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Understanding Regional Patterns of Overdose Deaths Related to Opioids and Psychostimulants

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Ethics approval
The study was approved by the Penn State University Institutional Review Board.

Declaration of interest
The authors declare that they have no conflict of interest. The authors alone are responsible for the content and writing of the article.

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Abstract

Background: As overdose rates increase for multiple substances, policymakers need to identify geographic patterns of substance-specific deaths. In this study, we describe county-level opioid and psychostimulant overdose patterns and how they correlate with county-level social vulnerability measures.

Methods: A cross-sectional observational study, we used nationwide 2016–2018 restricted access Centers for Disease Prevention and Control county-level mortality files for 1,024 counties. We estimated quartiles of opioid and psychostimulant overdose mortality and provided estimates of their association with county-level Social Vulnerability Index (SVI) percentile.

Results: There was high opioid and psychostimulant overdose mortality in the Middle Atlantic, South Atlantic, East North Central, and Mountain regions. The Central US had the lowest opioid and psychostimulant overdose mortality rates. Counties with higher SVI scores (i.e. higher social vulnerability) were significantly more likely to experience high opioid and high psychostimulant overdose (high-high) mortality. A 10-percentile increase in SVI score was associated with a 3.1 percentage point increase in the likelihood of being a high-high county ($p < 0.001$) in unadjusted models and a 1.5 percentage point increase ($p < 0.05$) in models adjusting for region.

Conclusion: Our results illustrated the heterogenous geographic distribution of the growing concurrent opioid and psychostimulant overdose crisis. The substantial regional variation we identified highlights the need for local data to guide policymaking and treatment planning. The association of opioid-psychostimulant overdose mortality with social vulnerability demonstrates the critical need in impacted counties for tailored treatment that addresses the complex medical and social needs of people who use both opioids and psychostimulants.

Keywords

Opioids; psychostimulant; overdose mortality; county mortality; social vulnerability

1. Introduction

Policymakers and public health professionals across the United States have paid considerable attention to the opioid epidemic. Despite focusing significant resources on prevention and treatment, overdose deaths have continued to increase and opioid use disorder (OUD) rates remain high. (Kariisa et al., 2021; Mason et al., 2021; Saloner et al., 2021; Segel & Winkelman, 2021; Twillman et al., 2020) Worryingly, illicit opioid use has increasingly involved fentanyl and other synthetic opioids, that pose greater risk of overdose than prescription opioids. (Haley & Saitz, 2020; Wilson et al., 2020) Two emerging substance use trends further complicate efforts to prevent and treat substance use disorders (SUD) and overdose: first, psychostimulant use, particularly methamphetamine, has reemerged as a growing problem; (Cano & Huang, 2021; Ellis et al., 2018; Shearer et al., 2021) second, use of multiple illicit substances has become increasingly common, with hospitalizations involving both opioids and psychostimulants such as methamphetamine rising. (Compton et al., 2021; Ellis et al., 2018; Hedegaard et al., 2021; Khatri et al., 2018; Winkelman et al., 2018) The rise of concurrent psychostimulant and opioid use and the associated mortality may require prevention, harm reduction, and treatment services that are different than initiatives aimed at earlier waves of the opioid crisis.

Medications for opioid use disorder (MOUD), including methadone, buprenorphine, and naltrexone, are the most effective treatments for OUD. (Mohlman et al., 2016; Volkow et al., 2014) State and federal policymakers have increasingly provided funding as well as changed policies to expand patients' access to MOUD, especially focusing on increased access to buprenorphine in the primary care setting. (Brooklyn & Sigmon, 2017; Miele et al., 2020; Reif et al., 2020; Winograd et al., 2020; Winstanley et al., 2020) For example, Pennsylvania established a state program called the Pennsylvania Coordinated Medication Assisted Treatment (PacMAT), which uses an expert-guided community-based approach to support health systems' ability to provide MOUD to patients.(Pennsylvania Department of Health, 2020; Wolf, 2019) Similarly, policymakers have become more receptive to opioid overdose harm reduction strategies such as widespread distribution of naloxone, (Clark et al., 2014; Commonwealth of Pennsylvania, 2017; Erfanian et al., 2018) distribution of fentanyl test strips, (Krieger et al., 2018; Krieger et al., 2018; Peiper et al., 2019) and safe consumption sites. (Beletsky et al., 2008; Harris et al., 2018) On the other hand, compared to opioid use disorder, there are more limited pharmacological interventions to treat methamphetamine use disorder which limits effective treatment options for individuals who may use psychostimulants along with opioids. (Chan et al., 2019; Heinzerling et al., 2014; Paulus & Stewart, 2020; Trivedi et al., 2021) As such, the dynamic and locally varying nature of the overdose crisis means that the rise of methamphetamine use has complicated public health, public safety, and treatment efforts.

Geographic characteristics may also be important in understanding the risk of overdose death. (Dasgupta et al., 2017; Hollingsworth et al., 2017; Monnat et al., 2019) A number of studies have examined county-level factors associated with higher rates of opioid overdose mortality finding that counties with worse economic conditions and those in rural areas had worse access to treatment and higher opioid overdose mortality rates compared with areas with higher median incomes or that were more urban, respectively. (Haffajee et al., 2019; Langabeer et al., 2020; Monnat et al., 2019) Fewer studies have examined county characteristics related to psychostimulant overdose mortality, except in terms of regional patterns finding higher rates in the western and southwestern US; none have evaluated regional variation in or county-level factors associated with the overlap of opioid and psychostimulant mortality.(Jalal et al., 2018)

Thus, in the current study we make two primary contributions to the addiction literature. First, we provide geographic evidence of the complex patterns of opioid and methamphetamine across counties in the US. Second, we examine the association between these different county-level patterns of opioid and methamphetamine overdose mortality rates and a measure of social vulnerability. Specifically, we provide evidence of how well the validated Social Vulnerability Index (SVI) from the US Centers for Disease Control and Prevention (CDC) (Centers for Disease Control & Prevention, 2021) associates with county-level overdose patterns. Better delineation of regional trends and associated geographic characteristics can assist policymakers and other stakeholders in developing tailored public health efforts at the local level to address the increasing complexity of the substance use crisis.

2. Materials and methods

2.1. Data source

For all analyses, we used 2016–2018 restricted access CDC county-level mortality files. (National Center for Health Statistics, 2020) We were granted permission by the National Center for Health Statistics to use these deidentified, individual-level data that include decedent's county of death. These data provide information on all deaths within the United States including information on date, cause of death, and county and state of death. Using a well-established approach, (Ruhm, 2017, 2018; Segel & Winkelman, 2021) we identified both opioid-related and psychostimulant-related overdose deaths. Specifically, we identified overdose deaths using International Classification of Diseases, Tenth Revision (ICD-10) codes X40-X44, X60–64, X85, or Y10-Y14 for the primary cause of death. We further separately identified opioid and psychostimulant overdose deaths using multiple causes of death codes using codes T40.1-T40.4 and T40.6 for opioid deaths and T43.6 for psychostimulant deaths. We then calculated county-level death rates as the number of deaths per 100,000 population using estimates from the 2016–2018 US Census Bureau.(US Census Bureau, 2021a) To ensure adequate sample size, we combined all three years of mortality data to calculate the average, annual county-level mortality rates for opioid and psychostimulant overdose deaths.

2.2. Overdose mortality outcomes

To identify areas of high and low mortality, we then calculated the quartile of opioid and psychostimulant overdose mortality based on the definitions described above. We defined a county as "high" mortality as the top quartile of mortality for a specific substance and as "low" mortality as the bottom quartile. We then defined four categories of county-level overdose mortality: (i) low opioid mortality, low psychostimulant mortality (i.e. bottom quartile of mortality for each substance); (ii) high opioid mortality, low psychostimulant mortality; (iii) low opioid mortality, high psychostimulant mortality; (iv) high opioid mortality, high psychostimulant mortality. We restricted our analyses to these four categories to focus on the most extreme cases to understand potential county-level correlates of these categories of overdose mortality, a commonly used approach. (Hall et al., 2020; Kazerouni et al., 2021)

2.3. County social vulnerability measures

To understand differences in county characteristics across categories of overdose mortality, we primarily focused on components of the CDC's SVI data from 2018 (Centers for Disease Control & Prevention, 2021) The SVI is a validated measure (Centers for Disease Control & Prevention, 2021) that includes four components: (1) socioeconomic status (including measures of the poverty rate, unemployment rate, per capita income, and percent with less than a high school diploma); (2) household composition and disability (including measures of the percent aged 65 and older, the percent under age 18, the percent with a disability, and the percent of single parent households among households with children under age 18);

(3) minority status and language (including measures of percent minority and percent of individuals ages 5 and older who speak English “less than well); and (4) housing type and transportation (including measures of the percent of housing in structures with 10 or more units, the percent living in mobile homes, the percent of occupied housing with more people than rooms, the percent of households with no vehicle, and the percent of people living in group quarters). Each of the components, as well as the overall index, are constructed by the CDC. Each county is ranked according to each theme as well as an overall ranking of social vulnerability. The overall SVI takes a value between 0 and 1 with a value of 1 indicating a county with the highest social vulnerability. Finally, in sub-analyses we also accounted for the standard 9 Census regions (using the Census regions of New England, Mid-Atlantic, East North Central, West North Central, South Atlantic, East South Central, West South Central, Mountain, and Pacific with Table A3 defining which states are included in each region (US Census Bureau, 2021b)).

2.4. Statistical analysis

Analytically, we first used graphical analysis to map the four categories of counties within the US using a graphing approach described by Huber (Huber, 2020) and Naqvi. (Naqvi, 2021, 2023) This provides initial evidence of potential regional variation in the relative likelihood of each of the categories of opioid and psychostimulant overdose mortality. Second, we compared mean values of the component SVI values, and region across each of our 4 categories of overdose deaths. We used Kruskal-Wallis tests to test for statistically significant differences across counties.

Next, we used multivariate linear regression analysis to estimate the association between overall SVI and category of overdose mortality at the county level. For our primary analyses, we estimated three sets of these regressions. First, we estimated unadjusted versions that just included a measure of the overall SVI percentile (between 0 and 1). Second, we estimated versions of the regression that included region. To test the robustness of our results, we conducted sensitivity analyses. First, we re-estimated our results but weighted the regressions by the population of the county, in order to give counties with larger populations greater weight compared to the baseline analysis where each county was weighted equally. Second, we re-estimated our regressions using an indicator for whether the county had an above median SVI or not, as opposed to a continuous measure of SVI percentile. For all regressions, we limited our sample to counties that were in one of the 4 categories overdose mortality. Analyses were not pre-registered although we did hypothesize that counties with higher social vulnerability scores (i.e. more socially vulnerable) would have higher overdose mortality rates.

3. Results

Of the 3,106 counties in the data, 536 (17.3%) were low psychostimulant-low opioid mortality counties, 318 (10.2%) were high psychostimulant-high opioid mortality counties, 103 (3.3%) were high opioid-low psychostimulant counties, and 67 (2.2%) were high psychostimulant-low opioid counties. Figure 1 shows the geographic distribution of counties according to the 4 categories of opioid/psychostimulant overdose mortality. The map indicates a few regional patterns to highlight. First, there is a large swath through the middle of the country with low per capita overdose mortality (both opioid and psychostimulant) as shown by Figure 1. Second, we see concentrations of high psychostimulant-high opioid mortality in the East North Central, East South Central, and Mountain regions. Third, while few areas have low psychostimulant but high opioid overdose mortality, most of these counties are in the South Atlantic area. Finally, high psychostimulant but low opioid counties appear through the West North Central and West South Central regions as well as into the Mountain region.

Comparing characteristics of counties in each of the 4 overdose mortality categories we focus on several key results Table 1. First, the high psychostimulant-high opioid overdose mortality counties are relatively more likely to have non-elderly adults, single parent households, areas with housing structures of 10+ units, households with no vehicle, to be in metro areas (defined as a Rural-Urban Continuum Code of 1–3),(United States Department of Agriculture Economic Research Service, 2016) and to be in the East North Central, South Atlantic, East South Central, and Pacific regions but less likely to have a high proportion of racial and ethnic minorities. We observed relatively worse socioeconomic status in counties with high psychostimulant overdose deaths (both those with concomitantly high opioid mortality as well as counties with low high psychostimulant but low opioid overdose mortality).

Table 2 presents the regression results with several main findings. First, we observed that counties with higher SVI scores (i.e. higher social vulnerability) were more likely to be high opioid and high psychostimulant overdose mortality (i.e. high-high) as well as high psychostimulant but low opioid overdose mortality. For example, a 10-percentile increase in SVI score was associated with a 3.1 percentage point increase in the likelihood of being a high-high county ($p < 0.001$) in the unadjusted model and a 1.5 percentage point increase ($p < 0.05$) in the model that controlled for region. Conversely, counties with lower SVI scores were more likely to have low psychostimulant -low opioid overdose mortality as well as low psychostimulant but high opioid overdose mortality. We also found that relative to being in the New England region, counties in other regions were significantly more likely to have low psychostimulant and opioid mortality but significantly less likely to have low psychostimulant and high opioid overdose mortality. The only other regional differences were that the West North Central region was significantly more likely to have high psychostimulant and low opioid overdose mortality; while the East North Central was significantly more likely to have high psychostimulant -high opioid mortality.

The results of our sensitivity analysis are presented in Table A1 and Table A2. As Table A1 shows, in our population-weighted regressions we continued to observe greater SVI scores associated with a significantly higher likelihood of high psychostimulant and low opioid mortality, but not any other county-level mortality category. While we continued to observe a positive association between SVI score and high psychostimulant -high opioid mortality, the estimates were no longer statistically significant. Finally, we observed broadly similar estimates of the association with region with one main exception to highlight. When weighting by population, we observed significantly higher rates of high psychostimulant

-high opioid mortality for the South Atlantic, East South Central, Mountain, and Pacific regions relative to New England.

We also re-estimated each regression substituting an indicator for whether the county had an above median SVI score in place of the SVI percentile score. Table A2 presents these results. We generally found similar results—the signs of the coefficients for the SVI indicator in each regression are similar to those in Table 2, although the coefficients tended to be small in magnitude.

4. Discussion

As the nature of the overdose crisis continues to evolve, understanding the varying patterns of overdose mortality across the US is critical to tailoring clinical practice, public health resources, and health policy. Our findings provide several insights into county-level factors associated with psychostimulant and opioid mortality. First, consistent with our hypothesis, areas with higher social vulnerability (high SVI scores) were significantly more likely to be counties with both high psychostimulant and high opioid overdose mortality but also more likely to have high psychostimulant but low opioid mortality. The result highlights social vulnerabilities may be associated with greater psychostimulant overdose mortality even in counties with low opioid overdose mortality. This further indicates that treatment and public health approaches must facilitate ease of treatment access as areas with complex overdose patterns (i.e. high opioid and psychostimulant mortality) tended to be in counties with high social vulnerability. We found the opposite for high opioid but low psychostimulant mortality—this pattern appeared more likely in areas with lower social vulnerability. While SVI is clearly an important factor to identify areas of potentially higher substance-related overdose deaths, our results show the relationship is complex.

Our geographic results also show that high psychostimulant and high opioid overdose mortality is not limited to one or two regions, but has spread unevenly throughout the country. Historically, psychostimulant use and overdoses were concentrated in the West and Southwest, but this is no longer the case. While the opioid epidemic notably affected Appalachia and New England counties, (Rawson et al., 2019; Schalkoff et al., 2020) our results suggest a worrying pattern of higher rates of both psychostimulant and opioid overdoses in these areas, which may necessitate new policy or public health strategies. Our results indicate that areas with high psychostimulant-high opioid overdose mortality appear to be more likely to be experiencing social vulnerability suggesting efforts to address the polysubstance overdose crisis should also address social and structural factors associated with higher county-level overdose mortality rate.

We also note several limitations to the study. One is that while SVI is a validated measure of areas with greater social needs and is associated with a number of health outcomes, (Flanagan et al., 2018; Lehnert et al., 2020) the measure is not perfect as it relies on publicly available Census data so may miss other, more difficult to measure social vulnerabilities and structural barriers to treatment.(Lehnert et al., 2020) A couple of other studies have broadly examined the association between the SVI and overdoses (Frankenfeld & Leslie, 2019; Yedinak et al., 2021) but none have specifically examined the association between the

SVI and patterns of opioid and psychostimulant overdose mortality. Second, our analyses are at the county level so necessarily mask important individual-level variation. However, county is still an important level of analysis as state and federal funds often flow to county governments and health departments. Third, overdose mortality may be subject to under-reporting. (Ruhm, 2018). Fourth, our data are cross-sectional and so only represent a single point in time. Future analyses could examine how some of these patterns may change temporally.

5. Conclusions

As the US faces a rapidly changing overdose crisis, our results highlight that there is no single, common pattern of psychostimulant and opioid overdose mortality. Although there appears to be some evidence of regional patterns, this hides widespread pockets of high psychostimulant and opioid overdose mortality as well as significant regional heterogeneity in overdose mortality. We find that counties with psychostimulant overdose mortality occurs in states with high SVI, regardless of opioid mortality. Yet, counties with high opioid overdose mortality but low psychostimulant overdose mortality do not have high SVI scores. Critically, investment in social and economic policy, not just treatment, may be important in areas with high overdoses rates from multiple substances compared with areas where only opioid overdoses predominate. Thus, policymakers, providers, and public health officials need local data in order to tailor prevention and treatment efforts with a particular need to facilitate treatment for the socially vulnerable.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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References

Beletsky L, Davis CS, Anderson E, & Burris S (2008). The law (and politics) of safe injection facilities in the United States. American Journal of Public Health, 98(2), 231–237. 10.2105/AJPH.2006.103747 [PubMed: 18172151]

Brooklyn JR, & Sigmon SC (2017). Vermont hub-and-spoke model of care for opioid use disorder: development, implementation, and impact. Journal of Addiction Medicine, 11(4), 286–292. 10.1097/ADM.0000000000000310 [PubMed: 28379862]

Cano M, & Huang Y (2021). Overdose deaths involving psychostimulants with abuse potential, excluding cocaine: State-level differences and the role of opioids. Drug and Alcohol Dependence, 218, 108384. 10.1016/j.drugalcdep.2020.108384 [PubMed: 33158665]

Centers for Disease Control and Prevention. (2021). CDC/ATSDR SVI data and documentation download. https://www.atsdr.cdc.gov/placeandhealth/svi/data_documentation_download.html

Chan B, Freeman M, Kondo K, Ayers C, Montgomery J, Paynter R, & Kansagara D (2019). Pharmacotherapy for methamphetamine/amphetamine use disorder-a systematic review and meta-analysis. Addiction (Abingdon, England), 114(12), 2122–2136. 10.1111/add.14755 [PubMed: 31328345]

Clark AK, Wilder CM, & Winstanley EL (2014). A systematic review of community opioid overdose prevention and naloxone distribution programs. Journal of Addiction Medicine, 8(3), 153–163. 10.1097/ADM.0000000000000034 [PubMed: 24874759]

Commonwealth of Pennsylvania. (2017). Governor Wolf Announces $5 Million Funding for Naloxone to First Responders.

Compton WM, Valentino RJ, & DuPont RL (2021). Polysubstance use in the U.S. opioid crisis. Molecular Psychiatry, 26(1), 41–50. 10.1038/s41380-020-00949-3 [PubMed: 33188253]

Dasgupta N, Beletsky L, & Ciccarone D (2017). Opioid crisis: No easy fix to its social and economic determinants. American Journal of Public Health, 108(2), 182–186. 10.2105/AJPH.2017.304187 [PubMed: 29267060]

Ellis MS, Kasper ZA, & Cicero TJ (2018). Twin epidemics: The surging rise of methamphetamine use in chronic opioid users. Drug and Alcohol Dependence, 193, 14–20. 10.1016/j.drugalcdep.2018.08.029 [PubMed: 30326396]

Erfanian E, Collins AR, & Grossmam D (2018). The impact of naloxone access laws on opioid overdose deaths in the U.S (Working Paper 2018–03). https://ideas.repec.org/p/rri/wpaper/2018wp03.html

Flanagan BE, Hallisey EJ, Adams E, & Lavery A (2018). Measuring community vulnerability to natural and anthropogenic hazards: The centers for disease control and prevention's social vulnerability index. Journal of Environmental Health, 80(10), 34–36.

Frankenfeld CL, & Leslie TF (2019). County-level socioeconomic factors and residential racial, Hispanic, poverty, and unemployment segregation associated with drug overdose deaths in the United States, 2013–2017. Annals of Epidemiology, 35, 12–19. 10.1016/j.annepidem.2019.04.009 [PubMed: 31080000]

Haffajee RL, Lin LA, Bohnert ASB, & Goldstick JE (2019). Characteristics of US counties with high opioid overdose mortality and low capacity to deliver medications for opioid use disorder. JAMA Network Open, 2(6), e196373–e196373. 10.1001/jamanetworkopen.2019.6373 [PubMed: 31251376]

Haley DF, & Saitz R (2020). The opioid epidemic during the COVID-19 pandemic. JAMA, 324(16), 1615–1617. 10.1001/jama.2020.18543 [PubMed: 32945831]

Hall OT, Hall OE, Rood KM, McKiever ME, Teater J, & Senay A (2020). Pregnancy-associated mortality due to accidental drug overdose and suicide in Ohio, 2009–2018. Obstetrics & Gynecology, 136(4), 654–656. 10.1097/AOG.0000000000004066 [PubMed: 32925615]

Harris RE, Richardson J, Frasso R, & Anderson ED (2018). Perceptions about supervised injection facilities among people who inject drugs in Philadelphia. International Journal of Drug Policy, 52, 56–61. 10.1016/j.drugpo.2017.11.005 [PubMed: 29241143]

Hedegaard H, Miniño AM, & Warner M (2021). Co-involvement of opioids in drug overdose deaths involving cocaine and psychostimulants. NCHS Data Brief, (406), 1–8. https://pubmed.ncbi.nlm.nih.gov/33814035/

Heinzerling KG, Swanson A-N, Hall TM, Yi Y, Wu Y, & Shoptaw SJ (2014). Randomized, placebo-controlled trial of bupropion in methamphetamine-dependent participants with less than daily methamphetamine use. Addiction (Abingdon, England), 109(11), 1878–1886. 10.1111/add.12636 [PubMed: 24894963]

Hollingsworth A, Ruhm CJ, & Simon K (2017). Macroeconomic conditions and opioid abuse. Journal of Health Economics, 56, 222–233. 10.1016/j.jhealeco.2017.07.009 [PubMed: 29128677]

Huber C (2020). How to create choropleth maps using the COVID-19 data from Johns Hopkins University. https://blog.stata.com/2020/04/07/how-to-create-choropleth-maps-using-the-covid-19-data-from-johns-hopkins-university/

Jalal H, Buchanich JM, Roberts MS, Balmert LC, Zhang K, & Burke DS (2018). Changing dynamics of the drug overdose epidemic in the United States from 1979 through 2016. Science, 361(6408), eaau1184. 10.1126/science.aau1184 [PubMed: 30237320]

Kariisa M, Seth P, Scholl L, Wilson N, & Davis NL (2021). Drug overdose deaths involving cocaine and psychostimulants with abuse potential among racial and ethnic groups – United States, 2004–2019. Drug and Alcohol Dependence, 227, 109001. 10.1016/j.drugalcdep.2021.109001 [PubMed: 34492555]

Kazerouni NJ, Irwin AN, Levander XA, Geddes J, Johnston K, Gostanian CJ, Mayfield BS, Montgomery BT, Graalum DC, & Hartung DM (2021). Pharmacy-related buprenorphine access barriers: An audit of pharmacies in counties with a high opioid overdose burden. Drug and Alcohol Dependence, 224, 108729. 10.1016/j.drugalcdep.2021.108729 [PubMed: 33932744]

Khatri UG, Viner K, & Perrone J (2018). Lethal fentanyl and cocaine intoxication. New England Journal of Medicine, 379(18), 1782–1782. 10.1056/NEJMc1809521 [PubMed: 30380395]

Krieger MS, Goedel WC, Buxton JA, Lysyshyn M, Bernstein E, Sherman SG, Rich JD, Hadland SE, Green TC, & Marshall BD (2018). Use of rapid fentanyl test strips among young adults who use drugs. International Journal of Drug Policy, 61, 52–58. 10.1016/j.drugpo.2018.09.009 [PubMed: 30344005]

Krieger MS, Yedinak JL, Buxton JA, Lysyshyn M, Bernstein E, Rich JD, Green TC, Hadland SE, & Marshall BDL (2018). High willingness to use rapid fentanyl test strips among young adults who use drugs. Harm Reduction Journal, 15(1), 7. 10.1186/s12954-018-0213-2 [PubMed: 29422052]

Langabeer JR, Chambers KA, Cardenas-Turanzas M, & Champagne-Langabeer T (2020). County-level factors underlying opioid mortality in the United States. Substance Abuse, 43(1), 76–82. 10.1080/08897077.2020.1740379 [PubMed: 32186475]

Lehnert EA, Wilt G, Flanagan B, & Hallisey E (2020). Spatial exploration of the CDC's Social Vulnerability Index and heat-related health outcomes in Georgia. International Journal of Disaster Risk Reduction, 46, 101517. 10.1016/j.ijdrr.2020.101517

Mason M, Welch SB, Arunkumar P, Post LA, & Feinglass JM (2021). Notes from the field: Opioid overdose deaths before, during, and after an 11-week COVID-19 stay-at-home order—cook county, Illinois, January 1, 2018–October 6, 2020. Morbidity and Mortality Weekly Report, 70(10), 362–363. 10.15585/mmwr.mm7010a3 [PubMed: 33705372]

Miele GM, Caton L, Freese TE, McGovern M, Darfler K, Antonini VP, Perez M, & Rawson R (2020). Implementation of the hub and spoke model for opioid use disorders in California: Rationale, design and anticipated impact. Journal of Substance Abuse Treatment, 108, 20–25. 10.1016/j.jsat.2019.07.013 [PubMed: 31399272]

Mohlman MK, Tanzman B, Finison K, Pinette M, & Jones C (2016). Impact of medication-assisted treatment for opioid addiction on medicaid expenditures and health services utilization rates in Vermont. Journal of Substance Abuse Treatment, 67, 9–14. 10.1016/j.jsat.2016.05.002 [PubMed: 27296656]

Monnat SM, Peters DJ, Berg MT, & Hochstetler A (2019). Using census data to understand county-level differences in overall drug mortality and opioid-related mortality by opioid type. American Journal of Public Health, 109(8), 1084–1091. 10.2105/AJPH.2019.305136 [PubMed: 31219718]

Naqvi A (2021). Stata graphs: Bi-variate maps. https://medium.com/the-stata-guide/stata-graphs-bi-variate-maps-b1e96dd4c2be

Naqvi A (2023). Bimap: Stata module to produce bivariate maps. https://econpapers.repec.org/software/bocbocode/S459063.htm

National Center for Health Statistics. (2020). 1989–2018 Detailed Mortality – All Counties, as compiled from data provided by the 57 vital statistics jurisdictions through the Vital Statistics Cooperative Program.

Paulus MP, & Stewart JL (2020). Neurobiology, clinical presentation, and treatment of methamphetamine use disorder: A review. JAMA Psychiatry, 77(9), 959–966. 10.1001/jamapsychiatry.2020.0246 [PubMed: 32267484]

Peiper NC, Clarke SD, Vincent LB, Ciccarone D, Kral AH, & Zibbell JE (2019). Fentanyl test strips as an opioid overdose prevention strategy: Findings from a syringe services program in the Southeastern United States. International Journal of Drug Policy, 63, 122–128. 10.1016/j.drugpo.2018.08.007 [PubMed: 30292493]

Pennsylvania Department of Health. (2020). Wolf administration announces latest PacMAT grant recipients to help fight the opioid addiction epidemic. https://www.media.pa.gov/Pages/Health-Details.aspx?newsid=921

Rawson RA, Rieckmann T, Cousins S, McCann M, & Pearce R (2019). Patient perceptions of treatment with medication treatment for opioid use disorder (MOUD) in the Vermont hub-and-spoke system. Preventive Medicine, 128, 105785. 10.1016/j.ypmed.2019.105785 [PubMed: 31362002]

Reif S, Brolin MF, Stewart MT, Fuchs TJ, Speaker E, & Mazel SB (2020). The Washington State Hub and Spoke Model to increase access to medication treatment for opioid use disorders. Journal of Substance Abuse Treatment, 108, 33–39. 10.1016/j.jsat.2019.07.007 [PubMed: 31358328]

Ruhm CJ (2017). Geographic variation in opioid and heroin involved drug poisoning mortality rates. American Journal of Preventive Medicine, 53(6), 745–753. 10.1016/j.amepre.2017.06.009 [PubMed: 28797652]

Ruhm CJ (2018). Corrected US opioid-involved drug poisoning deaths and mortality rates, 1999–2015. Addiction (Abingdon, England), 113(7), 1339–1344. 10.1111/add.14144 [PubMed: 29430760]

Saloner B, Whitley P, LaRue L, Dawson E, & Huskey A (2021). Polysubstance use among patients treated with buprenorphine from a national urine drug test database. JAMA Network Open, 4(9), e2123019. 10.1001/jamanetworkopen.2021.23019 [PubMed: 34505888]

Schalkoff CA, Lancaster KE, Gaynes BN, Wang V, Pence BW, Miller WC, & Go VF (2020). The opioid and related drug epidemics in rural Appalachia: A systematic review of populations affected, risk factors, and infectious diseases. Substance Abuse, 41(1), 35–69. 10.1080/08897077.2019.1635555 [PubMed: 31403903]

Segel JE, & Winkelman TNA (2021). Persistence and Pervasiveness: Early Wave Opioid Overdose Death Rates Associated With Subsequent Overdose Death Rates. Public Health Reports, 136(2), 212–218. 10.1177/0033354920969171 [PubMed: 33301695]

Shearer RD, Shippee ND, & Winkelman TNA (2021). Characterizing trends in methamphetamine-related health care use when there is no ICD code for “methamphetamine use disorder”. Journal of Substance Abuse Treatment, 127, 108369. 10.1016/j.jsat.2021.108369 [PubMed: 34134872]

Trivedi MH, Walker R, Ling W, Dela Cruz A, Sharma G, Carmody T, Ghitza UE, Wahle A, Kim M, Shores-Wilson K, Sparenborg S, Coffin P, Schmitz J, Wiest K, Bart G, Sonne SC, Wakhlu S, Rush AJ, Nunes EV, & Shoptaw S (2021). Bupropion and naltrexone in methamphetamine use disorder. New England Journal of Medicine, 384(2), 140–153. 10.1056/NEJMoa2020214 [PubMed: 33497547]

Twillman RK, Dawson E, LaRue L, Guevara MG, Whitley P, & Huskey A (2020). Evaluation of trends of near-real-time urine drug test results for methamphetamine, cocaine, heroin, and fentanyl. JAMA vNetwork Open, 3(1), e1918514–e1918514. 10.1001/jamanetworkopen.2019.18514

United States Department of Agriculture Economic Research Service. (2016). Rural-urban continuum codes. http://www.ers.usda.gov/data-products/rural-urban-continuum-codes

US Census Bureau. (2021a). Annual county population estimates 2010–2020. https://www2.census.gov/programs-surveys/popest/datasets/2010-2020/counties/totals/

US Census Bureau. (2021b). Census regions and divisions of the United States. https://www2.census.gov/geo/pdfs/maps-data/maps/reference/us_regdiv.pdf

Volkow ND, Frieden TR, Hyde PS, & Cha SS (2014). Medication-assisted therapies–tackling the opioid-overdose epidemic. New England Journal of Medicine, 370(22), 2063–2066. 10.1056/NEJMp1402780 [PubMed: 24758595]

Wilson N, Kariisa M, Seth P, Smith H, & Davis NL (2020). Drug and opioid-involved overdose deaths - United States, 2017–2018. Morbidity and Mortality Weekly Report, 69(11), 290–297. 10.15585/mmwr.mm6911a4 [PubMed: 32191688]

Winkelman TNA, Admon LK, Jennings L, Shippee ND, Richardson CR, & Bart G (2018). Evaluation of amphetamine-related hospitalizations and associated clinical outcomes and costs in the United States. JAMA Network Open, 1(6), e183758–e183758. 10.1001/jamanetworkopen.2018.3758 [PubMed: 30646256]

Winograd RP, Wood CA, Stringfellow EJ, Presnall N, Duello A, Horn P, & Rudder T (2020). Implementation and evaluation of Missouri’s Medication First treatment approach for opioid use disorder in publicly-funded substance use treatment programs. Journal of Substance Abuse Treatment, 108, 55–64. 10.1016/j.jsat.2019.06.015 [PubMed: 31277891]

Winstanley EL, Lander LR, Berry JH, Mahoney JJ III, Zheng W, Herschler J, Marshalek P, Sayres S, Mason J, & Haut MW (2020). West Virginia's model of buprenorphine expansion: Preliminary results. Journal of Substance Abuse Treatment, 108, 40–47. 10.1016/j.jsat.2019.05.005 [PubMed: 31221524]

Wolf T (2019). Pennsylvania's use of federal funding to address the opioid epidemic. https://www.congress.gov/116/meeting/house/110367/documents/HHRG-116-IF02-20200114-SD022.pdf

Yedinak JL, Li Y, Krieger MS, Howe K, Ndoye CD, Lee H, Civitarese AM, Marak T, Nelson E, Samuels EA, Chan PA, Bertrand T, & Marshall BD (2021). Machine learning takes a village: Assessing neighbourhood-level vulnerability for an overdose and infectious disease outbreak. International Journal of Drug Policy, 96, 103395. 10.1016/j.drugpo.2021.103395 [PubMed: 34344539]

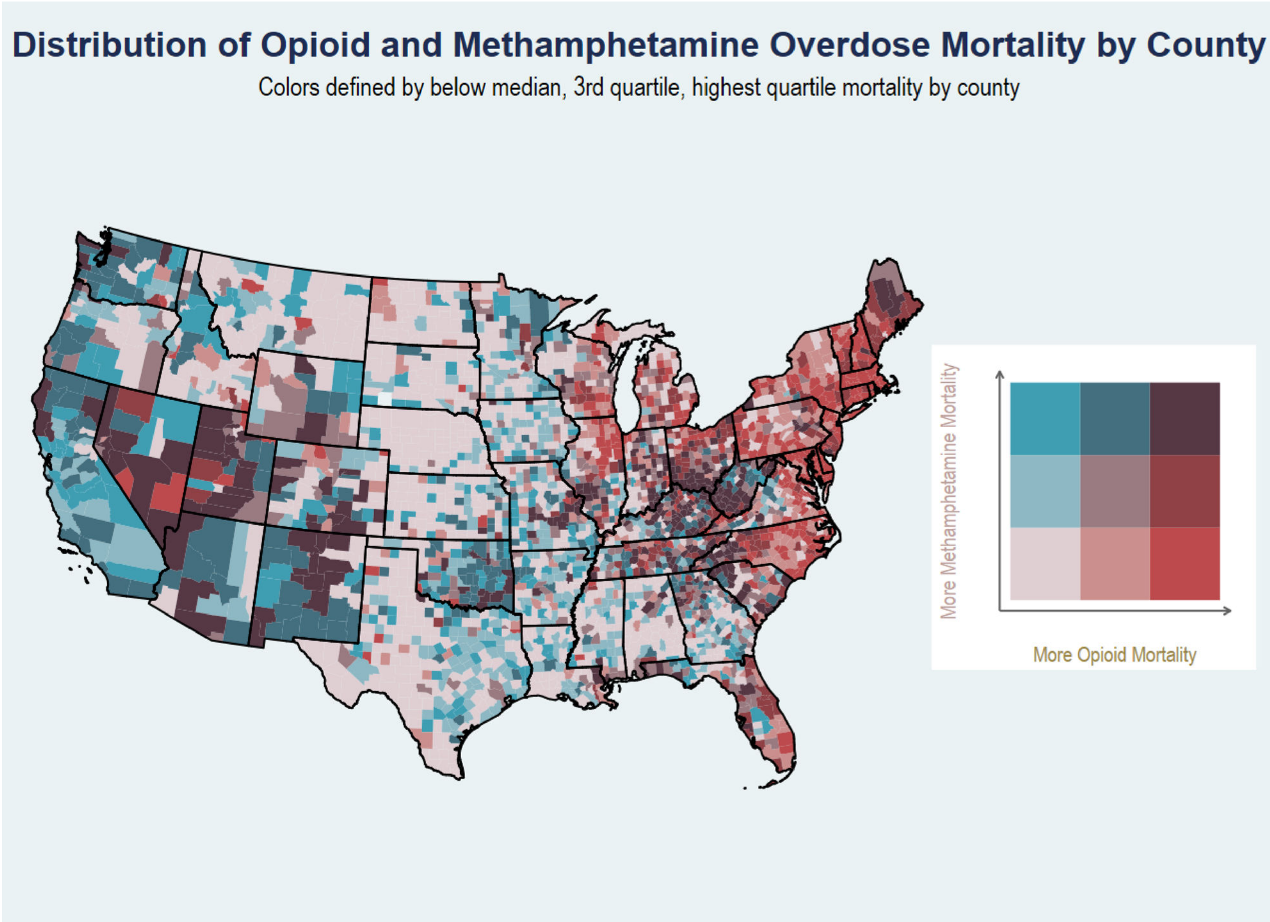

Figure 1.
County-level map of opioid and psychostimulant quartiles of overdose mortality between 2016 and 2018.

Table 1.

Comparison of county characteristics by quartile of opioid and psychostimulant mortality.

	Low (Q1) Psychostimulant Low (Q1) Opioid (n = 536 counties)	Low (Q1) Psychostimulant High (Q4) Opioid (n = 103 counties)	High (Q4) Psychostimulant Low (Q1) Opioid (n =67 counties)	High (Q4) Psychostimulant High (Q4) Opioid (n = 318 counties)	p-value (Kruskal-Wallis test)
% below poverty [AP]	45.4% (31.6)	46.0% (27.8)	58.2% (28.7)	58.2% (24.5)	<0.001
Unemployment rate (age 16+ work force) [AP]	37.4% (34.0)	50.8% (29.2)	46.0% (35.6)	59.0% (23.9)	<0.001
Per capita income [AP]	52.0% (28.9)	48.4% (28.1)	63.2% (27.2)	56.7% (25.0)	<0.001
% <HS diploma (age 25+) [AP]	47.9% (32.4)	48.8% (28.0)	60.8% (30.8)	55.6% (23.7)	<0.001
% age 65 + [AP]	64.0% (28.4)	61.3% (27.6)	56.9% (27.7)	48.8% (25.5)	<0.001
% age <18 [AP]	50.5% (29.8)	38.2% (29.4)	52.2% (30.0)	46.3% (25.7)	<0.001
% with disability [AP]	50.9% (29.0)	53.6% (28.4)	56.0% (28.1)	61.3% (27.5)	<0.001
% single parent households with children <18 [AP]	38.2% (32.4)	44.5% (30.9)	48.7% (28.3)	52.2% (24.7)	<0.001
% minority (i.e. all except NH White) [AP]	44.1% (32.6)	47.0% (28.2)	55.5% (28.8)	42.0% (27.4)	0.008
% age 5+ who speak English “less than well” [AP]	38.3% (32.7)	43.7% (26.8)	46.2% (34.8)	44.7% (28.8)	0.003
% of housing in structures with 10+ units [AP]	33.3% (25.7)	39.2% (27.8)	27.7% (23.4)	51.5% (28.5)	<0.001
% mobile homes [AP]	52.2% (27.1)	49.9% (31.2)	62.6% (26.7)	54.7% (28.4)	0.013
% of occupied housing units with more people than rooms [AP]	41.0% (33.0)	41.3% (28.9)	55.1% (33.8)	49.3% (24.6)	<0.001
% households with no vehicle [AP]	38.7% (31.1)	50.5% (30.6)	44.3% (32.7)	56.4% (26.2)	<0.001
% of person in group quarters [AP]	45.8% (30.6)	48.6% (30.7)	58.4% (30.3)	46.3% (26.9)	0.011
Region - New England (CT ME MA NH RI VT)	0.0% (0.0)	8.7% (28.4)	0.0% (0.0)	0.9% (9.7)	<0.001
Region - Mid-Atlantic (NJ NY PA)	1.1% (10.5)	7.8% (26.9)	0.0% (0.0)	2.2% (14.7)	<0.001
Region - East North Central (IL IN MI OH WI)	7.1% (25.7)	17.5% (38.2)	1.5% (12.2)	20.1% (40.2)	<0.001
Region - West North Central (IA KS MN MO NE ND SD)	45.5% (49.8)	3.9% (19.4)	35.8% (48.3)	5.7% (23.1)	<0.001
Region - South Atlantic (DE DC FL GA MD NC SC VA WV)	4.7% (21.1)	36.9% (48.5)	9.0% (28.8)	24.8% (43.3)	<0.001
Region - East South Central (AL KY MS TN)	9.5% (29.4)	8.7% (28.4)	6.0% (23.9)	22.0% (41.5)	<0.001
Region - West South Central (AR LA OK TX)	20.5% (40.4)	5.8% (23.5)	26.9% (44.7)	5.3% (22.5)	<0.001
Region - Mountain (AZ CO ID MT NV NM UT WY)	10.4% (30.6)	9.7% (29.8)	17.9% (38.6)	15.4% (36.2)	0.069
Region - Pacific (AK CA HI OR WA)	1.1% (10.5)	1.0% (9.9)	3.0% (17.1)	3.5% (18.3)	0.085894

	Low (Q1) Psychostimulant Low (Q1) Opioid (n = 536 counties)	Low (Q1) Psychostimulant High (Q4) Opioid (n = 103 counties)	High (Q4) Psychostimulant Low (Q1) Opioid (n =67 counties)	High (Q4) Psychostimulant High (Q4) Opioid (n = 318 counties)	p-value (Kruskal-Wallis test)
Metro (RUCC 1–3)	10.4% (30.6)	35.0% (47.9)	6.0% (23.9)	44.7% (49.8)	<0.001
Non-metro (RUCC 4–9)	89.6% (30.6)	65.0% (47.9)	94.0% (23.9)	55.3% (49.8)	<0.001

Abbreviations: Q1 (quartile 1 or lowest quartile); Q4 (quartile 4 or highest quartile); HS (high school); NH White (non-Hispanic White); RUCC (Rural Urban Continuum Codes); also postal abbreviation for US states; AP (Average percentile – note this is the average county-level percentile of each SVI measure).

Table 2.

Rearession-based estimates of the association between SVI and quartile of opioid and psychostimulant overdose mortality.

	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
	[1] Low (Q1) Psychostimulant, Low (Q1) Opioid county		[2] Low (Q1) Psychostimulant, High (Q4) Opioid county		[3] High (Q4) Psychostimulant, Low (Q1) Opioid county		[4] High (Q4) Psychostimulant, High (Q4) Opioid county	
SVI score	−0.362 ***	−0.161 **	−0.02	−0.105 **	0.071 *	0.118 ***	0.311 ***	0.149 **
Region - New England		REF		REF		REF		REF
Region - Mid-Atlantic		0.304 **		−0.357 *		−0.014		0.066
Region - East North Central		0.333 ***		−0.589 ***		−0.006		0.261 *
Region - West North central		0.834 ***		−0.741 ***		0.088 ***		−0.181
Region - South Atlantic		0.225 ***		−0.457 ***		<0.001		0.232
Region - East South central		0.445 ***		−0.641 ***		−0.017		0.213
Region - West South central		0.793 ***		−0.668 ***		0.072 *		−0.197
Region - Mountain		0.465 ***		−0.656 ***		0.077 **		0.114
Region - Pacific		0.343 ***		−0.672 ***		0.068		0.26
n = 1,024 counties								

* $p < 0.05$

** $p < 0.01$

*** $p < 0.001$.

Abbreviations: SVI (Social Vulnerability index).

Models [1], [2], [3], [4] estimated separately.