

Appendix S2: Systematic Search and Review Abstraction

Records included in the review:

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	Reference	Research Design	Population, size, & setting	Intervention	Outcome or Phenomenon Studied	Study Data	Findings	Limitations
1	Al Achkar et al., 2018	Level II (Quasi-experimental) Observational (analytic) cohort study	State of Indiana	Indiana state legislation mandating PDMP use Implemented December 2013	Amount of opioids (MEDs) dispensed per day	2011 - 2014 Indiana PDMP	Mandated PDMP use associated with decrease in opioids dispensed after legislation implemented	Lacked comparison state
2	Arnold, et al., 2021	Level II (Quasi-experimental) Observational (analytic) cohort study	Veterans Health Administration (US national)	PDMP mandates from before Aug 2013 in Ohio, Kentucky, West Virginia, Tennessee, New Mexico	<ul style="list-style-type: none"> • Rate of prescription opioid discontinuation among Veterans receiving chronic opioid therapy through the VA • Average daily opioid dose 	2009 - 2015 Veterans Administration data	PDMP mandates not consistently associated with decrease in the quantity of opioids prescribed	<ul style="list-style-type: none"> • Study in unique VA healthcare setting with separate national policy re: PDMP use may not be generalizable to other settings • Sole use of VA data may miss care received outside of the VA
3	Aulet et al., 2019	Level II (Quasi-experimental) Observational (analytic) cohort study	University of Vermont Medical Center Burlington, VT Patients that underwent rhinoplasty and/or septoplasty procedures	Vermont state legislation mandating PDMP use Implemented July 2017	Amount of opioids (# pills & MMEs) prescribed to patients after surgery	2016 - 2018 Facility EHR	Mandated PDMP use associated with decrease in opioids prescribed after legislation implemented	May not be generalizable to other settings: one facility, small sample

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4	Ayres & Jalal, 2018	Level II (Quasi-experimental) Observational (analytic) cohort study	US National	PDMP legislation across all US states	Amount of opioids (MEDs) dispensed per day per 100 people	2006 - 2015 CDC (QuintilesIMS) sample of prescriptions dispensed by retail pharmacies	<ul style="list-style-type: none"> • PDMPs not effective in reducing opioid dispensing rates unless physicians are required to access the PDMP • Study results driven entirely by urban counties. More affluent counties were more responsive to policies. 	<ul style="list-style-type: none"> • Analysis was on prescription rates per 100 people • Did not have data on the amount, length, or type of opioid
5	Bachhuber et al., 2019	Level II (Quasi-experimental) Observational (analytic) cohort study	New York City, NY	New York state legislation mandating PDMP use Implemented August 2013	Rate of risky opioid prescribing per quarter: <ul style="list-style-type: none"> • 5+ prescriber episodes • 5+ prescriber episodes & 5+ pharmacy episodes, or • Cash payment for prescriptions 	2011 - 2015 New York PDMP	While instances were rare, mandated PDMP use associated with decrease in rates of potentially problematic opioid prescribing	May not be generalizable to other states
6	Bao et al., 2016	Level II (Quasi-experimental) Observational (analytic) cohort study	24 states with PDMPs: AL, AZ, CA, CO, CT, IL, IN, IA, LA, ME, MI, MN, MS, NE, NM, NC, ND, OH, OK, SC, TN, VT, VA, WV	PDMPs becoming available to healthcare providers online in 24 study states	Rate of prescribing of at least one Schedule II opioid analgesic in pain-related ambulatory care visits	2001 - 2010 National Ambulatory Medical Care Survey (NAMCS)	PDMP implementation associated with sustained reduction in rate of Schedule II opioid prescribing.	Limitations from using a source of data that is a sample of ambulatory care visits

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7	Bao et al., 2018	Level II (Quasi-experimental) Observational (analytic) cohort study	48 US states with PDMPs (all states except MO & PA)	PDMP legislation regarding mandated PDMP use & the use of delegates to access PDMP data	Amount of risky opioid prescribing: <ul style="list-style-type: none"> • 7+ days overlapping opioid prescriptions • 3+ opioid prescriptions from 3+ prescribers • 7+ days of overlapping opioid and benzodiazepine prescriptions, or • 120+ MME daily dose 	2011 - 2015 Health Care Cost Institute's private insurance claim database	<ul style="list-style-type: none"> • Mandated PDMP use associated with reduction in risky opioid prescribing • Use of delegates for PDMP retrieval associated with reduction in risky opioid prescribing 	Possible confounding effect of state laws regarding opioid use disorder (OUD) prevention that do not pertain to PDMP
8	Buchmueller & Carey, 2018	Level II (Quasi-experimental) Observational (analytic) cohort study	US National Medicare	PDMP legislation across US	Amount of risky opioid prescriptions: <ul style="list-style-type: none"> • 120+ MED daily dose • Overlapping opioid prescriptions • 5+ prescribers • 5+ pharmacies, or • 4+ new patient visits 	2007 - 2013 5% random subsample of Part D & Fee-for-Service Medicare prescription & medical claims	<ul style="list-style-type: none"> • PDMPs not effective in reducing risky prescribing if use not mandated • Mandated PDMP use associated with decreases in excessive opioid quantity & doctor shopping behavior 	<ul style="list-style-type: none"> • Limitations from using a source of data that is a sample of Medicare recipients • May not be generalizable to all Medicare recipients or patients overall

	Reference	Research Design	Population, size, & setting	Intervention	Outcome or Phenomenon Studied	Study Data	Findings	Limitations
9	Buchmueller, Carey, & Meille, 2020	Level II (Quasi-experimental) Observational (analytic) cohort study	State of Kentucky (intervention) compared to State of Indiana (control)	State of Kentucky legislation mandating PDMP use Implemented 2012	<ul style="list-style-type: none"> • Total MME prescribed per quarter & average MME per day • Whether the provider writes any opioids prescriptions & number of patients to whom they prescribe opioids • Number of days supplied per patient 	2012 - 2013 Kentucky PDMP Indiana PDMP	<ul style="list-style-type: none"> • Compared to Indiana, Kentucky's mandated PDMP use associated with decrease in opioid prescribing • Significant number of low-volume providers stopped prescribing opioids altogether after mandated PDMP use. • Also decrease in opioid prescriptions for patients without multiple providers & single-use acute patients 	Possible confounding effect of Kentucky pain clinic regulations
10	Castillo-Carniglia et al., 2021	Level II (Quasi-experimental) Observational (analytic) cohort study	Counties in States of California (intervention) compared to counties in Florida & Washington (control)	Changes in California state PDMP Implemented 2016 <ul style="list-style-type: none"> • Proactive reports • Mandatory registration 	<ul style="list-style-type: none"> • Amount of opioids prescribed per 100 state residents • Patients' mean daily MMEs • Prescribers' mean number of opioid prescriptions & mean daily MME prescribed • % of patients with risky prescriptions, defined as: <ul style="list-style-type: none"> • >90 MME/day; • Overlapping prescriptions for opioids and benzodiazepines, or • Multiple opioid prescribers 	2012 - 2017 Florida PDMP	Changes in California PDMP (mandatory registration & proactive reports): <ul style="list-style-type: none"> • associated with decreases in mean daily MMEs prescribed & some risky prescribing behavior • Not associated with significant changes in rate of opioid prescribing & other risky prescribing measures 	Analysis cannot be parsed to determine: <ul style="list-style-type: none"> • The effect of mandatory registration & proactive reporting separate from each other • Prescribing patterns by provider types or settings

	Reference	Research Design	Population, size, & setting	Intervention	Outcome or Phenomenon Studied	Study Data	Findings	Limitations
11	Chang et al., 2016	Level II (Quasi-experimental) Observational (analytic) cohort study	States of Florida (intervention) & Georgia (control)	Florida state legislation regarding mandatory PDMP use & pill mill regulation	Comparison of high-volume opioid prescribers versus all other prescribers in: <ul style="list-style-type: none"> • Number & proportion of patients prescribed opioids • Proportion of prescriptions dispensed as opioids • Average MME & days supply per transaction • Total number & volume of opioids dispensed 	2010 - 2012 IMS Health's LRx Lifelink database (retail prescription transactions)	<ul style="list-style-type: none"> • Compared to Georgia, Florida's high-volume opioid prescribers experienced large relative reductions in number, MME, & volume of opioid prescriptions among high-volume opioid prescribers, but not other providers • Florida opioid prescriptions remained concentrated among high-volume prescribers 	<ul style="list-style-type: none"> • Limitations due to data just coming from retail pharmacy transactions • Possible confounding effect of Florida's pill mill regulation • Analysis not done on whether prescriptions were clinically appropriate or whether transactions were associated with patient morbidity/mortality.
12	Chang et al., 2018	Level II (Quasi-experimental) Observational (analytic) cohort study	States of Florida (intervention) & Georgia (control)	Florida state legislation regarding mandatory PDMP use & pill mill regulation	Comparison of patients with high-risk prescriptions versus all other patients <ul style="list-style-type: none"> • Average MME & average days supplied per transaction, • Total opioid volume across all prescriptions 	2010 - 2012 IMS Health's LRx Lifelink database (retail prescription transactions)	Compared to Georgia, Florida's patients with high-risk prescriptions experienced relative reductions in number, MME, & volume of opioid prescriptions.	<ul style="list-style-type: none"> • Limitations due to data just coming from retail pharmacy transactions • Possible confounding effect of Florida's pill mill regulation • Analysis not done on whether prescriptions were clinically appropriate or whether transactions were associated with patient morbidity/mortality.

	Reference	Research Design	Population, size, & setting	Intervention	Outcome or Phenomenon Studied	Study Data	Findings	Limitations
13	Danagoulain, et al., 2021	Level II (Quasi-experimental) Observational (analytic) cohort study	Hospital system (5 hospitals) based in Detroit, Michigan Emergency departments	State of Michigan legislation mandating PDMP review & patient informed consent for prescription opioids, & limiting supply of opioid prescriptions	MME & MLE (lorazepam) for opioids & benzodiazepines prescribed for inpatient & emergency department discharges	Aug 2016 - March 2019 Hospital system EHR	Legislation on opioid prescriptions <ul style="list-style-type: none"> Induced a decline in MME, but rate differed between clinical specialties Associated with an increase in MLE suggesting a potential substitution of opioids for benzodiazepine prescriptions 	<ul style="list-style-type: none"> Because several mandates were implemented at the same time, not possible to determine effect of each mandate Findings from a single hospital system may not be generalizable to other settings
14	Derleth et al., 2020	Level II (Quasi-experimental) Observational (analytic) cohort study	Emergency & urgent care departments in Mayo Clinic Health System (Wisconsin)	Wisconsin state legislation mandating PDMP use April 2017	<ul style="list-style-type: none"> Amount of opioids (MME) prescribed after an urgent care encounter % of encounters where an opioid was prescribed 	2016 - 2017 Health System EHR	PDMP use mandate associated with a reduction in opioids prescribed per encounter & % of encounters that resulted in an opioid prescription.	<ul style="list-style-type: none"> Not known if reduction was sustained because of the study period Patient outcomes not known
15	Deyo et al., 2018	Level II (Quasi-experimental) Observational (analytic) cohort study	State of Oregon	State of Oregon PDMP (voluntary use)	<ul style="list-style-type: none"> Number of patients with at least 1 opioid prescription Mean dose per prescription Number of patients with risky prescriptions, defined as: <ul style="list-style-type: none"> ≥ 90 MME/day Overlapping opioid and benzodiazepine prescriptions (within 30 days), or >3 opioid prescribers in any 2-month interval 	2011 - 2014 Oregon PDMP	<ul style="list-style-type: none"> PDMP implementation associated with decrease in per capita numbers of inappropriate opioid prescriptions & MMEs & number of pills dispensed Registered PDMP users did not show greater declines in study measures than non-registrants Frequent PDMP users continued to prescribe less than infrequent users (change apparent at baseline) 	<ul style="list-style-type: none"> Statistical analysis not adjusted for prescriber demographics or clinical specialty information Changes in established prescribing habits may require more time & longer periods of observation

	Reference	Research Design	Population, size, & setting	Intervention	Outcome or Phenomenon Studied	Study Data	Findings	Limitations
16	Dowell et al., 2016	Level II (Quasi-experimental) Observational (analytic) cohort study	States of AL, AZ, CA, CO, CT, ID, IL, IN, IA, KY, LA, ME, MA, MI, MN, MS, NE, NV, NM, NC, ND, OH, OK, SC, TN, UT, VT, VA, WV & the District of Columbia	State legislation mandating PDMP use & regulating pain clinics	MME dispensed per state resident per year	2006 - 2013 IMS Health's National Prescription Audit (estimates of prescriptions for each state based on a representative sample of retail pharmacies that dispense nearly 80% of all prescriptions in the US)	States with mandated PDMP use & pain clinic laws saw significant reductions in opioid prescribing rates. Pain clinic laws alone did not significantly reduce opioid prescribing	<ul style="list-style-type: none"> • Limitations due to data just coming from retail pharmacy transactions • Limited post-intervention study period because of how recently some laws were implemented
17	Graetz, et al., 2023	Level II (Quasi-experimental) Observational (analytic) cohort study	US National Medicare Oncologists & hematologists who prescribed opioids in the US between 2013 - 2019 (n = 9,746)	PDMP use in states without mandated use, mandated use without cancer exemption, & mandated use with cancer exemption	% of patients with opioid prescriptions	2013 - 2019 Medicare Part D	After mandated use of PDMPs, the % of patients prescribed opioids decreased, but there was a bigger decrease in states without a cancer exemption	Findings limited to oncologists & hematologists; may not be generalizable to other clinicians
18	Gupta, et al., 2021	Level II (Quasi-experimental) Observational (analytic) cohort study	Emergency department of a suburban tertiary care academic medical center (PA)	State of Pennsylvania PDMP implementation in Aug 2016	Ratio of patients with a numeric pain rating scale >0 & given ≥1 opioid prescription upon discharge	Dec 2014 - May 2018 Medical center EHR	PDMP implementation was associated with a significant decrease of opioid prescriptions among patients complaining of severe pain, men, & those between ages 18 - 63 years	<ul style="list-style-type: none"> • CDC guidelines for prescribing opioids for chronic pain were published in March 2016 so PDMP implementation may not be the sole reason behind reductions • Findings from a single facility may not be generalizable to other ER settings

	Reference	Research Design	Population, size, & setting	Intervention	Outcome or Phenomenon Studied	Study Data	Findings	Limitations
19	Haffajee et al., 2018	Level II (Quasi-experimental) Observational (analytic) cohort study	States with stronger PDMP laws versus other states: KY with MO NM with TX TN with GA NY with NJ	PDMP legislation in study sites Study states with stronger PDMP laws: KY, NM, TN, NY	<ul style="list-style-type: none"> Number & mean MMEs dispensed Mean MMEs & length of risky prescriptions 	2010 - 2014 OptumInsight (private health insurance claims)	Versus their comparisons, all 4 states with stronger PDMP laws experienced reductions in MMEs & number of opioids dispensed.	<ul style="list-style-type: none"> Limitations due to data just coming from private health insurance Patient outcomes not known
20	Henry, et al., 2021	Level II (Quasi-experimental) Observational (analytic) cohort study	State of California	Prescription Drug Overdose Prevention Initiative (est 2015) which includes PDMP registration mandate	Monthly per 1000 county residents: <ul style="list-style-type: none"> # of opioid prescriptions # of patients with >90 MME per day 	2011 - 2018 California PDMP	Mandatory PDMP registration associated with a significant decrease in rate of opioid prescribing overall & prescribing of >90 MME per day	Initiative included components other than mandated PDMP registration, & coincided with updates to California PDMP & national overdose prevention efforts; effect of mandatory registration alone not known
21	Khobrani et al., 2019	Level II (Quasi-experimental) Observational (analytic) cohort study	50-bed emergency department in State of Arizona Name not mentioned	Arizona state legislation mandating PDMP use Implemented October 2017	For discharges from ER for back pain: <ul style="list-style-type: none"> Proportion of patients who were prescribed opioids upon discharge MMEs prescribed per patient 	2017 - 2018 Medical center's EHR	<ul style="list-style-type: none"> No significant reduction in MMEs or the proportion of patients who were prescribed opioids after discharge There was an increase in the amount of NSAIDs prescribed post-legislation 	<ul style="list-style-type: none"> May not be generalizable to other settings: one facility, small sample No information about individual providers' PDMP use or opioid-prescribing behavior Changes may require more time & longer periods of observation
22	Le, et al., 2022	Level II (Quasi-experimental) Observational (analytic) cohort study	US National Patients with a new cancer diagnosis between Jan 2014 - Dec 2014	PDMP registration & use mandates in the US	<ul style="list-style-type: none"> % patients with opioid prescription Total days, daily MED & cumulative MED of opioid prescriptions 	2013 - 2015 IQVIA Inc PharMetrics Plus data (prescription claims)	PDMP registration & use mandates were associated with a reduction in length of opioid treatment & cumulative MED after initial cancer diagnosis	Categorization of state PDMP policies into use & registration mandates did not capture other policy differences between states (e.g., cancer exemption)

	Reference	Research Design	Population, size, & setting	Intervention	Outcome or Phenomenon Studied	Study Data	Findings	Limitations
23	Liang et al., 2021	Level II (Quasi-experimental) Observational (analytic) cohort study	US National Medicaid enrollees	PDMP data use mandates for benzodiazepines	For benzodiazepine prescriptions; per state per quarter per 100 Medicaid enrollees: <ul style="list-style-type: none"> • Quantity • MDE • Overall spending 	2010 - 2017 Medicaid State Drug Utilization data (outpatient)	PDMP mandates for benzodiazepines were not associated with quantity, dosage, or money spent on benzodiazepine prescriptions	<ul style="list-style-type: none"> • PDMP benzodiazepine mandates were enacted relatively recently so data may not reflect the full realized effect of the mandate • Data may not be generalizable to emergency departments or non-Medicaid populations
24	Lin et al., 2018	Level II (Quasi-experimental) Observational (analytic) cross-sectional	US National	US states & their PDMP legislation categorized as: <ul style="list-style-type: none"> • No PDMP • Voluntary registration & use • Mandatory registration • Mandatory use 	For a sample of ambulatory care visits for chronic pain, back pain & arthritis/joint pain: <ul style="list-style-type: none"> • Yes/no: visit resulted in a prescription for pain (both opioid and non-opioid agents) • Yes/no: visit resulted in an opioid prescription 	2012 National Ambulatory Medical Care Study (NAMCS)	Stronger PDMP laws not associated with reductions in amount of opioids & other pain medications prescribed	<ul style="list-style-type: none"> • Classification of PDMPs may be too coarse • Study excluded records from 11 less populous states & DC
25	Lin et al., 2019	Level II (Quasi-experimental) Observational (analytic) cross-sectional	US National	States' PDMP legislation categorized as: <ul style="list-style-type: none"> • No PDMP • Voluntary registration & use • Mandatory registration • Mandatory use • State PDMP data sharing agreements with: <ul style="list-style-type: none"> • no border states • all border states • some border states 	For a sample of ambulatory care visits for chronic pain, back pain & arthritis/joint pain: <ul style="list-style-type: none"> • Yes/no: visit resulted in a prescription for pain (both opioid and non-opioid agents) • Yes/no: visit resulted in an opioid prescription 	2014 National Ambulatory Medical Care Study (NAMCS)	PDMP data sharing agreements were not associated with reductions in amount of opioids & other pain medications prescribed	Classification of PDMPs & PDMP data-sharing agreements may be too coarse

	Reference	Research Design	Population, size, & setting	Intervention	Outcome or Phenomenon Studied	Study Data	Findings	Limitations
26	Maierhofer, et al., 2021	Level II (Quasi-experimental) Observational (analytic) cohort study	State of North Carolina	State of North Carolina policy on opioid prescribing: <ul style="list-style-type: none"> • PDMP implementation (2010) • State medical board initiative investigating high-volume prescribers (May 2016) • Legislation limiting opioid prescribing & mandating PDMP use (April 2018) 	For opioid prescriptions: <ul style="list-style-type: none"> • Rate of prescribing to new patients • % of ongoing prescriptions • Total days supply • MME 	Jan 2006 - Aug 2018 Claims data from private health insurance provider in North Carolina	<ul style="list-style-type: none"> • Rates of new & ongoing opioid prescriptions were not associated to the implementation of a voluntary-use PDMP but sharply declined following the medical board initiative & legislative action • Mean total days' supply declined sharply after 2018 legislation limiting opioid prescribing • MME declined steadily without notable impact from any of the three policies 	<ul style="list-style-type: none"> • Other notable factors that could have influenced study results: OxyContin reformulation (2010) & CDC guidelines for treating chronic pain (2016) • Dataset did not include uninsured, Medicaid, & Medicare patients
27	Manders & Abd-Elsayed, 2020	Level II (Quasi-experimental) Observational (analytic) cohort study	State of Wisconsin	Wisconsin state legislation mandating PDMP use Implemented April 2017	Number of monthly prescriptions dispensed divided by drug classes (opioids, benzodiazepines, stimulants & other)	2015 - 2019 Wisconsin PDMP	Mandated PDMP use was associated with significant reduction in opioid & benzodiazepine subgroups. However, the number of stimulants was preserved or slightly increased.	<ul style="list-style-type: none"> • Lacked comparison state • Wisconsin PDMP has extra functionalities, like proactive reporting, that may have augmented the effects of the study

	Reference	Research Design	Population, size, & setting	Intervention	Outcome or Phenomenon Studied	Study Data	Findings	Limitations
28	McDonald, et al., 2019	Level I Experimental (randomized) parallel group	State of Nevada	Unsolicited notification, to their doctors, of the prescription histories of patients with multiple prescriptions from multiple providers	Schedule II-IV controlled drugs dispensed to patients with multiple opioid prescriptions from multiple prescriptions: <ul style="list-style-type: none"> • Number of distinct providers & pharmacies used • Number & MMEs of opioids dispensed 	2011 - 2014 Nevada PDMP	Providers who received unsolicited reporting were more likely to discontinue prescribing when compared to providers who were not notified. But patients with multiple prescriptions from multiple providers appeared to replace providers who would not supply them with prescriptions	<ul style="list-style-type: none"> • Study only applies to effectiveness of unsolicited notification, not effectiveness of PDMPs in general • The study cannot provide information about why prescribers continued prescribing to patients with multiple providers nor why patients had multiple providers.
29	McGinty, et al., 2022	Level II (Quasi-experimental) Observational (analytic) cohort study	13 states that implemented a single opioid-prescribing- related law between 2008 - 2019 For PDMP law analysis: CO, ID	Implementation of a single state law involving prescribing caps, pill mills, or PDMP use or registration	<ul style="list-style-type: none"> • Proportion of patients receiving any opioid or nonopioid pain treatment per month • Mean days' supply & MME of opioids per day, per patient, per month 	2008 - 2019 IBM MarketScan (inpatient, outpatient, pharmacy claims)	Implementation of a single state law involving prescribing caps, pills mills, or PDMP use or registration was not associated with a change in opioid or nonopioid pain treatment	<ul style="list-style-type: none"> • Results may not be generalizable to the uninsured or those on public insurance • Data cannot ascertain clinical appropriateness of the prescriptions

	Reference	Research Design	Population, size, & setting	Intervention	Outcome or Phenomenon Studied	Study Data	Findings	Limitations
30	Meara, et al., 2016	Level II (Quasi-experimental) Observational (analytic) cohort study	US National Disabled Medicare beneficiaries 21-64 years; excluded those with cancer or end-stage renal disease, or who were receiving palliative care	US legislation over controlled substances between 2006 - 2012; PDMP-related mandates were included in the analysis	Annual prevalence of patients with: <ul style="list-style-type: none"> • ≥ 4 opioid prescribers or • > 120 mg daily MME 	2006 - 2012 Medicare Parts A, B, & D (fee for service) claims	PDMP implementation was not associated with reductions in potentially hazardous opioid prescriptions	<ul style="list-style-type: none"> • Study population has higher rates of opioid use, coexisting complex medical conditions, & poverty; results may not be generalizable to the general population • Substantial legislation surrounding controlled substances were passed after the study period; the data would not have reflected the effect of these laws • Laws may have needed more time to effect prescribing patterns
31	Meinhofer, 2018	Level II (Quasi-experimental) Observational (analytic) cohort study	US National PDMP-related legislation	Laws related to PDMP access & use	Grams per 100,000 persons of opioids & stimulants in Schedules I, II, & some from Schedule III	2000 - 2013 DEA ARCOS (medication sales)	<ul style="list-style-type: none"> • PDMP implementation & PDMP data access to healthcare providers not associated with drug quantities • However, required PDMP use reduced prescription opioid and stimulant quantities • There is potential substitution of controlled substance prescriptions to illegal drugs 	Limitations noted about the analysis of overdose deaths, but that outcome is not covered in this literature review

	Reference	Research Design	Population, size, & setting	Intervention	Outcome or Phenomenon Studied	Study Data	Findings	Limitations
32	Moyo et al., 2017	Level II (Quasi-experimental) Observational (analytic) cohort study	Medicare States with online access to PDMPs versus states without online access to PDMPs: FL with GA LA with AR NE with WI NJ with MD VT with NH	PDMP implementation in the studied states as defined as the date when prescribers & dispensers had access to PDMP data online	Mean daily MME, number & total volume of Schedule II - V opioid prescriptions	2007 - 2012 Prescription claims of random 5% subsample of Medicare Part D participants	PDMPs associated with reductions in some measures of opioid amount (Schedule II & III), but not with others (total opioids & Schedules IV & V).	<ul style="list-style-type: none"> • May not be able to generalize findings to non-study states • Dissimilarities in how PDMPs are structured between different states. may have influenced the program's impact on outcomes.
33	Myrga et al., 2020	Level II (Quasi-experimental) Observational (analytic) cohort study	Large academic hospital (not named) in Western Pennsylvania Patients who underwent prostate or renal surgery	Pennsylvania state legislation mandating PDMP use Implemented January 2017	Opioid prescriptions upon discharge: <ul style="list-style-type: none"> • Amount of 5 mg oxycodone equivalents prescribed • % of patients receiving an opioid prescription 	2016 - 2017 Medical center EHR	<ul style="list-style-type: none"> • Overall, for opioid naive & opioid exposed patients, mandated PDMP use was associated with a decrease in median 5 mg oxycodone equivalents, but not % of patients receiving an opioid prescription. • However, results differed between physicians 	<ul style="list-style-type: none"> • May not be generalizable to other settings: one facility, small sample • Changes may not have been sustained • Possible confounding effect of CDC Guidelines on Chronic Opioid Prescribing (March 2016) • No determination made as to appropriateness of prescription

	Reference	Research Design	Population, size, & setting	Intervention	Outcome or Phenomenon Studied	Study Data	Findings	Limitations
34	Nguyen, et al., 2023	Level II (Quasi-experimental) Observational (analytic) cohort study	State of Kentucky as compared to the State of Indiana (2012 - 2013)	State of Kentucky legislation mandating PDMP use (July 2012)	% of patients (per 1000) that have ≥1 opioid & ≥1 benzodiazepine prescription that overlap for at least 7 days, & whether the overlapping prescriptions were from a single prescriber or separate prescribers	2010 - 2016 Kentucky PDMP	Kentucky's mandated PDMP use was associated with a decrease in the rate of overlapping opioid - benzodiazepine prescriptions, mostly because of a reduction in initiation of overlapping prescriptions or a discontinuation of either the opioid or benzodiazepine prescription	A confounding factor could be Kentucky's regulation of pain clinics.
35	Ozturk et al., 2021	Level II (Quasi-experimental) Observational (analytic) cohort study	US National	Online access to PDMP became available	For adults (18 - 64 years) without cancer-related pain & with disability conditions: <ul style="list-style-type: none"> • Having any opioid prescription • Number & cumulative MMEs of opioid prescriptions • Incidence of extended opioid use 	2000 - 2014 Medical Expenditure Panel Survey (MEPS)	PDMPs did not reduce initial or ongoing opioid prescriptions for individuals with disabilities who use opioids	<ul style="list-style-type: none"> • Possible confounding effect of pill mill laws • No determination made as to appropriateness of prescription
36	Rubin, et al., 2022	Level II (Quasi-experimental) Observational (analytic) cohort study	Lahey Hospital & Medical Center (Burlington, MA) or Boston Medical Center (Boston, MA) Patients who underwent certain surgeries	State of Massachusetts legislation mandating PDMP use (Oct 2016)	MME & length of days of opioid prescriptions upon discharge for patients who underwent tonsillectomy, parotidectomy, thyroidectomy or direct laryngoscopy & biopsy with or without rigid esophagoscopy and/or rigid bronchoscopy	Oct 2015 - Oct 2019 Medical Centers' EHRs	There was a significant decrease in mean overall MME prescribed after PDMP implementation	Prescription data may not reflect actual use by the patient

	Reference	Research Design	Population, size, & setting	Intervention	Outcome or Phenomenon Studied	Study Data	Findings	Limitations
37	Sacarny, et al., 2023	Level I Experimental (randomized) parallel group	State of Minnesota	<p>3 different letters from the Minnesota Board of Pharmacy to physicians with patients with ≥5 days of overlapping prescriptions for opioids– benzodiazepines or opioids– gabapentinoids</p> <ol style="list-style-type: none"> 1. Informing them about mandated PDMP use 2. Listing patients on their panel who have co- prescriptions 3. Letter with both of the above 	<ul style="list-style-type: none"> • % of physicians who used the PDMP at all during the study period • # of patients with co-prescriptions • # of physicians who registered for PDMP access 	<p>2021 n = 12,000 physicians with patients with co-prescriptions between Nov 2020 - Feb 2021 Assigned to one of 4 study branches: Letter 1 (see “intervention” column), Letter 2, Letter 3, or No Letter</p> <p>Minnesota PDMP data was used to identify physicians & track outcomes for 60 days after the initial mailing</p>	<ul style="list-style-type: none"> • Study branches for Letter 1 (inform re: PDMP use mandate) & Letter 3 (PDMP use mandate + list of patients with co-prescriptions) were associated with increased PDMP use & PDMP registration, but not with a change in the # of patients with co-prescriptions • Study branch Letter 2 (list of patients with co-prescriptions) was not associated with a change in the # of searches or the # of co-prescriptions 	Only 1 state included in the study - results may not be generalizable to other states
38	Sacks et al., 2021	Level II (Quasi-experimental) Observational (analytic) cohort study	States of AK, AR, AZ, CA, CT, DE, GA, IL, IN, KY, LA, MA, MD, MN	Legislation mandating PDMP use implemented by 2018	<p>For 20% random sample of all enrollees & 100% sample of all patients who ever filled an opioid prescription:</p> <ul style="list-style-type: none"> • Average MMEs per day of opioids • Number of refills in the initial spell 	2007 - 2018 Claims database of large, national insurer with employer- sponsored plans & Affordable Care Act Exchange plans	Mandatory use of PDMPs associated with reduction in days supply of opioids and number of refills dispensed to new users	<ul style="list-style-type: none"> • Not known if reduction was sustained past the study period • Limitations from using a source of data from one national insurer

	Reference	Research Design	Population, size, & setting	Intervention	Outcome or Phenomenon Studied	Study Data	Findings	Limitations
39	Sahebi-Fakhrabad, et al., 2023	Level II (Quasi-experimental) Observational (analytic) cohort study	State of Tennessee & neighboring states: KY, VA, WV, OH, IN, IL, NC, SC, GA, AL, MS, AR, & MO	State PDMP & pill mill regulations in Tennessee & neighboring states	Supply of opioid prescriptions (per capita pill volume) at the level of dispensers & distributors (excluding manufacturers)	2006 - 2014 DEA ARCOS (medication sales)	<ul style="list-style-type: none"> Both PDMP & pill mill regulations impact the supply of opioids; pill mills appeared to have the greater impact However, opioids may be shifted from states with stricter regulations to states with laxer regulations. 	Not noted by authors
40	Strickler et al., 2019	Level II (Quasi-experimental) Observational (analytic) cohort study	States of KY, OH, WV (intervention) versus CA & VA (control - no PDMP use mandate as of Dec 2016)	PDMP use mandates in between 2010 - 2015 in KY, OH & WV	By quarter, rate of (per 100,000 state residents): <ul style="list-style-type: none"> Prescriptions for all opioids Patients with risky prescriptions, defined as: <ul style="list-style-type: none"> 5+ pharmacies 5+ prescribers 2 overlapping opioid prescriptions Overlapping opioid & benzodiazepine prescription 90+ cumulative MME 	2010 - 2016 Data from state PDMP	<ul style="list-style-type: none"> Rate of prescriptions for all opioids & rate of risky prescriptions decreased in KY & OH (not WV) Authors conclude that PDMP mandates have the potential to reduce risky opioid prescribing practices. Variation in the laws may explain why the effectiveness varied between states. 	Possible confounding effect of state laws regarding opioid use disorder (OUD) prevention that do not pertain to PDMP (e.g., pill mill regulation)
41	Suffoletto et al., 2018	Level II (Quasi-experimental) Observational (analytic) cohort study	15 different hospitals in a single health system in Pennsylvania Emergency departments	Pennsylvania state legislation mandating PDMP use Implemented August 2016	% of patients discharged with an opioid prescription & with a prescription for >12 tablets before & after PDMP mandate	2015 - 2017 Health system EHR	<ul style="list-style-type: none"> Opioids prescribing rate decreased pre- & post-legislation, but the rate of decrease accelerated after the legislation. There was heterogeneity in opioid prescribing across hospitals & patient diagnosis 	<ul style="list-style-type: none"> Possible confounding effect of CDC Guidelines on Chronic Opioid Prescribing (March 2016) Analysis not done on whether prescriptions were clinically appropriate.

	Reference	Research Design	Population, size, & setting	Intervention	Outcome or Phenomenon Studied	Study Data	Findings	Limitations
42	Sun et al., 2018	Level II (Quasi-experimental) Observational (analytic) cohort study	Non-federal Emergency Departments (ED) in the State of Washington Medicaid patients	Automated "pushed" PDMP queries on patients with risky prescriptions	Pre- & post-automated queries: Number & MME of Schedule II or III opioids prescribed to Medicaid recipient after an ED encounter	2013 - 2015 Washington State Health Care Authority	<ul style="list-style-type: none"> Automated PDMP queries were not significantly associated with reductions in opioid prescribing or quantities even in patients with previous potentially problematic opioid prescriptions Findings suggest limited efficacy of automated queries in reducing opioid prescribing in ED settings. 	<ul style="list-style-type: none"> Limitations due to focus on Medicaid beneficiaries, in ED, in a single state Analysis not done per provider Not confirmed whether ED providers accessed the automated query; only that it was generated
43	Toce, et al., 2023a	Level II (Quasi-experimental) Observational (analytic) cohort study	US National	States with legislation mandating PDMP review Control: States without this mandate	% of enrollees (per 100) with opioid prescriptions for adolescents & young adults (13 - 25 years)	Jan 2008 - Dec 2019 Unnamed commercial health insurance company with 10% of US market share (claims)	Mandated PDMP use mandates were associated with a significant decrease in mean annual % opioids prescriptions for adolescents & young adults	<ul style="list-style-type: none"> Findings may not be generalizable to other populations, e.g., those on public insurance or the uninsured Cannot exclude the effect of other factors on opioid prescribing or the presence of secular changes
44	Toce, et al., 2023b	Level II (Quasi-experimental) Observational (analytic) cohort study	US National	States with legislation mandating PDMP review Control: States without this mandate	% of enrollees (per 100) with benzodiazepine prescriptions for adolescents & young adults (13 - 25 years)	Jan 2008 - Dec 2019 Unnamed commercial health insurance company with 10% of US market share (claims)	Mandated PDMP use mandates were associated with a significant decrease in mean annual % benzodiazepine prescriptions for adolescents & young adults	<ul style="list-style-type: none"> Findings may not be generalizable to other populations, e.g., those on public insurance or the uninsured Unable to ascertain whether prescriptions were clinically appropriate

	Reference	Research Design	Population, size, & setting	Intervention	Outcome or Phenomenon Studied	Study Data	Findings	Limitations
45	Townsend, et al., 2022	Level II (Quasi-experimental) Observational (analytic) cohort study	US National Black vs white patients; < 65 years old not diagnosed with cancer or receiving palliative care or	PDMP mandated use	Binary variables: <ul style="list-style-type: none"> • Ave daily dose of ≥ 90 MME • ≥ 7 days of overlapping opioid prescriptions • ≥ 1 day of concurrent opioid & benzodiazepine prescriptions • > 3 prescribers for opioids prescriptions • > 3 pharmacies to fill opioid prescriptions 	2007 - 2018 Optum Clinformatics Data Mart (prescription claims)	PDMP mandates appeared to reduce rates of all outcomes of potentially inappropriate prescriptions, but in 4 out of 5, effects appeared limited to, or larger in, Black patients compared with White patients	<ul style="list-style-type: none"> • Data not available on prescriptions paid for in cash • Unable to ascertain whether prescriptions were clinically appropriate
46	Underwood, et al., 2021	Mixed methods Observational (analytic) cohort study Document review	Jurisdictions funded by the CDC's Prevention for States (PfS) program: AZ, CA, CO, CT, DE, IL, IN, KY, ME, MD, MA, NE, NV, NM, NY, NC, OH, OK, OR, PA, RI, SC, TN, UT, VT, VA, WA, WV, WI Compared to jurisdictions that were not funded	Prevention for States funding was for: enhancing PDMP use & implementing community or insurer/health system interventions	Total # of prescriptions per month for ≥ 90 MME daily, divided by census population & multiplied by 100	2014 - 2019 IQVIA Xponent data (retail pharmacies)	<ul style="list-style-type: none"> • High-dose opioid dispensing declined in all states, regardless of whether they received PfS funding between 2014 - 2019 • High-dose opioid dispensing rates were not significantly different between those who received funding & those who did not • However, PfS activities, including real-time PDMP reporting, were associated with decreases in high-dose dispensing rates over time 	PfS activities may have contributed to changes, but causal conclusions cannot be reached because of potential other efforts to address the opioid overdose epidemic

	Reference	Research Design	Population, size, & setting	Intervention	Outcome or Phenomenon Studied	Study Data	Findings	Limitations
47	Underwood, et al., 2023	Mixed methods Observational (analytic) cohort study Document review	Jurisdictions funded by the CDC's Prevention for States (PfS) program: AZ, CA, CO, CT, DE, IL, IN, KY, ME, MD, MA, NE, NV, NM, NY, NC, OH, OK, OR, PA, RI, SC, TN, UT, VT, VA, WA, WV, WI Compared to jurisdictions that were not funded	Prevention for States funding was for: enhancing PDMP use & implementing community or insurer/health system interventions	Analysis of which PFs activities were associated with changes in opioid dispensing outcomes Collected data on: <ul style="list-style-type: none"> PfS activities implemented MME per capita Substantive opioid dispensing outcome = if MME per capita was below mean MME for 2014 - 2019 Determined whether activities were necessary (causal) or sufficient	2016 - 2019 PfS annual progress reports 2014 - 2019 IQVIA Xponent data (retail pharmacies) Dec 2017 - Feb 2018 Semi-structured interviews with program director, program manager, & one other team member	Three combinations of activities were sufficient for > ave state MME reduction; the combination that included PDMP-related activities was: Proactive PDMP reporting, but not moving towards real-time PDMP data reporting + improving uptake of opioid prescribing guidelines Authors suggested that states can best reduce opioid dispensing by building upon existing policies & interventions	<ul style="list-style-type: none"> Study could not control for other contextual factors There is no standard for what an appropriate mean MME is
48	Wang, et al., 2021	Level II (Quasi-experimental) Observational (analytic) cohort study	University of Pennsylvania School of Dental Medicine Philadelphia, PA	Pennsylvania state legislation mandating PDMP use Implemented January 2017	Name & number of pills prescribed after third molar extractions conducted by oral & maxillofacial surgeons (OMS) on patients across seven 6 month periods	2016 - 2019 Dental EHR	After mandated use, patients were much less likely to receive an opioid analgesic & the number of pills in opioid prescriptions also decreased	<ul style="list-style-type: none"> Possible confounding effects from other variables Limitations due to data just coming from one facility
49	Watson et al., 2021	Level II (Quasi-experimental) Observational (analytic) cohort study	Beth Israel Deaconess Medical Center Boston, MA Emergency department	Massachusetts state legislation mandating PDMP Implemented October 2016	Monthly % of adult patients discharged from the ED with an opioid prescription	2010 - 2018 Facility EHR	Prior to the mandated use, ED opioid prescribing was declining. The mandate did not change the rate of decline in ED opioid prescribing but was associated with a non-sustained drop in opioid prescribing immediately following enactment	<ul style="list-style-type: none"> Analysis did not account for MMEs, number of days, number of pills Research design precludes the ability to infer a causal relationship. Patient outcomes not known

	Reference	Research Design	Population, size, & setting	Intervention	Outcome or Phenomenon Studied	Study Data	Findings	Limitations
50	Wen et al., 2017	Level II (Quasi-experimental) Observational (analytic) cohort study	US National Medicaid	State legislation mandating registration and/or use of PDMPs	Amount of drugs & spending on drugs through fee-for-service & managed care Medicaid	2011 - 2014 Medicaid State Drug Utilization Files (CMS)	<ul style="list-style-type: none"> ● PDMP mandates of any kind, associated with reduction in Schedule II opioids. ● For drugs commonly used for cancer pain, there was no significant change in the number of prescriptions or of Medicaid spending on these drugs 	<ul style="list-style-type: none"> ● Analysis not done on whether prescriptions were clinically appropriate. ● Did not have data on prescriber registration with & use of PDMP ● Analysis of patient-level measures such as daily MME & risky prescriptions was not possible.
51	Wen et al., 2019	Level II (Quasi-experimental) Observational (analytic) cohort study	US National Medicaid	Stronger PDMP state legislation = requiring both registration & use of PDMPs in most clinical circumstances,	Number of opioid prescriptions covered by Medicaid on a quarterly, per 1,000-Medicaid enrollee basis	2011 - 2016 Medicaid State Drug Utilization Files (CMS)	Stronger PDMP mandates associated with lower rates of opioid prescriptions concentrated mainly in Schedule II opioids. No discernible change in the prescription rate of Schedule III-V opioids	<ul style="list-style-type: none"> ● Research design precludes the ability to infer a causal relationship. ● Analysis of patient-level measures such as daily MME & risky prescriptions was not possible. Similarly, could not contact sub analyses per diagnosis or types of controlled substances
52	Winstanley et al., 2018	Level II (Quasi-experimental) Observational (analytic) cohort study	State of Ohio	Ohio Board of Pharmacy mailing letters to prescribers that failed to check PDMP before prescribing an opioid or benzodiazepine informing them they could be fined up to \$20,000 for non-compliance (August 2016)	<ul style="list-style-type: none"> ● Days' supply of opioids or benzodiazepines ● Mean MME per opioid prescription ● Number of multiple-provider episodes 	2014 - 2017 Ohio PDMP	<ul style="list-style-type: none"> ● Letters associated with a decrease in the mean quantities (number of pills) of opioids & benzodiazepines dispensed ● Letters also associated with reduction in multiple provider episodes 	<ul style="list-style-type: none"> ● Possible confounding effect from other variables ● Letters did not distinguish between new patients versus patients with whom clinicians had established relationships ● Limitations due to single state included in analysis

	Reference	Research Design	Population, size, & setting	Intervention	Outcome or Phenomenon Studied	Study Data	Findings	Limitations
53	Yarbrough, 2018	Level II (Quasi-experimental) Observational (analytic) cohort study	Medicare MA, FL, KS, OR, AK, DE, MT, NJ, RI, SD, TX, WA, AR, GA, WI, WY Control: MD, MO, NE, NH, PA	Online access to a PDMP (2011 - 2013) Control states had not implemented an online PDMP by 2013	For Schedules II-IV prescriptions for Medicare Part D recipients: Total days supply written for each drug for each provider in a given year	2010 - 2013 Physician-level Medicare Part D prescribing data (CMS)	<ul style="list-style-type: none"> • PDMPs associated with a small decrease in opioids • Findings suggest some substitution toward lower schedule opioids • Findings suggest not requiring PDMP use largely eliminate effect of monitoring on prescribing 	<ul style="list-style-type: none"> • Effects may be different for younger patients • Analysis did not include prescription dosages or prescriptions paid for in cash
54	Young et al., 2018	Level I Experimental (randomized) parallel group	Individuals with multiple provider episodes in the State of Massachusetts Control group: Comparison group closely matched on demographics & baseline prescription history whose prescribers were not in intervention	Unsolicited report of patient's 12-month controlled substance prescription history sent to each prescriber of the patients with multiple provider episodes	<ul style="list-style-type: none"> • Number of Schedule II opioid prescriptions • Number of prescribers visited • Number of pharmacies used • Quantity, number of days, total MME, average daily MME of Schedule II opioid prescriptions 	2010 - 2011 Massachusetts PDMP	<ul style="list-style-type: none"> • Intervention group had significantly greater decreases in the number of prescribers, pharmacies & schedule II opioids relative to the comparison group. There were also significantly greater dosage units, total days' supply, total MME, & average daily MME for the intervention group • However, a sub analysis of patients with an average daily dose of >100 MMEs showed no significant decrease 	<ul style="list-style-type: none"> • Analysis not done on whether prescriptions were clinically appropriate. • Matched comparison group based on demographics & baseline prescription history, but there could have been other variables that were more influential • Limitations due to single state included in analysis • Online access to PDMP happened concurrent with unsolicited report - may be a confounder

	Reference	Research Design	Population, size, & setting	Intervention	Outcome or Phenomenon Studied	Study Data	Findings	Limitations
55	Zeiner, et al., 2021	Level II (Quasi-experimental) Observational (analytic) cohort study	Emergency department of Hartford Hospital, a large academic tertiary medical center (Hartford, CT)	State of Connecticut legislation mandating PDMP use (Oct 2015)	Opioids prescribed upon patient discharge from ED	Medical center EHR Jan -June 2015 compared to Jan -June 2016 Cumulative MME of solid opioids per prescription	There was a statistically significant decrease in cumulative MMEs after the legislation primarily because of less Schedule II opioid prescriptions	<ul style="list-style-type: none"> Retrospective analysis of data from a single urban, level I trauma and tertiary care center may not be generalizable to other settings General awareness of the opioid crisis may have contributed to prescriber practices independent of the law
56	Zhang et al., 2021	Level II (Quasi-experimental) Observational (analytic) cohort study	AL, AZ, CA, CO, CT, ID, IL, IN, IA KY, LA, ME, MA, MI, MN, MS, NE, NV, NM, NC, ND, OH, OK, SC, TN, UT, VT, VA, WV (states with active prescriber online access to a PDMP by end of 2010)	State legislation mandating PDMP use for all prescribers in all clinical circumstances (comprehensive PDMP mandate) As compared to “non comprehensive” mandates (all other PDMP mandates)	For patients 18 - 64 years old with diagnosis of sickle cell disease or cancer with bone metastasis <ul style="list-style-type: none"> Probability of being prescribed an opioid after an ED visit MMEs of opioid dispensed 	2011 - 2017 Health Care Cost Institute (HCCI) claims data	Comprehensive use mandates were associated with significant decreases in opioids dispensed with sickle cell disease or cancer with bone metastasis following ED encounters	Analysis not done on whether prescriptions were clinically appropriate.