OR, odds ratio; PDMP, prescription drug monitoring program; SE, standard error.

Table 2. Studies of Prescription Drug Monitoring Programs and Opioid Diversion and Supply

First Author, Year (Reference No.)	No. of States	Years	Population	Outcome	PDMP Exposure Definitions	Findings	PDMPS Association
Reisman, 2009 (36)	50	1997–2003	ARCOS and TEDS data	Shipments in grams of prescription opioid per 100,000 population per year	PDMPs were considered active if they reported schedule II, III, or both, opioids and maintained information on the prescription date, the prescribing health professional, the patient's name and address, and the medication's name, dosage, amount prescribed, and the dosing information	PDMP states had significantly reduced oxycodone shipments compared with the control group (time-series linear regression $\beta = -370.9$, $P = 0.02$). None of the other 3 opioids demonstrated statistically significant associations.	Yes
Surratt, 2014, (37)	1 (Florida)	2009–2012	RADARS data on the diversion of prescription opioids	Quarterly diversion rates for each opioid class per 100,000 population	Florida's PDMP collects and stores prescribing and dispensing data for all controlled substances in schedules II, III, and IV dispensed within the state, uploaded within 7 days of dispensing; registration is voluntary	Multilevel modeling results revealed significant declines in diversion rates for several prescription opioids after PCL and PDMP implementation: oxycodone (slope = -1.31, $P = 0.03$), morphine (slope = -0.13, $P = 0.05$), methadone (slope = -0.23, $P < 0.01$), and hydrocodone (slope = -0.49, $P = 0.08$)	Yes
Ali, 2017 (35)	36	2004–2014	NSDUH data on individual-level substance-use attitudes and behaviors	Sources of NMPRs	Operational PDMPs, and PDMPs based on whether they had provisions requiring mandatory access by providers and mandatory prescriber enrollment	Operational PDMPs reduced odds of having $\geq$2 doctors as an NMPR source. Specifically, PDMPs with a mandatory access provision reduced the odds of doctor shopping by 80% ($P < 0.05$) and having a fake prescription by 75% ($P < 0.10$). PDMPs without provision of mandatory enrollment or access reduced the odds of doctor shopping by 56% ($P < 0.05$) and having a fake prescription by 50% ($P < 0.10$)	Yes

Abbreviations: ARCOS, Automation of Reports and Consolidated Orders System; NSDUH, National Survey of Drug Use and Health; NMPR, nonmedical use of prescription pain relievers; PCL, pain clinic legislation; PDMP, prescription drug monitoring program; RADARS, Researched Abuse, Diversion and Addiction-Related Surveillance; TEDS, treatment episode data sets.

Table 3. Studies of Prescription Drug Monitoring Programs and Opioid-Related Morbidity and Substance-Use Disorders

First Author, Year (Reference No.)	No. of States	Years	Population	Outcome	PDMP Exposure Definitions	Findings	PDMPS Association
Reisman, 2009 (36)	50	1997–2003	ARCOS, and TEDS data	The number of inpatient prescription opioid–rehabilitation admissions per 100 total drug rehabilitation admissions and the percent change in the state prescription opioid rehabilitation admission rates	PDMPs were considered active if they reported schedule II, III, or both, opioids and maintained information on the prescription date, health professional, the patient's name and address, and the medication's name, dosage, and other information	PDMP states mitigated increases in opioid admissions ($P = 0.063$) and lower odds of patients entering an inpatient drug rehabilitation program (OR = 0.78, 95% CI: 0.76, 0.79)	Yes
Reifler, 2012 (41)	44	2003–2009	RADARS data on prescription opioids and stimulant drugs	Self-reported use of a prescription or illicit opioid to get high in the past 30 days measured as oxycodone use rates per 100,000 persons and 1,000 URDD	Date of implementation was considered the date when the PDMP began collecting prescription data. A subset of superior PDMPs was identified on the basis of programs that have been implemented for a long time (at least by the start of 2002), provide PDMP data reports, and capture data on drugs at least through schedule IV	PDMPs are associated with mitigated upward trends of opioid substance-use disorders. Intentional exposure to Poison Center increased 1.002 times per quarter in PDMP states and 1.019 times per quarter in non-PDMP states. For opioid treatment, the predicted increase was 1.026 per quarter in PDMP states and 1.049 times per quarter in non-PDMP states	Yes
Maughan, 2015 (40)	11 US metropolitan areas	2004–2011	DAWN quarterly data on ED visits related to licit and illicit drug use	Rate of ED visits involving opioid analgesics per quarter, per 100,000 metropolitan area residents	The first date on which a prescriber accessible PDMP was present in a state was considered the PDMP implementation date	PDMP implementation was not associated with a difference in the rate of ED visit related to opioid analgesics visits, mean difference of 0.8 visits (95% CI: −3.7, 5.2) per 100,000 residents per quarter	No
Ali, 2017 (35)	36	2004–2014	NSDUH data on individual-level substance-use attitudes and behaviors	NMPRs measured as 1) past-year NMPR use, 2) past-year DSM-IV substance-use disorder of NMPR, 3) past-year NMPR initiation based on respondents' answers to dates of first use, and 4) past-year days of NMPR use	Operational PDMPs, and PDMPs based on whether they had provisions requiring mandatory access by providers and mandatory prescriber enrollment	PDMPs had no association with past-year use, past-year substance-use disorder, and past-year initiation. Operational PDMPs did reduce past-year of NMPR use by 10 days ($P < 0.05$). PDMPs with mandatory access and enrollment provisions reduced past-year of NMPR use by 20 days ($P < 0.01$)	No/Yes

Table continues

Table 3. Continued

First Author, Year (Reference No.)	No. of States	Years	Population	Outcome	PDMP Exposure Definitions	Findings	PDMPS Association
Brown, 2017 (22)	1 (New York)	2010–2015	SPARCS quarterly data on opioids use disorders	The number of ED and inpatient admissions for prescription opioid overdose after I-STOP implementation	I-STOP and mandatory database consultation before prescribing a controlled substance	Overdose admissions attributed to prescription opioids leveled off after I-STOP implementation (slope = −0.01, $P = 0.98$), although the before- and after-implementation slopes were not statistically different (f = 1.04, $P = 0.37$)	Yes
Buchmueller, 2018 (38)	10	2007–2013	Claims data from Medicare prescription drug program (Medicare Part D)	The measure of the share of Part D enrollees who take any opioids at all	Laws requiring providers to access PDMP data under certain circumstances before prescribing or filling a prescription	The "must access" PDMPs reduced in 2.4% the share of Part D enrollees taking opioids, in 6% the share of overlapping claims, and 5% the share of persons with an opioid substance-use disorder with >7 months' supply	Yes
Pauly, 2018 (42)	50 and D.C.	2004–2014	Truven administrative claims data	The number of RxORP on each state-month	PDMPs were defined as operational when they allowed data access to either prescribers or law enforcement officials. The study also examined 5 PDMP features	Operational PDMP states mitigated increases in RR of RxORP over time relative to non-PDMP states. Non-PDMP states experienced an average annual increase in the rate of RxORP of 9.51%, whereas PDMP states experienced an average annual increase in RxORP of 3.17%	Yes
Grecu, 2019 (39)	32	2003–2014	TEDS data	Admissions to facilities for substance-use disorder treatment	Mandatory access PDMPs	Mandatory access PDMPs were significantly associated with 1.9–2.4 fewer treatment admissions per 10,000 individuals among individuals aged ≥12 years. This represents a 20%–26% decrease compared with the year before implementation. Most of the association was driven by admission for treatment of opioid substance-use disorder	Yes

Abbreviations: ARCOS, Automation of Reports and Consolidated Orders System; CI, 95% confidence intervals; DAWN, Drug Abuse Warning Network; D.C., District of Columbia; DSM, Diagnostic and Statistical Manual of Mental Disorders; ED, emergency department; I-STOP, Internet System for Tracking Over-Prescribing; NMPR, nonmedical use of prescription pain relievers; NSDUH, National Survey of Drug Use and Health; OR, odds ratio; PDMP, prescription drug monitoring program; RADARS, Researched, Abuse, Diversion and Addiction-Related Surveillance; RR, relative risk; RxORP, rates of prescription opioid-related poisonings; SPARCS, Statewide Planning and Research Cooperative System; TEDS, treatment episode data sets; URDD, nique recipients of dispensed drug.

Table 4. Studies of Prescription Drug Monitoring Programs and Opioid-Related Deaths

First Author, Year (Reference No.)	No. of States	Years	Population	Outcome	PDMP Exposure Definitions	Findings	PDMPs Association
Paulozzi, 2011 (29)	50 and D.C.	1999–2005	CDC multiple cause of death data	Rates of opioid overdose deaths	19 operational PDMP states, defined as capable of collecting data and distributing data to ≥1 authorized users of the data 13 proactive PDMP states, defined as those generating reports for prescribers, dispensers, or law enforcement authorities without being solicited 4 high-reporting PDMP states with >100 solicited or unsolicited reports per 10,000 population to doctors, dispensers, or other recipients	Mortality rates for opioid overdose (3.13/100,000 person-years, mean SE, 0.25) was higher among states with an operational PDMP than among states without an operational PDMP (2.20/100,000 person-years, mean SE, 0.10) Mortality rates for opioid overdose (3.30/100,000 person-years, mean SE, 0.29) was higher among states with a proactive PDMP that were among states without an operational PDMP Mortality rates for opioid overdose (6.57/100,000 person-years, mean SE, 0.70) was higher among states with a high-reporting PDMP than among states without an operational PDMP	No
Li, 2014 (44)	50 and D.C.	1999–2008	CDC multiple cause of death data	Drug overdose death rates by state-quarters	PDMP implementation was the date when an electronic collection of prescription drug data began. Four characteristics were examined: 1) type of governing agency; 2) committee oversight; 3) no access provision by practitioners; and 4) statutory authority to monitor noncontrolled substances	Overall, the implementation of a PDMP was associated with an 11% increase in drug overdose deaths. The increased number of deaths was consistent for each of the 4 PDMP features examined.	No
Delcher, 2015 (43)	1 (Florida)	2003–2012	Medical Examiners Commission data on drug-related deaths	Monthly deaths determined by medical examiners to be caused by oxycodone, not including deaths where oxycodone was merely present	Florida's PDMP pre- and postimplementation. Mean PDMP query rate on oxycodone caused death	Oxycodone-caused deaths declined to 24.7 deaths (95% CI: −42.9, −6.4) per month after the implementation of Florida's PDMP. For every PDMP query per health care provider, oxycodone-caused deaths declined at a rate of by 0.23 persons/month ($P < 0.01$)	Yes

Table continues

Table 4. Continued

First Author, Year (Reference No.)	No. of States	Years	Population	Outcome	PDMP Exposure Definitions	Findings	PDMPs Association
Dowell, 2016 (25)	38 and D.C.	2006–2013	CDC multiple cause of death data	Rate of prescription opioid–overdose deaths per 100,000 residents and combined drug overdose deaths per 100,000 residents	Mandated provider review of information from PDMP before prescribing	The implementation of mandating PDMP use and pill-mill laws was significantly associated with reductions of 1.20 opioid-overdose deaths per 100,000 residents ($P < 0.05$) and of 1.10 combined drug–overdose deaths per 100,000 residents ($P < 0.05$)	Yes
Patrick, 2016 (46)	34	1999–2013	CDC multiple cause of death data	Annual rate of opioid-related overdose deaths per 100,000 population in each state	PDMP implementation was the date when began collection data, number of drugs monitored, update frequency, the mandate of registration/use	PDMP implementation was associated with a reduction of 1.12 (95% CI: −1.68, 0.55) opioid-related–overdose deaths per 100,000 population annually after implementation. Programs that monitored ≥4 drug schedules and updated their data at least weekly were associated with greater reductions in opioid-related–overdose deaths	Yes
Nam, 2017 (45)	34	1999–2014	CDC multiple cause of death data	Drug overdose death rates by state-years	The state- and year-specific PDMP operation status, as operated = 1, not operated = 0	PDMPs were not associated with reductions in overall drug overdose or prescription opioid–overdose death rates	No
Phillips, 2017 (47)	50 and D.C.	2011–2014	CDC multiple cause of death data	Total opioid-related deaths for each state and the age-adjusted opioid-related–overdose death rates per 100,000 people by state	Dichotomized, measured on whether a state requires prescribers and dispensers to access PDMP data in certain circumstances and those states without such requirement	The presence of a PDMP with a mandatory access provision increased in 11.4% ($P = 0.005$) the mean annual age-adjusted opioid-related death rate. For every additional year since enactment, PDMP increased the mean age-adjusted opioid-related deaths by 5.8% ($P = 0.005$)	No
Grecu, 2019 (39)	32	2003–2014	CDC multiple cause of death data	Mortality rates per 100,000 individuals calculated at the county, year, and age levels	Mandatory access PDMPs	The implementation of mandatory access provisions is associated with about 0.62 (SE, 0.241) fewer opioid-related deaths per 100,000 individuals aged 18–24 years old	Yes

Abbreviations: CDC, Centers for Disease Control and Prevention; CI, confidence interval; D.C., District of Columbia; PDMP, prescription drug monitoring program; SE, standard error.

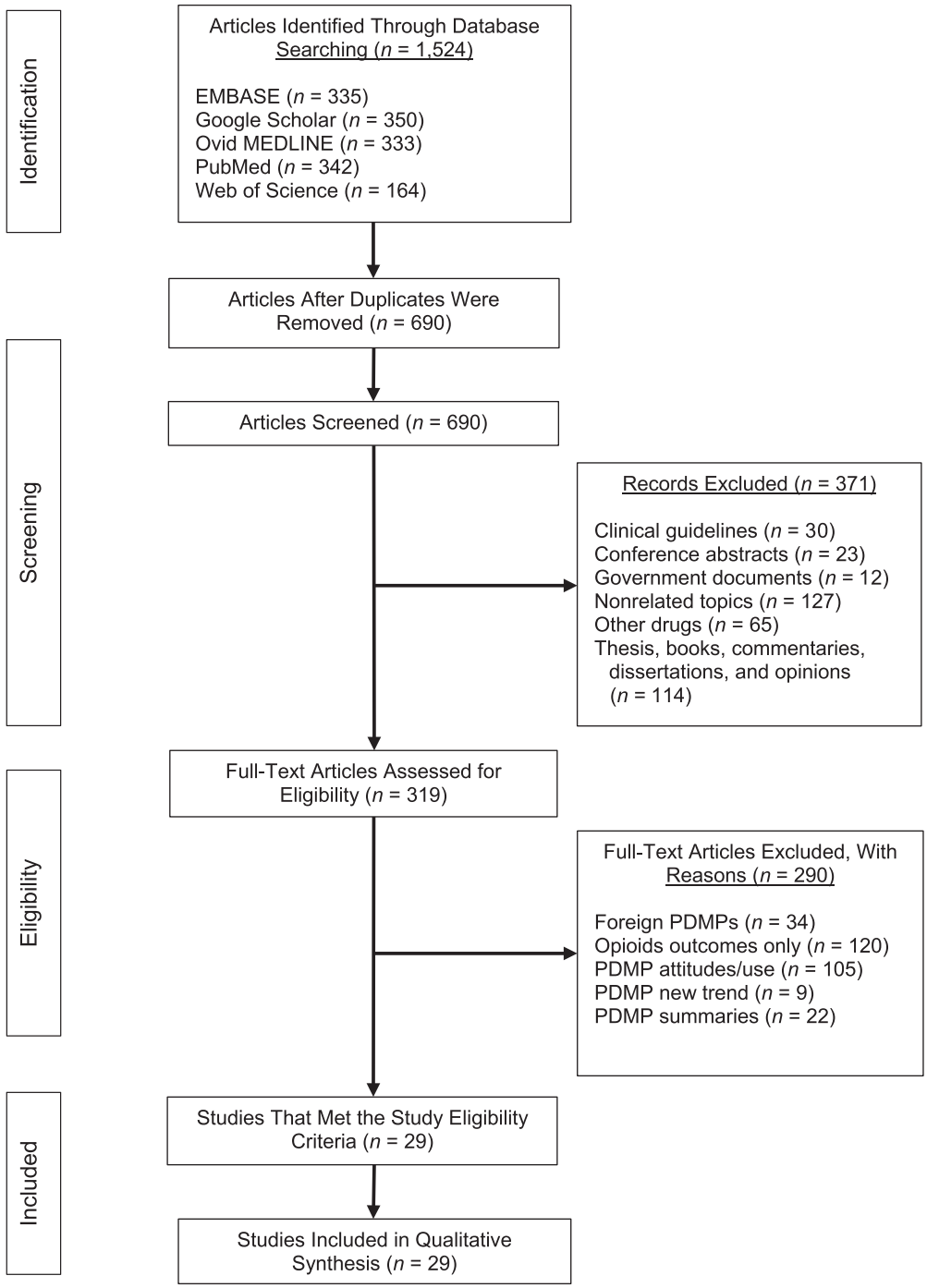

Figure 1. Flow diagram of identification, screening, eligibility, and selection of studies for the review of prescription drug monitoring programs (PDMPs) and prescription opioid–related outcomes.

of past-year nonmedical use of prescription pain relievers (35); flattened the number of inpatient and emergency department visits attributed to prescription opioid overdoses (22); reduced share of Medicare Part D enrollees with a substance-use disorder who had overlapping claims and the share of Part D enrollees with more than 7 months' supply of prescription opioids (38); reduced treatment admission rates for substance-use disorders in treatment facilities (39); and mitigated increases in rates of prescription opioid–related poisonings (42).

Last, 8 studies assessed the impact of PDMPs on the prescription opioid–related deaths domain and their results conflicted, with half the studies suggesting post-PDMP reductions in the number of deaths (25, 39, 43, 46) and half reporting no change (29, 45, 47) or an increase (44) (Table 4). The reported reductions included fewer monthly deaths from oxycodone overdose in Florida (43), that the implementation of pain clinic laws and mandated provider review of PDMP data were associated with reduced prescription opioid–overdose death rates (25), and fewer deaths from opioid-related overdoses per 100,000 population in the year after implementation (46). Finally, states that implemented PDMPs had fewer deaths related to opioid substance-use disorders among individuals aged 18–24 years (39).

PDMPs' features and prescription opioid–related outcomes

Mandatory access to PDMP data before writing a prescription was the most common feature examined among the included studies. Of the 11 studies that reported reductions in the prescribing behaviors domain, 4 examined and attributed reductions in prescription behavior outcomes to the mandatory access provision (20, 25, 31, 33); 7 studies did not examine mandatory access provisions (19, 23, 24, 28, 30, 32, 34). In the diversion and supply domain, 1 study assessed and ascribed the associations to the mandatory access provision (35); 2 did not examine the provision (36, 37). Of the 7 studies that found PDMP associations with morbidity and substance-use disorder outcomes, 5 studies evaluated the mandatory access provision and found that the provision was associated with leveling off or reducing overdose admissions (22, 39) and reducing opioid substance-use disorder outcomes (35, 38, 42); 2 studies did not examine the mandatory access provision (36, 41). And of the 4 studies in the deaths domain with reported associations, 2 studies reported postimplementation reductions in prescription opioid–related deaths associated with the mandatory access provision (25, 39), 1 study found no association between the mandatory access provision and mortality rates (46), and 1 did not examine this provision (43). Also, monitoring more than schedule II substances (23, 24, 32, 36, 37, 41–43, 46) and requiring providers to register in PDMPs (23, 24, 30, 32, 33, 35, 37, 43, 46) were, respectively, the second and third most common examined feature associated with reductions in opioid-related outcomes (Web Table 2).

In the prescription behaviors domain, 5 studies found no association between PDMP implementation and prescribing behaviors. Of these 5 studies, 3 examined the mandatory access provision. The first study found no changes in dispensed opioids when the mandatory access provision was optional (21). In the second study, the mandatory access provision of New York's PDMP did not change the number of prescriptions filled (22). In the third study, a mandatory query of PDMP data was not associated with the odds of a physician prescribing an opioid analgesic (26). The other 2 studies in the prescribing behaviors domain did not examine the mandatory access provision (27, 29).

In the morbidity and substance-use disorders domain, 2 studies reported no association among PDMP implementation, morbidity, and substance-use disorders (35, 40). One study did examine the mandatory access and enrollment provision and found no association with outcomes of nonmedical use of prescription pain relievers (35). However, the authors of that study did find that PDMPs without the provision of mandatory access or enrollment were associated with a 56% reduction in the odds of doctor-shopping for nonmedical use of prescription pain relievers (35). Of the 4 studies reporting non-PDMP associations in the deaths domain, 2 studies examined the mandatory access provision. One study reported that a nonaccess provision significantly increased the adjusted risk ratio of drug overdose death (44). The other study reported that the mandatory access provision was associated with an increase in the annual adjusted opioid-related death rate (47).

DISCUSSION

Prescription drug monitoring program characteristics vary by state and over time, posing a formidable methodological challenge to evaluation research. From our review of the available literature, it was evident that the reported results regarding associations between PDMPs and prescription opioid–related outcomes varied markedly across studies and outcome domains. Nevertheless, 68%, 100%, and 87% of the analyses reviewed suggested that implementation of PDMPs was associated with reductions in prescribing behaviors, diversion and supply, and the prevalence of opioid-related morbidity and substance-use disorders, respectively.

Studies in the opioid prescribing behaviors domain examined the most diverse set of outcome measures. Most of the studies that assessed prescribing behaviors found reductions of various prescribing measures (19, 20, 23–25, 30, 31, 33) or modifications to prescribing behaviors of high-risk prescribers and patients (23, 24). Opioid use can cause serious adverse health outcomes (48–52); thus, interventions that reduce prescribing behaviors might be considered beneficial. Despite this, no study to date that we found in our search has investigated whether the reductions in prescribing behaviors due to the use of PDMP data improve long-term population health outcomes, such as reducing opioid use disorders and nonfatal and fatal opioid overdoses. Among the studies that found no association between PDMPs and the number of opioid prescriptions, 1 investigated the association between PDMP implementation and the number of opioid prescriptions in emergency department visits. The authors did not find an association after PDMP implementation (27). A possible explanation for this finding is that emergency departments often handle a high volume of patients, and physicians might be more prone to process each patient more rapidly, leaving less time to consult PDMP data.

Decedents in approximately 40% of prescription opioid-related deaths obtain opioids from multiple sources (53), potentially indicative of doctor shopping. Prescription drug monitoring program evidence in this review indicated that implementation was associated with declines in receiving opioid prescriptions from multiple providers (ie, doctor

shopping) (35), fewer quantities of opioid shipments (36), and lower rates of diversion (37). Additional research is needed to confirm PDMPs' role in reducing nonphysician sources; that might have an impact on reducing the opioid epidemic. For the opioid-related morbidity and substance-use disorders domain, PDMPs reduced opioid-related admissions in emergency departments (22, 42) and inpatient services (22, 36, 39, 42). Prescription drug monitoring programs also reduced admissions for prescription opioid rehabilitation (36), mitigated self-reported rates of opioid substance-use disorders (41), and reduced past-year days of nonmedical use of prescription pain relievers (35). Prescription drug monitoring program implementation also reduced the percentage of Medicare enrollees taking opioids with overlapping claims and with more than 7 months of supply (38). Only 1 study in the opioid-related morbidity and substance-use disorders domain found no post-PDMP change in opioid-related morbidity outcomes (40). Although these findings suggest that PDMPs can mitigate some of the prescription opioid–related harms, more evidence is needed to examine whether PDMPs might also divert people with substance-use disorders to substituting prescription opioids with heroin and other illicit drugs (54). Finally, consistent with a previous review (9), we found insufficient evidence that an operational PDMP significantly affects deaths related to opioid poisonings.

During our search, we identified an upward trend in the research literature. Recently published studies were more likely to examine associations between specific PDMP features and prescription opioid–related outcomes (7, 55–62). Although examining associations for each PDMP feature falls beyond the scope of this review, all included studies reported results for at least 1 specific PDMP feature. Also, almost all studies reported an overall PDMP association. Mandatory access to PDMP data before writing a prescription was the most examined feature in the pertinent literature. When included in the analysis, the mandatory access provision was associated with reductions in prescribing behaviors (20, 25, 31, 33), diversion outcomes (35), hospital admissions (22, 39), substance-use disorders (38, 42), and mortality rates (25, 39). Although this information is useful because it identifies a specific PDMP feature associated with potential benefits, more research examining the intended and unintended consequences of the mandatory access provision is still needed (63). Two other PDMP features examined were the monitoring more than schedule II drugs (23, 24, 32, 36, 37, 41–43, 46) and requiring registration (23, 24, 30, 32, 33, 35, 37, 43, 46).

Collecting data without a mandate to use or register was the most common feature among studies that found no association between PDMPs and prescription behaviors, substance-use disorders, and mortality outcomes. These findings are consistent with those of a previous systematic review investigating PDMPs and nonfatal and fatal drug overdoses (9). The mandatory provider review, provider authorization to access PDMP data, frequency of reports, and monitoring of nonscheduled drugs features had low-strength evidence for associations with reductions in overdose deaths (9). Research into specific PDMP operational features is needed to identify best practices. Two recent studies applied novel approaches to assess PDMP heterogeneity. Authors of 1 study developed a subjective PDMP robustness score based on the presence or absence of specific operational features (55) and the authors of the other study used latent transition analysis to classify PDMPs into 3 different latent classes based on the set of operational features present during 3 different time intervals (1999–2004, 2005–2009, 2010–2016) (7). These approaches aimed at capturing PDMP heterogeneity are likely to represent the future of PDMP studies; however, research is needed to identify the best approach to assessing PDMP heterogeneity and consequences of PDMP heterogeneity on population health outcomes.

Our review has several limitations. First, we were not able to perform any meta-analysis in this systematic review because of the different measures used to estimate prescription opioid–related outcomes and the significant overlapping in data sources and periods across studies. For instance, 7 of 8 studies that examined opioid-related deaths used the US Centers for Disease Control and Prevention multiple-cause-of-death data with overlapping years. Second, we were unable to isolate PDMP associations from other policy interventions. For example, some state and local governments (e.g., Florida) have implemented other parallel intervention programs such as naloxone distribution programs, "pill mill" laws, and medication-assisted treatment programs, which may confound the true impact of PDMPs. As such, studies that reported on combined policy results received a lower quality assessment. Third, we did not include outcomes related to illicit opioids in the analysis. As the burden of illicit substance-use disorders increases (64), more evidence is urgently needed to understand and mitigate the impact of PDMPs on unintended consequences, such as increased use of heroin, cocaine, and methamphetamines. Fourth, the assessment of opioid-related harms, both fatal and nonfatal, may be subject to misclassification. Inaccurate information on death certificates or hospital records may affect the results of studies included in this review. Lack of specificity in disease classification systems (65) and regional variation in the reporting of data (66) have been documented as potential causes of misclassification, therefore warranting caution when interpreting the findings. Fifth, only half of the studies had a good quality score. Some of the limitations of studies using observational data include confounding factors, misclassification of outcomes, missing data, different study periods, lack of power, and particularly, the diversity between PDMPs. The new trend for assessing PDMPs, while accounting for the variation and evolution of PDMP features between and within states (7, 55), will benefit and strengthen future studies. Finally, the impact of specific PDMP features on prescription opioid–related outcomes was not considered in this review. However, we found mandatory PDMP data consultation before prescribing was the most examined feature among the included studies.

Literature update

The rapid increase in the research literature on PDMPs and the opioid epidemic is both exciting and challenging. New evaluation research will aid efforts to reduce

prescription opioid–related harm. However, the continuing change in the evidence base also makes it difficult for us to ensure the currency and relevance of this systematic review. The results included in this review were updated up to January 9, 2019. In this section, we describe studies indexed in PubMed and published between January 10 and August 8, 2019, that would have met our inclusion criteria. The search identified 26 records; of these, only 2 met our inclusion criteria. In the first study, Castillo-Carniglia et al. (67) investigated the relationship between the implementation of online PDMP and rates of hospitalizations related to prescription opioids and heroin overdoses over time. The authors reported that online PDMPs were associated with lower rates of prescription opioid–related hospitalizations. In the second study, by Liang and Shi (68), no significant associations were found between PDMP data access for benzodiazepines and fatal benzodiazepine- or prescription opioid–related drug overdoses. Finally, we have provided a table summarizing other available literature that missed this review's inclusion criteria but were included in the 3 reviews (8–10) described in the background section (Web Table 3).

CONCLUSION

This systematic review provides an updated assessment of the research evidence for US state PDMPs and prescription opioid–related outcomes. Despite considerable variation in program characteristics, PDMPs showed consistency in reporting reductions in opioid prescribing, diversion and supply of opioids, and opioid-related morbidity and substance-use disorders. Research is needed to determine whether reducing opioid prescribing, supply, and diversion affects patient- and population-level long-term outcomes. Given that PDMPs have been implemented across the United States, more evidence is needed to inform state legislators and program administrators to optimize the effectiveness and efficiency of this policy intervention to control the opioid epidemic.

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