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Interstate data sharing of prescription drug monitoring programs and associated opioid prescriptions among patients with non-cancer chronic pain

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ABSTRACT

All fifty states have implemented prescription drug monitoring programs (PDMPs) to reduce misuse and diversion of controlled drugs. Interstate PDMP data sharing has been called for by clinical practitioners, but evidence to support the effectiveness of PDMP data sharing is lacking. This study examined whether PDMP interstate data sharing with bordering states was associated with prescriptions of opioids. This was a cross-sectional study that included patients with non-cancer chronic pain from the 2014 National Ambulatory Medical Care Survey (weighted N = 66,198,751; unweighted N = 2846). Multinomial logistic regression was performed to examine the association between PDMP interstate data sharing status and patients' being prescribed opioids for pain treatment, controlling for covariates guided by the Eisenberg's model of physician decision-making. Findings indicated that patients residing in states with interstate PDMP data sharing with all or partial bordering states were not less likely to be prescribed opioids compared to those living in states without interstate data sharing. Other factors such as patient age, health insurance type, new patient status, and physician adoption of electronic medical records were associated with the likelihood of patients' being prescribed opioids. This study concluded that current practice of interstate PDMP data sharing with bordering states was not associated with patients' being prescribed opioids for non-cancer chronic pain treatment. Future studies and policy efforts that unravel technological, legal, and political barriers to reciprocal and equal interstate data sharing with bordering states should be warranted to inform PDMP redesign and in turn, augment overall PDMP effectiveness in reducing misuse of prescription opioids.

1. Introduction

One of the greatest public health challenges facing the United States public health community is the misuse of prescription opioids and associated consequences of dependence, overdose, and death (Dart et al., 2015; Kolodny et al., 2015; Paulozzi, 2012; Sairam Atluri and Manchikanti, 2014). Moreover, opioid misuse causes notable healthcare and societal costs (Coben et al., 2010). Although opioid seeking and misuse are patient behaviors, previous studies have indicated these behaviors may be attributable to providers' suboptimal prescribing of opioid analgesics (Dineen and DuBois, 2016; Lin et al., 2018). Studies also have shown that opioid prescriptions have increased since 1990s (Volkow and McLellan, 2011), with approximately 1 in 5 patients with non-cancer pain liberally prescribed opioids in office-based and other ambulatory settings (Daubresse et al., 2013).

States have implemented policies aimed to alleviate the opioid crisis; all states and District of Columbia (D.C.) have implemented prescription drug monitoring programs (PDMPs) that enable registered prescribers and pharmacists to obtain nearly real-time information on patients' prescriptions for opioids and other controlled medications. PDMPs are designed to enhance physicians' safe prescribing practices as well as prevent drug-seeking by “doctor shopping.” However, PDMPs are statewide programs that collect patient prescription records only within the state and many PDMPs do not engage in interstate communication, a notable limitation since patients can easily engage in “doctor shopping” by crossing state borders (Cepeda et al., 2013) because prescribers and pharmacies in other states may not know a patient's prescription history. Therefore, sharing patient prescription information with PDMPs of bordering states may be crucial in achieving the PDMP goals of reducing patient drug seeking and enhancing

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physician safe prescribing practice.

In practice, interstate data sharing practices vary widely by state; there are multiple interstate data sharing platforms including PMP InterConnect, RxCheck, and RxSentry for PDMPs (American Pharmacists Association [APhA], 2015; Bao et al., 2016). Currently, PMP InterConnect is the most popular platform to share PDMP data among states. The PMP InterConnect is funded by the pharmaceutical industry and is governed by the National Association of Boards of Pharmacy, which has the largest number of active member states (Haffajee et al., 2015). As of January 2018, over forty state PDMPs are engaged in data sharing programs with at least one other state's PDMP program through PMP InterConnect. All interstate data sharing platforms require PDMPs to meet technical and security standards in order to share data and many requirements are based on guidelines from the Prescription Monitoring Information Exchange (PMIX) National Architecture (National Association of Boards of Pharmacy [NABP], 2012; Prescription Drug Monitoring Program Training and Technical Assistance Center [PDMP TTAC], 2018).

PDMP interstate data sharing is not uniformly implemented by all state PDMPs. States that have implemented a PDMP do not necessarily have an interstate data sharing agreement with other states. Moreover, while states may have had an interstate PDMP data sharing agreement with another state, they may not necessarily have an agreement with their *bordering* state(s). As of 2014, Alabama, Connecticut, Delaware, Maine, Mississippi, Montana, North Carolina, South Carolina, Utah, and Vermont did not have interstate data sharing agreements with PDMPs of their bordering states, although they share PDMP data with non-bordering states (identified based on data from PDMP TTAC, 2015). The Center for Excellence at Brandeis University conducted a survey of PDMPs in 2014 and asked for their interstate data sharing status (PDMP TTAC, 2015). Based on the 2014 survey, while 49 states had implemented PDMPs, there were only 21 states that had interstate data sharing agreements with any of their *bordering* state(s). Among them, Indiana and Michigan are the only two states that had PDMP interstate data sharing agreements with *all* of their bordering states; other 19 states had only agreement(s) with partial bordering states (Table 1).

PDMP interstate data sharing may be needed to enhance PDMP effectiveness by improving physician prescribing practices, thereby reducing patient opioid seeking (e.g., doctor shopping). A study from field experts indicated that an ideal PDMP should include interstate accessibility since the lack of interstate data sharing limits PDMPs' functionality (Perrone and Nelson, 2012; Shepherd, 2014). In their interviews with clinicians and administrators (N = 35), Finklea et al. (2012) reported that respondents generally believed that PDMPs need to be redesigned to include interstate data sharing (Finklea et al., 2012). In another qualitative study with clinicians (N = 78), respondents indicated their desire to have access to data from other states' PDMPs; they believed this would allow them to better evaluate patients' medication history, which is especially critical for physicians who have patients commuting among different states (Hildebran et al., 2014). Despite clinicians' belief that PDMP data sharing is important and will help control drug-seeking, few studies have investigated the impact of PDMP interstate data sharing on physician prescribing of opioid analgesics.

To fill the literature gaps regarding the effect of PDMP interstate data sharing on analgesic prescribing practices, we examined how PDMP interstate data sharing with bordering states was associated with patients being prescribed opioids for non-cancer chronic pain treatment. This study focused on non-cancer chronic pain patients who are at risk to exposure to opioid pain medications and, thus, at risk for opioid dependence and other adverse outcomes (Chou et al., 2015; Dowell et al., 2016). Cancer patients were excluded due to clinical acceptance of prescribing cancer patients with opioids (Portenoy et al., 2018). We used data from the 2014 National Ambulatory Medical Care Survey (NAMCS) and focused on PDMP data sharing with bordering states because doctor shoppers often travel across state borders to fill extra prescriptions (Cepeda et al., 2013).

2. Methods

2.1. Conceptual framework

We applied the Eisenberg model of physician decision-making as the conceptual framework to depict physicians' opioid prescribing patterns. The Eisenberg Model posits that physician decision-making is influenced by four groups of sociological factors that include: physician characteristics (e.g., primary care physician vs. specialist), patient characteristics (e.g., sex, race/ethnicity), physician's relationship with the healthcare system (e.g., ownership of practice setting), and physician's relationship with the patient (e.g., new/old patient) (Eisenberg, 1979). The Eisenberg model has been widely used in previous studies that characterize physician treatment prescribing patterns (Godwin et al., 2011; Tamblyn et al., 2003; Wilkes et al., 2000) including opioid prescribing (Lin et al., 2018).

2.2. Data and study sample

Data from the 2014 NAMCS were used. The NAMCS is a nationally-representative survey conducted by the National Center for Health Statistics and the Centers for Disease Control and Prevention (CDC, 2016). The NAMCS provided information of outpatient visits (including physician specialty, reasons for the visit, source of payment for the visit, diagnoses, and prescribed medications) to non-federally employed office-based physicians (CDC, 2016). The 2014 NAMCS also included state identifiers of 18 more populous states for this study to identify the status of a PDMP's interstate data sharing agreement. We further utilized the NAMCS census division identifiers to identify a state's PDMP interstate data sharing status if the state was within a census division

Table 1
PDMP interstate data sharing status in the U.S. in 2014.

PDMP interstate data sharing status	States
No PDMP	District of Columbia[a], Missouri[a]
PDMP with no data sharing agreement with any bordering states	Alabama[a], Alaska[a,b], California, Connecticut, Delaware[a], Florida, Georgia, Hawaii[a,b], Iowa[a], Maine, Maryland[a], Massachusetts, Mississippi[a], Montana[a], Nebraska[a], New Hampshire, New York, North Carolina, Oklahoma[a], Oregon, Pennsylvania, Rhode Island, South Carolina[a], Texas, Utah[a], Vermont, Washington, Wyoming[a]
PDMP with data sharing agreement with partial bordering states	Arizona, Arkansas[a], Colorado[a], Idaho[a], Illinois, Kansas[a], Kentucky[a], Louisiana[a], Minnesota[a], Nevada[a], New Jersey, New Mexico[a], North Dakota[a], Ohio, South Dakota[a], Tennessee, Virginia, West Virginia[a], Wisconsin
PDMP with data sharing agreement with all bordering states	Indiana, Michigan

Data source: compiled by this study.

[a] Not included in this study due to lack of state identifiers in NAMCS or inability to identify interstate data sharing status based on NAMCS census division identifiers.

[b] Not included in this study due to no bordering states.

where all of the included states had the same PDMP data sharing status (i.e., no interstate data sharing, data sharing with partial bordering states, or with all bordering states). In particular, Connecticut, Maine, New Hampshire, Rhode Island, and Vermont belong to the New England census division and all of them had no interstate data sharing with any bordering state(s), which allowed us to determine these additional five states' PDMP interstate data sharing status for inclusion even without their state identifiers. We finally included a total of 23 states in this study (Table 1).

We included adult patients with non-cancer chronic pain in this study. Following previous studies (Edlund et al., 2010; Martin et al., 2011), we defined non-cancer chronic pain patients as those with general chronic pain, back pain, and arthritis/joint pain and without cancer, identified by the ICD-9-CM diagnosis codes provided by the NAMCS (see Appendix A for detailed ICD-9-CM diagnosis codes). This study was considered a non-human subjects study by the Institutional Review Board of Indiana University due to the public availability of the NAMCS data.

2.3. Measurement

2.3.1. Outcome variable

Treatment being prescribed for non-cancer chronic pain is the outcome variable, which was categorized as a patient being prescribed no pain medication, only non-opioid pain medication, or any opioid medication. Table 2 summarizes the pain medications included in this study based on two clinical practice guidelines for non-cancer chronic pain treatment (American Society of Anesthesiologists [ASA], 2012; Chou et al., 2009). Note that a patient prescribed a combo medication that includes both opioid and non-opioid agents (e.g., acetaminophen/hydrocodone) was categorized as prescribed an opioid medication.

2.3.2. Primary independent variable

Implementation of PDMP interstate data sharing agreement with bordering state(s) was the primary independent variable, which was categorized as had interstate PDMP data sharing agreement with *no* bordering states, with *partial* bordering state(s), and with *all* bordering states. Each state's interstate data sharing information was from the survey conducted by the Center for Excellence (PDMP TTAC, 2015) and we further identified the status of interstate data sharing with bordering state(s) based on geography (see Table 1). This variable was coded as a categorical variable.

2.3.3. Covariates

Inclusion of covariates was based on the Eisenberg model. The covariates included primary care physician (i.e., those in internal medicine, family medicine, or pediatrics) or specialist, patient's sex, age, race/ethnicity, primary source of payment (private insurance, Medicare, Medicaid, or others), owner of practice settings (physician or physician group, medical center or hospital, or health insurance plans), practice region (Northeast, Midwest, South, or West), metropolitan status, whether a physician had adopted electronic medical records, and whether a patient was seen by the physician before (i.e., new patient status). All variables were coded as categorical variables.

2.4. Analytical approach

We first computed descriptive statistics for each variable. We conducted Chi-square tests to examine the differences among patients prescribed different types of pain treatment on each of the variables. We then performed a multinomial logistic regression to examine factors (in particular, PDMP interstate data sharing status) that may influence the treatment prescribed to patients for non-cancer chronic pain treatment (i.e., prescribed no pain medication, only non-opioid pain medication, and any opioid medication). Notably, prescribed any opioid medication was used as the reference outcome in the multinomial logistic regression model. All statistical analyses were weighted based on the patient-visit weight and clustered stratum of the NAMCS survey sampling scheme to reflect national generalizability, where the Taylor linearization method was used for variance estimation as recommended by the NAMCS (CDC, 2016). All statistical analyses were performed using Stata® 14.2.

3. Results

This study included a total of 2846 (unweighted) non-cancer chronic pain patients, representing a 66,198,751 (weighted) patient population. Table 3 shows the descriptive statistics of the variables by type of treatment prescribed by physicians. Among the study sample, 41.8% were not prescribed any pain medications, whereas 25.0% were prescribed only non-opioid pain medications and 33.1% were prescribed any opioid pain medications. Concerning PDMP interstate data sharing status, 67.8% resided in states with no interstate PDMP data sharing with any bordering states, whereas 24.6% in states that had PDMP data sharing with *partial* bordering states and 7.6% in states that had PDMP data sharing with *all* bordering states. In this national sample, 37.8% of the patients with non-cancer chronic pain were male, approximately 70% aged older than 50 years, 73.9% were non-Hispanic white, 42.3% were treated by primary care physicians, 86.5% were prior patients of the physician, and 44.0% used private insurance as the primary source of payment. In terms of physician relationship with health system, 80.3% patients were treated in a practice setting owned by physicians or physician groups, 31.9% of the practices were in the south, and 95.4% of the practices were in metropolitan areas.

Table 4 shows the results of the multinomial logistic regression that examined factors that may influence treatment prescribed to a patient for non-cancer chronic pain (i.e., prescribed no pain medication, only non-opioid pain medication, and any opioid medication), where prescribed any opioid medication was used as the reference outcome. Odds ratios (ORs) were reported to indicate the odds of being prescribed no

Table 2
Pain medications included in this study.

Type of pain medication	Medications included
Opioid medications	• Drugs containing alfentanil, buprenorphine, butorphanol, codeine, dihydrocodeine, fentanyl, hydrocodone, hydromorphone, levorphanol, meperidine, methadone, morphine, nalbuphine, oxycodone, oxymorphone, pentazocine, remifentanil, tapentadol, tramadol
Non-opioid medications	• **Antidepressants**: SNRIs (duloxetine, milnacipran, venlafaxine) and TCAs (amitriptyline, imipramine, maprotiline) • **NSAID agents**: Aspirin, diflunisal, choline magnesium trisalicylate, salsalate, naproxen, ibuprofen, ketoprofen, flurbiprofen, oxaprozin, diclofenac, etodolac, indomenthacin, tolmetin, sulindac, meloxicam, piroxicam, meclofenamate, mefenamic, nabumetone • **COX-2 inhibitor**: Celecoxib • Salicylates • Pregabalin and gabapentin

SNRI: serotonin-norepinephrine reuptake inhibitor (that have indications for pain treatment).
TCA: tricyclic antidepressants (that have indications for pain treatment).
NSAID: nonsteroidal anti-inflammatory drug agents.

Table 3
Descriptive statistics of study sample (U.S. adult patients with non-cancer chronic pain) by type of treatment prescribed by physicians.

Variable	Not prescribed any pain medication	Prescribed only non-opioid pain medication	Prescribed any opioid pain medication
	N = 27,685,109 (41.8%)	N = 16,578,237 (25.0%)	N = 21,935,405 (33.1%)
1. PDMP data sharing with bordering states			
With no bordering state	18,314,692 (27.7%)	10,944,093 (16.5%)	15,630,881 (23.6%)
With partial bordering states	7,709,685 (11.6%)	4,287,301 (6.5%)	4,277,702 (6.5%)
With all bordering states	1,660,732 (2.5%)	1,346,843 (2.0%)	2,026,822 (3.1%)
2. Physician characteristics			
Primary care physician	10,599,231 (16.0%)	8,241,561 (12.4%)	9,180,266 (13.9%)
Specialist	17,085,879 (25.8%)	8,336,676 (12.6%)	12,755,139 (19.3%)
3. Patient characteristics			
Sex			
Male	10,649,533 (16.1%)	5,554,766 (8.4%)	8,816,589 (13.3%)
Female	17,035,576 (25.7%)	11,023,471 (16.7%)	13,118,816 (19.8%)
Age			
18–25	713,256 (1.1%)	506,579 (0.8%)	209,132 (0.3%)
26–49	7,208,817 (10.9%)	3,661,714 (5.3%)	6,775,679 (10.2%)
50–64	9,620,433 (14.5%)	6,475,929 (9.8%)	8,171,301 (12.3%)
65 and above	10,142,604 (15.3%)	5,934,015 (9.0%)	6,779,294 (10.2%)
Race/ethnicity			
Non-Hispanic white	20,616,433 (31.1%)	11,702,437 (17.7%)	16,620,777 (25.1%)
Non-Hispanic black	2,246,471 (3.4%)	1,435,199 (2.2%)	1,826,443 (2.8%)
Hispanic	4,175,239 (6.3%)	2,596,377 (3.9%)	2,951,695 (4.5%)
Other	646,966 (1.0%)	844,223 (1.3%)	536,490 (0.8%)
Primary source of payment			
Private insurance	13,660,690 (20.6%)	6,955,362 (10.5%)	8,490,266 (12.8%)
Medicare	8,857,636 (13.4%)	5,930,611 (9.0%)	8,138,174 (12.3%)
Medicaid	1,698,126 (2.6%)	1,360,348 (2.1%)	2,380,022 (3.6%)
All others	2,616,322 (4.0%)	1,264,529 (1.9%)	2,123,511 (3.2%)
4. Physician relationship with health system			
Owner of practice settings			
Physician or physician group	22,568,127 (34.1%)	12,293,403 (18.6%)	18,298,900 (27.6%)
Medical center or hospital	1,941,009 (2.9%)	1,170,277 (1.8%)	1,052,643 (1.6%)
Health insurance plans	2,483,981 (3.8%)	2,107,558 (3.2%)	1,665,047 (2.5%)
Practice region			
Northeast	7,545,793 (11.4%)	5,104,868 (7.7%)	4,451,559 (6.7%)
Midwest	4,570,905 (6.9%)	3,023,492 (4.6%)	3,705,093 (5.6%)
South	9,096,575 (13.7%)	4,776,564 (7.2%)	7,276,954 (11.0%)
West	6,471,836 (9.8%)	3,673,313 (5.6%)	6,501,799 (9.8%)
Metropolitan status	26,449,472 (40.0%)	15,801,683 (23.9%)	20,924,632 (31.6%)
Adopted electronic medical records: Yes	23,132,751 (34.9%)	14,584,529 (22.0%)	16,866,983 (25.5%)
5. Physician-patient relationship			
Patient seen before: Yes	22,897,138 (34.6%)	14,117,904 (21.3%)	20,244,085 (30.6%)

Notes: 1. Data source: 2014 National Ambulatory Medical Care Survey; 2. total unweighted N = 2846; total weighted N = 66,198,751; 3. A Chi-square test was conducted to test the difference among the three groups on each categorical variable.

pain medications or only non-opioid medications comparing with being prescribed any opioid pain medications. Patients who were aged 25–49, compared to those aged 18–25, were more likely to be prescribed any opioid pain medications (comparing with being prescribed no pain medications or only non-opioid medications), after adjusting for the effects of all the other covariates. Patients with Medicare and Medicaid coverage were more likely to be prescribed opioid pain medications (comparing to being prescribed no pain medications or only non-opioid medications) than those who had private insurance coverage. Patients who were seen by the physician before were more likely to be prescribed opioid pain medications than new patients. Patient residing in the West region were less likely to be prescribed only non-opioid pain medications then those in the Northeast region whereas those who were seen by physicians who had adopted electronic medical records were more likely to be prescribed only non-opioid pain medications. Nevertheless, we did not find significant association of PDMP interstate data sharing status and likelihood of being prescribed any opioid pain medications.

4. Discussion

To our knowledge, this study is the first analysis that examined how PDMP interstate data sharing was associated with patients' being prescribed opioids. We used data from the nationally-representative 2014 NAMCS to examine if interstate PDMP data sharing with bordering states was associated with opioid prescriptions to treat patients' non-cancer chronic pain. We found that patients who resided in states that shared PDMP data with all or partial bordering states were not less likely to be prescribed opioids compared to patients living in states without interstate data sharing agreements.

Despite interstate PDMP data sharing has been believed by clinical practitioners and administrators to enhance PDMP effectiveness in improving physician safe prescribing of opioids and thus, reduce patient drug seeking (Cepeda et al., 2013; Hildebran et al., 2014), our findings could not provide evidence to support the effectiveness. In fact, there are practical issues that have dissipated the effectiveness of interstate data sharing agreements with bordering states. First, interstate PDMP data sharing agreement is not necessarily mutual; one state that shares PDMP data with another state does not necessarily gain access to another PDMP's data. By way of example, in 2014 Florida's PDMP shared data with Connecticut, whereas Florida's PDMP did not have access to Connecticut's (PDMP TTAC, 2015). This lack of reciprocity may be due to diverse PDMP designs as well as political and legal confidentiality concerns. Second, different PDMPs require different

Table 4
Pain treatment and opioid prescription by multinomial logistic regression.

	Not prescribed any pain medication (vs. prescribed any opioid)		Prescribed only non-opioid pain medication (vs. prescribed any opioid)	
	OR	95% CI	OR	95% CI
1. PDMP data sharing with bordering states				
With no bordering state	–	–	–	–
With partial bordering states	1.56	(0.87, 2.78)	1.36	(0.69, 2.67)
With all bordering states	0.56	(0.23, 1.33)	1.17	(0.47, 2.87)
2. Physician characteristics				
Primary care physician	0.88	(0.54, 1.45)	1.38	(0.85, 2.24)
3. Patient characteristics				
Sex: Male	0.98	(0.74, 1.29)	0.88	(0.66, 1.17)
Age				
18–25	–	–	–	–
26–49	0.37	(0.15, 0.90)	0.23	(0.08, 0.63)
50–64	0.44	(0.17, 1.12)	0.36	(0.12, 1.07)
65 and above	0.82	(0.31, 2.19)	0.46	(0.15, 1.44)
Race/ethnicity				
Non-Hispanic white	–	–	–	–
Non-Hispanic black	0.95	(0.58, 1.55)	1.10	(0.57, 2.13)
Hispanic	1.23	(0.80, 1.88)	1.25	(0.70, 2.21)
Other	1.27	(0.43, 3.76)	2.86	(1.34, 6.11)
Primary source of payment				
Private insurance	–	–	–	–
Medicare	0.44	(0.30, 0.65)	0.64	(0.42, 0.97)
Medicaid	0.41	(0.25, 0.67)	0.48	(0.26, 0.87)
All others	0.96	(0.59, 1.56)	0.85	(0.48, 1.51)
4. Physician relationship with health system				
Owner of practice settings				
Physician or physician group	0.70	(0.38, 1.29)	0.81	(0.41, 1.63)
Medical center or hospital	–	–	–	–
Health insurance plans	0.84	(0.28, 2.49)	1.57	(0.45, 5.54)
Practice region				
Northeast	–	–	–	–
Midwest	1.07	(0.45, 2.55)	0.56	(0.22, 1.40)
South	0.77	(0.37, 1.60)	0.55	(0.27, 1.11)
West	0.68	(0.34, 1.36)	0.47	(0.23, 0.96)
Metropolitan status	1.08	(0.61, 1.92)	1.12	(0.61, 2.06)
Adopted electronic medical records: Yes	1.52	(0.64, 3.61)	2.50	(1.16, 5.40)
5. Physician-patient relationship				
Patient seen before: Yes	0.41	(0.26, 0.64)	0.43	(0.28, 0.67)
Intercept	8.50	(1.90, 38.04)	3.26	(0.62, 17.16)

Data source: 2014 National Ambulatory Medical Care Survey.
Total unweighted N = 2538; total weighted N = 60,948,003.
OR: odds ratio.
CI: confidence interval.

control medications to be reported and monitored. For example, several PDMPs (e.g., California, West Virginia, and Maine) do not require Schedule V controlled medications to be reported and monitored. This implies that even two states have had PDMP data sharing agreements, the scope of prescription drug history to be shared is not necessarily equal, which may handicap the effectiveness of data sharing.

Currently there are only 21 states in the U.S. that have a PDMP data sharing agreement with any of their bordering states. There have been barriers that have hindered successful implementation of interstate PDMP data sharing. First, there is neither unified PDMP interstate data-sharing platforms nor standardized sharing requirements. Currently, the three coexisting platforms all require PDMPs to meet technical security standards to build interstate data sharing hubs and agreements, where the requirements vary in different platforms (APhA, 2015). Thus, PDMPs would need to join and comply with different platforms' requirements in order to obtain access to other programs' data. Undeniably, having multiple platforms prolongs the process to implement the interstate data sharing among states. Extra compliance requirements could bring additional burdens to PDMPs, and there are few financial incentives to meet requirements and engage in sharing. Additionally, as discussed earlier, data sharing agreements are not always between bordering states, which may not be beneficial in reducing cross-border drug seeking. Furthermore, legislation barriers may prevent PDMPs from interstate data sharing. A case study from the CDC concluded that if there are legislative mandates of integration and interpretability, the states are more likely to have data sharing programs (CDC, 2017). Otherwise, laws may prevent states to implement interstate data sharing. Future studies that unravel the barriers, including the political and legal barriers to strong and reciprocal interstate data sharing are needed.

Although our study findings indicate that interstate PDMP data sharing was not associated with patients' likelihood of being prescribed opioids, there are indeed other possible factors that may have contributed to the ineffectiveness of PDMPs. For example, not all operating PDMPs have mandatory query requirement before a physician prescribes opioids (Lin et al., 2018). Without such mandatory requirements, healthcare providers do not have liabilities if PDMP data are not checked before prescribing. Even with this requirement, a study found that checking PDMP data could impose significant burdens to clinicians and beat their turnover benchmark due to limited time and human resources (Stucke et al., 2018). As indicated by a previous study (Lin et al., 2018), more studies are needed to explore the factors that may influence physicians' compliance to PDMP requirement to enhance the overall effectiveness of PDMPs.

This study also found several physician- and patient-related factors associated with opioid prescriptions among patients with non-cancer chronic pain. Specifically, we found that patients having Medicare and Medicaid health insurance coverage were more likely to be prescribed opioids for their non-cancer chronic pain. It has been indicated in previous studies that governmental health insurance plans, compared with private insurance plans, had not been able to effectively implement mechanisms to monitor deviant prescribing behaviors (Daly, 2009; Sparrow, 2009). We also found that patients who were seen by physicians who adopted electronic medical records were less likely to be prescribed opioids for their non-cancer chronic pain. Electronic medical record systems have been shown to facilitate physicians' tracking of patients' previous and current medical records, including chronic pain history (Fernando et al., 2012; Tian et al., 2013). Future interventions may be tailored to the special needs of the group of physicians who have yet adopted electronic medical records. Additionally, researchers have been calling for the integration of the PDMP and electronic medical record systems that will help remove technological and time constraints for pain medication prescribers (Elder et al., 2018), and in turn curtail possible patient drug seeking behaviors. It is noteworthy that the integration of the PDMP and electronic medical record systems should also consider cross-state compatibility to avoid further data sharing constraints across states.

There are limitations of this study. First, although the NAMCS is a nationally-representative survey, this study included only 23 states due to the inability to differentiate all states. Additionally, the NAMCS data only included patients in ambulatory settings with non-federally employed physicians. Thus, results may not be generalizable to all U.S. healthcare settings. Second, due to the cross-sectional nature of this study, we cannot assess causality; future studies with longitudinal data that allow for causal inferences are needed. Third, this study included

only patients with non-cancer chronic pain and thus, results may not be generalizable to patients prescribed pain medications for other conditions. Fourth, the NAMCS data rely on provider self-report and thus are subject to survey, recall, and response biases. Furthermore, it is impossible to differentiate general and pain-related special clinics (e.g., pain management clinics) using the NAMCS data. Finally, this study examined any prescription pain and/or opioid prescribing—it did not assess the quality of that prescribing. Thus, suboptimal prescribing or potentially problematic prescribing patterns were not assessed. And it is these problematic behaviors which often are the subject to PDMP scrutiny. We believe our findings can provide a foundation for future studies, particularly those that further define pain medication prescribing patterns and how PDMP interstate data sharing agreements may affect such prescribing patterns. It is notable that PDMPs vary regarding program design and implementation beyond interstate data sharing status. Future studies that examine interstate data sharing requirements may need to consider other characteristics of PDMPs (e.g., PDMP requirements for physician query, see Lin et al. (2018); and PDMP regulatory strength, see Pardo (2017)) when evaluating PDMP effectiveness.

5. Conclusions

While all states in the U.S. have initiated or implemented a PDMP with an aim to reduce misuse of opioid analgesics, it is believed by clinicians and administrators that providing prescribers the access to other PDMPs' data could be a promising way to enhance PDMP effectiveness. However, our study that analyzed physician-report data from a nationally-representative survey found that patients resided in states that had interstate PDMP data sharing with all or partial bordering states were not less likely to be prescribed opioids to treat their non-cancer chronic pain than those residing in states that did not have interstate data sharing with bordering states. Future studies and policy efforts that unravel technological, legal, and political barriers to reciprocal and equal interstate data sharing with bordering states should be warranted to inform PDMP redesign and in turn, augment overall PDMP effectiveness in reducing misuse of prescription opioids.

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Conflict of interest

None.

Appendix A. ICD-9-CM codes for patient identification

Condition	ICD-9-CM codes
General chronic pain	338.0, 338.2, 338.21, 338.22, 338.28, 338.29, and 338.4
Back pain	724.1, 724.2, 724.5, and 307.89
Arthritis/joint pain	95.6, 95.7, 98.5, 99.3, 136.1, 274, 277.2, 287.0, 344.6, 353.0, 354.0, 355.5, 357.1, 390, 391, 437.4, 443.0, 446, 447.6, 696.0, 710, 711, 712, 713, 714, 715, 716.0, 716.2, 716.8, 716.1, 716.3–0.9, 719.0, 719.4–0.9, 719.2–0.3, 720, 721, 725, 726, 727, 728.0–0.3, 728.6–0.9, 729.0, 729.1, and 729.4
Cancer	140.x–172.9, 174.x–215.9, 217–229.10, 235–239.9, and 338.3

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