Pediatric Drug Overdose Mortality: Contextual and Policy Effects for Children Under 12

Brian C. Kelly[a], **Mike Vuolo**[b], **Laura C. Frizzell**[b]

[a]Department of Sociology, Purdue University, West Lafayette, Indiana;

[b]Department of Sociology, The Ohio State University, Columbus, Ohio

Abstract

Background: We determine trends in fatal pediatric drug overdose from 1999 to 2018 and describe the influence of contextual factors and policies on such overdoses.

Methods: Combining restricted CDC mortality files with data from other sources, we conducted between-county multilevel models to examine associations of demographic and socioeconomic characteristics with pediatric overdose mortality and a fixed-effects analysis to identify how changes in contexts and policies over time shaped county-level fatal pediatric overdoses per 100,000 children under 12.

Results: Pediatric overdose deaths rose from 0.08/100,000 children in 1999 to a peak of 0.19/100,000 children in 2016, with opioids accounting for an increasing proportion of deaths. Spatial patterns of pediatric overdose deaths are heterogenous. Socioeconomic characteristics are not associated with between-county differences in pediatric overdose mortality. Greater state expenditures on public welfare (b=−0.099; CI:[−0.193,−0.005]) and hospitals (b=−0.222; CI:[−.437,−.007]) were associated with lower pediatric overdose mortality. In years when a Good Samaritan law is in effect, the county-level pediatric overdose rate was lower (b=−0.095; CI: [−0.177,−0.013]).

Conclusions: Pediatric overdose mortality increased since 1999, peaking in 2016. Good Samaritan laws and investment in hospitals and public welfare may temper pediatric overdoses. Multi-faceted approaches using policy and individual intervention is necessary to reduce pediatric overdose mortality.

Address correspondence to: Mike Vuolo, Department of Sociology, The Ohio State University, 238 Townshend Hall, 1885 Neil Avenue Mall, Columbus, OH 43210, USA. Phone #: 614 292-3646 vuolo.2@osu.edu.

Introduction

Overdose mortality escalated considerably in the United States over the past several decades, growing from 16,849 overdose deaths in 1999 to 70,630 in 2019, representing a change in rate from 6.1 per 100,000 persons to 21.6 per 100,000 persons.(1–3) Research has indicated several waves of overdose, initially resulting from misuse of prescription opioids followed by increases in overdose from heroin and drug market adulteration with synthetic opioids.(4) However, although opioids have been a central focus in recent years, overdose mortality has steadily increased for decades for a wide range of substances, including psychostimulants and benzodiazepines.(5) Opioids undoubtedly remain a considerable problem, but only more recently has attention focused on a wider array of overdoses. Also, while growth in substance-related problems among adolescents and adults has received substantial attention, (6–8) the overdose crisis's impact on young children has received less consideration.

Young children have experienced thousands of drug-related events requiring emergency intervention annually.(9–11) Reports of deaths specifically from prescription opioids increased among young children as the overdose crisis evolved.(11–12) While recognition that drug-related mortality presents a problem for children grows, relatively few studies have investigated contexts contributing to this problem. Many studies examining drug-related problems in pediatric populations have focused on neonatal abstinence syndrome rather than early childhood risks.(13–15) Investigating policies and contexts that shape drug overdose deaths within the pediatric population is especially important to facilitate resource mobilization.

Drug-related overdose mortality functions differently for children under 12 than for older individuals.(16) Drug abuse and dependence are extremely rare at this life course stage, and adverse events do not typically occur because of intentions to experience intoxication. Further, specifically regarding prescription drugs, opioid prescriptions for children in the U.S. remained relatively stable over time, while adult prescriptions increased.(16–17) Thus, we anticipate that patterns of mortality may differ for young children compared to adolescents and adults, who intentionally use substances for intoxication.

A key source of pediatric drug overdoses includes unintentional ingestion of substances found around the home; most pediatric overdoses occur in residential settings,(11) especially through household exposure to adults' prescription medications.(18) Indeed, children have higher odds of overdose if a parent has been prescribed an opioid.(19) The greatest risk for younger children occurs for children less than 5 years old.(20) Some scholars suggest that mismatches between prescribed quantity and patient pain management needs has led to leftover medications, creating risks for unintentional overdoses among children.(21) Children may also be placed at risk by the presence of illicit drugs within the home, making parental drug dependence a concern related to pediatric overdose.(22) In some of the most nefarious instances, intentional poisonings of children have been reported.(23) In addition to threats to individual lives, overdoses within pediatric populations have strained resources at children's hospitals and pediatric intensive care units.(24) These problems may be patterned across society, and identification of contextual factors associated with pediatric overdoses may facilitate better intervention.

Beyond the importance of social contexts, several policies have been implemented within the U.S. to address overdose mortality.(25–30) Although more directly affecting adults, certain policies may affect pediatric overdoses by reducing prescription and illicit drugs within the home or increasing lifesaving opportunities. Prescription drug monitoring programs and pain clinic prescribing limits may directly reduce the number of scheduled psychoactive medications in circulation by tempering prescribing and encouraging more responsible prescribing. They may also indirectly reduce illicit substances by impeding pathways from dependence on prescription drugs to illicit drugs.(31–32) Expanded naloxone access impacts opportunities for intervention with overdoses from opioids by increasing availability of a medication that can reverse an opioid overdose; this is the only policy specific to opioids, but as described below, opioid overdoses comprise a significant proportion of pediatric overdoses in the U.S. Good Samaritan laws – which protect those who call emergency services at the site of an overdose from criminal or civil penalties related to drugs present – may reduce hesitation by adults to call 911 in the event of a pediatric overdose from any psychoactive substance but particularly those illicitly obtained, thus increasing the rapidity by which first responders arrive. Although not implemented directly in response to overdoses, medical marijuana laws may provide alternative pain therapies that reduce prescribed opioids within the house.(33) Identifying the impact of these laws on pediatric overdoses remains important but understudied. The United States is a particularly unique place to study the role of such policies on child health since these policies have been implemented thus far at the state-level rather than the federal level, leading to variability across the U.S. over time.

Current Study

This paper examines pediatric overdose mortality since 1999 and assesses contextual and policy factors shaping overdose among this vulnerable population. We first examine trends in pediatric drug overdose deaths within the U.S. from 1999 to 2018. We then examine the geography of pediatric overdose mortality. Subsequently, we utilize between-county multilevel models to examine how county and state contextual characteristics are associated with pediatric overdose mortality. We conclude with a fixed-effects analysis identifying how changes over time, including policy implementation, have affected pediatric overdose mortality.

Methods

Overdose Mortality Data

We utilized Centers for Disease Control and Prevention (CDC) restricted access mortality files, 1999–2018, which include records on every death in the U.S. Cause of death codes allowed the identification of drug overdoses. Our primary outcome is the mortality rate due to psychoactive drug (substances that affect psychological states by causing changes in mood, sensations, feelings, or behavior) overdoses among children under 12 per 100,000 children under 12. As the CDC files contain all deaths, we note that while we focus on deaths among children under 12, we make comparisons to overdoses as a whole as well as by other age groups such as adolescents (12–17) and adults (18 and older). We utilized the CDC's operational definition for drug overdoses.(34) Such deaths have ICD-10 underlying

cause codes of "drug poisoning" X40-X44 (unintentional), X60-X64 (intentional self-harm), X85 (assault/homicide), and Y10-Y14 (undetermined/unknown). We deviate from the strict CDC definition to examine only overdose deaths specific to psychoactive substances – prescription or illicit – to eliminate poisoning via alcohol, household chemicals, or other medications, such as non-psychoactive prescribed substances (e.g. antibiotics) and common over-the-counter drugs (e.g. Tylenol). Thus, underlying overdose causes were combined with ICD-10 multiple causes codes for psychoactive drugs: T40.0-T40.9 (Poisoning by, adverse effect of and underdosing of narcotics and psychodysleptics), T42.0-T42.8 (Poisoning by, adverse effect of and underdosing of antiepileptic, sedative- hypnotic and antiparkinsonism drugs), and T43.0-T43.9 (Poisoning by, adverse effect of and underdosing of psychotropic drugs, not elsewhere classified) as well as the code T50.9 for an unspecified substance (for more specific T-codes within these groupings, see Appendix B). All substances belong to a single classification code, such that there is no overlap; however, there are categories for undetermined substance, and more than one substance of different categories can be present for a single death. We aggregated deaths to county-levels and calculated overdose mortality rates. Unlike public use data, restricted data contain no suppressed information, permitting more precise analysis of counties, including those with fewer than 10 deaths per year, which is typical for pediatric overdoses. Due to CDC restrictions on the reporting of rare outcomes in our agreement for restricted data access, specifically prohibition on the report of death counts or rates based on counts of nine or fewer, exact numerical values cannot be displayed in some instances.

County- and State-level Factors

From the Census Bureau's American Community Survey, we included time-varying county-level factors: unemployment rate, median household income, and percentage over 25 with a Bachelor's, foreign born, female-headed households, Non-Hispanic Black, and Hispanic. From the Annual Survey of State Government Finances, we included state-level per-capita spending on education, public welfare, hospitals, and health. County-level population denominators to calculate rates were obtained from the CDC.

Policy Data

We utilized the Prescription Drug Abuse Policy System (PDAPS) for a comprehensive listing of state policy passage between 1999 and 2016. We then created a state-year dataset to account for the presence of policies during the period of observation. Policies assessed included Prescription Drug Monitoring Programs, Expanded Naloxone Access, Good Samaritan Laws, Pain Clinic Prescribing Restrictions, and Medical Marijuana Laws. Although there is heterogeneity in how these laws are implemented across states, we focus on base level implementation within our analyses to account for the widest range of such policies. Policies are coded 1 for full years when they were active, and 0 otherwise.

Analysis

As an underexplored area of research, we first examined temporal and spatial variation descriptively. Beyond generalized national trends, total rates of fatal overdose from 1999 to 2018 were calculated for each state, which were then set into quintiles given the restricted data use agreement. We assessed percent change for each state and used a cutoff for percent

change of 5 or greater (in either direction) and denoted this visually in our results section through an indicator of increase (+) or decrease (−) next to the state abbreviation on maps. States that experienced no percent change of 5 or greater in either direction have no indicator of change next to the state abbreviation.

We then conducted multilevel linear regression models for the years 1999 to 2016 (the last year in which the policy data is available) using two approaches. First, we assessed between-effects of state- and county-level contexts on pediatric overdose mortality. We note that pediatric overdoses are a rare event, particularly at the county-level. By using between-effects, we can combine data across years by utilizing the county-level average over the entire period as the outcome. These analyses assess how differences in the averages of characteristics between locations are associated with the average pediatric overdose rate. Second, we used fixed-effects models, a causal method for observational data, to determine the effect of these characteristics and policy implementation over time.(35–37) Their strength is the elimination of unobserved heterogeneity by differencing all predictors and the outcome from its county-specific average. Fixed effects estimators are robust to observed or unobserved time-invariant omitted variables, which removes constant county-level effects. In this way, policies become analogous to a "treatment" in an experimental setting. While this method is more sensitive to the rarity of the event since the unit of analysis is now every year, the strength of the method allows for an examination of the effect of policy on pediatric overdoses. To account for temporal patterns in overdose rates and provide estimates of the effect of policies independent of that pattern, the fixed-effects models included covariates for year. Finally, we included a standard error cluster correction for the state to account for the dependencies between counties in each state in the fixed-effects model (the cluster correction is not compatible with between-effects). We conducted all analyses in Stata 16.0.

Within the U.S., there are 3,142 counties across 17 years. The two smallest counties were excluded because population estimates for this age group are unreliable. Thirteen counties restructured boundaries, such that within models we start those series at years when boundaries are the same as the present; prior years are not comparable. Thus, our models include 50,079 county-year observations. Descriptive statistics are shown in Appendix A for the interested reader.

Results

Trends in pediatric mortality during the overdose crisis are presented in Figure 1. Between 1999 and 2018 over a thousand children under 12 died from drug overdoses (N = 1,348), and the rate more than doubles from 0.08 per 100,000 children in 1999 to approximately 0.19 per 100,000 children in the peak year, 2016 ($p<.05$). The sharpest escalation occurred early during the overdose crisis, from 1999 until 2007, experiencing a temporary decrease, and then returning to higher levels before declining again. The figure also depicts the proportion of overdoses attributable to opioids. From 1999 to 2007, opioid overdoses accounted for approximately half of pediatric overdose deaths on average. From 2010 onward, opioid overdoses accounted for two-thirds to three-quarters of pediatric overdose mortality. Thus, over time, opioids accounted for a greater proportion of pediatric overdose deaths. Appendix B provides further breakdown of the substances involved both alone and in combination.

The most common substances were prescription opioids (involved alone or in combination in 37.9% of deaths), methadone (21.9%), and synthetic opioids (11.4%). Heroin accounted for a small proportion of pediatric deaths (2.0%). Yet, a sizable number of deaths were due to psychostimulants (8.4%), cocaine (6.8%), and benzodiazepines (5.0%). For most substances, including non-opioids, the majority of deaths were due to that substance alone. But this fact should not diminish deaths involving multiple drugs. One notably different pattern is that most benzodiazepine deaths (73.2%) involved another substance.

In terms of cause, overdoses are coded as either unintentional, intentional, homicide, or unknown. Figure 2 identifies differences within the data between children under 12 and both adolescents and adults. For children under 12, 42.8% were coded unintentional, 0.7% intentional, 24.4% homicide, and 32.1% unknown. By contrast, for teens 12–17, suicide (18.9%) and unintentional overdoses (70.5%) were predominant. For adults, the vast majority were unintentional (80.7%). Homicide is negligible for adolescents and adults, and these older groups also have a smaller proportion coded as unknown. We also note that the root cause of "unintentional" overdoses is distinct given that adolescents and adults pursue intoxication with known risks while children likely experience purely unintentional poisonings.

Turning to Figure 3, we show the distribution of pediatric overdose death rates across states. The map displays the annual overdose rate averaged across a twenty-year period (1999 to 2018). Overall, the map shows many similarities to the total overdose rate, of which pediatric overdoses are an exceedingly small part. For example, the pediatric overdose rates were highest in areas such as Appalachia, Oklahoma, and Montana, and lowest in areas such as the "Great Plains" states, New York, New Jersey, Virginia, Texas, and California. In terms of change between the five-year average in the earliest and most recent years, 32 states observed increases of five percent or more, while only 7 states experienced a decrease of 5 percent or more. We also draw the reader's attention to the total overdose trend diverging from changes over the past twenty years, as there have been increases in states with generally low rates, such as New York, and decreases in states with generally high rates, such as Oklahoma.

We extend the analysis of geographic differences through assessing differences in overdose mortality between counties related to county-level social and demographic characteristics. Within Table 1, we present the results of the multilevel linear regression model assessing these between-county effects. County metropolitan status and the next eight variables presented within the table permit us to examine differences between counties on the basis of the average of these characteristics. Notably, the results indicate that average differences between counties in socio-demographic factors had no measurable effect on the average pediatric overdose mortality rate. For state characteristics, we assessed four types of public expenditures. Of these four factors, greater state expenditures on public welfare and hospitals were associated with significantly lower pediatric overdose mortality rates. Specifically, a $1 increase in public welfare and hospital expenditures per capita was associated with a pediatric overdose rate lower by 0.099 (–0.193,–0.005) and 0.222 (–0.437,–0.007), respectively.

Table 2 presents results from fixed-effects regression models assessing the effects of within-county changes. Of the county-level factors noted above, increases in female-headed households led to a decrease in pediatric overdose mortality (B=−0.037, (−0.064, −0.010); no other factors had an effect. Although the relative between-state values mattered, within-state changes to state expenditures over time did not affect the overdose rate. Among policies included within the fixed-effects model, only the passage of Good Samaritan laws had a significant effect on pediatric overdose mortality. In years when a Good Samaritan law is in effect, the county-level pediatric overdose rate was lower by 0.095 (−0.177, −0.013).

Discussion

Our results reiterate the increasing burden of pediatric overdoses.(11) Rates of overdose mortality among children under 12 have more than doubled from 1999 to the peak in 2016, suggesting that psychoactive substances became an increasing threat to pediatric populations, although with slight reductions in more recent years. The proportion of overdoses accounted for by opioids escalated during this time, indicating that wider opioid use played an increasing role in U.S. child deaths during the 21st century. Yet, while opioids constitute a considerable proportion of fatal pediatric overdoses, by no means is this problem limited to opioids.

The geography of pediatric overdose mortality highlighted on the map indicates a pattern mostly similar to overall overdose rates, implying that comprehensive solutions should also attend to pediatric deaths. Perhaps surprisingly, however, the pediatric overdose rate was in the lower quintiles for some states hit hard by fatal overdoses such as Massachusetts and Rhode Island, and in the higher quintiles for some states with typically lower overall overdose rates such as Georgia and Arkansas.(38) The few states that do not match patterns for overall overdose mortality highlight the extent to which pediatric overdose deaths are distinct from those seen in adolescents and adults. To this end, U.S. states experiencing low overall overdose mortality should not be confident that pediatric overdoses are under control. Careful attention to preventing harm to children remains an important task throughout the country.

Our findings indicate that socio-demographic characteristics of counties largely do not have significant effects on between-county pediatric overdose mortality. This is notable for several reasons. Foremost, the socioeconomic resources of counties are not related to child overdose death rates. These findings are particularly important as prior research identified county-level inequality as associated with child maltreatment.(39) In other words, counties with higher socioeconomic profiles do not protect against pediatric overdoses, while counties with poorer socioeconomic profiles do not exacerbate this adverse outcome. Additionally, we do not find pediatric overdose mortality to be specific to rural or urban regions. Overall, the pediatric overdose problem is one that reaches across broad segments of the population.

Although county-level socioeconomic characteristics are not associated with mortality, our results indicate that state-level spending may differentiate pediatric overdoses across locales. Counties within states that on average spend more on public welfare and hospitals had

lower pediatric overdose mortality. These findings suggest that public programs may create opportunities to mitigate occurrences of overdoses as well as reduce fatalities due to greater hospital coverage and emergency resources within the state. Indeed, Massachusetts, despite a high overall overdose rate, was in the lowest quintile for pediatric overdose mortality and is known for its wide pediatric healthcare coverage.(40)

With respect to state policies, the implementation of Good Samaritan laws significantly reduced pediatric overdose mortality rates. These laws may accelerate contact with first responders by reducing adults' conscious or unconscious fears of punishment should children experience a drug overdose, thus leading to more rapid 911 calls. This is not to say that adults are engaging in callous disregard for the well-being of children in states that do not have these laws, although this may occur, but in instances where even hesitation of a few brief moments may prove fatal, the presence of these laws may facilitate more rapid contact with first responders. Additional research is needed on this issue.

A complicating factor in pediatric overdoses is that some opioids within households are needed for the treatment of chronic pain, and also some pediatric exposures may occur as a result of a family member engaged in maintenance therapies with drug treatment.(41) Thus, the need to prevent pediatric exposures without disrupting patient care remains a fine line. Although efforts to attenuate the overdose crisis have largely focused on teenagers and adults, attention to overdose mortality must include efforts to reduce risks for pediatric populations. Steps may be taken to intervene on pediatric overdoses and improved outcomes are most feasibly produced through combined strategies for the prevention of medication overdoses.(42) In the course of clinical interactions with individuals receiving psychoactive medications (including children and adults), clinicians and other providers should counsel adults on steps that may reduce the likelihood that young children will come into contact with these substances. Proper prescribing for children may reduce potential exposures, as there are often mismatches between medical need and prescribing for children.(21) Take-back programs may also facilitate reduced child exposures, although research indicates that such programs are underutilized by parents.(43) Patients should be encouraged to leave medications in bottles with a "child-resistant" safety cap and to fully re-secure the cap after each use.(44) Unit dose packaging may also be a means of reducing the liabilities of unintentional ingestion by children.(45–46) Patients also should be reminded to store psychoactive substances in locked storage inaccessible to children, and if a lock is unavailable to ensure these drugs are stored in a high location inaccessible to children (keep it out of reach), as promoted by the "Up and Away" campaign.(47) This advice extends to patients in medication assisted treatment programs, as substances such as methadone comprise a notable proportion of pediatric overdose deaths. Harm reduction organizations working with people who use illicit substances should counsel clients to use similar methods to prevent children from accessing psychoactive drugs. Patients and clients should also be reminded of Good Samaritan laws, so that rapid responses may reduce the likelihood that an unexpected ingestion of drugs by a child turns fatal. When prescription medications are no longer in use, they should be disposed of rather than left in the household. Parents should also inform visitors to follow these house rules and to play an active role in keeping substances away from children in the home. For children who are old enough to understand, parents can also directly explain to children that substances not prescribed for them may be

toxic and harmful. As noted above, these approaches should be adopted across the populace, as no groups are immune to the risks of pediatric overdose.

Limitations

Importantly, pediatric overdoses are a rare event, which makes counts of death sensitive to coding errors by medical professionals assessing cause of death. Scholars have identified that mortality data quality for drug overdose varies across states and these may affect between-state estimates of overdose mortality.(48) Such coding could also account for some geographic differences between pediatric overdose mortality and that for the population at large, although such coding issues would have to be systematic at the state-level and confined to pediatric deaths for that to be the case. Further, we concentrate on the overall psychoactive drug overdose rate (inclusive of prescribed and illicit substances) rather than any specific substance due to this rarity. The strengths of our modeling approaches counter some of the problems with this issue, but caution is necessary nonetheless. We note that we included all psychoactive substances regardless of controlled status because CDC coding uses ambiguous "other/unidentified" categories when a substance cannot be identified with certainty. In cases where the drug can be identified with certainty, only 13 of 1127 deaths in our analysis are due to non-controlled substances. We also recognize the limitation in the number of deaths of unknown intent within the data.

Additionally, counties are imperfect measures of geographic space. While an improvement over state-level measures, size and number of counties vary across states. Although we included a large battery of county- and state-level factors as well as county fixed effects, we also recognize other factors may affect pediatric overdoses. This caution is particularly relevant for the between-effects results. However, the within-effects model is robust to observable or unobservable static factors. Finally, we only examine mortality, and the effects on non-fatal drug-related events could be different.

Conclusions

In the midst of extraordinary growth in drug overdose rates, fatal overdoses among U.S. children have received limited attention. Over two decades, pediatric overdose mortality in the U.S. more than doubled with a recent slight decline from the 2016 peak. Although pediatric overdoses are rare relative to those experienced by adolescents and adults, Good Samaritan laws potentially reduce pediatric overdose mortality and supportive state spending may also help to maintain a lower average rate. The geographic distribution demonstrates that states with low adult overdose mortality may still need to consider such approaches. The inability of young children to act in their own interests – unlike adolescents and adults who can take proactive steps to mitigate risks – means that understanding factors that temper overdose mortality remains particularly important to reduce the risk of pediatric overdoses.

Funding Source:

Appendix A: Descriptive statistics (pooled over counties and year, *N* = 50,079)

	Average/% (SD)
County-level Overdose Rate	
All pediatric psychoactive substance overdoses	.14 (2.46)
State-level Policies	
Prescription drug monitoring program	68.62%
Good Samaritan law for drug overdoses	9.55%
Naloxone possession – no criminal liability	1.60%
Medical marijuana	15.42%
Pain management clinic law	11.16%
State-level Per Capita Expenditures ($)	
Education	1.71 (.42)
Public Welfare	1.24 (.42)
Hospitals	.17 (.12)
Health	.15 (.08)
County-level Demographics	
Unemployment rate	4.19 (1.81)
Median household income	41,761 (11,461)
Percent living in poverty	11.40 (5.65)
Percent with bachelor's degree	13.36 (6.63)
Percent foreign-born	4.09 (5.33)
Percent female-headed households	6.39 (2.45)
Percent Black	9.25 (14.35)
Percent Hispanic	7.81 (12.86)
Large Central Metro	2.14%
Large Fringe Metro	11.70%
Medium Metro	11.82%
Small Metro	11.41%
Micropolitan	20.45%
Noncore	42.48%

Appendix B.: Descriptive information on all psychoactive substances involved in pediatric overdoses, 1999–2018.

Substance (ICD-10 code)	N (%)	% single substance	% combination
Prescription opioid (T40.2)	427 (37.9%)	82.2%	17.8%
Methadone (T40.3)	247 (21.9%)	91.1%	8.9%
Synthetic opioid (T40.4)	128 (11.4%)	78.1%	21.9%
Psychostimulants (T43.6)	95 (8.4%)	86.3%	13.7%
Cocaine (T40.5)	77 (6.8%)	75.3%	24.7%

Substance (ICD-10 code)	N (%)	% single substance	% combination
Antidepressants (T43.0, T43.2)	75 (6.7%)	69.3%	30.7%
Benzodiazepines (T42.4)	56 (5.0%)	26.8%	73.2%
Unidentified narcotic (T40.6)	50 (4.4%)	64.0%	36.0%
Other sedatives (T42.6, T42.7, T42.8)	39 (3.5%)	66.7%	33.3%
Antipsychotics (T43.3, T43.5)	38 (3.4%)	60.5%	39.5%
Heroin (T40.1)	23 (2.0%)	39.1%	60.9%
Barbiturates (T42.3)	12 (1.1%)	75.0%	25.0%

Note: Percentage of deaths do not add to 100 because multiple psychoactive substances can be involved in a single death. There is no overlap for substances classified within different categories.

References

1. Birnbaum HG et al. Societal costs of prescription opioid abuse, dependence, and misuse in the United States. Pain Med. 2011;12(4):657–667. [PubMed: 21392250]

2. Dart RC et al. Trends in opioid analgesic abuse and mortality in the United States. N Engl J Med. 2015;372(3):241–248. [PubMed: 25587948]

3. Hedegaard H, Miniño AM, Warner M. Drug Overdose Deaths in the United States, 1999–2019. NCHS Data Brief, no 394. 2020; Hyattsville, MD: National Center for Health Statistics; 2020.

4. Ciccarone D The triple wave epidemic: supply and demand drivers of the US opioid overdose crisis. Int J Drug Pol. 2019 9;71:183.

5. Jalal H et al. Changing dynamics of the drug overdose epidemic in the United States from 1979 through 2016. Science 208;361(6408):eaau1184.

6. Bohnert ASB et al. Overdose and adverse drug event experiences among adult patients in the emergency department. Addict Behav. 2018;86:66–72. [PubMed: 29198490]

7. Martins SS et al. Prescription opioid use disorder and heroin use among youth nonmedical prescription opioid users from 2002 to 2014. Addict Behav. 2017;65:236–241. [PubMed: 27614657]

8. Whiteside LK et al. Nonmedical prescription opioid and sedative use among adolescents in the emergency department. Pediatrics. 2013;132(5):825–832. [PubMed: 24167166]

9. Allen JD et al. Prescription opioid exposures among children and adolescents in the United States: 2000–2015. Pediatrics. 2017;139(4):e20163382. [PubMed: 28320869]

10. Lovegrove MC, Weidle NJ, Budnitz DS. Trends in emergency department visits for unsupervised pediatric medication exposures, 2004–2013. Pediatrics. 2015;136(4):e821–e829. [PubMed: 26347435]

11. Gaither JR, Shabanova V, Leventhal JM. US national trends in pediatric deaths from prescription and illicit opioids, 1999–2016. JAMA Netw Open. 2018;1(8):e186558. [PubMed: 30646334]

12. Wang GS, Olsen H, Severtson G, Green JL, Dart, RC. The impact of the prescription opioid epidemic on young children: trends and mortality. Drug Alcohol Depend. 2020;211:107924. [PubMed: 32178937]

13. Patrick SW, Davis MM, Lehmann CU, Cooper WO. Increasing incidence and geographic distribution of neonatal abstinence syndrome: United States 2009 to 2012. J. Perinatol 2015;35(8):650–655. [PubMed: 25927272]

14. Tolia VN et al. Increasing incidence of the neonatal abstinence syndrome in U.S. neonatal ICUs. N Engl J Med. 2015;372(22):2118–2126. [PubMed: 25913111]

15. Patrick SW, Schumacher RE, Horbar JD, et al. Improving care for neonatal abstinence syndrome. Pediatrics. 2016;137(5):e20153835. [PubMed: 27244809]

16. Gummin DD et al. 2018 Annual report of the American Association of Poison control centers' National Poison Data System (NPDS): 36th annual report. Clin. Toxicol 2019;57(12):1220–1413.

17. Groenewald CB, Rabbitts JA, Gebert T, Palermo TM. Trends in opioid prescriptions among children and adolescents in the United States: a nationally representative study from 1996 to 2012. Pain. 2016;157(5):1021–1027. [PubMed: 26716995]

18. Bailey JE, Campagna E, Dart RC. The underrecognized toll of prescription opioid abuse on young children. Ann. Emerg. Med 2009;53(4):419–424. [PubMed: 18774623]

19. Finkelstein Y et al. Overdose risk in young children of women prescribed opioids. Pediatrics. 2017;139(3):e20162887. [PubMed: 28219963]

20. Burghardt LC, Ayers JW, Brownstein JS, Bronstein AC, Ewald MB, Bourgeois FT. Adult prescription drug use and pediatric medication exposures and poisonings. Pediatrics. 2013;132(1):18–27. [PubMed: 23733792]

21. Voepel-Lewis T, Wagner D, Tait AR. Leftover prescription opioids after minor procedures: an unwitting source for accidental overdose in children. JAMA Pediatr. 2015;169(5):497–498. [PubMed: 25798880]

22. Graham J, Leonard J, Banerji S, Wang GS. Illicit drug exposures in young pediatric patients reported to the National Poison Data System, 2006–2016. J. Pediatrv 2020;219:254–258.

23. Yin S Malicious use of pharmaceuticals in children. J Pediatr. 2010;157(5):832–836. [PubMed: 20650468]

24. Kane JM, Colvin JD, Bartlett AH, Hall M. Opioid-related critical care resource use in US children's hospitals. Pediatrics. 2018;141(4):e20173335. [PubMed: 29507166]

25. Davis CS, Carr D. Legal changes to increase access to naloxone for opioid overdose reversal in the United States. Drug Alcohol Depend. 2015;157:112–120. [PubMed: 26507172]

26. Davis CS, Carr D. State legal innovations to encourage naloxone dispensing. J Am Pharm Assoc. 2017;57(2):S180–S184.

27. Fishman SM, Papazian JS, Gonzalez S, Riches PS, Gilson A. Regulating opioid prescribing through prescription monitoring programs: balancing drug diversion and treatment of pain. Pain Med. 2004;5(3):309–324. [PubMed: 15367312]

28. Gugelmann HM, Perrone J. Can prescription drug monitoring programs help limit opioid abuse? JAMA. 2011;306(20):2258–2259. [PubMed: 22110107]

29. Haegerich TM, Paulozzi LJ, Manns BJ, Jones CM. What we know, and don't know, about the impact of state policy and systems-level interventions on prescription drug overdose. Drug Alcohol Depend. 2014;145:34–47. [PubMed: 25454406]

30. Wheeler E, Davidson PJ, Jones TS, Irwin KS. Community-based opioid overdose prevention programs providing naloxone—United States, 2010. MMWR Morb Mortal Wkly Rep. 2012;61(6):101. [PubMed: 22337174]

31. Carlson RG, Nahhas RW, Martins SS, Daniulaityte R. Predictors of transition to heroin use among initially non-opioid dependent illicit pharmaceutical opioid users: A natural history study. Drug Alc Depend, 2016;160, 127–134.

32. Mars SG, Bourgois P, Karandinos G, Montero F, Ciccarone D. (2014). "Every 'never' I ever said came true": transitions from opioid pills to heroin injecting. Int J Drug Pol, 2014;25(2), 257–266.

33. Powell D, Pacula RL, Jacobson M. Do medical marijuana laws reduce addictions and deaths related to pain killers?. J Health Econ, 2018;58, 29–42. [PubMed: 29408153]

34. Scholl L, Seth P, Kariisa M, Wilson N, Baldwin G. Drug and opioid-involved overdose deaths — United States, 2013–2017. MMWR Morb Mortal Wkly Rep. 2019;67(5152):1419.

35. Allison P Fixed Effects Regression Models. Thousand Oaks, CA: SAGE; 2009.

36. Halaby CN. Panel models in sociological research: theory into practice. Annu Rev Sociol. 2004;30(1):507–544.

37. Winship C, Morgan SL. The estimation of causal effects from observational data. Annu Rev Sociol. 1999;25(1):659–706.

38. Rudd RA, Seth P, David F, Scholl L. Increases in drug and opioid-involved overdose deaths— United States, 2010–2015. MMWR Morb Mortal Wkly Rep, 2016; 65(50 & 51), 1445–1452. [PubMed: 28033313]

39. Eckenrode J, Smith EG, McCarthy ME, Dineen M. Income inequality and child maltreatment in the United States. Pediatrics. 2014;133(3):454–461. [PubMed: 24515511]

40. Kenney GM, Long SK, Luque A. Health reform in Massachusetts cut the uninsurance rate among children in half. Health Aff. 2010;29(6):1242–1247.

41. Post S, Spiller HA, Casavant MJ, Chounthirath T, Smith, G. A. Buprenorphine exposures among children and adolescents reported to US poison control centers. Pediatrics, 2018;142(1), e20173652. [PubMed: 29941678]

42. Budnitz DS, Salis S. Preventing medication overdoses in young children: an opportunity for harm elimination. Pediatrics, 2011;127(6), e1597–e1599. [PubMed: 21555494]

43. Egan KL et al. Disposal of prescription drugs by parents of middle and high school students. J Child Ad Subs Abuse, 2019; 28(2), 92–98.

44. Rodgers GB. The safety effects of child-resistant packaging for oral prescription drugs: two decades of experience. JAMA. 1996 6 5;275(21):1661–5. [PubMed: 8637140]

45. Hampp C et al. The role of unit-dose child-resistant packaging in unintentional childhood exposures to Buprenorphine–Naloxone tablets. Drug Safety, 2020; 43(2), 189–191. [PubMed: 31745829]

46. Wang GS, Severtson SG, Bau GE, Dart RC, Green, JL.Unit-dose packaging and unintentional buprenorphine-naloxone exposures. 2018; Pediatrics, 141(6).

47. Centers for Disease Control and Prevention. "Up and Away" campaign. https://www.cdc.gov/medicationsafety/protect/campaign.html

48. Buchanich JM, Balmert LC, Williams KE, Burke DS. The effect of incomplete death certificates on estimates of unintentional opioid-related overdose deaths in the United States, 1999–2015. Pub Health Rep. 2018 7;133(4):423–31. [PubMed: 29945473]

Impact Statement

Pediatric fatalities from psychoactive substances have risen within the U.S. since 1999.

Higher levels of state spending on public welfare and hospitals are significantly associated with lower pediatric overdose mortality rates.

The implementation of Good Samaritan laws is significantly associated with lower pediatric overdose mortality rates

We identified no county-level sociodemographic factors associated with pediatric overdose mortality.

The findings indicate a multi-faceted approach to the reduction of pediatric overdose is necessary.
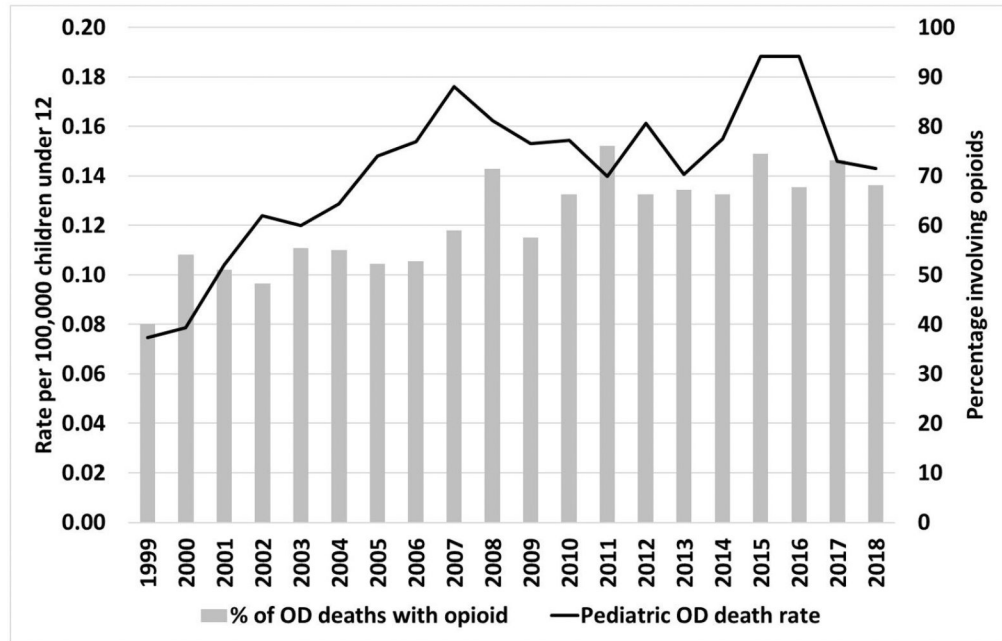
Figure 1:
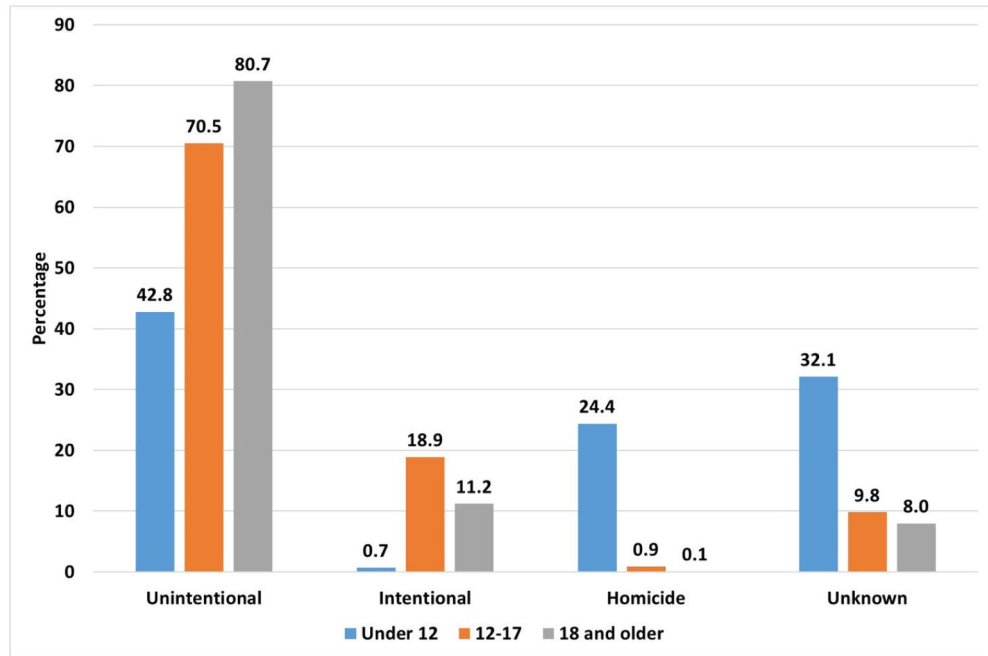Pediatric overdose mortality rate and percentage involving opioids

Figure 2:
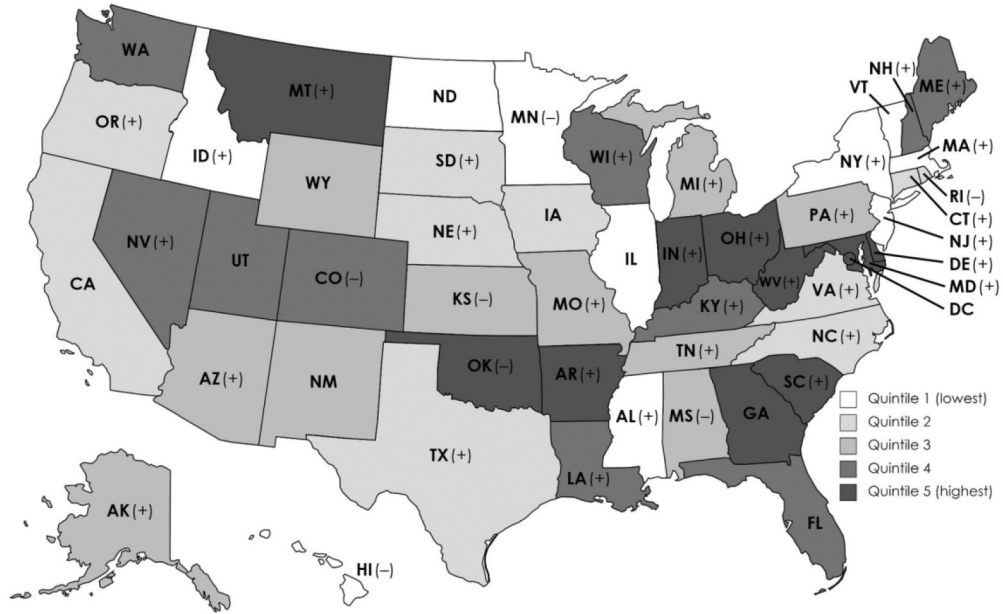Coded cause of overdose deaths by age, 1999–2018

Figure 3:

Pediatric drug overdose rate averaged over annual rates 1999 to 2018 by state

Note: Due to CDC restrictions on the reporting of rare outcomes in our agreement for restricted data access, specifically prohibition on the report of death rates based on counts of nine or fewer, numerical values of quintile boundaries are not displayed. The plus (+) and minus (−) indicate an increase or decrease, respectively, of 5 percent or more in the five-year average in the start (1999–2003) and end (2014–2018) of our observation period.

Table 1:

Between-county models identifying associations of social contexts with county-level pediatric overdose mortality rate

	B (95% CI)
Metropolitan Status (Ref. Large Central)	
Large fringe metro	−.096 (−.273, .080)
Medium Metro	−.111 (−.284, .063)
Small Metro	−.092 (−.268, .083)
Micropolitan (nonmetro)	−.065 (−.238, .108)
Noncore	−.125 (−.300, .049)
Unemployment rate	0.013 (−.007, .034)
Median household income	−.003 (−.007, .002)
Poverty rate	.003 (−.006, .012)
Bachelor's degree	.001 (−.004, .007)
Foreign born	−.001 (−.008, .006)
Female-headed households	.004 (−.015, .024)
Black	.001 (−.002, .003)
Hispanic	−.001 (−.004, .001)
State education expenditures	.078 (−.002, .157)
State public welfare expenditures	−.099 (−.193, −.005) [*]
State hospital expenditures	−.222 (−.437, −.007) [*]
State health expenditures	.193 (−.208, .594)
Constant	.227 (−.071, .524)
Counties, observations	3140, 50079

[*] $p<0.05$,

[**] $p<0.01$,

[***] $p<0.001$

Table 2:

Fixed-effects models predicting county-level pediatric overdose mortality rate

County contexts	B (95% CI)
Unemployment rate	−0.027 (−.058, .003)
Median household income	0.007 (−.005, .018)
Poverty rate	0.017 (−.002, .036)
Bachelor's degree	0.000 (−.007, .007)
Foreign born	−0.012 (−.037, .013)
Female-headed households	−0.037 (−.064, −.010) **
Black	0.021 (−.005, .048)
Hispanic	−0.023 (−.064, .018)
State education expenditures	.059 (−.093, .210)
State public welfare expenditures	0.070 (−.093, .234)
State hospital expenditures	−0.098 (−.415, .218)
State health expenditures	0.035 (−.445, .515)
Policies	
Prescription Drug Monitoring Program	0.010 (−.064, .085)
Naloxone access	0.018 (−.121, .157)
Good Samaritan law	−0.095 (−.177, −.013) *
Pain clinic maximum prescription law	0.074 (−.025, .174)
Medical marijuana	0.011 (−.103, .125)
Constant	−0.141 (−.478, .196)
Counties, observations	3140, 50079

*
$p < 0.05$,

**
$p < 0.01$,

***
$p < 0.001$

Note: Within-model also includes fixed effects for county. Model includes a state cluster correction for standard errors.