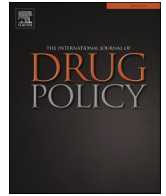


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## Review

## A scoping review of law enforcement drug seizures and overdose mortality in the United States

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## ABSTRACT

**Background:** Leveraging law enforcement drug seizure data to better respond to the overdose crisis requires an understanding of available evidence and knowledge gaps regarding relationships between drug seizures and overdose mortality.

**Objective:** This scoping review summarized peer-reviewed literature on associations between law enforcement drug seizures and drug-related mortality in the United States (US) in the era of illicitly-manufactured fentanyl, comparing study data sources, measures, methodologies, settings, and findings.

**Methods:** We identified 388 non-duplicate records from three online databases searched on May 23, 2023. After title/abstract and full-text screening by two independent reviewers, 14 studies met the criteria for inclusion. The included studies tested the association between a measure related to law enforcement drug seizures and an overdose mortality outcome in the US and were published in English, in peer-reviewed journals, during or after 2013.

**Results:** Four of 14 studies (29%) included data from the entire US, while the remaining studies focused on an individual state/city/county or a group of states/cities/counties. Synthetic opioid/fentanyl seizures represented the most frequently examined drug seizure category, and overdose deaths overall (involving any drugs) represented the most frequently examined outcome. Most studies used counts/rates of drug seizures, with fewer studies examining dosage/weight, drug combinations, the proportion of drug seizures involving a specific drug, or spatiotemporal distribution. The majority (86%) of studies reported at least one statistically significant positive association between a law enforcement drug seizure measure and an overdose mortality outcome, most consistently for fentanyl-related seizures. Results were relatively less consistent for seizures involving stimulants and other drugs.

**Conclusions:** Studies in this review provided consistent evidence that fentanyl-related seizure measures are positively associated with overdose mortality outcomes, despite the limitations inherent in drug seizure data, even in the absence of available information regarding seizure weight or dosage.

Changes over time in the drugs most implicated in overdose deaths in the United States (US) have prompted attention to both drug supply and demand (Cerdá et al., 2021). During the first decade of the 21<sup>st</sup> century, increases in deaths involving prescription opioids highlighted the role of opioid analgesic availability and use, assessed through measures related to opioid prescriptions, pharmaceutical industry opioid marketing, and “pill mills” (e.g., Hadland et al., 2019; Sauber-Schatz et al., 2013; Strickler et al., 2020). After the first decade of the 21<sup>st</sup> century, deaths involving prescription opioids plateaued while deaths involving street-sold drugs (e.g., illicitly-manufactured fentanyl and stimulants)

escalated (Spencer et al., 2022), rendering measures related to street-sold drugs increasingly relevant. Nonetheless, indicators of street-sold drugs have been examined less frequently. For example, in a systematic review of county-level predictors of drug overdose mortality (Cano et al., 2023), 27 of the 56 studies (published 2013–2022) included a predictor or control related to prescription opioids, while only four studies included any measure related to fentanyl availability, and only one study examined a predictor related to stimulants.

Potential data sources regarding street drug characteristics include law enforcement data, clinical samples (Twillman et al., 2020), and

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community drug-checking programs (which generate data primarily for harm-reduction purposes but may also be used for public health surveillance; Dasgupta & Figgatt, 2022). Considering that community drug-checking programs do not currently operate at a large scale across the US, law enforcement forensic laboratories represent a relatively more extensive source of street drug data. Drugs seized by law enforcement may be conceptualized as snapshots of illicit drug supplies and measures of the extent to which different drugs (and adulterants) are prevalent in local drug markets (Zibbell et al., 2019). Seized drugs may also be considered measures of law enforcement activities that disrupt illicit drug markets (Lowder et al., 2022) and influence overdose risk (Mohler et al., 2021; Ray et al., 2023).

Beyond differences in the conceptualization of drug seizure measures, studies examining associations between US drug seizures and overdose deaths have used several different data sources and methodologies. This area of research is therefore particularly suited for a *scoping review*, which aims to identify available evidence and clarify conceptualizations, measures, and methods of study (Munn et al., 2018). Timely data on law enforcement drug seizures are increasingly accessible to researchers and public health agencies (National Forensic Laboratory Information System, 2023; Pitts et al., 2023), requiring an understanding of the existing literature and knowledge gaps regarding links between drug seizure measures and overdose mortality.

The present scoping review summarizes peer-reviewed literature on associations between law enforcement drug seizures and drug-related mortality in the US in the post-2013 era of illicitly-manufactured fentanyl. The review aims to identify: the specific measures and data sources used for drug seizures; the drug-related mortality outcomes that have been examined; the statistical analyses used; the settings (e.g., individual states, US overall) and populations examined; and the overall study findings regarding the associations between law enforcement drug seizure measures and drug mortality. Throughout this review, we use the term “drug seizures” for clarity and consistency with many of the studies included in the review; nonetheless, drug seizure measures do not include the totality of drugs seized by law enforcement, since only a portion of seized drugs are tested by forensic laboratories and subsequently reported in laboratory databases (Pitts et al., 2023).

## Methods

This review was based on PRISMA-ScR guidelines (Tricco et al., 2018; see Appendix A for the completed PRISMA-ScR checklist) and was not pre-registered. Eligibility criteria included: a measure related to law enforcement drug seizures (of any type); a measure related to drug-related mortality (of any intent or involving any drug); a statistical test of association between the two aforementioned measures; a setting within the United States, whether the entire country or a certain area, in the general population or a specific subpopulation; publication in English; and a publication date during or after the year 2013, which represents the approximate beginning of the era of illicitly-manufactured fentanyl (Centers for Disease Control and Prevention, 2023). Peer-reviewed reports of original, empirical research or reviews were eligible for inclusion, while conference abstracts, non-peer reviewed sources (e.g., books, theses, dissertations, working papers), and commentaries were excluded.

Using search terms based on iterative searches and terminology found in relevant studies identified during preliminary searches, the final searches were completed in PubMed, Scopus, and ProQuest on May 23, 2023. The search terms used in each database are provided in Appendix B and are summarized as: *Anywhere in text, any of the terms* [“overdose\*”, “drug death\*”, “drug mortality”, “drug-related death\*”, “drug-related mortality”, “opioid death\*”, “opioid mortality”, “opioid-related death\*”, “opioid-related mortality”, “fentanyl death\*”, “heroin death\*”, “poisoning death\*”, “poisoning mortality”, “drug poisoning\*”], *and, in the abstract or title, any of the terms* [“drug seizure\*”, “law enforcement seizure\*”, “law enforcement submission\*”, “law

enforcement drug submission”, “drug exhibit\*”, “opioid exhibit\*”, “fentanyl exhibit\*”, “heroin exhibit\*”, “cocaine exhibit\*”, “methamphetamine exhibit\*”, “amphetamine exhibit\*”, “carfentanil exhibit\*”, “xylazine exhibit\*”, “opioid seizure\*”, “fentanyl seizure\*”, “heroin seizure\*”, “cocaine seizure\*”, “methamphetamine seizure\*”, “amphetamine seizure\*”, “carfentanil seizure\*”, “xylazine seizure\*”, “National Forensic Laboratory Information System”, “Drug Enforcement Administration”, “crime lab\*”, “seizures involving opioids”, “seizures involving synthetic opioids”, “seizures involving fentanyl”, “seizures involving heroin”, “seizures involving cocaine”, “seizures involving methamphetamine”, “seizures involving amphetamine\*”, “seizures involving carfentanil”, “seizures involving xylazine”].

Records retrieved from each database were uploaded in Zotero software for de-duplication, and all non-duplicate records were uploaded in Rayyan software (Ouzzani et al., 2016) for title/abstract screening. Title/abstract screening was completed by two independent reviewers (MC and PT or MH) to exclude records unrelated to the review topic (see the screening questions in Appendix C), and any discrepancies were resolved by a third reviewer (KS). Full-text screening (for all records not excluded during title/abstract review) was also completed by two independent reviewers (MC and PT, MH, or KS) to determine whether each study met inclusion criteria, with discrepancies resolved via discussion and consensus or a third independent reviewer (SO). For all studies that met inclusion criteria, one reviewer (MC) charted data regarding study title, author(s), year of publication, setting, drug seizure measure and source, overdose mortality measure, analysis methods employed, and main findings regarding statistically significant associations between drug seizure measures and drug mortality measures (Appendix D). A second reviewer (PT or SO) verified the extracted data. A risk of bias assessment was not applicable for this scoping review on a relatively new and diverse area of literature (Peters et al., 2020).

## Results

### Included studies

As detailed in the PRISMA flow diagram (Fig. 1), 616 records were retrieved, 228 duplicates were removed, and title/abstract screening was completed for the remaining 388 non-duplicate records. After the title/abstract review stage, 24 records remained. Additionally, three new records were added at this stage: two publications that had been published after the search date (identified via an ongoing Google Scholar alert), and one publication in a peer-reviewed journal that was not indexed in PubMed/Scopus/ProQuest (which had been identified during preliminary searches). Full-text screening was completed for 27 manuscripts, of which 13 were excluded, resulting in a total of 14 studies included in the review. Appendix E lists examples of articles excluded at the full-text review stage.

### Included studies' settings

Table 1 provides the included studies' publication years and settings. All studies were published between 2014 and 2023, and most (12 of 14) were published between 2019 and 2023. Almost half of the included studies (6 of 14) used data from one state only, including five studies focusing on Ohio (Hall et al., 2021; Rosenblum et al., 2020; Tran et al., 2021; Zibbell et al., 2019; Zibbell et al., 2022) and one study examining Kentucky (Slavova et al., 2017); two other studies examined data from one city/county (Indianapolis/Marion County; Mohler et al., 2021; Ray et al., 2023), and one study used data from a group of cities and counties (the Washington/Baltimore High Intensity Drug Trafficking Area; Lowder et al., 2022). Only four studies (Jalal & Burke, 2021; Sumner et al., 2022; Zibbell et al., 2023; Zoorob, 2019) included data from the entire US, while one other study included 27 states across the US (Gladden et al., 2016).

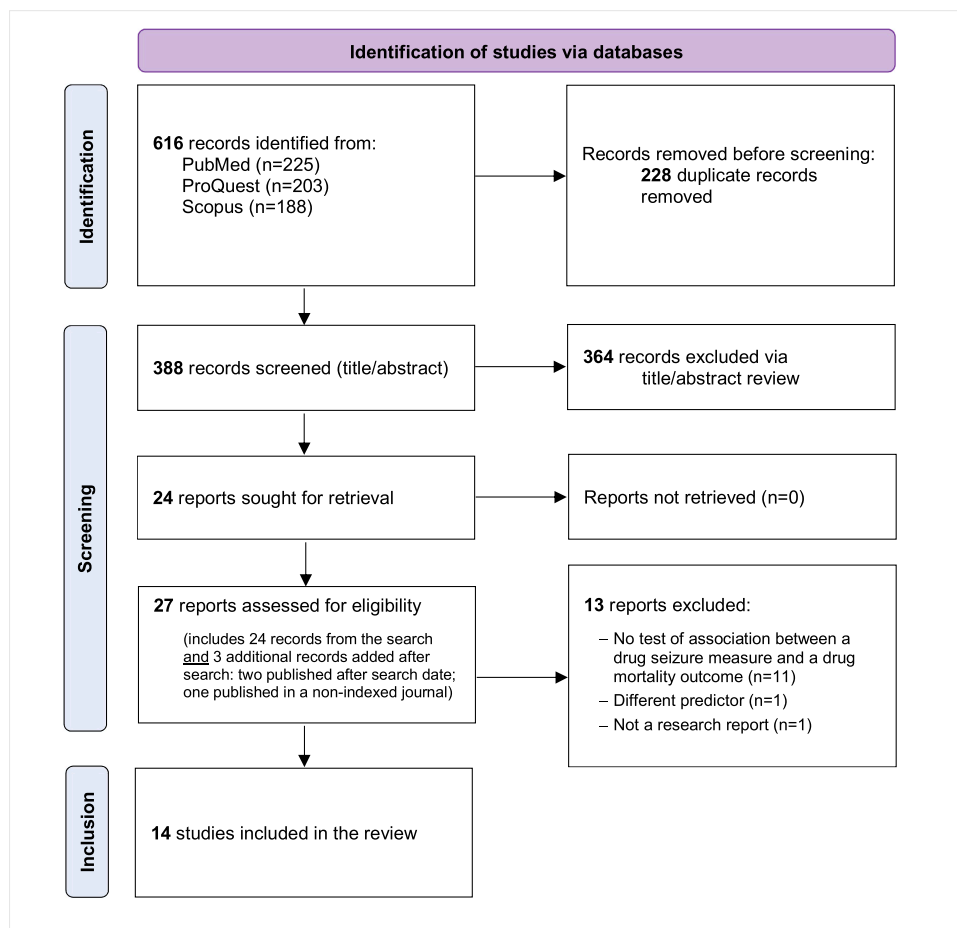


Fig. 1. PRISMA flow diagram for study identification, screening, and inclusion.

### Included studies' measures and methods

As detailed in Table 2, drug seizure measures in 12 of the 14 included studies comprised a drug seizure count or rate per population (Gladden et al., 2016; Hall et al., 2021; Jalal & Burke, 2021; Lowder et al., 2022; Rosenblum et al., 2020; Slavova et al., 2017; Sumner et al., 2022; Tran et al., 2021; Zibbell et al., 2019; Zibbell et al., 2022; Zibbell et al., 2023; Zoorob, 2019), while two studies examined the date and location of drug seizures (Mohler et al., 2021; Ray et al., 2023). Three studies also examined drug seizure measures by dosage or weight (Lowder et al., 2022; Tran et al., 2021; Zibbell et al., 2019), and three studies (Rosenblum et al., 2020; Zibbell et al., 2019; Zibbell et al., 2023) additionally examined percentages of different drugs in law enforcement seizures. The specific types of drugs included in seizure measures and overdose outcomes varied across studies, as depicted in Fig. 2; synthetic opioids/fentanyl represented the most frequently examined drug seizure category, and overdose deaths overall (involving any drugs) represented the most frequently examined overdose outcome.

Units of analysis also differed between studies (Table 2), including (but not limited to) county-month (e.g., Rosenblum et al., 2020), county-year (e.g., Lowder et al., 2022), and state-year (e.g., Zoorob, 2019). While several studies measured drug seizure measures and overdose outcomes contemporaneously (e.g., Gladden et al., 2016; Jalal & Burke, 2021; Slavova et al., 2017; Zoorob, 2019), other studies in the review included time lags ranging from one month or less (e.g., Mohler et al., 2021; Ray et al., 2023) to one year (e.g., Lowder et al., 2022), and some studies examined multiple time lags or leads (e.g., Mohler et al., 2021; Ray et al., 2023; Rosenblum et al., 2020; Sumner et al., 2022; Tran et al., 2021). In terms of methods of analysis, 10 of the included

studies (Hall et al., 2021; Jalal & Burke, 2021; Lowder et al., 2022; Rosenblum et al., 2020; Tran et al., 2021; Sumner et al., 2022; Zibbell et al., 2019; Zibbell et al., 2022; Zibbell et al., 2023; Zoorob, 2019) used regression analyses, while three studies (Gladden et al., 2016; Slavova et al., 2017; Sumner et al., 2022) reported correlation coefficients and two studies (Mohler et al., 2021; Ray et al., 2023) used Knox tests.

### Included studies' findings

Table 3 provides the included studies' main findings regarding significant associations between drug seizure measures and drug mortality outcomes. Overall, 12 of the 14 included studies (Gladden et al., 2016; Jalal & Burke, 2021; Lowder et al., 2022; Ray et al., 2023; Rosenblum et al., 2020; Slavova et al., 2017; Sumner et al., 2022; Tran et al., 2021; Zibbell et al., 2019; Zibbell et al., 2022; Zibbell et al., 2023; Zoorob, 2019) reported at least one statistically significant association between a law enforcement drug seizure measure and increased overdose mortality. In addition, another study used drug seizure measures to develop a "lethality index" (based on ratios of counts of different types of drug seizures and drug deaths, as measured in one year) which accounted for 93% of the year-to-year (2009-2018) variance in Ohio's unintentional drug overdose deaths (Hall et al., 2021).

Drug seizure measures that were generally positively associated with overdose mortality outcomes included seizures involving: drugs overall (Lowder et al., 2022); opioids overall (Ray et al., 2023); fentanyl/fentanyl analogs/synthetic opioids (Gladden et al., 2016; Rosenblum et al., 2020; Slavova et al., 2017; Tran et al., 2021; Zibbell et al., 2019; Zibbell et al., 2022; Zibbell et al., 2023; Zoorob, 2019); and the fentanyl analog carfentanil in particular (Jalal & Burke, 2021);

**Table 1**  
Identifying information for the studies (n=14) included in the scoping review.

Author(s)	Publication Year	Title	Setting
Gladden et al.	2016	Fentanyl law enforcement submissions and increases in synthetic opioid-involved overdose deaths—27 states, 2013–2014	27 states
Hall et al.	2021	Street-drug lethality index: A novel methodology for predicting unintentional drug overdose fatalities in population research	Ohio
Jalal & Burke	2021	Carfentanil and the rise and fall of overdose deaths in the United States	United States
Lowder et al.	2022	Supply-side predictors of fatal drug overdose in the Washington/Baltimore HIDTA region: 2016–2020	45 localities in the Washington/Baltimore High Intensity Drug Trafficking Area
Mohler et al.	2021	A modified two-process Knox test for investigating the relationship between law enforcement opioid seizures and overdoses	Indianapolis/Marion County, Indiana
Ray et al.	2023	Spatiotemporal analysis exploring the effect of law enforcement drug market disruptions on overdose, Indianapolis, Indiana, 2020–2021	Indianapolis/Marion County, Indiana
Rosenblum et al.	2020	The rapidly changing US illicit drug market and the potential for an improved early warning system: Evidence from Ohio drug crime labs	Ohio (87 counties)
Slavova et al.	2017	Heroin and fentanyl overdoses in Kentucky: Epidemiology and surveillance	Kentucky
Sumner et al.	2022	Estimating weekly national opioid overdose deaths in near real time using multiple proxy data sources	United States
Tran et al.	2021	A statistical analysis of drug seizures and opioid overdose deaths in Ohio from 2014 to 2018	Ohio
Zibbell et al.	2019	Association of law enforcement seizures of heroin, fentanyl, and carfentanil with opioid overdose deaths in Ohio, 2014–2017	Ohio (88 counties)
Zibbell et al.	2022	Association between law enforcement seizures of illicit drugs and drug overdose deaths involving cocaine and methamphetamine, Ohio, 2014–2019	Ohio (88 counties)
Zibbell et al.	2023	Associations between opioid overdose deaths and drugs confiscated by law enforcement and submitted to crime laboratories for analysis, United States, 2014–2019: an observational study	United States
Zoorob	2019	Fentanyl shock: The changing geography of overdose in the United States	United States

Rosenblum et al., 2020; Tran et al., 2021; Zibbell et al., 2019). Results were mixed for seizures of other drugs, such as stimulants. Below, we detail study findings based on the types of drug seizure measures examined, focusing primarily on statistically significant main results regarding seizures of drugs overall, opioids overall, different types of opioids, and stimulants.

#### *Seizures of drugs overall*

In a study of the Washington/Baltimore High Intensity Drug Trafficking Area (Lowder et al., 2022), the number of drug seizure cases was significantly and positively associated with next-year (2016–2020) mortality rates for drug overdoses, opioid-related overdoses, and fentanyl-related overdoses (in county-year models also including dosage units per capita of specific drugs, trafficking/money laundering organization disruptions, socioeconomic, demographics, and opioid prescribing).

#### *Seizures of opioids overall*

In a study using 2014–2018 data from Indianapolis/Marion County, Indiana, fatal overdoses were spatiotemporally clustered around opioid seizures (at 100, 250, 500, and 1,000 meters and 3, 7, 14, and 21 days), yet this did not significantly differ pre- versus post- seizure (Mohler et al., 2021). In a subsequent study (including three of the same authors), using more recent data (2020–2021) from Indianapolis/Marion County, Indiana, fatal overdoses were spatiotemporally clustered around opioid seizures (at 100 meters/7 days, 250 meters/14 days, and 500 meters/21 days), and fatal overdose clustering was significantly higher post- opioid seizure at these distances/times (Ray et al., 2023).

#### *Seizures of specific types of opioids*

When considering specific types of opioids, seizures of fentanyl and other synthetic opioids were most consistently associated with increased overdose mortality across the studies in the review. In a national study using state-quarter data from 2014–2019, seizures of fentanyl/fentanyl-related compounds had the strongest association with increases in opioid-related overdose deaths, and heroin seizures were also associated with increases in opioid overdose deaths (in multivariate models including multiple drug seizure measures and state and quarter fixed effects; Zibbell et al., 2023). Similarly, another national study using data from 2014–2019 reported that weekly seizures of heroin/synthetic opioids were positively correlated with opioid-involved overdose deaths (Sumner et al., 2022). Zoorob's 2019 national study, which used state-year data from 2011–2017, also documented a positive, significant association between fentanyl/synthetic opioid seizure rates and drug overdose mortality rates (in models with state and year fixed effects and population weights). In a different national study predicting states' 2017–2018 changes in per capita drug overdose deaths based on 2017–2018 changes in per capita fentanyl, carfentanil, and heroin seizures, a significant positive association was observed only for carfentanil seizures (in a multivariate model; Jalal & Burke, 2021).

The results of the national studies described in the previous paragraph were generally consistent with results from the subnational studies included in the review. Using data from Kentucky (2013–2016), Slavova and colleagues' 2017 study documented a significant and positive correlation between monthly numbers of fentanyl seizure submissions and fentanyl-involved overdose deaths, while no significant correlation was observed between heroin seizures and heroin-involved deaths. In another study including 27 states, states' 2013–2014 changes in fentanyl seizure submissions were positively correlated with 2013–2014 changes in synthetic opioid-involved overdose deaths (Gladden et al., 2016).

Four different studies from Ohio also added to results regarding seizures of fentanyl and its analogs. First, a study using monthly data

**Table 2**  
Information regarding measures and methods used in the included studies.

Author(s), Year	Drug seizure measure	Drug seizure data source	Overdose mortality measure	Time lag between predictor and outcome	Analysis Methods
Gladden et al., 2016	2013-2014 change in rate of fentanyl submissions, per state	National Forensic Laboratory Information System	2013-2014 change in synthetic opioid-involved overdose death rates, per 100,000	None specified	Pearson correlation
Hall et al., 2021	Numbers of drug seizures involving fentanyl, cocaine, prescription opioids, heroin, amphetamines, and benzodiazepines, per year	Ohio Bureau of Criminal Investigation crime lab data	Number of unintentional drug overdose deaths per year (square root transformed)	None specified	Linear regression analysis predicting unintentional drug overdose deaths from a "lethality index" based on counts of drug seizures and drug deaths
Jalal & Burke, 2021	2017-2018 state-level change in heroin, fentanyl, and carfentanil seizures, per capita	National Forensic Laboratory Information System annual reports	2017-2018 change in state-level drug overdose deaths, per capita	None specified	Multivariate regression analysis predicting 2017-2018 change in drug overdose deaths per capita by 2017-2018 change in per capita seizures of heroin, fentanyl, and carfentanil
Lowder et al., 2022	Total number of drug seizures and dosage units per capita for drug seizures of: cocaine; methamphetamine; fentanyl; prescription opioids; heroin and other opiates, per county-year	Washington/Baltimore High Intensity Drug Trafficking Area Performance Management Process database	Crude mortality rates for drug overdose, opioid-involved overdose, and fentanyl-involved overdose, per county-year	One-year lag	Mixed-effects regression models predicting county-level overdose rates by number of drug seizures, dosage units per capita for specific drugs, and trafficking/money laundering organization disruptions, adjusting for socioeconomic, demographic, and opioid prescribing measures
Mohler et al., 2021	Number of opioid-related seizures by day and address	"Property room" of Indianapolis Metropolitan Police Department	Accidental drug overdose deaths by day and address	Excluded overdoses and seizures that occurred on the same day; different time frames (e.g., 3, 7, 14, 21 days) examined for time between seizure and overdose	Modified two process Knox test to examine spatial and temporal clustering of opioid seizures and drug overdose deaths pre- and post- drug seizures
Ray et al., 2023	Opioid- and stimulant-related numbers of drug seizure events, by time and location	Drug seizure data from the Indianapolis Metropolitan Police Department	Number of accidental fatal overdoses	Seven, 14-, and 21-days post drug seizures	Two-sample Knox test to identify excess space-time clustering between drug seizures and drug overdose deaths; pre-post test for event rates
Rosenblum et al., 2020	Numbers of drug seizures for fentanyl, carfentanil, other fentanyl analogs, heroin, benzodiazepines, MDMA, and other synthetic stimulants, by county-month; percentages also examined in supplemental material	Ohio Bureau of Criminal Investigation crime lab data	Unintentional drug overdose deaths, by county-month, for counties overall and small, medium, and large counties	Seizure and overdose data measures in same month, as well as three, two, or one month before or after the drug seizure date	Poisson regression analysis predicting overdose death counts by multiple different types of drug seizures, with county and month fixed effects, county-specific time trends, and time-varying poverty, income, unemployment, opioid prescribing, and suboxone prescribing measures; robust standard errors clustered by county
Slavova et al., 2017	Numbers of heroin and fentanyl submissions, per month	Kentucky State Police crime labs	Numbers of fentanyl- or heroin-involved overdose deaths, per month	None specified	Pearson correlation
Sumner et al., 2022	Number of heroin/synthetic opioid submissions, per day	National Forensic Laboratory Information System	Number of opioid-involved overdose deaths, per week	Different lags (up to 16 weeks) tested	Least absolute shrinkage and selection operator regression model predicting weekly opioid-involved overdose deaths by data from drug seizures, emergency department visits, and drug searches/posts on Google, Twitter, and Reddit; Pearson correlations also provided for each predictor and outcome.
Tran et al., 2021	Numbers of fentanyl, carfentanil, and fentanyl/analog seizures, overall and within different weight ranges, per month	Ohio Bureau of Criminal Investigation crime lab data	Number of unintentional drug overdose deaths, per month	Different lengths of lags tested	Linear regression models predicting number of overdose deaths by number of fentanyl seizures (log-transformed, as well as a quadratic term); cross-correlation function and autoregressive integrated moving average models also used
Zibbell et al., 2019	Numbers of heroin, fentanyl, carfentanil, cocaine, and methamphetamine seizures, overall, in percentages of different drug combinations, and numbers	Ohio Bureau of Criminal Investigation	Numbers of opioid-involved overdose, per month	None specified	Multivariate, generalized, autoregressive, conditional-heteroskedasticity models predicting opioid overdose deaths by multiple drug seizure

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Table 2 (continued)

Author(s), Year	Drug seizure measure	Drug seizure data source	Overdose mortality measure	Time lag between predictor and outcome	Analysis Methods
	within different weight ranges, per month				measures, adjusting for opioid prescribing rates and linear and quadratic time trends, with a single-lagged dependent variable (per supplemental material)
Zibbell et al., 2022	Rates (per 100,000 persons) of seizures containing: methamphetamine without fentanyl; methamphetamine with fentanyl; cocaine without fentanyl; cocaine with fentanyl; fentanyl without methamphetamine or cocaine; opioids excluding fentanyl; and all other drugs, per month	Ohio Bureau of Criminal Investigation	Rates (per 100,000 persons) of: stimulant-involved; methamphetamine-involved; and cocaine-involved overdose deaths, among adults, per month	One-month lag (in sensitivity analyses)	Multivariate, generalized, autoregressive, conditional heteroskedasticity models predicting overdose death rates by multiple different seizure rates, with a linear time trend and single-lagged dependent variable
Zibbell et al., 2023	Counts and proportions of drug seizures involving heroin, prescription opioids, fentanyl and fentanyl-related compounds, cocaine, methamphetamine, and benzodiazepines, by state-quarter	National Forensic Laboratory Information System	Counts of opioid-involved overdose deaths by state, month, quarter, and year; percentages of opioid overdose deaths involving different drug combinations	One-quarter lag (in sensitivity analysis)	Two-way (state and quarter) fixed effects models; primary specification consisting of a Poisson model predicting opioid-involved overdose deaths from seizures of various opioids, stimulants, and benzodiazepine reports per 100,000 by state and quarter, with an offset for state population and robust standard errors
Zoorob, 2019	Rate of fentanyl/analog/synthetic opioid seizures, log-transformed, per state-year	National Forensic Laboratory Information System via Freedom of Information Act request	Age-adjusted drug overdose deaths, per state-year	None specified	Two-way fixed effects ordinary least squares regression and two-stage least squares regression models, predicting overdose rates by fentanyl seizure rates or with an instrumental variable (state centroid longitude multiplied by linear time trend), with population weights and standard errors two-way clustered by state and year

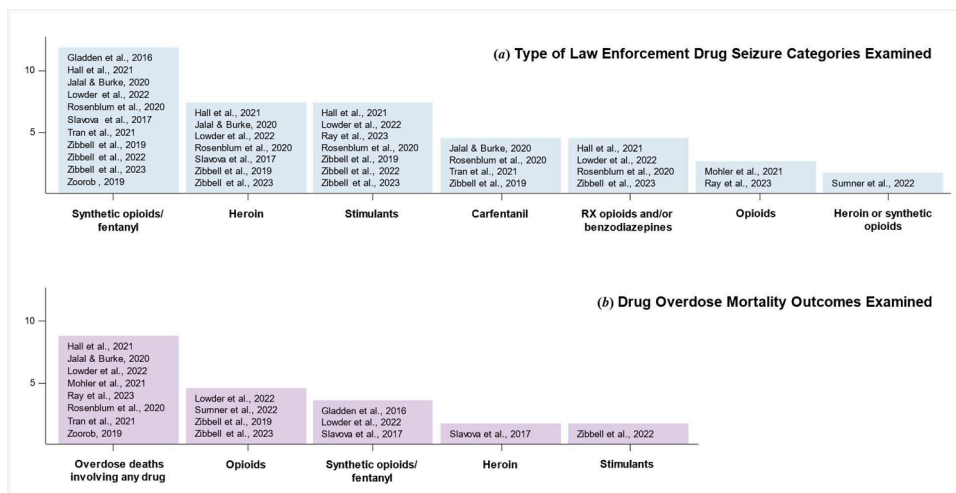


Fig. 2. Number of studies examining (a) different types of drug seizure categories and (b) different types of drug overdose deaths. Notes. The y-axis indicates frequency of studies. Counts are not mutually exclusive, as some studies examined multiple measures. Abbreviations: RX, prescription.

from Ohio, 2014-2017, documented significant positive associations between both fentanyl seizures and carfentanil seizures and opioid-related overdose deaths (in multivariate models with multiple drug seizure measures, opioid prescribing rates, linear and quadratic time trends, and a single-lagged dependent variable; Zibbell et al., 2019). Seizures of fentanyl without methamphetamine or cocaine were also significantly positively associated with stimulant and cocaine overdose deaths in a different study using 2014-2019 monthly data from Ohio (in

multivariate models with multiple seizure rates, a linear time trend, and a single-lagged dependent variable; Zibbell et al., 2022). Another study using monthly data from Ohio, 2014-2018, found a stronger correlation between the monthly number of fentanyl/analog seizures and overdose deaths, relative to the number of carfentanil seizures and overdose deaths (Tran et al., 2021). This study also specified that there was no statistically significant lag/lead between monthly fentanyl seizures and overdose deaths, and that numbers of smaller-weight drug seizures

**Table 3**  
Main findings reported by the studies included in the scoping review.

Author(s), Year	Main findings regarding associations between drug seizures and drug mortality
Gladden et al., 2016	In 27 states examined: <ul style="list-style-type: none"> <li>• 2013-2014 changes in fentanyl submissions were correlated (<math>r=0.95</math>) with changes in synthetic opioid-involved overdose deaths</li> </ul>
Hall et al., 2021	In Ohio, 2009-2018: <ul style="list-style-type: none"> <li>• The authors' "lethality index" (based on counts of drug seizures and drug deaths) accounted for 93% of the variance in unintentional drug overdose deaths.</li> </ul>
Jalal & Burke, 2021	In a model predicting US state-level 2017-2018 change in per capita drug overdose deaths based on 2017-2018 changes in per capita carfentanil, fentanyl, and heroin seizures: <ul style="list-style-type: none"> <li>• A significant positive association was observed only for carfentanil seizures.</li> </ul>
Lowder et al., 2022	In the Washington/Baltimore High Intensity Drug Trafficking Area, in county-year models with measures of drug seizure cases overall, dosage units per capita for specific drugs, trafficking/money laundering organization disruptions, and socioeconomic, demographics, and opioid prescribing: <ul style="list-style-type: none"> <li>• The number of drug seizure cases was significantly and positively associated with next-year (2016-2020) drug overdose mortality rates, and fentanyl-involved mortality rates.</li> <li>• Dosage units of cocaine seized per capita were also significantly positively associated with opioid- and fentanyl-involved mortality rates.</li> </ul>
Mohler et al., 2021	In Indianapolis/Marion County, 2014-2018: <ul style="list-style-type: none"> <li>• Although fatal overdoses were spatiotemporally clustered around opioid drug seizures at distances/times examined (100, 250, 500, and 1,000 meters and 3, 7, 14, and 21 days), there was no significant difference pre- and post- seizure.</li> </ul>
Ray et al., 2023	In Indianapolis/Marion County, 2020-2021: <ul style="list-style-type: none"> <li>• For all distances/times examined (100 meters/7 days, 250 meters/14 days, 500 meters/21 days): Opioid-related seizures significantly associated with spatiotemporal clustering of drug overdose deaths, significantly higher post- than pre-seizure.</li> <li>• Only for lowest distance/time examined (100 meters/7 days): stimulant-related seizures significantly associated with spatiotemporal clustering of drug overdose deaths, significantly higher post- than pre- seizure.</li> </ul>
Rosenblum et al., 2020	In Ohio, 2010-2017, in models including various drug seizure measures, unemployment, poverty, income, opioid and suboxone prescribing, county and month fixed effects, and county-month linear trends: <ul style="list-style-type: none"> <li>• County-level seizures of fentanyl, carfentanil, and other fentanyl analogs were significantly and positively associated with overdose deaths overall.</li> <li>• Significant association for fentanyl seizures was observed in medium and large counties; for carfentanil, in large counties only; for other fentanyl analogs, in small, medium, and large counties.</li> <li>• Fentanyl seizures positively associated with overdose deaths most strongly in the same month, but also in the month prior and second month after; carfentanil seizures positively associated with overdose deaths in three months prior and in the same month, and to a lower extent in the month after; other fentanyl analog seizures negatively associated with overdose deaths two to three months prior, yet positively associated with overdose deaths in the same month and three following months.</li> <li>• Direction and significance of results regarding seizures of other drugs (e.g., benzodiazepines) differed between analyses.</li> </ul>
Slavova et al., 2017	In Kentucky, 2013-2016: <ul style="list-style-type: none"> <li>• Monthly numbers of fentanyl submissions were significantly and positively correlated with numbers of fentanyl-involved overdose deaths.</li> <li>• No significant correlation observed between heroin submissions and heroin-involved deaths.</li> </ul>
Sumner et al., 2022	In the US, 2014-2019: <ul style="list-style-type: none"> <li>• The Pearson correlation coefficient between heroin/synthetic opioid drug submissions and weekly opioid-involved overdose deaths was 0.61.</li> </ul>

**Table 3 (continued)**

Author(s), Year	Main findings regarding associations between drug seizures and drug mortality
Tran et al., 2021	In Ohio, 2014-2018: <ul style="list-style-type: none"> <li>• The monthly number of seizures of fentanyl/analogs had a stronger correlation with overdose deaths than carfentanil seizures</li> <li>• There was no statistically significant lag between fentanyl seizures and overdose deaths.</li> <li>• Approximately 59% of the variance in overdose deaths in any given month was attributed to fentanyl seizures in that month.</li> <li>• Numbers of smaller-weight drug seizures had a stronger association with overdose deaths than larger-weight seizures.</li> <li>• The positive association between the number of fentanyl seizures (overall and by weight) and overdose deaths persisted in autoregressive models.</li> </ul>
Zibbell et al., 2019	In Ohio, 2014-2017, in multivariate models including multiple drug seizure measures, opioid prescribing rates, linear and quadratic time trends, and single-lagged dependent variable: <ul style="list-style-type: none"> <li>• Fentanyl seizures and carfentanil seizures significantly and positively associated with opioid overdose deaths.</li> </ul>
Zibbell et al., 2022	In Ohio, 2014-2019, in multivariate models including multiple drug seizure measures, linear time trends, and a single-lagged dependent variable: <ul style="list-style-type: none"> <li>• Seizures of cocaine with fentanyl were significantly positively associated with stimulant and cocaine overdose deaths.</li> <li>• Seizures of methamphetamine with fentanyl were significantly and positively associated with methamphetamine overdose deaths.</li> <li>• Seizures of methamphetamine without fentanyl were significantly and negatively associated with stimulant and cocaine overdose deaths.</li> <li>• Seizures of fentanyl without methamphetamine or cocaine were significantly and positively associated with stimulant and cocaine overdose deaths.</li> </ul>
Zibbell et al., 2023	In the US, 2014-2019, in multivariate models including multiple drug seizure measures and state and quarter fixed effects: <ul style="list-style-type: none"> <li>• Fentanyl/fentanyl-related compound seizure counts showed the strongest association with increases in opioid overdose deaths.</li> <li>• Heroin seizure counts were also associated with increases in opioid overdose deaths.</li> <li>• Methamphetamine and cocaine seizure counts were associated with decreases in opioid overdose deaths.</li> <li>• When modeling proportions/percentages of seizures involving each drug, instead of counts of seizures, only the percentage of fentanyl/fentanyl-related seizures was significantly associated with increased opioid overdose deaths.</li> </ul>
Zoorob, 2019	In the US, 2011-2017, in models with state and year fixed effects and population weights: <ul style="list-style-type: none"> <li>• Fentanyl/synthetic opioid seizure rate was positively and significantly associated with drug overdose mortality rates.</li> </ul>

(more likely to contain fentanyl) had a stronger association with overdose deaths than larger-weight seizures (Tran et al., 2021). Finally, in Rosenblum and colleagues' 2020 analysis of county-month data from Ohio, 2010-2017, seizures of fentanyl, carfentanil, and other fentanyl analogs were significantly and positively associated with overdose deaths (in models including multiple drug seizure measures, economic characteristics, opioid prescribing, suboxone prescribing, county and month fixed effects, and county-month linear trends). These associations varied by county population size: the significant positive association for fentanyl seizures was observed in medium and large counties; for carfentanil, in large counties only; and for other fentanyl analogs, in small, medium, and large counties (Rosenblum et al., 2020). This study also examined various time gaps between seizures and overdose measures, finding that: fentanyl seizures were positively associated with overdose deaths in the same month, and to a lower extent in the month prior and second month after; carfentanil seizures were associated with higher overdose deaths in the same month and in the three months prior, and to a lower extent in the month after; and other fentanyl analog seizures

were negatively associated with overdose deaths two to three months prior but positively associated with overdose deaths in the same month and increasingly positively associated in the three following months (Rosenblum et al., 2020).

### Seizures of stimulants

Drug seizure measures involving stimulants yielded mixed and nuanced findings. In a national study using state-quarter data from 2014-2019, methamphetamine and cocaine seizures were associated with decreases in opioid overdose deaths (in multivariate models including multiple drug seizure measures and state and quarter fixed effects; Zibbell et al., 2023). In contrast, in the Washington/Baltimore High Intensity Drug Trafficking Area, dosage units of cocaine seized per capita were significantly positively associated with next-year (2016-2020) opioid and fentanyl mortality rates (in county-year models accounting for drug seizure cases, dosage units per capita of specific drugs, trafficking/money laundering organization disruptions, socioeconomics, demographics, and opioid prescribing; Lowder et al., 2022). In Ray and colleagues' 2023 analysis of data (2020-2021) from Indianapolis/Marion County, Indiana, fatal overdoses were spatiotemporally clustered around stimulant seizures, significantly higher post-than pre-seizure, only at the lowest distance and shortest time frame examined (100 meters and 7 days). Finally, a study using monthly data from Ohio, 2014-2019, indicated that results regarding stimulant seizures varied based on whether the stimulants were seized in combination with fentanyl (using multivariate models with multiple drug seizure measures, linear time trends, and a single-lagged dependent variable; Zibbell et al., 2022). For example, seizures of cocaine *with* fentanyl were significantly positively associated with stimulant and cocaine overdose deaths, and seizures of methamphetamine *with* fentanyl were significantly positively associated with methamphetamine-related overdose deaths; in contrast, seizures of methamphetamine *without* fentanyl were significantly negatively associated with stimulant and cocaine-related overdose deaths (Zibbell et al., 2022).

### Discussion

This scoping review included 14 peer-reviewed empirical studies examining associations between law enforcement drug seizure measures and drug overdose mortality outcomes in the US. Most (86%) studies had been published in or after 2019, while only 14% had been published between 2014-2018, suggesting a recently growing area of research. The majority of studies were limited to an individual state or region, rather than the entire US, with the state of Ohio overrepresented among studies included in the review. Most studies used counts/rates of drug seizures, with fewer studies examining dosage/weight (e.g., Lowder et al., 2022; Tran et al., 2021), drug combinations (e.g., Zibbell et al., 2022), proportion-based measures (e.g., proportion of drug seizures involving a specific drug; Zibbell et al., 2023), or spatiotemporal distribution (Mohler et al., 2021; Ray et al., 2023). Many of the studies included in the review (e.g., Gladden et al., 2016; Hall et al., 2021; Jalal & Burke, 2021; Rosenblum et al., 2020; Slavova et al., 2017; Sumner et al., 2022; Zibbell et al., 2019; Zibbell et al., 2022; Zibbell et al., 2023; Zoorob, 2019) conceptualized drug seizure measures primarily as proxies of illicit drug supply characteristics, gauges of the extent to which different substances and adulterants are prevalent in the street drugs available in any given area and time period. Comparatively fewer studies in the review (Lowder et al., 2022; Mohler et al., 2021; Ray et al., 2023) conceptualized drug seizures as measures of law enforcement activities that influence rates of fatal overdoses.

A 2007 systematic review on drug enforcement (Mazerolle et al., 2007, p. 122) reported that drug seizures (primarily in Australia) evidenced no "effect" on drug use, overdose, or deaths in three studies but were associated with reductions in heroin overdose deaths in one study. In the present scoping review, none of the studies indicated that law

enforcement seizures of synthetic opioids, or opioids overall, were associated with reduced overdose deaths. On the contrary, both overall drug seizures and overall opioid seizures were associated with increased overdose mortality outcomes (Lowder et al., 2022; Ray et al., 2023). Moreover, despite variation in data sources, measures, overdose mortality outcomes, settings, time frames, and units of analysis, ten (Gladden et al., 2016; Jalal & Burke, 2021; Rosenblum et al., 2020; Slavova et al., 2017; Sumner et al., 2022; Tran et al., 2021; Zibbell et al., 2019; Zibbell et al., 2022; Zibbell et al., 2023; Zoorob, 2019) of 11 studies that examined associations between some type of synthetic opioid-related seizure (e.g., fentanyl, carfentanil, synthetic opioids overall) and an overdose mortality outcome provided evidence of a significant positive association; the association was not statistically significant in the other study (after adjusting for the other variables included in the models; Lowder et al., 2022). Results regarding associations between overdose mortality and seizures of other drug types (e.g., heroin, stimulants) varied, in some cases null (e.g., Rosenblum et al., 2020; Slavova et al., 2017), and in other cases positive (e.g., Lowder et al., 2022) or negative (e.g., Rosenblum et al., 2020; Zibbell et al., 2023).

Although the studies included in this scoping review documented associations between drug seizure measures and overdose mortality, the causal pathways or mechanisms that explain these associations were not *directly* tested by the studies in the review. Nonetheless, studies offered potential explanations linking drug seizures and overdose deaths. For example, several different explanations were proposed for increased spatiotemporal clustering of overdose deaths following opioid seizures in Indianapolis/Marion County (Ray et al., 2023), including: interruptions in individuals' opioid tolerance levels after the arrest of their supplier (Dasgupta, 2023; Dietze, 2023); individuals increasingly using drugs in hidden locations or injecting hastily in an attempt to avoid arrest (Dietze, 2023); and individuals' loss of usual suppliers (Ray et al., 2023), as qualitative research indicates that some people who use drugs identify using a trusted supplier as an overdose-protective strategy (Carroll et al., 2020; Rhodes et al., 2019; Victor et al., 2020). At the same time, other studies in the review (e.g., Rosenblum et al., 2020; Zibbell et al., 2019; Zibbell et al., 2023; Zoorob, 2019) suggested that associations between drug seizure measures and overdose mortality outcomes may be a function of factors that are not directly measurable—namely, the underlying characteristics or composition of the illicit drug supply at any given time and place. For example, more fentanyl-related seizures likely signify a higher prevalence of fentanyl/analogues in the local illicit drug supply, and thus greater possible exposure to fentanyl/analogues among individuals who use drugs, accompanied by more deaths involving fentanyl/analogues and more deaths overall (Zibbell et al., 2023).

When conceptualizing drug seizures as measures of illicit drug supply characteristics, seizures of drugs that are most lethal and most frequently involved in overdose deaths would be expected to have the strongest association with overall overdose mortality rates (Zibbell et al., 2023). This was consistent with the findings of several studies in the review, as seizures of synthetic opioids (e.g., fentanyl, carfentanil) were more strongly associated with higher overdose death rates (Rosenblum et al., 2020; Zibbell et al., 2023) than seizures of drugs relatively less frequently implicated as principal causes of acute drug poisoning deaths (e.g., methamphetamine; Zibbell et al., 2023). Also consistent with the conceptualization of drug seizure measures as reflections of the extent to which drug supplies are dominated by particularly potent and lethal substances, researchers in one of the studies in this review (Hall et al., 2021) were able to account for 93% of the year-to-year variance in Ohio's drug overdose deaths across ten years by using drug seizure and drug death data to estimate the "lethality" of different drugs, and subsequently applying this lethality index along with the number of seizures of each substance (as a proxy for the relative representation of different substances in the underlying street drug supply).

Drug seizure measures and drug overdose deaths may be associated



through multiple different pathways operating simultaneously across different levels (e.g., individual, community) and different timeframes (e.g., proximal vs. long-term), including the potential pathways mentioned previously, as well as others (Rosenblum et al., 2020). For example, researchers have chronicled how illicit drug markets respond to drug control measures by supplying increasingly potent substances that increase overdose risk, especially in the absence of sufficient demand-side interventions to address pain and addiction (Beletsky & Davis, 2017). In the context of associations between drug seizure measures and overdose mortality, additional research would be necessary to help clarify the relative contributions of different potential mediators/explanatory variables and formally test moderators of these associations. Nonetheless, as noted by the authors of one of the studies in the review (Rosenblum et al., 2020), the utility of drug seizure measures specifically in early warning systems or forecasting overdose deaths relies on the correlation between drug seizure measures and drug mortality—irrespective of causality (based on the distinction between prediction and causal inference/explanation/etiology; Hernán et al., 2019; Shmueli, 2010; van Diepen et al., 2017).

Although a formal quality assessment was outside of the scope and purpose of this review (as a scoping review; Peters et al., 2020), it may be relevant to mention some of the limitations inherent in drug seizure data (Pitts et al., 2023). Drug seizure data do not represent a census or random sample of the illicit drug supply (Pitts et al., 2023). Moreover, national sources of US drug seizure data (such as the National Forensic Laboratory Information System-Drug) do not include all laboratories, and not all drugs that are seized are analyzed and recorded in drug seizure data (Pitts et al., 2023). Some subnational data sources provide information about weights, dosage equivalents, or combinations of drugs within each seizure submission (Lowder et al., 2022; Tran et al., 2021; Zibbell et al., 2019), yet in most studies in the review, drug seizure measures did not include information about weight or dosage. Therefore, it is notable that, regardless of the aforementioned data limitations, studies in the review provided relatively consistent evidence that fentanyl-related seizure measures are positively associated with overdose mortality rates. This offers support for the utility of drug seizure measures in reflecting characteristics of illicit drug supplies and predicting overdose mortality rates (Rosenblum et al., 2020) in spite of drug seizures' well-documented limitations (Pitts et al., 2023), and even in the absence of available information regarding seizure weight/dosage.

### Review limitations

Studies in this review were limited to peer-reviewed publications located via PubMed, Scopus, or ProQuest. Although non-peer-reviewed (e.g., gray literature) sources may have provided additional evidence, we chose peer-reviewed manuscripts to limit results to studies that had undergone independent review, considering that quality assessment is not typically part of the scoping review process (Peters et al., 2020). The review topic incorporated studies with a variety of measures and methodologies, precluding a formal meta-analysis; at the same time, the review scope did not encompass additional potential measures of the illicit drug supply, such as data from undercover law enforcement drug purchases (Hempstead & Yildirim, 2014) or community drug-checking programs (Dasgupta & Figgatt, 2022). The main results summarized for each study consisted solely of results regarding fatal overdoses, rather than results regarding related outcomes such as non-fatal overdoses, and not all details from each study (e.g., strength of associations, nonsignificant associations, robustness checks) were included in the summary of findings. Finally, since this scoping review covered a relatively recent and expanding area of research, it is likely that additional relevant studies were published after the review process concluded.

### Conclusions

The use of law enforcement drug seizure data to characterize the

illicit drug supply represents a burgeoning area of research that has been applied to understand local, regional, or national trends and predict or forecast overdose deaths. Results of the studies included in this review may be relevant for research study design, as many observational and quasi-experimental studies that aim to identify policy-related, social, or economic influences on overdose deaths rely on statistical adjustment for time-varying differences between states or counties, such as drug supply characteristics. Results from the present review suggest that in the contemporary era of synthetic opioids, statistical adjustment for measures such as fentanyl-related seizure rates may help account for the variation attributable to time/region differences in fentanyl's pervasiveness in local US drug supplies. Beyond use in research design, drug seizure measures may also provide more timely information about drug trends, in light of the delays and limitations in mortality data (Hall et al., 2021; Rosenblum et al., 2020; Zibbell et al., 2023); for example, the emerging adulterant xylazine has been reported in drug seizure data from nearly all US states, yet state-level data on xylazine-involved overdose deaths are limited (Cano et al., 2024) since xylazine is not yet routinely included in post-mortem toxicology procedures across all jurisdictions in the US (Spencer et al., 2023). The studies in this scoping review support the potential of drug seizure measures as part of public health surveillance (Hall et al., 2021; Rosenblum et al., 2020; Sumner et al., 2022) to help organizations and governments respond more quickly to changes in drug supplies. Nonetheless, as US illicit drug markets continually evolve (Rosenblum et al., 2020) and novel substances are increasingly reported (Papsun et al., 2022), additional research will be necessary to examine the extent to which seizures of other substances may be associated with overdose mortality.

### CRediT authorship contribution statement

**Manuel Cano:** Conceptualization, Investigation, Visualization, Writing – original draft. **Patricia Timmons:** Investigation, Writing – review & editing. **Madeline Hooten:** Investigation, Writing – review & editing. **Kaylin Sweeney:** Investigation, Writing – review & editing. **Sehun Oh:** Investigation, Writing – review & editing.

### Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

### Ethics approval

The authors declare that the work reported herein did not require ethics approval because it did not involve animal or human participation.

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