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Association of Prescription Drug Monitoring Program use with Opioid Prescribing and Health Outcomes: A Comparison of Program users and Non-users

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Abstract

Prescription drug monitoring programs (PDMPs) are a response to the prescription opioid epidemic, but their impacts on prescribing and health outcomes remain unclear, with conflicting reports. We sought to determine if prescriber use of Oregon's prescription drug monitoring program (PDMP) led to fewer high-risk opioid prescriptions or overdose events. We conducted a retrospective cohort study from October, 2011 through October, 2014, using statewide PDMP data, hospitalization registry, and vital records. Early PDMP registrants (n=927) were matched with clinicians who never registered during the study period, using baseline prescribing metrics in a propensity score. Generalized estimating equations were used to examine prescribing trends following PDMP registration, using 2-month intervals. We found a statewide decline in measures of per capita opioid prescribing. However, compared with non-registrants, PDMP registrants did

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not subsequently have significantly fewer patients receiving high-dose prescriptions; overlapping opioid and benzodiazepine prescriptions, inappropriate prescriptions, prescriptions from multiple prescribers, or overdose events. At baseline, frequent PDMP users wrote fewer high-risk opioid prescriptions than infrequent users; this persisted during follow-up with few significant group differences in trend. Thus, although opioid prescribing declined statewide after implementing the PDMP, registrants did not demonstrate greater declines than non-registrants.

Keywords

Prescription Drug Monitoring Program; opioids; risky prescribing; health policy; cohort study

INTRODUCTION

Prescription opioid use in the United States increased over much of the past two decades, with parallel increases in opioid-related overdoses, mortality, hospitalization, and addiction treatment.[24,25,28] One response has been creation of electronic internet-based prescription drug monitoring programs (PDMPs) in nearly every state, tracking outpatient prescriptions for controlled substances. By allowing prescribers and pharmacists to view all prescriptions for controlled substances from all sources, these programs were intended to facilitate judicious prescribing and to illuminate the activities of prescribers, pharmacies, and patients. Creating and using these systems became a central recommendation of the White House Office of National Drug Control Policy[13] and a part of recent opioid prescribing recommendations from the Centers for Disease Control (CDC).[10]

Despite growing use, the impact of PDMPs on opioid prescribing and health outcomes remains unclear.[12] Some studies suggested important changes in prescribing and overdose risk,[2,27] while others reported little or no impact.[4,21,22,29] Only a few studies quantified effects on overdose hospitalizations or mortality, with conflicting results.[21,22,27,29] Most PDMP evaluations compared states with and without such programs, or prescribing patterns before and after implementation. Such comparisons may be confounded by other influences on prescribing (e.g., new medical literature, clinical guidelines, insurance coverage policies, media reports, and other changes in public policy). State-to-state variations in PDMP design and policies are substantial, and may also influence comparisons.[26]

Like most states, Oregon experienced increases in opioid prescribing, misuse, and overdoses after 2000.[25] The state implemented a PDMP that became available to clinicians in September, 2011, with voluntary registration and use.[8] Seeking to minimize some confounding risks in previous studies, we evaluated Oregon's PDMP by comparing prescribing patterns and patient outcomes of clinicians with similar baseline prescribing patterns who did or did not register to use the system.

The analyses had 3 aims:

1. Describe statewide trends in opioid prescribing and health impact of opioids (opioid-related deaths and hospitalizations) following initiation of the PDMP.

2. Compare changes in opioid prescribing between early PDMP registrants and non-registrants. Among PDMP registrants, we also examined changes in prescribing according to frequency of PDMP use.

3. Assess the likelihood of opioid-related mortality or hospitalization among patients of clinicians who were early registrants versus those who did not register for the PDMP.

We hypothesized that opioid prescribing and related hospitalization and death declined statewide following initiation of the PDMP (Aim 1). We further hypothesized that clinicians who registered for the PDMP, compared to those who did not, would decrease the proportion of patients with high opioid doses, the proportion with risky co-prescriptions, the number with opioid prescriptions from multiple prescribers, and the number of inappropriate prescriptions. Similarly, we hypothesized that among registrants, those who used the PDMP frequently would demonstrate greater changes in these measures than those who used the PDMP infrequently (Aim 2). Finally, we hypothesized that, compared with non-registrants, registrants would have fewer patients who were hospitalized or died from opioid overdoses (Aim 3).

METHODS

Overview

This project was approved by Institutional Review Boards at Oregon Health & Science University and the Public Health Division of the Oregon Health Authority, where the PDMP is housed. Data were obtained from the Oregon PDMP, Oregon vital records, and a statewide hospital discharge registry. We first examined statewide trends in prescribing and health outcomes following initiation of the PDMP. To better assess the degree to which those trends might be related to PDMP use, we then compared changes in opioid prescribing patterns between clinicians who registered for the PDMP during 3 early months of operation and those who never registered. We focused on early registrants because they were more likely than later registrants to write frequent and high-dose opioid prescriptions, and others have reported that high-risk prescribers are disproportionately responsive to state policices.[6] Because of substantial differences in opioid prescribing during the pre-registration period between those who did or did not register for the PDMP, we identified pairs of early-registered and nonregistered clinicians with similar pre-registration prescribing patterns. Finally, we compared opioid prescribing between registrants who accessed the PDMP frequently, and those who accessed it infrequently.

The Oregon PDMP

Licensed prescribers are encouraged to register online, and pay a small annual fee for use of the PDMP. The program is accessible online with a password at all times, but is not integrated with electronic medical records. Oregon neither requires registration nor mandates use of the PDMP system in any specific circumstances. Prescribers can voluntarily access an online “dashboard” that identifies patients with unusual prescription patterns, but there is no proactive alert system that identifies patients with alarming doses, numbers of prescribers, or drug combinations.

Preparation of PDMP data

Our de-identified analytic file included PDMP data from October 1, 2011 through October 31, 2014. Patient age was categorized by a public health analyst into 10-year intervals to maximize anonymity. Gender, ethnicity, race, other demographic data, and payment source were not collected during study years.

Oregon's PDMP is maintained by a commercial vendor. Because the vendor uses a largely deterministic, proprietary algorithm for matching prescription fills for a single patient, it may not always uniquely identify patients in the face of nicknames, misspellings, transposed digits or characters, name changes, or changes in residence. A public health analyst therefore used probabilistic linking software (The Link King v7.1.21)[3,5] to match individuals within and between data sets, based on name, birthdate, and ZIP Code.

Inclusion of prescriptions

We identified opioid preparations using Food and Drug Administration (FDA) National Drug Codes. Tramadol was not included in the PDMP during study years, and we excluded buprenorphine-naloxone combinations. Conversion reference tables from CDC were used to calculate "morphine milligram equivalents" (MME) for each prescription fill. A clinical pharmacist (NO) assigned a conversion factor if one was not available, as well as designation as long- or short-acting, based on information from the drug name and drugs with equivalent features.[23]

Inclusion of Clinicians

The primary analysis included "early registrants" who registered for the PDMP in December, 2011 through February, 2012, the "registration interval". This provided 2 months (October and November, 2011) of PDMP data prior to registration for all clinicians (the "baseline interval"). Non-registrants were clinicians who had not registered for the PDMP as of October, 2014.

Clinicians who never wrote a prescription for opioids in our data set were excluded. We also excluded clinicians who registered for the PDMP before December 1, 2011, because we could not obtain 2 full months of baseline prescribing data.

Measures of PDMP Querying Behavior

To compare registrants who frequently accessed the PDMP with those who did not, we examined the ratio of database queries to opioid prescriptions filled over the full length of our database. We defined high and low use based on the median ratio, approximately 1 query for every 6 opioid prescriptions.

Outcome measures

The primary prescribing outcomes were 4 metrics associated with an increased risk of opioid overdose: high doses (≥ 90 MME/day), overlapping opioid and benzodiazepine prescriptions, opioid prescriptions from multiple prescribers (≥3 in any 2-month interval), and inappropriate opioid prescriptions.[9,10,14,30] The definition of "high dose" corresponded to a recommendation in recent CDC guidelines that discouraged prescriptions exceeding this

dose.[10] Although the Oregon PDMP did not record a days' supply during the study years, we defined an opioid prescription as overlapping a benzodiazepine prescription if it occurred within 30 days before or after the benzodiazepine prescription. The definition of an "inappropriate opioid prescription" was adapted from a previous study,[9] and represented a new prescription for the same opioid following a prescription of at least 30 tablets, occurring within 7 days, from a different prescriber. These were chosen as primary outcomes because of the previously demonstrated associations with outcome risks.

Secondary Measures included 10 additional measures of opioid prescribing designed to capture numbers of prescriptions, doses per prescription and related factors (Table 1). Trends were examined by calculating prescribing metrics for each 2-month interval from October, 2011 through September, 2014.

We identified opioid-related deaths from Oregon vital records and opioid-related hospitalizations from the hospital discharge registry. Heroin-related deaths and hospitalizations were excluded, as were events if no opioid prescription was filled in the prior 5-months. A death or hospitalization was linked to the most recent prescriber of an opioid, sedative-hypnotic, or carisoprodol for that patient.

International Classification of Diseases, Version 9 Clinical Modification (ICD-9-CM) diagnosis codes for relevant hospitalizations were described earlier.[7]

Propensity Matching of PDMP Registrants and Non-registrants

Because PDMP registrants and non-registrants differed substantially in baseline opioid prescribing (Table 1) we undertook a propensity score matching process, using baseline prescribing measures. We performed one-to-one matching of registered and non-registered providers based on a propensity score derived from a multivariable logistic model that included all 14 prescribing metrics listed in Table 1 and an indicator for urban or rural ZIP code. We required a caliper of 0.05 standard deviation of the propensity score.

Statewide Population-based prescribing

We used quarterly data for measures of statewide prescribing and health outcomes. State population estimates for denominators were updated annually, using estimates from Portland State University's Population Research Center. For context, the state population is approximately 4 million. We focused on 7 measures that gave a broad view of statewide prescribing patterns in terms of overall volume of opioid prescribing, use of multiple prescribers and pharmacies, potentially inappropriate prescribing, and health outcomes (hospitalization and death).

Examination of later PDMP registrants

Because early PDMP registrants differed from later registrants in their pre-registration prescribing patterns, we conducted an additional analysis comparing clinicians who registered a year after initiation of the PDMP with those who had not registered at all prior to October 2014. As with the early registrants, we used propensity score matching to identify pairs of clinicians with similar pre-registration prescribing patterns. We included a

6-month enrollment window (October 1, 2012 through March 31, 2013) because enrollment was slower at this point than early in the PDMP's existence.

Analysis

The propensity score matching was tested by examining standardized mean differences (SMD) in the prescribing metrics before and after matching. An SMD of <0.1 is considered a negligible imbalance of covariate means between groups.[1]

The primary comparison between matched PDMP registrants and non-registrants was an assessment of prescribing trends over time, aggregating prescription data into 2-month intervals. For these analyses we used generalized estimating equations (GEE) regression modeling with robust sandwich variance estimators (GEE Poisson model for count data and GEE Gaussian regression for percentage data). The GEE models included an indicator for PDMP registration status, categorical time, and their interaction, as well as any factors that were imbalanced after propensity score matching. We clustered all models by matched provider and used a first-order autoregressive covariance structure to account for within-provider temporal correlation. We tested changes in prescribing outcomes over time between groups through an omnibus test of the two-way interaction between the indicator for PDMP registration and categorical time (termed parallel lines test).

To facilitate an understanding of actual numbers of prescriptions, patients, or doses, we also tabulated cumulative means of the prescribing metrics in the short term (6 months following the registration period) and the longer term (30 months following the registration period). Differences in rates were tested using a GEE Poisson model accounting for clustering of matched pairs assuming an exchangeable correlation structure and were adjusted for rural or urban physician location.

Comparisons between registrants who queried the PDMP frequently or infrequently were similarly performed using GEE Poisson models. Because these groups had substantial baseline prescribing differences, we adjusted the prescribing outcomes using Poisson regression, with the baseline prescribing metric and urban or rural location as covariates.

Deaths and hospitalizations were tabulated in the 6-month and 30-month intervals, then compared using a two-sample exact rate ratio test.[11] Analysis was conducted using SAS v. 9.4 (SAS Institute, Inc.) and R version 3.3.2; statistical significance was set at p-value<0.05.

RESULTS

Statewide trends

Statewide, there was a decrease in the number of opioid units (overwhelmingly pills, but including liquid doses, suppositories, patches, and injections) dispensed per capita beginning in the first quarter of PDMP operation and continuing through 3 years of operation (from 16.9 to 15.0 units per capita per quarter, Figure 1a). Similarly, there was a gradual downward trend in the total number of daily morphine equivalents dispensed per capita (from 2.80 per quarter to 2.41, Figure 1b).

In contrast, there was no decrease in the number of patients (per 1,000 population) with ≥ 4 prescribers or using ≥ 4 pharmacies in the previous 12 month period (Figures 1 c and d). The number of inappropriate prescriptions per 1,000 population showed a slight gradual decline (From 1.11 to 0.86, Figure 1e).

The statewide number of opioid-related hospitalizations and overdose deaths per 1,000 population remained relatively constant over 3 years following initiation of the PDMP (Figure 1f).

Prescribers and overall prescriptions

There were 17,734 clinicians who wrote at least one opioid prescription between September 1, 2011 and October 31, 2014. Of these, 964 registered for the PDMP during our early registration interval. There were 12,005 who had not registered by October 31, 2014 (Figure 2). Baseline prescribing characteristics of registrants and non-registrants were substantially different, with non-registrants prescribing fewer opioids by every measure (Table 1). The propensity matching process successfully matched 927 early registrants with an equal number of non-registrants (Table 1), with SMDs less than 0.1 for all prescribing metrics. After matching, only urban or rural location of the clinician had an SMD >0.1, so this was used as a covariate in GEE models.

The matched (registered and non-registered) clinicians combined wrote a mean of 75 opioid prescriptions during the 2-month baseline period, provided to a mean of 45 individual patients. The most common prescriptions were for short-acting opioids combined with acetaminophen, including hydrocodone, oxycodone or codeine (n = 93,498, 68% of prescriptions).

Comparing Registrants and Non-Registrants

The numbers of patients with high dose prescriptions, multiple prescribers, or inappropriate prescriptions fell gradually over time, in both registered and non-registered groups (Figure 3). However, contrary to our hypothesis, registered clinicians did not show greater or faster declines than non-registrants, either in the short-term or the long-term following PDMP registration (Figure 3 and Table 2). In fact, except for inappropriate prescriptions, registrants wrote slightly more of these prescriptions, though differences were small. The proportion of opioid prescriptions that overlapped with benzodiazepine prescriptions remained nearly flat in both groups, but with significantly more among registrants than non-registrants (Figure 3). In cumulative analyses over 30 months, registrants wrote significantly more high-dose prescriptions and overlaps, though non-registrants wrote more inappropriate prescriptions (Table 2).

Among secondary prescribing outcomes, all showed gradual declines among both registered and non-registered prescribers. Where significant group differences occurred, the non-registrants generally demonstrated greater decreases (Table 2, online supplemental Figure 1).

Cumulative prescription opioid-related hospitalizations and deaths were greater among patients of registrants than among those of non-registrants, in both 6-month and 30-month

follow-up intervals (Table 2). Except for short term mortality, differences were statistically significant.

Frequent PDMP Users versus Infrequent Users

When comparing registrants who frequently queried the PDMP with those who infrequently queried, we found differences in prescribing patterns, even at baseline. Those who became frequent PDMP users demonstrated significantly more cautious opioid prescribing by several metrics both at baseline and throughout the follow-up period (Figure 4, Supplemental Figure 2, and Table 3). Differences between frequent and infrequent PDMP users were small, and most comparisons were not statistically significant.

Patients of registrants who queried frequently experienced significantly fewer opioid-related hospitalizations than those of registrants who queried infrequently. Cumulative overdose deaths were similar between groups (Table 3).

Analysis of Later Registrants

In our additional analysis, we compared later (1 year later) PDMP registrants with matched non-registrants. The propensity matching process successfully matched 653 later registrants with an equal number of non-registrants (Supplemental Table 2), with SMDs less than 0.1 for all but one prescribing metric. As with early registrants, subsequent opioid prescribing metrics were not significantly lower among later registrants than among non-registrants (online supplement Table 3).

DISCUSSION

Following implementation of Oregon's PDMP, there were statewide declines in per capita numbers of inappropriate opioid prescriptions, MMEs dispensed, and pills dispensed. Despite these changes, opioid-related deaths and hospitalizations remained stable. Contrary to our hypothesis, prescribers who registered for the PDMP did not demonstrate greater declines than non-registrants with regard to subsequent numbers of high-dose opioid prescriptions, overlaps with benzodiazepines, patients with multiple prescribers, inappropriate prescriptions, patients with at least one opioid prescription, mean dose per prescription, mean dose per patient, or numbers of patients using multiple pharmacies. In fact, for some measures, registrants demonstrated more high-risk prescribing than matched non-registrants. Furthermore, there were more opioid-related hospitalizations and deaths among patients of registrants than of matched non-registrants.

Registrants who used the PDMP frequently showed less opioid prescribing and fewer opioid-related hospitalizations than infrequent PDMP users, but the prescribing pattern was apparent even at baseline. More cautious prescribers were apparently more likely to make frequent use of the PDMP, rather than frequent use making prescribers more cautious. More generally, it seems unlikely that use of the PDMP caused greater opioid prescribing, hospitalizations, or deaths among registrants than among non-registrants. Rather, it appears that in spite of matching, prescribers (and corresponding patient mix) were self-selected into user or non-user categories with somewhat differing average prescribing patterns.

Among prescribers who did *not* register for the PDMP, there were decreases in the number who wrote at least one opioid prescription per 2-month interval, mean pills per prescription, opioid dose per prescription, and total morphine equivalents per patient per month. Thus, it appears that non-registered prescribers, who outnumbered registered prescribers, accounted for some of the statewide trends.

Among nonregistered prescribers, the number of clinicians who wrote any opioid prescription fell more than among clinicians who registered to use the PDMP, though both declined (supplemental Figure 1J). This raises the possibility of patient migration from non-registered clinicians to those who were registered and who were perhaps more likely to prescribe opioids. In part, this could result from clinicians dismissing problematic patients from their practices.[17,20] Such migration might account for smaller changes in some prescribing metrics among registrants than among non-registrants.

We can speculate that some of the statewide decline in opioid prescribing may have resulted from an "observer effect" in which clinicians perceived that prescribing patterns were being more closely scrutinized. Clinician registration and use of the PDMP did not appear to explain observed changes in prescribing. However, registrants may have shared experiences using the PDMP with non-registrants, potentially influencing their prescribing behaviors. Other factors in the environment were likely important, such as greater reporting of opioid prescribing and related mortality in professional publications, greater media coverage of these trends, new clinical guidelines, and new reimbursement restrictions. For example, in the spring of 2012, the Oregon Health Authority implemented a Medicaid prior authorization program for opioid doses exceeding 120 MME/day. This was followed by a substantial and rapid decline in high-dose Medicaid opioid pharmacy claims.[15]

Though the apparent lack of impact of the PDMP is disappointing, this remains a relatively new innovation in clinical care. More experience, system refinements, and related policy changes may be needed before reaching conclusions about efficacy. In surveys and interviews, clinicians generally welcome the information from PDMPs, but have noted barriers such as cumbersome access and navigation requirements, time demands, difficulty integrating complex information, and uncertainty how to respond to the information.[16–18, 20,31,33,34]

PDMP Refinements might include the use of prescriber "dashboards" of higher risk patients, proactive alerts, mandatory registration, mandatory querying for certain prescriptions, improved online interfaces, and integration into electronic medical records. Some states have incorporated some of these approaches, and there is modest evidence to support their use,[26] but their application has been inconsistent. There is some evidence to suggest that useful policies outside the PDMP might include prior authorization requirements for high-dose prescriptions or for long-acting opioids and "pill mill" laws such as those implemented in Florida.[19]

Further, greater PDMP impact may require better training of clinicians in use of this relatively new innovation. Such training may be important because previous studies have

suggested that clinicians vary widely regarding frequency of PDMP use, responses to the data, and approaches to discussion with patients.[16–18,20]

Our study has some important strengths. We are unaware of other studies that have compared prescribing behavior, hospitalization, and mortality among PDMP system registrants and non-registrants. We also have used a particularly broad range of outcome measures, and a novel measure of querying frequency (the ratio of a clinician's PDMP queries to opioid prescriptions filled). We believe such methods, as well as improved conceptual models,[12] may be useful for further studying the impacts of PDMP system differences and system improvements.

Our study has important limitations, as well. We have no prescriber demographic or clinical specialty information to compare registrants and non-registrants or to use for adjustment in statistical models. We also have no data regarding patient diagnoses. Thus, differences in patient diagnostic mix between PDMP registrants and non-registrants could be important, though we matched carefully on prescribing patterns. Changes of established prescribing habits in response to implementing the PDMP may require more time and longer periods of observation. We could not directly track migration of patients from one clinician to another. Propensity score matching reduces baseline group differences but is not as effective as random allocation in producing equivalent study groups. However, random allocation to PDMP registration or frequency of use is infeasible. We had no way to account for prescribers who left the state or stopped practicing after being included in the study. The PDMP does not capture inpatient prescriptions, those filled at federal facilities, or those filled out of state. The apparent lack of change in opioid-related mortality or hospitalization with overall declines in prescribing could partly reflect greater use of illicit drug sources in the face of decreasing dosages. States with differing PDMP content, requirements for use, prescriber alerts, and other PDMP features might have different results.[26]

In conclusion, although there was a statewide decline in several measures of per capita opioid prescribing, PDMP registrants did not demonstrate greater declines than non-registrants. Refinements in the PDMP program and related policies may be necessary to improve their impact. Future studies may profitably focus on implementing and rigorously evaluating such refinements, including development of "best practices" for clinicians in using and responding to PDMP data.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Highlights

- We asked if a prescription drug monitoring program (PDMP) changed opioid risks.
- We matched early PDMP registrants with similarly prescribing non-registrants.
- Prescribing risk generally decreased among both registrants and non-registrants.
- Frequent PDMP users showed similar trends to infrequent users.
- Factors other than PDMP appeared to have greater influence on prescribing trends.

Perspective

Factors other than PDMP use may have had greater influence on prescribing trends. Refinements in the PDMP program and related policies may be necessary to increase PDMP impact.

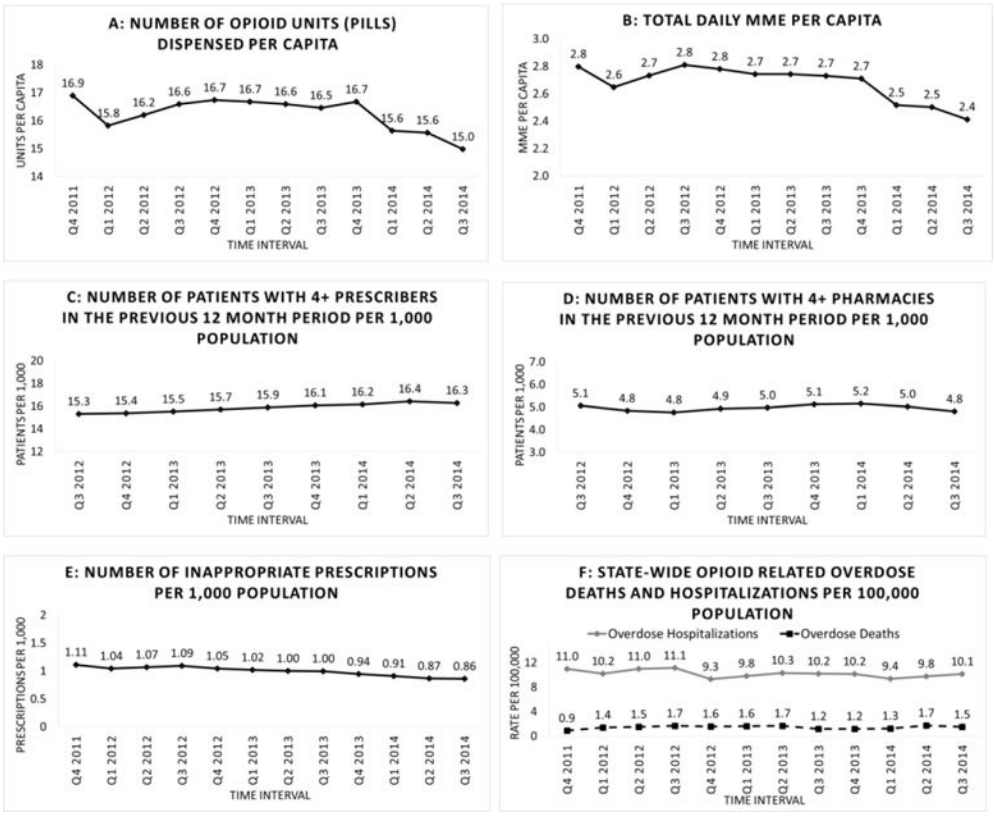

Figure 1.

Statewide Oregon trends in selected measures of opioid prescribing and impact, October 2011–September, 2014

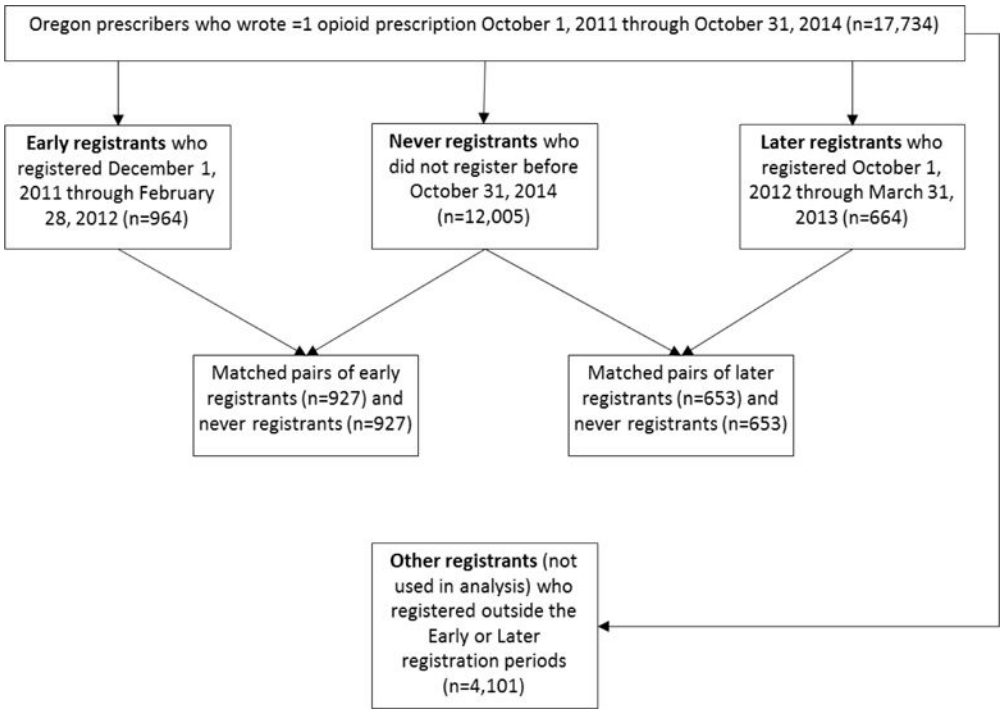

Figure 2.
Derivation of prescriber samples for analysis.

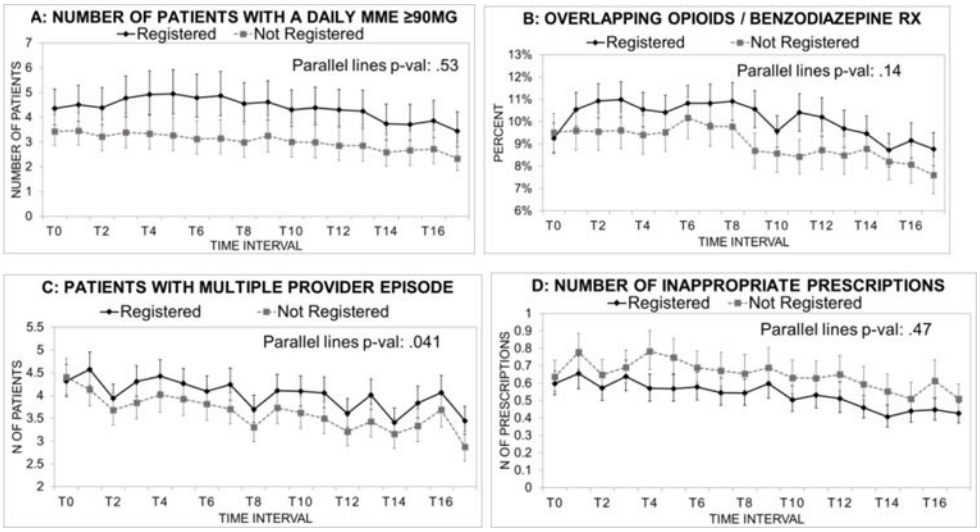

Figure 3.

Trends in primary prescribing outcomes, comparing early PDMP registrants and matched non-registrants. Data are means per prescriber.[a]

a Data are based on GEE models adjusted for urban or rural location of the prescriber. Error bars are 95% confidence intervals. T0 through T16 represent 2-month time intervals beginning with October and November, 2011. Inappropriate opioid prescriptions are those where a second prescription with the same drug name, from a different prescriber, was filled within 7 days of a first prescription that contained ≥30 pills. A “multiple provider episode” refers to a patient with ≥ 3 opioid prescribers in the 2 month interval

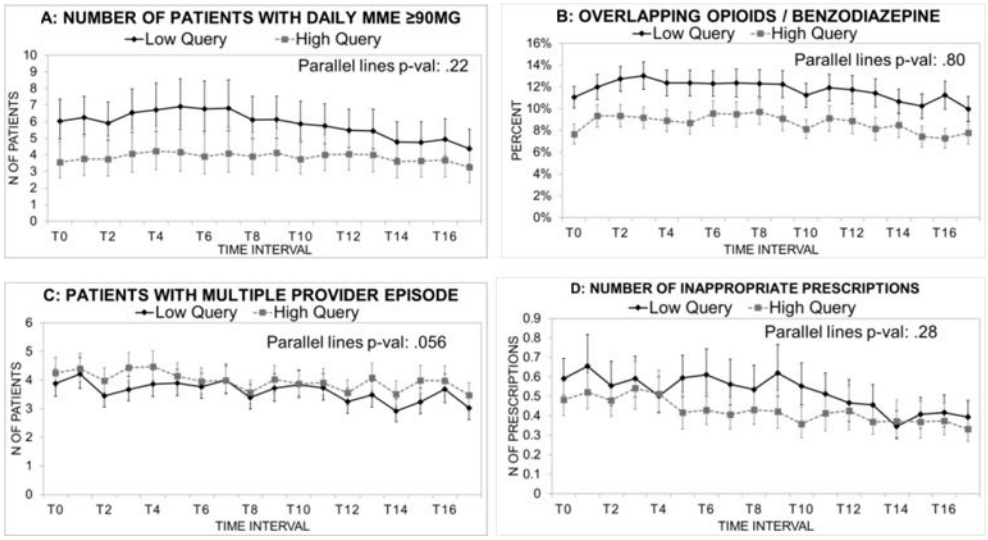

Figure 4.

Trends in primary prescribing outcomes among registrants, comparing frequent users (>1 query per 6 prescriptions) with infrequent users.[a] Data are means per prescriber.

[a] Data are based on GEE models adjusted for urban or rural location of the prescriber. Error bars are 95% confidence intervals. T0 through T16 represent 2-month time intervals beginning with October and November, 2011. Inappropriate opioid prescriptions are those where a second prescription with the same drug name, from a different prescriber, was filled within 7 days of a first prescription that contained ≥30 pills. A “multiple provider episode” refers to a patient with ≥ 3 opioid prescribers in the 2 month interval.

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Table 1

Baseline opioid prescribing of PDMP early registrants and non-registrants, before and after propensity score matching[a]

	Before matching			After propensity score matching		
Prescribing metric, per prescriber during the 2-month baseline time period, mean (SD)	Non-Registered n = 12,005	Registered n = 964	SMD[b]	Non-Registered n = 927	Registered n = 927	SMD[b]
Primary prescribing outcomes						
Opioid patients with an average daily MME ≥90 over the time period (2 months)[c]	0.79 (3.9)	6.06 (17.0)	0.428	3.9 (9.9)	4.5 (11.4)	0.063
% of opioid prescriptions that overlap a sedative-hypnotic prescription within 30 days[d]	5.8 (14.5)	9.6 (10.6)	0.296	9.5 (13.3)	9.2 (10.5)	0.024
Patients with ≥ 3 opioid prescribers in a 2 mo. interval	1.3 (3.2)	4.8 (6.2)	0.717	4.5 (6.4)	4.5 (5.7)	<0.001
Inappropriate opioid prescriptions[e]	0.23 (0.9)	0.59 (1.1)	0.354	0.60 (1.4)	0.56 (1.1)	0.030
Secondary prescribing outcomes						
Opioid prescriptions	18.5 (44.2)	88.0 (125)	0.743	72.9 (88.2)	76.3 (103)	0.036
Benzodiazepine prescriptions	6.0 (20.5)	29.7 (48.0)	0.643	24.8 (43.5)	25.8 (39.3)	0.025
Units per opioid prescription (most often pills)	26.7 (40.4)	49.0 (36.3)	0.583	47.6 (37.4)	47.5 (35.6)	0.002
Patients who filled at least one opioid prescription	12.0 (24.8)	51.1 (56.6)	0.897	44.8 (47.4)	46.0 (49.3)	0.026
% of patients with overlapping long-acting and short-acting opioid prescriptions within 30 d	2.8 (10.0)	6.0 (9.2)	0.329	5.4 (10.3)	5.5 (8.5)	0.017
Opioid prescriptions per patient with at least one opioid prescription	1.4 (0.60)	1.6 (0.51)	0.292	1.6 (0.93)	1.5 (0.49)	0.054
Total MME per prescription[c]	273 (606)	616 (692)	0.529	568 (754)	578 (649)	0.014
Total MME per patient with at least one opioid prescription[c]	694.6 (1,851.6)	1,454.0 (1,825.7)	0.413	1,298.0 (1,713.7)	1,345.6 (1,653.7)	0.028
Patients with ≥ 3 opioid-dispensing pharmacies in 2 mo.	0.91 (3.1)	4.5 (8.9)	0.538	3.4 (6.1)	3.7 (6.4)	0.056
Prescribers with at least 1 opioid prescription in baseline period, n (%)	7,089 (59.1)	878 (91.1)	0.797	846 (91.3)	841 (90.7)	0.019
Geographic Location						
Prescribers in an urban location, n (%)	9,538 (80)	707 (73)	0.144	629 (68)	672 (73)	0.102

[a] Matching based on all covariates and a caliper of .05 SD of the propensity score using "baselline" data from October – November, 2011. Registrants are those who registered in December 2011 – February 2012, and non-registrants were those who never registered before November, 2014.

[b] SMD = Standardized Mean Difference

[c] Metrics that use MME exclude prescriptions that did not have complete conversion factor, quantity, or strength information (0.2% of opioid prescriptions). MME calculations exclude buprenorphine and pentazocine.

[d] "Sedative-hypnotics" included benzodiazepines, non-benzodiazepine sedative-hypnotics, and carisoprodol.

[e] Inappropriate opioid prescriptions are those where a second prescription with the same drug name, from a different prescriber, was filled within 7 days of a first prescription that contained ≥30 pills.

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Table 2

Prescribing and health outcomes for matched registered and non-registered prescribers in the months following the "registration interval".

	Prescribing in the 6 month interval March 2012-August, 2012			Prescribing in the 30 month interval March 2012-August, 2014		
Prescribing metric, *per prescriber*, adjusted mean (95% CI)[a] (deaths and hospitalizations are group totals)	**Non- Registered n = 927**	**Registered n = 927**	**p- value**	**Non- Registered n =927**	**Registered n =927**	**p-value**
Primary prescribing outcomes						
Opioid patients with an average daily MME ≥90 in the interval[b]	4.46 (3.77, 5.26)	6.04 (5.08, 7.17)	.012	6.08 (5.25, 7.05)	7.98 (6.91, 9.22)	.012
% of opioid prescriptions that overlap a sedative-hypnotic prescription within 30 days[c]	11.0% (10.2, 11.9)	12.2% (11.4, 12.9)	.043	12.2% (11.3, 13.1)	13.3% (12.5, 14.1)	.050
Patients with ≥ 3 opioid prescribers in any 2 mo. interval	5.76 (5.21, 6.36)	5.99 (5.50, 6.53)	.540	31.7 (28.9, 34.6)	35.1 (32.5, 38.0)	.088
Inappropriate opioid prescriptions[d]	1.78 (1.58, 2.01)	1.48 (1.31, 1.67)	.035	8.30 (7.38, 9.32)	6.58 (5.89, 7.34)	.006
Secondary prescribing outcomes						
Opioid prescriptions	207 (189, 226)	245 (224, 267)	.006	939 (855, 1031)	1162 (1067, 1267)	.001
Benzodiazepine prescriptions	72.6 (64.6, 81.7)	87.6 (79.3, 96.7)	.014	326 (290, 366)	422 (383, 465)	.001
Units per opioid prescription (most often pills)	48.8 (46.2, 51.5)	51.3 (49.1, 53.6)	.146	50.7 (48.4, 53.1)	53.2 (51.0, 55.5)	.122
Patients who filled at least one opioid prescription	93.4 (87.0, 100.3)	105 (98.5, 112)	.016	321 (297, 347)	352 (329, 377)	.079
% of patients with overlapping long-acting and short-acting opioid prescriptions within 30 d	5.18% (4.59, 5.77)	6.00% (5.42, 6.57)	.057	5.59% (5.00, 6.19)	6.20% (5.60, 6.80)	.159
Opioid prescriptions per patient with at least one prescription	1.87 (1.78, 1.95)	2.14 (2.05, 2.23)	<.001	3.08 (2.85, 3.33)	3.61 (3.38, 3.85)	.002
Total MME per prescription[b]	569 (518, 625)	646 (600, 696)	.041	596 (553, 644)	656 (614, 701)	.061
Total MME per patient with at least one opioid prescription[b]	2,580 (2344, 2841)	2,974 (2721,3252)	.031	7,697 (7043, 8411)	8,934 (8155, 9787)	.017
Patients with ≥ 3 pharmacies in a 2 month interval	2.43 (2.20, 2.68)	2.84 (2.59, 3.12)	.016	14.7 (13.4, 16.2)	17.7 (16.3, 19.2)	.003
Percent of prescribers with at least 1 opioid prescription	91.3% (89.1, 93.0)	97.9% (96.7, 98.7)	<.001	97.4% (96.0, 98.2)	99.6% (98.9, 99.9)	.001
Health-related outcomes[e]						
Opioid related hospitalization	158	199	0.034	777	1087	<0.001
Opioid overdose death	12	11	1.00	19	44	0.002

[a] Mean adjusted rates from Poisson GEE models are presented with upper and lower confidence intervals.

[b] MME calculations exclude prescriptions with incomplete conversion factor, quantity, or strength information (0.2% of opioid prescriptions). MME calculations exclude buprenorphine and pentazocine.

[c] "Sedative-hypnotics" included benzodiazepines, non-benzodiazepine sedative-hypnotics, and carisoprodol

[d] Inappropriate opioid prescriptions are those where a second prescription with the same drug name, from a different prescriber, was filled within 7 days of a first prescription that contained ≥30 pills.

[e] Each event is attributed to the prescriber of the most recent opioid, benzodiazepine, or non-benzodiazepine sedative hypnotic prescription filled in the 5 months prior to the event. Some patients are counted multiple times, once for every hospitalization event. Heroin related events are excluded.

Table 3

Prescribing among PDMP-registrants who queried the PDMP frequently (>1 query per 6 opioid prescriptions) or infrequently.

	Prescribing in the 6 month interval March 2012-August, 2012			Prescribing in the 30 month interval March 2012-August, 2014		
Prescribing metric, *per prescriber*, adjusted mean (95% CI)[a] (deaths and hospitalizations are group totals)	**Prescribers with infrequent queries n = 464**	**Prescribers with frequent queries n = 463**	**p-value**	**Prescribers with infrequent queries n =464**	**Prescribers with frequent queries n =463**	**p-value**
Primary Prescribing Outcomes						
Opioid patients with an average daily MME ≥90 in the interval[b]	5.09 (4.27, 6.07)	3.56 (2.86, 4.43)	.015	6.73 (5.67, 7.98)	5.74 (4.62, 7.14)	.310
% of opioid prescriptions that overlap a sedative-hypnotic prescription within 30 days[c]	12.9% (12.0, 13.9)	11.1% (10.2, 12.1)	.016	13.7% (12.8, 14.6)	12.6% (11.5, 13.7)	.122
Patients with ≥ 3 opioid prescribers in any 2 mo. interval	5.75 (5.15, 6.42)	6.01 (5.43, 6.65)	.544	32.4 (29.2, 36.0)	35.8 (32.8, 38.9)	.123
Inappropriate opioid prescriptions[d]	1.50 (1.31, 1.72)	1.37 (1.15, 1.64)	.430	7.02 (6.19, 7.96)	5.93 (5.19, 6.78)	.081
Secondary prescribing outcomes						
Opioid prescriptions	226 (209, 245)	200 (182, 220)	.034	1066 (987, 1153)	977 (885, 1079)	.135
Benzodiazepine prescriptions	70.6 (64.5, 77.2)	67.0 (59.7, 75.2)	.452	348 (315, 383)	336 (293, 385)	.694
Units per opioid prescription (most often pills)	47.1 (44.4, 50.0)	44.8 (42.4, 47.4)	.297	48.3 (45.7, 51.0)	48.5 (45.6, 51.6)	.923
Patients who filled at least one opioid prescription	90.7 (84.2, 97.7)	100 (93.7, 108)	.053	296 (271, 322)	377 (347, 410)	<.001
% of patients with overlapping long-acting and short-acting opioid prescriptions within 30 d	6.19% (5.70, 6.68)	6.16% (5.46, 6.85)	.944	6.21% (5.71, 6.71)	6.47% (5.72, 7.22)	.588
Opioid prescriptions per patient with at least one opioid prescription	1.98 (1.90, 2.06)	1.89 (1.80, 1.99)	.132	3.24 (3.04, 3.44)	2.91 (2.69, 3.15)	.027
Total MME per prescription[b]	580 (530, 634)	502 (460, 548)	.013	580 (537, 626)	529 (488, 574)	.084
Total MME per patient with at least one opioid prescription[b]	2,654 (2467, 2856)	2,436 (2137, 2776)	.272	7,909 (7215, 8669)	7,580 (6687, 8593)	.589
Patients with ≥ 3 pharmacies in a 2 month interval	2.54 (2.27, 2.84)	3.14 (2.82, 3.49)	.004	15.6 (14.0, 17.5)	20.5 (18.7, 22.6)	<.001
Percent of prescribers with at least 1 opioid prescription	99.7% (98.4, 99.96)	99.5% (98.5, 99.9)	.305	99.78%[e]	99.57%[e]	–
Health-Related Outcomes (n)[f]						
Opioid related hospitalization	116	83	0.024	612	475	<0.001
Opioid overdose death	6	5	1.00	26	18	0.295

[a]Mean adjusted rates from Poisson GEE models are presented with upper and lower confidence intervals.

[b] Metrics that use MME exclude prescriptions that did not have complete conversion factor, quantity, or strength information (0.2% of opioid prescriptions). MME calculations exclude buprenorphine and pentazocine.

[c] "Sedative-hypnotics" included benzodiazepines, non-benzodiazepine sedative-hypnotics, and carisoprodol

[d] Inappropriate opioid prescriptions are those where a second prescription with the same drug name, from a different prescriber, was filled within 7 days of a first prescription that contained ≥30 pills.

[e] Unadjusted percentages. Statistical model did not converge because values are too close to 100% for both groups.

[f] Each event is attributed to the prescriber of the most recent opioid, benzodiazepine, or non-benzodiazepine sedative hypnotic prescription filled in the 5 months prior to the event. Some patients are counted multiple times, once for every hospitalization event. Heroin related events are excluded.

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