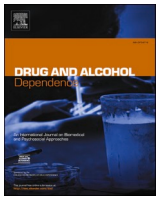
Drug and Alcohol Dependence 247 (2023) 109887

Contents lists available at ScienceDirect

Drug and Alcohol Dependence

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



Review

Prescription drug monitoring programs evaluation: A systematic review of reviews☆

Emma Tay [a,b,*], Meredith Makeham [c,d], Tracey-Lea Laba [e,f], Melissa Baysari [a]

[a] Faculty of Medicine and Health, School of Medical Sciences, Biomedical Informatics and Digital Health, The University of Sydney, Australia
[b] Drug Health Service, Western Sydney Local Health District, Australia
[c] Faculty of Medicine and Health, The University of Sydney, Australia
[d] Department of Clinical Medicine, Faculty of Medicine, Health and Human Sciences, Macquarie University, Australia
[e] Clinical and Health Sciences, University of South Australia, Australia
[f] Centre for Health Economics Research and Evaluation, The University of Technology Sydney, Australia

ARTICLE INFO

Keywords:
Prescription drug monitoring program
High risk medicines
Prescription medicines
Prescription shopping
Misuse
Diversion

ABSTRACT

Background: Prescription drug monitoring programs (PDMPs) are used to mitigate harms from high-risk medicines including misuse, prescription shopping, overdoses, and death. Previous systematic reviews report inconsistent findings. We undertook a systematic review of reviews to 1) describe and identify the methods and outcome measures used to evaluate PDMPs, 2) summarise existing evidence on outcomes and factors that influence PDMP success or benefit realisation.

Methods: MEDLINE, EMBASE, Scopus, Cochrane Database of Systematic Reviews, and PROSPERO were used to identify systematic reviews on PDMPs. Twelve papers met the inclusion criteria. Data extracted included review aim, study designs, settings, outcome measures, and key findings. Quality was assessed using AMSTAR 2 quality assessment tool.

Results: Review papers were categorised as outcome or process evaluation reviews. Process evaluation reviews described implementation processes, barriers and facilitators to PDMP use and/or implementation. Most (57%) papers described barriers which frequently included usability and data integration. Outcome evaluation papers reported impact of PDMPs on outcomes, which were opioid-focused, and findings were highly variable. Most reviews (67%) were rated as low quality, limiting the conclusions that can be drawn.

Conclusions: Inconsistent methods and outcome measures were used to evaluate PDMPs. No economic evaluations of PDMPs were found. Standardising assessment and reporting of results may improve the quality and confidence in an evidence-base to inform future roll-out and evaluation of PDMPs. Targeting barriers such as system-related challenges and negative end-user perceptions could improve sustained uptake of PDMPs, and potentially facilitate benefits realisation, including mitigating harms of high-risk prescription medicines.

1. Introduction

Prescription drug monitoring programs (PDMPs) are progressively being used to manage and mitigate risks and harms associated with high-risk prescription medicines. High-risk medicines targeted by PDMPs such as opioids, benzodiazepines, and gabapentinoids are often associated with misuse, prescription or doctor shopping, diversion, and with adverse outcomes including dependence, overdose, and death (Carey et al., 2018; Votaw et al., 2019; Evoy et al., 2017). PDMPs when occurring in real-time or near real-time, can facilitate improved tracking of data such as prescription or dispensing history, alert health care providers of high- or at-risk patients, and encourage or guide review and revision of prescriptions or dispensing activities or practices. Research has shown that PDMPs can directly or indirectly result in the employment of harm reduction or risk management strategies such as counselling regarding drug safety risks, prevention of misuse or diversion, and revision of treatment plans (Picco et al., 2021; Johnston et al., 2018).

☆ Protocol Registration: PROSPERO CRD42021251863.

* Corresponding author at: Faculty of Medicine and Health, School of Medical Sciences, Biomedical Informatics and Digital Health, The University of Sydney, Australia.
E-mail address: Emma.Tay@health.nsw.gov.au (E. Tay).

https://doi.org/10.1016/j.drugalcdep.2023.109887
Received 11 February 2023; Received in revised form 10 April 2023; Accepted 14 April 2023
Available online 20 April 2023

PDMPs can take different forms and are currently at various stages of implementation in the USA, Canada, Australia, and some European countries (Islam and McRae, 2014). PDMPs differ between and within countries, and often depend on their governing agencies, intended aims, healthcare structure and information technology systems. This variability also extends to the types of medicines or drugs monitored, mandates for PDMP access, the settings in which PDMPs are used, and the quality and content of data or information accessible in PDMPs (Fink et al., 2018; Hoppe et al., 2022). Access to PDMPs is also different depending on location. In some jurisdictions, access is restricted to health care providers such as prescribers and dispensers, and in others, PDMP access extends to regulators, insurance entities, and law enforcement officials (Hoppe et al., 2022; Martin et al., 2021). In these latter cases, PDMPs are used to assist in investigations of unusual prescribing and suspicions of prescription or doctor shopping and diversion activities (Perez et al., 2017; Block et al., 2018; Green et al., 2011).

As PDMPs are increasingly rolled out across the globe, it is important to understand whether these tools deliver benefits (i.e. produce outcomes) and why or why not (i.e. process outcomes). While a number of systematic reviews have been undertaken with PDMPs as a focus, these have mixed aims and methods and hence report mixed conclusions regarding the clinical impact and value of PDMPs (Picco et al., 2021; Fink et al., 2018; Martin et al., 2021; Robinson et al., 2021). This inconsistency makes it challenging to determine the likely outcomes following PDMP implementation and why these outcomes might be expected. The heterogeneity also prevents a thorough understanding of the most appropriate methods that could be used for evaluating future PDMPs in practice. To address this, we undertook a systematic review of reviews. The aims of our review were to 1) describe and identify the types of methods and outcome measures used to evaluate PDMPs, 2) summarise existing evidence on the outcomes achieved following PDMPs and the factors that may influence PDMP success or benefit realisation.

2. Methods

The protocol for this systematic review is registered on PROSPERO (CRD42021251863) (Appendix 1). A search was conducted on 26 March 2021 and 1 April 2022 using the databases MEDLINE, EMBASE, Scopus and Cochrane Database of Systematic Reviews to identify all systematic reviews on PDMP, from inception to search dates. Search terms used include 'real time prescription monitoring', 'prescription drug monitoring program', and 'prescription monitoring program', combined with MeSH term 'prescription drug monitoring program'. The search strategy appears in Appendix 2. The International Prospective Register of Systematic Reviews (PROSPERO) was also reviewed to identify pre-existing systematic reviews to avoid duplication of review. A start date of 2015 was selected as reviews conducted from this date would capture early studies undertaken prior to this time. We used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Moher et al., 2009) guidelines to guide our reporting of this systematic review.

2.1. Study selection

To be included, papers had to be systematic reviews of studies evaluating PDMPs. Scoping reviews were also included if they used a systematic approach to searching. All reviews of PDMPs, regardless of geographical location or operating system, were included. To capture all types of PDMPs, there were no limits on the classes of drugs monitored, or types of monitoring methods in these systems (if described). There were no restrictions on the study designs, methods or outcome measures included in reviews, so reviews that described both qualitative and quantitative research outcomes were included. This was to ensure all methods and outcome measures used to evaluate PDMPs were captured. Exclusion criteria were review papers not in English and review papers where PDMP was not the primary intervention of focus.

All articles resulting from the searches were imported into Covidence (http://www.covidence.org/) for screening. Following removal of duplicate articles, two reviewers (ET and MB) independently screened all the collected articles by title and abstract. Based on the inclusion and exclusion criteria, papers suitable for full text review were identified and also reviewed independently by the two reviewers. Any discrepancies regarding suitability for full text review or for inclusion after full text review were discussed between the two reviewers and inclusion was determined by consensus approach.

2.2. Data extraction and quality assessment

Data extracted from papers included review aim, study designs included in review papers, settings, duration of studies included in the reviews, and results. Data were extracted from summary tables of the review papers and included data from supplementary material where applicable. To obtain supplementary data that were cited but unavailable, the corresponding authors for relevant papers were contacted. If a results summary table or supplementary data were unavailable, data was then extracted from the results section (that is, main text) of the review papers. Data extraction was undertaken independently by two reviewers (ET and MB), followed by discussion and consensus agreement between the two reviewers, and subsequent final agreement by all authors.

Quality of the included systematic review papers were assessed using the AMSTAR 2 quality assessment tool (Shea et al., 2017). AMSTAR 2 is an adaptation of AMSTAR (Shea et al., 2007) to assist in the critical evaluation of systematic reviews of randomised and non-randomised healthcare related intervention studies (Shea et al., 2017). The AMSTAR 2 guides the generation of an overall assessment of confidence in a study's results, based on fulfilment of 16 items consisting of critical and non-critical domains within AMSTAR 2 (Shea et al., 2017). Critical and non-critical domains were determined by two reviewers (ET and MB) prior to quality being assessed. The items considered critical domains in our review are shown in Appendix 3 and the criteria for determining overall ratings are listed in Appendix 4. For this systematic review, we did not consider the lack of meta-analyses as a critical flaw, given the high heterogeneity of analytical methods used.

2.3. Data synthesis and analysis

To better describe the methods and outcome measures used to evaluate PDMPs in the included papers, data synthesised were categorised based on the types of evaluation undertaken. Based on the systematic reviews we identified, the review papers were grouped broadly into two types of evaluation - outcome evaluations, process evaluations (Kellogg Foundation, 2017; Hulscher et al., 2003; Centers for Disease Control and Prevention (CDC)). Papers were considered process evaluation studies when they described evaluations of PDMPs that included the implementation processes, barriers and facilitators to its use and/or implementation, and end-user acceptance and perceptions. Outcome evaluation papers were papers that reported on the impact or effectiveness of PDMPs, including economic outcomes (e.g. cost effectiveness). Meta-analysis was not performed due to the heterogeneity of the methodologies, outcomes, and analyses undertaken in the included review papers, in addition to the risk and challenges of potential misleading estimates resulting from overlapping data of individual studies in the included review papers (Smith et al., 2011). Instead, we undertook a narrative synthesis where outcome measures, and barriers to PDMP implementation and use were extracted directly from papers and grouped into broad themes. Barriers were categorised into those relating to systems, end-users and wider context of PDMP. Outcome measures were categorised as prescribing or dispensing outcomes, misuse, morbidity and mortality. This categorisation was undertaken independently with discussions and consensus agreement between the two reviewers (ET and MB).

3. Results

The initial search resulted in 3243 articles, with 1097 remaining after removal of duplicates. Following title and abstract screening, 22 proceeded to full text screening. Of these, 10 review papers met the inclusion criteria and were included in the review. The updated search generated 1004 articles, with 311 remaining after removal of duplicates. Of these, four articles proceeded to full text review and subsequently also met the inclusion criteria, two of which were identified in the initial search. In total, 12 articles were included in this review for data extraction and synthesis. Fig. 1 shows the systematic review literature search process, as guided by the PRISMA framework. Appendix 5 lists the review papers excluded following full text review, including reasons for exclusion.

Data extracted from the review papers appear in Table 1. Overall, seven review papers described outcome evaluations and seven described process evaluations. Two review papers reported on both outcome and process evaluations of PDMPs (Picco et al., 2021; Ponnapalli et al., 2018). Seven of the twelve review papers examined PDMPs specifically in the USA. Of those that did not restrict searches to USA studies, two identified studies from Canada and France, (Hoppe et al., 2022; Wilson et al., 2019) in addition to the USA.

3.1. Quality of review papers

Quality ratings of the review papers are shown in Table 1, with further details on each AMSTAR 2 item rating available in Appendix 6. Half (n=6) of the included papers were rated as "critically low", because these studies had more than one flaw or weakness in both the critical and non-critical domains in the AMSTAR 2 assessment. Two studies were rated a "low", while the remaining four studies were rated as "moderate".

3.2. Reviews focused on process evaluations of PDMP

3.2.1. Methods and processes examined in review papers

The studies included in process evaluation review papers were not limited to a particular study design and included both descriptive and analytic studies using both qualitative and quantitative approaches.

There was variability in the process outcomes of PDMPs reported, but overall, weaknesses or barriers to PDMP use or implementation were the primary outcomes described, appearing in the majority (4 of 7) of these review papers (Martin et al., 2021; Robinson et al., 2021; Ponnapalli et al., 2018; Alogaili et al., 2020). PDMP utilisation (or registration) and usability was described in one review paper to determine the impact of PDMP integration into electronic health records on use and end-user experience (Ponnapalli et al., 2018). Another review paper examined how knowledge and attitudes of PDMPs may impact upon PDMP intention to use, actual use, and dispensing practices in pharmacy end-users. Impact of PDMPs on clinical decision making was also examined in one review (Picco et al., 2021).

3.2.2. Process evaluations of PDMP implementation

Only one of the review papers utilised a theoretical model or framework (The Delone and McLean Information System Success Model) (Martin et al., 2021) to inform barrier identification. In this paper, the model was used to identify 142 barriers and 183 facilitators to the success of PDMP (Martin et al., 2021). Frequently reported barriers to PDMP use and implementation described in the four review papers are listed in Table 2. Time constraints and technological integration challenges were amongst the commonly reported barriers (Hoppe et al., 2022; Robinson et al., 2021; Ponnapalli et al., 2018).

One review paper that explored community pharmacists' perceptions of PDMPs using surveys found that positive attitudes and beliefs in the system's utility and efficacy, as well as being knowledgeable about PDMPs were positively correlated with use and intention to use PDMP (Johnston et al., 2018). Prevalence of PDMP use was reported in three review papers (Johnston et al., 2018; Robinson et al., 2021; Ponnapalli et al., 2018) and revealed that PDMPs were underutilised overall by healthcare providers. The uptake of PDMPs varied, with prescribers noted to use PDMPs more often than pharmacists in one study (Ponnapalli et al., 2018) although this difference was not significant (Robinson et al., 2021). Mandatory use was viewed negatively by end-users, (Ponnapalli et al., 2018) although it was also noted to be a facilitator to PDMP use and successful implementation (Martin et al., 2021).

The review paper which examined the impact of PDMP use on

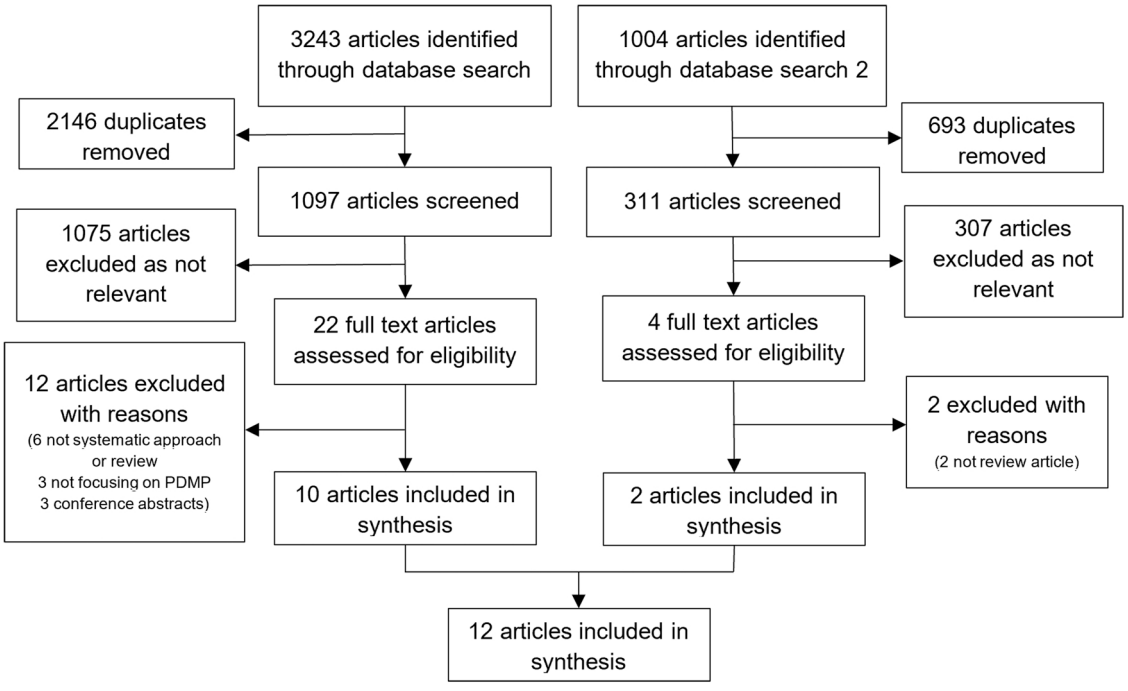


Fig. 1. Systematic review search process – PRISMA flow diagram. Note: PDMP = Prescription Drug Monitoring Program.

Table 1
(a)–(b). Characteristics of included systematic reviews of prescription drug monitoring programs (PDMPs).

(a) Process evaluation studies

Authors; years searched	Aim	Number of papers and designs included & excluded	Setting or population	Process outcomes	Overall conclusion	Quality overall rating (AMSTAR 2)
Martin et al. (2021); 2014 – 2019	To evaluate barriers and facilitators to PDMP Information System success in the USA	44 studies Included: • All study designs Excluded: • Outcome studies of PMDPs combined with other interventions • Studies of PDMP compared to other interventions	The USA	Barriers and facilitators to PDMP information system success	• 142 barriers and 183 facilitators to PDMP success were identified • Barriers to PDMP success related to information quality, intention to use, system quality, use, end-user satisfaction • Facilitators to PDMP success also related to information quality, system quality, intention to use, use, service quality, end-user satisfaction	Critically low
Alogaili et al. (2020); 2013 – 2018	To identify the strengths of PDMP in combating incidence of drug, and weaknesses of PDMP affecting its implementation viability in the USA	19 studies Included: • All study designs • Research papers and dissertations Excluded: • Systematic reviews • Book series or chapter • Proceedings	The USA	Strengths and weaknesses of PDMP	• PDMP weaknesses led to low implementation rate, but PDMP had shown to mitigate some issues • Strengths of PDMP include combating drug misuse, reducing doctor shopping, increased work efficiency and transparency • Weaknesses of PDMP related to implementation gap, infrastructure challenges, and data availability difficulties	Critically low
Robinson et al. (2021); Start – January 2018	• To determine the proportion of health care providers who access and use PDMP data • To identify common barriers to accessing PDMP data.	53 studies (56 publications) Included: • Primary research studies (including all study designs) Excluded: • Systematic reviews, editorials, abstracts, commentary, theses, or dissertations	Health care providers, the USA	• Prevalence of PDMP data use • Barriers to PDMP data utilisation	• Overall outcome revealed PDMPs are underutilised by health care providers and many barriers to the use of PDMPs exist • No significant difference in types of health care providers (e.g., physicians, pharmacists) who used PDMPs • 18 types of barriers identified, including time constraints (most reported), administrative burdens, low perceived value of PDMP data, and usability issues	Moderate
Johnston et al. (2018); January 2008 – October 2017	To identify and synthesise literature on attitudes and knowledge of community pharmacists regarding PDMP use and outcomes	15 studies Included: • All study designs	Community pharmacists in the USA	• Knowledge and attitudes regarding PDMP registration, use, and impact • Impact of attitudes and knowledge on PDMP registration and use • Dispensing practices and patient health outcomes relating to PDMP use	• Pharmacists' attitudes and knowledge of PDMPs had positive influence on likelihood of PDMP use. • 49%−69% pharmacists believed PDMPs to be convenient • When non-mandated, less pharmacists (20.9%) compared with physicians (53.2%) registered to use PDMP • Self-reported PDMP use led to fewer dispensation of controlled substance prescriptions, but not always, and providing more education and counselling to patients	Critically low
Ponnapalli et al. (2018); January 2010 – February 2018	To determine the impact of PDMP integration into electronic health records (EHR) on the utilisation and usability of PDMP	10 studies Included: • All study designs	The USA	• PDMP utilisation • PDMP usability	• Usability and EHR integration issues are barriers to effective PDMP use • Usage and registration rates of PDMP varied across providers and locations	Critically low

(continued on next page)

Table 1 (*continued*)

					• Poor PDMP utilisation due to the lack of standard integration to EHR • PDMP was perceived to be cumbersome and ineffective • Providers were opposed to mandated use	
Picco et al. (2021); Start – April 2021	To synthesise the literature on how PDMP use influences healthcare providers' clinical decision-making	39 studies (41 publications) Included: • All study designs Excluded: • Reviews • Letters • Commentaries • Conference abstracts	All settings and healthcare providers	• Impact of PDMP utilisation on clinical decision-making	• PDMP utilisation influenced clinical decision-making in 7 ways – changes to supply of controlled substances, refusal to prescribe or treat, risk mitigation strategies, communications between health providers and patients, provision of patient education and counselling, referrals and care coordination with other clinicians, and stigmatising clinical responses associated with PDMP use	Low
Hoppe et al. (2022); January 2015 – April 2021	To identify research on PDMP to extract and map the main themes highlighted in the studies	153 studies Included: • All study designs	All settings in all countries (The USA, Canada)	• Types of studies, designs, and populations • Research focus • Barriers and facilitators to PDMP • Applications to practice • Gaps in research	• Most studies were quantitative (70%), or reviews (11%). Half of the studies involved patients (mostly adults), while 47% involved healthcare providers • 75% studies investigated opioid-related outcomes, 53% on PDMP effectiveness, and 52% on PDMP implementation • 65% research focused on opioid prescribing trends, while 29% reported opioid-related misuse, hospitalisation, and emergency department visits • Time constraints was reported as the main barrier to PDMP use, followed by policy and practice barriers • Mandated use was the main facilitator to PDMP use, followed by perceived usefulness • 30% studies described PDMP as a risk mitigation tool • Key research gaps included the effectiveness of PDMP and use by healthcare professionals	Critically low

(b) Outcome evaluation studies.

Authors; years searched	Aim	Number of papers and designs included & excluded	Setting or population	Outcomes	Overall conclusion	Quality overall rating (AMSTAR 2)
Puac-Polanco et al. (2020); Start – January 2019	To evaluate the association between PDMP implementation and four domains of prescription opioid-related outcomes	29 studies Included: • Observational research designs • Papers with quantitative data or measures association between PDMP and prescription opioid related outcome Excluded: • No pre-post PDMP implementation comparison • Not published in peer-reviewed journals	The USA	• Opioid prescribing behaviours • Opioid diversion and supply • Opioid-related morbidity and substance use disorders • Opioid-related mortality	• PDMPs showed overall reduction in opioid-related outcomes (opioid prescribing behaviours, diversion, supply, morbidity) but not opioid-related mortality outcome	Low
Wilson et al. (2019); Start - January 2018	To synthesise evidence on PDMP effectiveness in changing opioid prescribing related outcomes	24 studies. Included: • Comparative studies (pre-post, controlled, case control, interrupted	All settings in all countries (The USA, Canada, and France)	• Volume of opioids prescribed/ dispensed • Rates of multiple provider use	• Overall, no evidence to support association between PDMPs and reduction in opioid prescribing and dispensing	Moderate

(*continued on next page*)

Table 1 (*continued*)

		time series, cluster randomised, controlled trial designs)		• Rates of inappropriate prescribing or dispensing practices • Rates of non-medical prescription opioid use	• Results on multiple provider use and rates of non-medical prescription opioid use were mixed	
Rhodes et al. (2019); Start - January 2018	To synthesise the effectiveness of PDMP status in reducing opioid-related harms and consequences	22 studies Included: • Comparative studies (pre-post, case control, controlled before/after, cluster randomised, controlled trial designs)	All USA jurisdictions with an implemented PDMP	• Illicit and problematic opioid use • Opioid-related care outcomes • Opioid-related adverse events • Opioid-related legal and criminal outcomes	• Overall, limited evidence to support effectiveness of PDMPs in reducing population-level opioid-related consequences and harms, with majority of outcomes showing no changes	Moderate
Ponnapalli et al. (2018); January 2010 – February 2018	To determine impact of PDMP on opioid-related clinical outcomes and other related metrics	14 studies Included: • All study designs	The USA	• Opioid prescriptions • Opioid-related outcomes	• Overall, PDMPs led to reduction in opioid prescriptions and use, while evidence on opioid related outcomes including poisoning and overdose deaths were mixed	Critically low
Fink et al. (2018); Start – December 2017	To determine association between PDMP or specific program features and the impact on changes to non-fatal and fatal drug overdoses, and to investigate other potential unintended consequences	17 studies Included: • Observational studies, dissertations	The USA	• Non-fatal drug (prescription opioid or heroin) overdoses • Fatal drug (prescription opioid or heroin) overdoses • Unintended consequences	• Insufficient evidence to associate PDMP implementation or specific program features to changes (increases or decreases) in non-fatal or fatal overdoses • Studies that examined unintended outcomes of heroin-related overdoses showed an increase in heroin-related hospital visits and admissions, but mixed results for fatal outcomes • The association between mandated PDMP use and heroin-related deaths was mixed	Moderate
Finley et al. (2017); January 2000 – May 2016	To describe the evidence on impact of PDMP policy and implementation on opioid misuse in the USA, and to propose a conceptual model for future evaluation of PDMP implementation	11 studies Included: • All study designs	The USA	• Opioid prescribing behaviour • Opioid diversion and supply • Opioid misuse • Opioid related morbidity and mortality	• Evidence on the impact of PDMPs as an opioid risk mitigation tool is mixed for opioid prescribing behaviour and opioid related morbidity and mortality • Opioid diversion and supply: PDMPs associated with reduction in oxycodone shipments and supply • PDMPs benefit was shown in mitigating opioid misuse in all populations in one study	Critically low
Picco et al. (2021); Start – April 2021	To synthesise the literature on how PDMP use influences healthcare providers' clinical decision-making	21 studies Included: • All study designs	All settings and healthcare providers	• Prescribing of controlled substances • Dispensing of controlled substances • Prescribing or recommending alternative medication	• Results were mixed regarding changes to supply of controlled substances following PDMP use • Prescribing: Proportion of prescribers reporting decreased prescribing ranged from 11% to 87%. • Dispensing: Decreased dispensing of controlled substances was reported in two studies, while one reported increased dispensing • Alternative medication: Pooled prevalence 37% PDMP use resulted in prescribing of alternative medications.	Low

Note: Study designs are as reported in reviews. PDMP = Prescription Drug Monitoring Program, EHR = Electronic Health Record, USA = The United States of America.

Table 2
Frequently reported barriers to PDMP implementation or use as reported in review papers.

PDMP system-related	End-user-related	Wider Context
• System quality – e.g., system design, performance • System usability – e.g., ease of use, slow processes • Information quality – e.g., incomplete data • Variability in PDMP characteristics across different states or localities	• Intention to use – e.g., registration issues • Use – e.g., complicated access or login process • End-user satisfaction – e.g., perceived usefulness, convenience, attitude • Time constraints • Workflow interruption • Lack of training or knowledge/awareness • Variable usage and registration rates across providers and locations • Concerns about privacy and confidentiality, professional autonomy	• Poor integration with existing EHR or information system • Lack of interstate data sharing • Data standardisation • Mandated use

Note: PDMP = Prescription Drug Monitoring Program, EHR = electronic health record.

healthcare providers' clinical decision making processes (Picco et al., 2021) determined that PDMPs influenced healthcare providers in seven ways. This included impacting clinicians' decisions regarding the supply of controlled substances, refusal to prescribe or treat, adopting risk mitigation strategies, changes to communication with patients and other providers, provision of education and counselling to patients, coordinating care and referrals to other providers, and changes to stigma or biased perceptions.

3.3. Reviews focused on outcome evaluations of PDMP

3.3.1. Methods and outcome measures in review papers

Reviews of outcome evaluations either included all studies irrespective of their study design, (Picco et al., 2021; Ponnapalli et al., 2018; Finley et al., 2017) or restricted studies to observational designs, (Fink et al., 2018; Puac-Polanco et al., 2020) or comparative study designs (Wilson et al., 2019; Rhodes et al., 2019).

As shown in Tables 1(b) and 3, common outcome measures used to evaluate PDMPs included prescribing and dispensing outcomes, and overdose events, but these varied widely between studies. Outcome measures were predominantly focused on opioid-related use and associated outcomes. This included both prescription and illicit opioids (primarily heroin), although the latter was only reported in three reviews (Fink et al., 2018; Ponnapalli et al., 2018; Rhodes et al., 2019). As shown in Table 3, six different outcome measures related to opioid prescribing and dispensing, five related to misuse, and there were 10 different measures used to describe morbidity and mortality outcomes (Table 3). No economic outcomes were examined.

3.3.2. Outcomes achieved following PDMP implementation

Overall, the majority (five of seven) of the included review papers concluded that there was limited or mixed evidence to support PDMPs' role in reducing opioid use, prescriptions and dispensations, and opioid related harms including hospital visits, non-fatal or fatal overdoses (Picco et al., 2021; Fink et al., 2018; Wilson et al., 2019; Finley et al., 2017; Rhodes et al., 2019). One review paper reported an association between PDMP and reduction in opioid related prescribing and diversion behaviour and morbidity outcomes but not opioid related mortality (Puac-Polanco et al., 2020). Another described a reduction in opioid prescriptions and use associated with PDMP implementation, however results on opioid related outcomes such as overdoses and deaths were inconclusive (Ponnapalli et al., 2018).

In addition to these mixed outcomes, PDMP implementation was associated with an increase in heroin related adverse outcomes (Fink et al., 2018; Ponnapalli et al., 2018). In one review, an increase in heroin related hospital visits was reported, as was an increase in heroin related deaths (found in three of five studies in this review paper), but evidence on heroin related death and its association with mandatory use of PDMP was mixed. There was no clear association between PDMP use and opioid-related legal and criminal outcomes (Rhodes et al., 2019).

Table 3
Variation in key outcome measures reported across included review papers.

Outcome	Descriptors of outcome measures used
Opioid prescribing or dispensing	• Opioid prescribing behaviour (Finley et al., 2017; Puac-Polanco et al., 2020) • Volume of opioids prescribed or dispensed (Wilson et al., 2019) • Rates of inappropriate prescribing or dispensing (Wilson et al., 2019) • Opioid prescriptions (and volume of use) (Ponnapalli et al., 2018) • Prescribing of controlled substances (Picco et al., 2021) • Dispensing of controlled substances (Picco et al., 2021)
Opioid misuse	• Opioid diversion and supply (Finley et al., 2017; Puac-Polanco et al., 2020) • Opioid related morbidity and *substance use disorders* (Puac-Polanco et al., 2020) • Rates of non-medical prescription opioid use (Wilson et al., 2019) • Illicit and problematic opioid use (Rhodes et al., 2019) • Opioid misuse (Finley et al., 2017)
Opioid related morbidity and mortality	• Opioid related *morbidity* and substance use disorders (Puac-Polanco et al., 2020) • Opioid related mortality (Puac-Polanco et al., 2020) • Opioid related morbidity and mortality (Finley et al., 2017) • Opioid related care outcomes (Rhodes et al., 2019) • Opioid related adverse outcomes (Rhodes et al., 2019) • Opioid related outcomes (Ponnapalli et al., 2018) • Non-fatal drug overdoses (Fink et al., 2018) • Fatal drug overdoses (Fink et al., 2018) • Non-fatal heroin related overdoses (Fink et al., 2018) • Fatal heroin related overdoses (Fink et al., 2018)

4. Discussion

This systematic review of reviews has revealed a USA-centric evidence base for PDMPs that describes process and outcome evaluations of primarily opioid-focused PDMPs. This is not unexpected as PDMPs have been used as part of a larger strategy to mitigate the growing opioid epidemic or crisis in the USA (Wilkerson et al., 2016). The reviews included in our review did not identify a consistent approach, framework, tool or measures to evaluate the effectiveness and implementation of PDMPs, and there was limited information reported on PDMP designs. The variability and inconsistency in methods and outcome measures used resulted in review papers concluding low overall confidence and conflicting evidence on PDMPs. Although most of the data generated were from USA-based PDMPs, there were likely differences between these PDMPs evaluated, including systems and types of medicines monitored, depending on the jurisdictions and access mandates, further limiting the ability to compare evidence of methods and outcome measures in these papers.

Many of the PDMP reviews evaluating outcomes were focused on opioid related outcomes, but the outcome measures used in these systematic reviews were variable, preventing comparisons to be drawn. In some cases, there was evidence that PDMP implementation was associated with an increase in heroin use related adverse outcomes although

studies on these were limited. Some suggested key drivers to the increase in heroin use following PDMPs were secondary to the reduction in access to prescription opioids due to more restricted prescribing practices (Ponnapalli et al., 2018) and the increasing cost of black market prescription opioids, leading to diversion to a comparatively cheaper and more accessible alternative (Fink et al., 2018).

There was a paucity of data relating to PDMPs' impact on other high-risk non-opioid medicines such as benzodiazepines and gabapentinoids. It is not clear whether these medicines were monitored on the PDMPs that were evaluated or alternatively, were not perceived to be the focus of PDMP implementation and so were not assessed. Just as PDMPs' impact on heroin use has been examined, these other non-opioid high-risk drugs merit investigation in light of their potential impact on patients and medication safety (Votaw et al., 2019; Evoy et al., 2017). This review has highlighted a significant gap in research: we currently know very little about whether the use of PDMPs directly or indirectly influences non-opioid medication usage, harms (whether intended or unintended), and other related outcomes.

Economic evaluation of PDMPs was also a notable gap in the included reviews. Health economic evaluations are critical for understanding the costs of PDMPs, their implementation and use, relative to benefits and effectiveness of PDMPs. This evidence could influence and drive service or program planning, and other efforts to improve and/or achieve program goals.

A key factor impacting effectiveness of PDMPs was uptake of the system by end-users. Poor uptake of PDMPs was reported to contribute to a failure to achieve desired benefits, (Robinson et al., 2021) and likely explains the mixed results reported in outcome evaluations. Underutilisation of PDMPs by healthcare providers was often attributed to barriers relating to poor usability of the system, including poor end-user satisfaction (Johnston et al., 2018; Martin et al., 2021; Robinson et al., 2021; Ponnapalli et al., 2018). Common usability issues identified included poor PDMP integration into health providers' clinical workflows and existing electronic health records (Martin et al., 2021; Ponnapalli et al., 2018) hence accessing data, system slowness and lag times, (Martin et al., 2021; Robinson et al., 2021) and lack of efficient navigation of the system, such as ease and simplicity of use (Martin et al., 2021). Another frequently reported barrier to provider use was time (Hoppe et al., 2022; Robinson et al., 2021). Improving overall ease of use of PDMPs, system quality and integration of PDMPs into existing interfaces, (Martin et al., 2021; Ponnapalli et al., 2018) to minimise interruptions to workflow and improve end-user experience, are therefore critical. Providing relevant support and training to use the system may also assist in managing technological or usability challenges, particularly those driven by unfamiliarly with the system.

Other important factors influencing PDMP uptake were end-users' knowledge of the system and perceived value. Improving knowledge and awareness of PDMPs was shown to influence intention to use and uptake of PDMPs (Johnston et al., 2018; Hoppe et al., 2022; Martin et al., 2021). Therefore targeting peri-implementation efforts on enhancing end-user knowledge, and making the value or usefulness of PDMPs highly visible to end-users would be beneficial in facilitating PDMP success or uptake following implementation.

Poor end-user uptake of PDMPs could also be combatted by enforcing mandatory use, with research showing lower rates of system registration by healthcare providers when PDMP use was not mandatory (Johnston et al., 2018). Not unexpectedly, our review revealed that mandating the use of PDMPs increased uptake of PDMPs (Johnston et al., 2018; Hoppe et al., 2022; Martin et al., 2021; Grecu et al., 2019) and their successful implementation, (Martin et al., 2021) although it is interesting to note that mandated use was also associated with negative end-user perceptions (Ponnapalli et al., 2018). An end-user experience survey showed that many providers were opposed to and did not comply with the mandatory PDMP usage requirements (Blum et al., 2016). The complexities associated with monitoring with mandatory use can also be challenging. In outcome evaluation reviews that examined impact of mandatory PDMP use, evidence of effectiveness was mixed. Some review papers reported an increase in opioid related overdoses, (Fink et al., 2018) others reported reductions in the quantity of opioids prescribed (Rasubala et al., 2015; Castillo-Carniglia et al., 2021).

This systematic review has some limitations. Generalisability of these results to other settings may be limited as data from countries outside of the USA were scarce. The included studies were heterogeneous, even if focusing on the same broad outcomes, they were measured in different ways (see Table 3). Most reviews were rated as low quality, thereby limiting the conclusions that can be drawn. As this was a review of reviews, there was overlap in terms of the individual studies included in review papers, but outcomes and conclusions of reviews varied due to inconsistencies in review aims and measures.

In conclusion, this review highlighted the lack of consistent methods and outcome measures used to evaluate PDMPs. Despite the rapid implementation of this technology across the globe, evidence of PDMPs' effectiveness is mixed. Whether, why and how PDMP benefits are realised, is invariably affected by the diverse methodology underpinning PDMP research. Success of this technology is highly dependent on uptake of the system by end-users, and many barriers to end-user uptake have been identified. Targeting barriers like poor usability are critical to improve end-user experience and perceptions, and thereafter PDMP utilisation, however our review identified gaps in what constitutes an effective PDMP design. Standardising evaluation and adopting a digital health evaluation framework (such as the practical guides by the World Health Organisation's monitoring and evaluating digital health interventions) (World Health Organization, 2016), to ensure process, outcome and economic elements of implementation are examined may improve the quality and confidence in an evidence-base to inform future roll-out of this important digital health tool.

Funding

None.

Role of funding source

This systematic review was unfunded.

CRediT authorship contribution statement

All authors contributed to the development of overall study strategy and presentation of results. ET and MB contributed to the development of the screening inclusion criteria, article screening, data extraction, quality assessment of studies. ET wrote the draft manuscript. All authors read, provided feedback and approved the final manuscript.

Declaration of Competing Interest

No conflict of interest to declare.

Acknowledgements

N/A.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.drugalcdep.2023.109887.

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