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Geographically specific associations between county-level socioeconomic and household distress and mortality from drug poisoning, suicide, alcohol, and homicide among working-age adults in the United States

Xue Zhang [a,c,*], Shannon M. Monnat [a,b,c]

[a] Lerner Center for Public Health Promotion and Population Health, Syracuse University, NY, 13244, USA
[b] Department of Sociology, Syracuse University, NY, 13244, USA
[c] Center for Policy Research, Syracuse University, NY, 13244, USA

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ABSTRACT

Background: Mortality rates from drug poisoning, suicide, alcohol, and homicide vary significantly across the United States. This study explores localized relationships (i.e., geographically specific associations) between county-level economic and household distress and mortality rates from these causes among working-age adults (25–64).

Methods: Mortality data were from the National Vital Statistics System for 2014–2019. County-level socioeconomic distress (poverty, employment, income, education, disability, insurance) and household distress (single-parent, no vehicle, crowded housing, renter occupied) were from the 2009–2013 American Community Survey. We conducted Ordinary Least Squares (OLS) regression to estimate average associations and Geographically Weighted Regression (GWR) to estimate localized spatial associations between county-level distress and working-age mortality.

Results: In terms of national average associations, OLS results indicate that a one standard deviation increase in socioeconomic distress was associated with an average of 6.1 additional drug poisoning deaths, 3.0 suicides, 2.1 alcohol-induced deaths, and 2.0 homicides per 100,000 population. A one standard deviation increase in household distress was associated with an average of 1.4 additional drug poisonings, 4.7 alcohol-induced deaths, and 1.1 homicides per 100,000 population. However, the GWR results showed that these associations vary substantially across the U.S., with socioeconomic and household distress associated with significantly higher mortality rates in some parts of the U.S than others, significantly lower rates in other parts of the U.S., and no significant associations in others. There were also some areas where distress overlapped to influence multiple causes of death, in a type of compounded disadvantage.

Conclusions: Socioeconomic and household distress are significant and substantial predictors of higher rates of drug poisoning mortality, suicide, alcohol-induced deaths, and homicide in specific regions of the U.S. However, these associations are not universal. Understanding the place-level factors that contribute to them can inform geographically tailored strategies to reduce rates from these preventable causes of death in different places.

1. Introduction

Drug poisonings, suicides, alcohol-induced deaths, and homicides are among the top external causes of mortality among working-age adults (ages 25–64) in the United States (U.S.) (Feldmeyer et al., 2022; Woolf & Schoomaker, 2019). They are also among the leading drivers of increases in overall mortality rates in this age group and the U. S.'s divergence in life expectancy from other high-income countries over the past three decades (National Academies of Sciences, Engineering, and Medicine, 2021). Among the most striking features of mortality from these causes is their unequal geographic distribution, with much higher rates in some parts of the country than in others (National Academies of Sciences, Engineering, and Medicine, 2021; Rossen, Khan, & Warner, 2014; Vierboom, Preston, & Hendi, 2019). Mortality rates from drug poisoning are disproportionately high in Appalachia, New England, the Industrial Midwest, and parts of the Southwest and

* Corresponding author. 426 Eggers Hall, Syracuse University, NY, 13244, USA.
E-mail addresses: xzhan315@syr.edu (X. Zhang), smmonnat@syr.edu (S.M. Monnat).

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Mountain West (Monnat, 2022; National Academies of Sciences, Engineering, and Medicine, 2021). High suicide and alcohol-induced death rates are clustered in the West (Keyes et al., 2023; National Academies of; Sciences, Engineering, and Medicine, 2021; Shiels et al., 2020), and high homicide rates are observed in the South (Amin, Yang, & Lynch, 2021). Explaining these large geographic disparities is critical to identifying strategies to reduce them.

Extensive research has implicated various markers of place-level socioeconomic and housing distress (or vulnerability) as risk factors for drug overdose, suicide, alcohol-induced deaths, and homicide. Higher rates of poverty, unemployment, income, disability, and low education have been shown to be associated with higher rates of one or more of these causes of death (Blake-Gonzalez, Cebula, & Koch, 2021; Carriere, Marshall, & Binkley, 2019; Case & Deaton, 2020; Feldmeyer et al., 2022; Fishman & Gutin, 2021; Graetz & Elo, 2022; Graetz, Preston, Peele, & Elo, 2020; Kerr et al., 2017; Lee, Wheeler, Zimmerman, Hines, & Chapman, 2023; Mobley & Taasoobshirazi, 2022; Monnat, 2018, 2019; Peters, Monnat, Hochstetler, & Berg, 2020; Piza, Wolff, Hatten, & Barthuly, 2023; Van Draanen, Tsang, Mitra, Karamouzian, & Richardson, 2020). Related markers of household instability or deprivation, such as percent female-headed households, household crowding, lack of access to transportation, and rental housing have also been shown to be associated with increased risk of these causes of death (Altekruse, Cosgrove, Altekruse, Jenkins, & Blanco, 2020; Bjorklund, 2023; Bradford & Bradford, 2020; Drake, Lemke, & Yang, 2022; Frankenfeld & Leslie, 2019; George et al., 2021; Gove, Hughes, & Galle, 1979; Graetz & Elo, 2022; Kerr et al., 2017; Wenz, 1984).

These relationships between socioeconomic and household resources and “fatal social problems” (Feldmeyer et al., 2022) can be understood within the context of fundamental cause theory (FTC) (Phelan, Link, & Tehranifar, 2010). FTC argues that higher socioeconomic status (e.g., income, education) facilitates access to knowledge, connections, safety, opportunities, and material resources (e.g., health insurance, quality housing, access to transportation), that reduce the likelihood of engaging in harmful health behaviors and becoming entangled in contexts that increase risk for fatal social problems. It stands to reason then, that *places* with larger relative shares of disadvantaged populations would have higher rates of mortality from these causes. Indeed, a place’s mortality rate is an emergent property of both the composition of populations and the place’s contextual characteristics.

The communities of distress and landscapes of despair frameworks lend support to the idea that socioeconomic and household vulnerabilities could manifest into fatal social problems (Feldmeyer et al., 2022; Monnat & Brown, 2017). Research demonstrates that concentrated place-level socioeconomic and household disadvantage and deprivation can contribute to collective frustration and hopelessness, community disinvestment, infrastructural decay, lower tax bases to provide necessary health-promoting services, crime, and substance misuse (McLean, 2016; Sampson & Groves, 2017). Within this framework, Case and Deaton (2015, 2017) suggested that increases in drug, alcohol, and suicide mortality rates may be connected to distressed socioeconomic conditions and subsequent hopelessness and despair. Others expanded this idea to argue that geographic, not just temporal trends, may be connected to these same social forces (Graham, Pinto, & Juneau, 2017; Monnat, 2018, 2019). Over 40 years ago, Rose (1978) likewise connected spatial differences in homicide rates to “geographies of despair”.

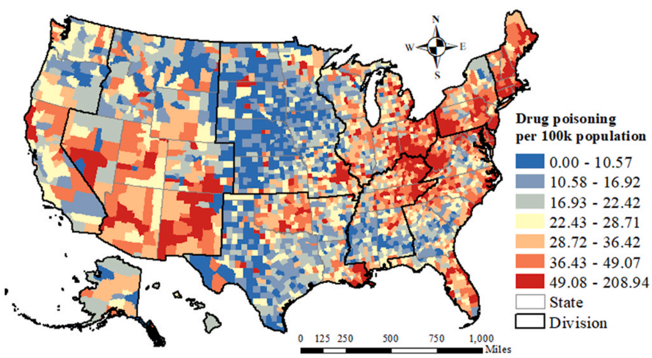
However, it is unclear whether the relationships between place-level socioeconomic and household distress and mortality rates are constant across space or if socioeconomic and household distress are more important contributors to mortality in some regions (or “spatial regimes”) than in others. Indeed, there may be spatial heterogeneity in the relationship between place-level distress and mortality rates (Yang, Delamater, Leslie, & Mello, 2016). The subnational spatial inequality framework (Lobao, Hooks, & Tickamyer, 2007) offers support for the idea that place-level distress may manifest differently in different places. This framework situates the social processes of mortality risk within their spatial contexts by emphasizing the importance of shared place-level attributes in how social processes and the inequities that follow unfold differently across the U.S. Both where individuals are located within geographic space (i.e., the spatially unequal distribution of vulnerable or at-risk groups [composition]) and structural factors within geographic space (context) are important to how inequalities emerge and operate (Burton, Lichter, Baker, & Eason, 2013; Lobao, 2004). The socioeconomic and household distress factors that may contribute to these four fatal social problems result from long processes of geographically uneven development, industrial restructuring, residential segregation, and policy regimes that eroded economic and family stability and mobility (especially for those without a four-year college degree). These changes have been inherently spatial, leading to social disorganization in many places in the U.S. Structural features of communities, such as policies, availability of drugs and guns, and access to social capital promoting institutions (to name a few) could either exacerbate or buffer against the adverse effects of socioeconomic and household distress on fatal social problems. Therefore, relationships between socioeconomic and household distress and mortality rates may be inconsistent across the U.S.

While research has not yet examined localized relationships between place-level distress and drug, alcohol, suicide, and homicide mortality rates in the U.S. overall, several empirical studies offer support for the spatial heterogeneity hypothesis. For example, studies of drug overdoses in specific regions, states, or cities using geographically-weighted regression (GWR) approaches have found that the associations between various place-level exposures and drug mortality rates varied over

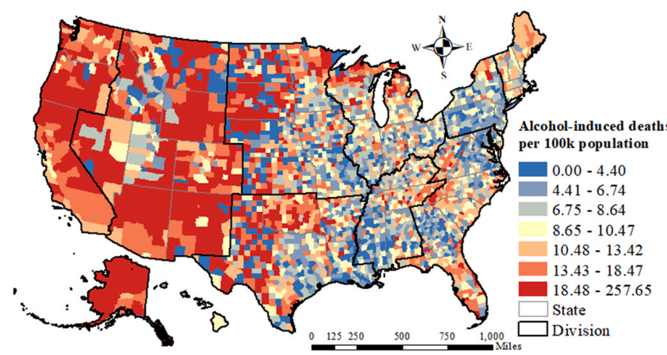
Table 1
Results from factor analysis: social vulnerability and household vulnerability.

	Socioeconomic vulnerability
Percentage of persons living in poverty	0.84
Percentage of civilian population (age 16+) in labor force who are unemployed	0.66
Per capita income	−0.89
Percentage of persons with a less than a four-year college (age 25+)	0.77
Percentage of the civilian noninstitutionalized population with a disability	0.76
Percentage of persons aged 18–64 without health insurance	0.72
Cronbach alpha	0.86
	Household vulnerability
Percentage of single-parent households with own children under age 18	0.75
Percentage of occupied housing units with no vehicle available	0.79
Percentage of occupied housing units with more occupants than number of rooms	0.73
Percentage of renter occupied housing units	0.71
Cronbach alpha	0.74

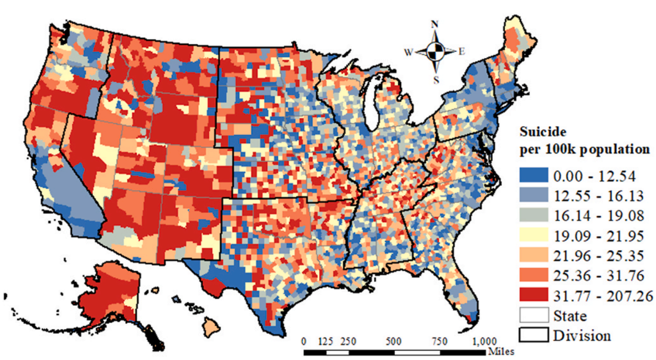
Note: Factor loading after varimax rotation.
Data source: American Community Survey, 2009–2013



N=3,142, Mean=29.4, Std. dev.=20.9, Min=0, Max=208.9
Fig. 1A. County-level drug poisoning mortality rates (deaths per 100,000 population), 2014-19
Note: Mortality rates are age adjusted



N=3,142, Mean=12.2, Std. dev.=14.1, Min=0, Max=257.7
Fig. 1C. County-level alcohol-induced mortality rates (deaths per 100,000 population), 2014-19
Note: Mortality rates are age adjusted



N=3,142, Mean=22.3, Std. dev.=12.8, Min=0, Max=207.3
Fig. 1B. County-level suicide rates (deaths per 100,000 population), 2014-19
Note: Mortality rates are age adjusted

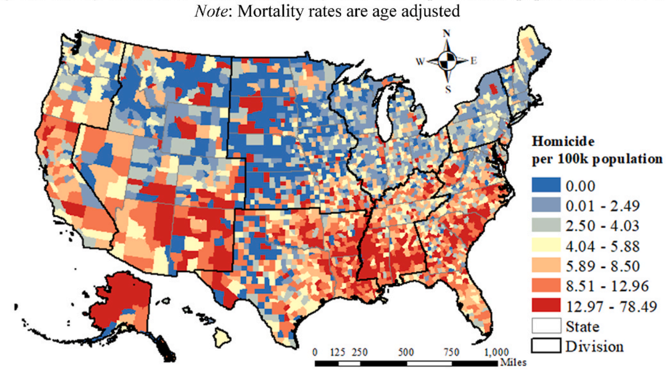


Fig.1D. County-level homicide rates (deaths per 100,000 population), 2014-19
N=3,142, Mean=6.7, Std. dev.=7.6, Min=0, Max=78.5
Note: Mortality rates are age adjusted

Fig. 1. County-level mortality rates from drug poisoning, suicide, alcohol-induced death, and homicide among U.S. working age adults (ages 25–64).
Note: Quantiles method with 7 categories in ArcGIS are used to categorize mortality rate from each cause of deaths.
Data source: National Vital Statistics System, 2014–2019

space (Kerry, Goovaerts, Vowles, & Ingram, 2016; Meng, 2023; Nesoff, Branas, & Martins, 2020; Pustz, Srinivasan, Larochelle, Walley, & Stopka, 2022). A national study of suicide using GWR found that county-level income inequality was not associated with suicide nationally, but was in specific regions of the country (Tran & Morrison, 2020).

In this study, we build on the existing research on drug poisoning mortality, suicide, alcohol-induced deaths, and homicide by identifying geographic differences in the relationships between place-level socioeconomic and household distress and these four causes of death among working-age adults, determining for which causes of death and specific spatial locations these factors matter most.

2. Methods

2.1. Data

The unit of analysis was the county (N = 3142). Counties are the smallest geographic unit for which mortality data are available for the entire nation (city-level rates are available only for metropolitan areas). Counties are also important administrative units that enact policies and deliver services that can affect health and mortality. We linked data across sources using county FIPS codes.

The outcomes were age-adjusted county-level mortality rates from drug poisoning, suicide, alcohol-induced deaths, and homicide for adults ages 25 to 64 from 2014 to 2019. We focused on working-age adults given the disproportionate contribution of these causes of death to their overall mortality rates and recent declines in life expectancy. We defined working age as 25–64, consistent with a recent consensus committee report on high and rising mortality rates among working-age adults produced by the National Academies of Sciences, Engineering, and Medicine (2021). The study period of 2014–2019 enabled us to 1) examine geographic variation in working-age adult mortality during a period when U.S. life expectancy declined (Woolf & Schoomaker, 2019), and 2) avoid large fluctuations that may be related to the COVID-19 pandemic (examining changes in these causes of death during the pandemic was beyond the scope of this study). We pooled deaths across the six-year period to avoid large fluctuations that can occur with annual rates in small population counties. We selected these four causes of death because they are among the causes of death that have increased the most among working-age adults in the U.S. over the past two decades (author calculations using data from CDC WONDER) and because of their contributions to rising working-age adult mortality rates.

Mortality data came from the restricted death certificate files of the National Vital Statistics System (NVSS). We extracted death counts for decedents ages 25–64 by county using the International Classification of Diseases, 10th Revision (ICD-10) codes for drug poisoning (X40-X44, X60-X64, X85, Y10–Y14); suicide (X66-X84, Y87); alcohol-induced deaths (E24.4, G31.2, G62.1, G72.1, I42.6, K70, R78.0, X45, X65, Y15); and homicide (X86-Y09, Y87.1). Consistent with other studies, we included suicides and homicides involving drug poisoning in the drug poisoning count (Elo, Hendi, Ho, Vierboom, & Preston, 2019; Monnat, 2020; National Academies of Sciences, Engineering, and Medicine, 2021). We computed age-adjusted mortality rates (deaths per 100,000 population) for each county using 10-year age intervals. County population counts came from the U.S. Centers for Disease Control and Prevention (CDC) bridged-race population estimates (U.S. Centers for Disease Control and Prevention & National Center for Health Statistics).

County-level predictors of distress (or vulnerability) came from the American Community Survey, 2009–13 to allow for a one-year lag for the association between exposures and mortality (but we note that the values for these predictors change very little from one year to the next given that the ACS is based on a rolling 5-year data collection). We selected our vulnerability measures based on the conceptual frameworks and literature we cited in the Introduction.[1] Each of the measures below has been found to be associated with county-level variation in one or more of the four causes of death we consider (Altekruse et al., 2020; Bjorklund, 2023; Blake-Gonzalez et al., 2021; Bradford & Bradford, 2020; Carriere et al., 2019; Case & Deaton, 2020; Drake et al., 2022; Feldmeyer et al., 2022; Fishman & Gutin, 2021; Frankenfeld & Leslie, 2019; George et al., 2021; Gove et al., 1979; Graetz & Elo, 2022; Graetz et al., 2020; Kerr et al., 2017; Lee et al., 2023; Mobley & Taasoobshirazi, 2022; Monnat, 2018, 2019; Peters et al., 2020; Piza et al., 2023; Van Draanen et al., 2020; Wenz, 1984). Collectively, these measures of socioeconomic and household vulnerability represent concentrated disadvantage and instability that can contribute to material deprivation, unsafe living conditions, insufficient access to health care, frustration and hopelessness, and exposure to contexts that increase risk for fatal social problems (Case & Deaton, 2020; Feldmeyer et al., 2022; McLean, 2016; Sampson & Groves, 2017).

Socioeconomic vulnerability is represented by an index that includes the percentage of individuals living in poverty, the percentage of the civilian population ages 16+ in the labor force who are unemployed, per capita income (reverse coded), the percentage of individuals ages 25+ without a four-year degree, the percentage of the civilian noninstitutionalized population with a disability, and the percentage of individuals aged 18–64 without health insurance. We created an index using the factor scores for these variables (alpha = 0.86).

Household vulnerability is represented by an index that includes the percentage of single-parent households with children under age 18, the percentage of occupied housing units without access to a vehicle, the percentage of occupied housing units with more occupants than rooms, and the percentage of renter-occupied housing units (alpha = 0.74).

Factor loadings for variables in both indices are shown in Table 1. Maps illustrating the geographic distribution of these two social vulnerabilities are shown in Appendix A. Socioeconomic vulnerability is highest throughout Appalachia, the Southern U.S., the desert Southwest, counties with American Indian reservations, parts of the West, and parts of Alaska. Household vulnerability is highest throughout the historical Black Belt, U.S.-Mexico border colonias, much of the Pacific, and Alaska.

Given significant county-level racial/ethnic composition differences in rates from these four causes (Amin et al., 2021; Lee et al., 2023; Monnat, Peters, Berg, & Hochstetler, 2019), we controlled for county percent non-Hispanic Black and percent Hispanic. We also attempted controlling for percent American Indian/Alaska Native. However, it was highly correlated with the socioeconomic vulnerability index, and including it in the models introduced severe multicollinearity. Given metropolitan status differences in all four causes of death (Monnat et al., 2019; National Academies of Sciences, Engineering, and Medicine, 2021), we controlled for metropolitan status using the USDA Economic Research Service's (ERS) 2013 Rural-Urban Continuum Codes (RUCC) (USDA Economic Research Service, 2020). We classified counties with RUCCs 1–3 as metropolitan (reference group) and counties with RUCCs 4–9 as nonmetropolitan (63% of counties). We conducted sensitivity analyses using alternative specifications for metropolitan status, including the full nine-category USDA ERS RUCC and the five-category Urban-Rural Classification Schema from the National Center for Health Statistics. Our findings were robust across these different specifications, consistent with findings from James, Brindley, Purser, and Topping (2022) who found persistence in the rural-urban mortality gap irrespective of the specific classification schema employed.

2.2. Analytical approach

We first show descriptive statistics and maps displaying the geographic distributions for drug poisoning, suicide, alcohol-induced death, and homicide rates. We then move to our analytic approach, which had two stages. In the first stage, we used Ordinary Least Squares (OLS) regression to examine the overall (i.e., national) associations between socioeconomic and household vulnerability and rates from the four causes of mortality. We weighted all models by the log of county

[1] Although the U.S. Centers for Disease Control and Prevention (CDC) has an existing Social Vulnerability Index (SVI) that integrates some county-level measures that are conceptually related to our four causes of death, the full index is not appropriate for this study because it was designed to classify vulnerability to natural or human-caused disasters, not vulnerability to mortality overall or to the specific causes of death we considered in this study. Therefore, it contains indicators that are not conceptually related to the four causes of death we considered (italicized below), and it misses factors that the frameworks we employed in the Introduction suggest are important to include for these four causes of death. Specifically, the CDC's SVI includes: poverty rate, unemployment rate, per capita income, percentage without a high school diploma, *percentage of persons age 65 +*, *percentage of persons under age 17*, percentage of civilians with a disability, percentage of single-parent households, *percentage of the population that are racial/ethnic minorities*, *percentage of persons who speak English less than well*, *percentage of multi-unit structures*, *percentage of mobile homes*, percentage of occupied housing units with more people than rooms, percentage of households with no vehicle, and *percentage of persons living in group quarters*). While some of these are appropriate for our study (e.g., percent poverty, percent single-parent households), others are not. For example, the CDC's SVI includes percent racial/ethnic minority and percentage of persons who speak English less than well. Although these are conceptually plausible vulnerabilities for getting people out of a household or disaster zone during an emergency, they are not conceptually well devised for understanding geographic disparities in our four causes of death. The minority vulnerability indicator includes all minority ethnoracial groups in one measure. However, mortality rates from the four causes we considered vary dramatically across ethnoracial minority groups, with low rates of all four among Asians and high rates of all four among American Indians/Alaska Native (Garnett & Spencer, 2021; Olfson, Cosgrove, Altekruse, Wall, & Blanco, 2021). In addition, whereas county percent Black population is associated with higher homicide rates, it is associated with lower suicide, drug poisoning, and alcohol-induced mortality rates (Case & Deaton, 2015; Liu et al., 2023; Monnat, 2020). Accordingly, while it is important to account for county racial/ethnic composition as a potential confounder (which we do), it is not appropriate to consider it as measure of distress or vulnerability in this study. Percentage of persons who speak English less than well is also not an appropriate measure of distress or vulnerability for this study. Being a non-English speaker is directly connected to immigrant status. Therefore, counties with larger shares of non-English speakers are counties with larger shares of immigrants. Yet mortality rates are lower in counties with larger percentage foreign born (Feldmeyer et al., 2022). The inherent assumption within the SVI that higher percent racial minority population and higher percentage of non-English speakers are associated with higher vulnerability to mortality from our causes of death is not well supported by the literature, making the SVI inappropriate for our analyses. The SVI also includes percentage ages 65+ and younger than 17 as indicators of vulnerability, when in fact, all four causes of death we considered are higher among working-age adults than among older adults or children (Gennuso, Blomme, Givens, Pollock, & Roubal, 2019; Kegler et al., 2022). In terms of socioeconomic vulnerabilities, the SVI includes percentage without a high school diploma. For the purposes of our analyses, the literature suggests that percentage without a four year college degree is the more appropriate indicator, given that this appears to be the major dividing line for health and mortality in the U.S. (Case & Deaton, 2020). The SVI also included the percentage of multi-unit structures, percentage of mobile homes, and percentage of persons living in group quarters. While these are plausible risk factors for natural disasters, they are not conceptually supported vulnerabilities for drug, alcohol, suicide, and homicide mortality. For example, multi-unit structures and group quarters, such as college dormitories and nursing homes, may be protective against the causes of death we considered in this study because they could be places that reduce social isolation and where residents can derive social support and material resources (Bower et al., 2023). The SVI does not include two factors that our conceptual framework suggest are important to our four causes of death – percentage ages 18–64 without health insurance and percentage renter-occupied housing units. In line with fundamental cause theory, health insurance coverage is a marker of access to health care, which can facilitate treatment for substance use and mental health problems. Renter occupied household units are a measure of residential instability and have been found to be associated with our four causes of death (Bjorklund, 2023; Drake et al., 2022; Monnat, 2018).

population to provide nationally representative estimates and avoid inflating the influence of small population counties (Montez et al., 2022; Pierce & Schott, 2020; Venkataramani, Chatterjee, Kawachi, & Tsai, 2016). Tests for multicollinearity did not raise concerns (VIF = 1.36). We conducted several sensitivity and robustness checks that we present after our main (preferred) OLS model results (tables shown in Appendices). Regardless of specific OLS model specification, however, the "naïve" OLS approach assumes that the observed relationships between the predictors and the outcomes are consistent across the U.S.

In the second stage, we aimed to understand how the associations between the social vulnerability indices and the four causes of death vary across different parts of the U.S. We used Global Moran's I to test whether mortality rates from drug poisoning, suicide, alcohol-induced deaths, and homicide are spatially correlated. We calculated spatial weights using contiguity edges to represent the connections or shared boundaries between neighboring counties. We then used Local Indicators of Spatial Association (LISA) to identify spatial clusters for each type of mortality. LISA maps show where there are clusters of counties that have high rates of mortality and clusters of counties with low rates of mortality. Finally, we used geographically weighted regression (GWR) to analyze local variation in relationships between the social vulnerability domains and the four mortality rates. GWR constructs separate OLS equations for every county, enabling us to identify spatial non-stationarity in the relationships between exposures and outcomes (LeSage, 2004, pp. 241–264; Wheeler & Páez, 2009). We used the adaptive Bisquare kernel type to assign weights to neighboring counties, and cross-validation to select the bandwidth that determines the range of influence of neighboring counties (See Appendix B for a justification for decisions about kernel selection and bandwidth). Finally, we conducted Leung tests (Leung, Mei, and Zhang (2000) for spatial non-stationary.

Collectively, these methods offer a comprehensive understanding of the national *and* local relationships between social vulnerability and the four causes of death. We used STATA 17 for the OLS regression and R and ArcGIS 10.8 for spatial analysis.

3. Results

3.1. Descriptive findings

Fig. 1 presents maps displaying the geographic distributions of age-adjusted mortality rates for drug poisoning, suicide, alcohol-induced deaths, and homicide (Fig. 1A–D). Average mortality rates were 29.4, 22.3, 12.2, and 6.7 deaths per 100,000 population for drug poisonings, suicides, alcohol-induced, and homicides. LISA maps (Fig. 2A–D) identify statistically significant clusters of mortality rates. Moran's I statistics indicate that rates for all four causes of death are spatially clustered: drug poisoning (Moran's I = 0.57, p < 0.001), suicide (Moran's I = 0.18, p < 0.001), alcohol-induced deaths (Moran's I = 0.26, p < 0.001), and homicide (Moran's Index = 0.36, p < 0.001).

Counties with clusters of high drug poisoning mortality rates ('High-High') are observed in New England, Appalachia, and parts of the desert Southwest, whereas low drug poisoning mortality clusters ('Low-Low') are found throughout the southeast and Mississippi Delta, central and northern Plains, mid-Texas, and northern Oregon (Fig. 2A). Counties with clusters of high suicide rates are observed in the Mountain West, desert southwest, and Alaska, whereas low rates are clustered in much of New York State, along the east coast, and sprinkled throughout the

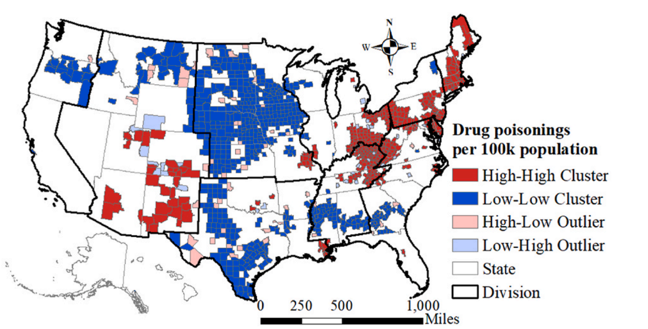


Fig. 2A. LISA for county-level drug poisoning mortality rates (deaths per 100,000 population), 2014-19
Note: Mortality rates are age adjusted

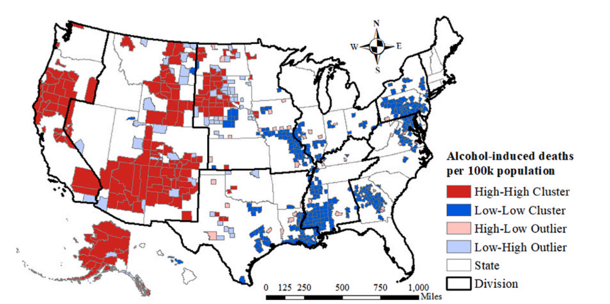


Fig. 2C. LISA for county-level alcohol-induced mortality rates (deaths per 100,000 population), 2014-19
Note: Mortality rates are age adjusted

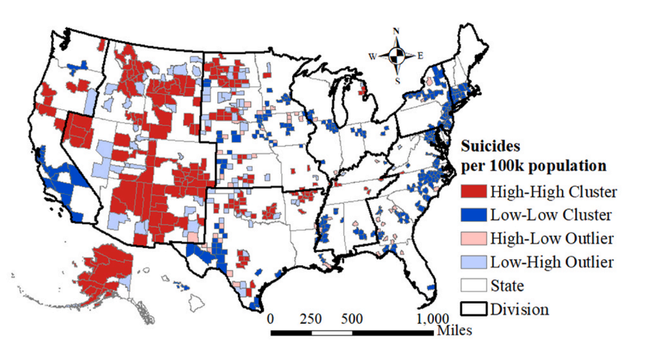


Fig. 2B. LISA for county-level suicide rates (deaths per 100,000 population), 2014-19
Note: Mortality rates are age adjusted

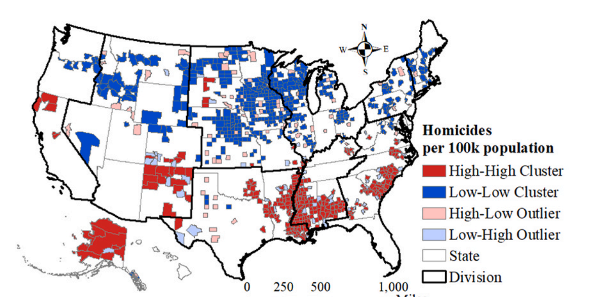


Fig. 2C. LISA for county-level homicide rates (deaths per 100,000 population), 2014-19
Note: Mortality rates are age adjusted

Fig. 2. Local Indicators of Spatial Association (LISA) for county-level mortality rates from drug poisoning, suicide, alcohol-induced deaths, and homicide among working age adults.
Note: 'High-High' denotes counties with above average mortality rates that are surrounded by neighboring counties with above average mortality rates. 'Low-Low' denotes counties with below average mortality rates that are surrounded by neighboring counties with below average mortality rates. 'High-Low' denotes counties with above average mortality rates surrounded by counties with below average mortality rates. 'Low-High' denotes counties with below average mortality rates surrounded by counties with above average mortality rates.
Data source: Author analysis of National Vital Statistics System data

Table 2
Results from ordinary least squares regression models identifying factors related to county-level mortality rates from drug poisoning, suicide, alcohol-induced deaths, and homicide, 2014–2019.

	Drug poisoning deaths (per 100,000 population)[1]		Suicides (per 100,000 population)[1]	
	Coeff	CIs	Coeff	CIs
Socioeconomic vulnerability (factor score)[2]	6.06**	(5.19, 6.94)	3.00**	(2.55, 3.45)
Household vulnerability (factor score) [2]	1.41**	(0.34, 2.49)	0.56	(-0.62, 1.75)
Percent Hispanic population[3]	−0.33**	(-0.40, −0.26)	−0.12**	(-0.17, −0.07)
Percent Non-Hispanic Black population[3]	−0.36**	(-0.42, −0.30)	−0.27**	(-0.31, −0.22)
Nonmetro county[4]	−12.68**	(-14.29, −11.08)	1.78**	(1.04, 2.53)
Constant	43.97**	(42.14, 45.79)	24.39**	(23.49, 25.29)
R2	0.13		0.14	
	Alcohol-induced deaths (per 100,000 population)[1]		Homicides (per 100,000 population)[1]	
	Coeff	CIs	Coeff	CIs
Socioeconomic vulnerability (factor score)[2]	2.06**	(1.39, 2.72)	1.98**	(1.75, 2.21)
Household vulnerability (factor score)[2]	4.66**	(2.86, 6.45)	1.11**	(0.72, 1.50)
Percent Hispanic population[3]	−0.07	(-0.14, 0.00)	−0.01	(-0.03, 0.01)
Percent Non-Hispanic Black population[3]	−0.32**	(-0.39, −0.24)	0.23**	(0.20, 0.26)
Nonmetro county[4]	1.27**	(0.55, 1.98)	−0.30	(-0.69, 0.10)
Constant	14.65**	(13.19, 16.11)	4.93**	(4.49, 5.38)
R2	0.17		0.45	

Notes: Mortality rates are age adjusted; Coeff = Coefficients, CIs: 95% Confidence Interval, Coefficients are standardized to a mean = 0 and standard deviation = 1. *p < 0.05, **p < 0.01, VIF = 1.36, Models are weighted by log of county population, 3142 counties.
Data sources: 1. National Vital Statistics System, 2014–2019; 2. Indices derived from factor analysis (Table 1); 3. American Community Survey 2009–2013; 4. USDA ERS Rural-Urban Continuum Codes, 2013.

Midwest, parts of Texas, and central California (Fig. 2B). Counties with clusters of high alcohol-induced deaths rates are observed in the northern Great Plains, Mountain West, Southwest, northern California and Southern Oregon, and Alaska, whereas low rates are clustered in the mid-Atlantic coastal region, Gulf Coast, and Mississippi Delta (Fig. 2C). Counties with clusters of high homicide rates are observed in parts of the South Atlantic, Gulf Coast, along the Mississippi Delta, northern New Mexico, northern California, and Alaska.

3.2. Results from OLS models

Results from OLS regression models (coefficients, and 95% confidence intervals (CI) reflecting $p < 0.05$) are shown in Table 2. The results from these models describe the overall (average national) relationship between the predictors and mortality rates from the four causes of death. In these national models, county-level socioeconomic vulnerability is associated with significantly higher rates of all four causes of death. Specifically, a one standard deviation increase in the socioeconomic vulnerability index was associated with 6.1 more drug poisoning deaths per 100,000 population (95% CI = 5.19, 6.94), 3.0 more suicides per 100,000 population (95% CI = 2.55, 3.45), 2.1 more alcohol-induced deaths (95% CI = 1.39, 2.72) per 100,000 population, and 2.0 more homicides (95% CI = 1.75, 2.21) per 100,00 population. County-level household vulnerability is associated with significantly

Table 3
Results from geographically weighted regression models summarizing factors related to county-level mortality rates from drug poisoning, suicide, alcohol-induced deaths, and homicide, 2014–2019.

	Drug poisoning deaths[1] (per 100,000 population, significant results (p < 0.05)					
	# of significant models	% of counties with significant coefficients	Significant coefficients			
			Mean	SD	Min	Max
Socioeconomic vulnerability[2]	937	29.82	9.15	5.30	−11.05	26.15
Household vulnerability[2]	590	18.78	10.75	10.57	−17.87	34.05
	Suicides[1] (per 100,000 population, significant results (p < 0.05)					
	# of significant models	% of counties with significant coefficients	Significant coefficients			
			Mean	SD	Min	Max
Socioeconomic vulnerability[2]	1953	62.16	4.62	2.43	1.72	12.14
Household vulnerability[2]	411	13.08	−2.29	4.73	−10.52	7.51
	Alcohol-induced deaths[1] (per 100,000 population, significant results (p < 0.05)					
	# of significant models	% of counties with significant coefficients	Significant coefficients			
			Mean	SD	Min	Max
Socioeconomic vulnerability[2]	951	30.27	6.93	3.78	2.40	18.06
Household vulnerability[2]	842	26.80	8.61	4.82	−4.29	16.85
	Homicides[1] (per 100,000 population, significant results (p < 0.05)					
	# of significant models	% of counties with significant coefficients	Significant coefficients			
			Mean	SD	Min	Max
Socioeconomic vulnerability[2]	1796	57.16	2.48	0.81	0.97	5.21
Household vulnerability[2]	845	26.89	2.13	1.38	−2.99	4.35

Note: Mortality rates are age adjusted.
Data sources: 1. National Vital Statistics System, 2014–2019, 2. Indices derived from factor analysis (Table 1).

higher rates of drug poisoning, alcohol-induced deaths, and homicide, but not suicide. Specifically, a one standard deviation increase in household vulnerability was significantly associated with 1.4 more drug poisoning deaths (95% CI = 0.34, 2.49) per 100,000 population, 4.7 more alcohol-induced deaths (95% CI = 2.86, 6.45) per 100,000 population, and 1.1 more homicides (95% CI = 0.72, 1.50) per 100,000 population.

Higher percent Hispanic and non-Hispanic Black were associated with significantly lower drug poisoning and suicide rates. Higher percent Black was also associated with significantly higher homicide rates but lower alcohol-induced death rates. Nonmetropolitan counties had a significantly lower average drug poisoning mortality rate, but significantly higher average suicide and alcohol-induced death rates.

3.2.1. OLS robustness checks and sensitivity analyses

We ran several robustness checks with the OLS models (shown in Appendix C), including.

a) *Alternative model specifications* without the population weight, with clustered standard errors at the state level to account for clustering of counties within states, and controlling for state fixed effects to account for the influence of unobserved state-level conditions on mortality (e.g., state policies). In each case, the substantive conclusions were unchanged, except that household vulnerability was positively associated with suicide when the model did not include a population weight. We suspect this is because suicide rates are higher in places with smaller populations.
b) *Stratified the analyses to consider results for mortality rates from 2014-2016 versus 2017–2019.* The substantive conclusions were similar to the main models, except that household vulnerability was not related to drug poisoning mortality rates from 2014 to 2016 but was positively related to drug poisoning rates from 2017 to 2019.
c) *Disaggregated our analyses of alcohol deaths by acute (i.e., alcohol poisoning) versus chronic.* Results were consistent with the main model results except that socioeconomic vulnerability was associated only with chronic alcohol deaths (by far the most common type) but not acute-alcohol deaths. This is consistent with the idea that deprivation may lead to the type of frequent excessive alcohol consumption that can induce organ diseases (such as cirrhosis of the liver).
d) *Stratified the analyses by sex.* The substantive conclusions were largely the same, except that household vulnerability was not associated with drug poisoning and homicide rates for females.
e) *Expanded the analyses to ages 15–64.* The substantive conclusions were unchanged, except that, whereas household vulnerability was not associated with suicide rates among ages 25–64, it was associated with significantly higher suicide rates for ages 15–64, suggesting that household vulnerability may be a more important risk for suicide in younger than older ages.
f) *Selected alternative years for the ACS measures (2012–16).* Results were the same as in the main models that used 2009–13.

3.3. Results from GWR models

Results from the GWR models that assess locally-specific relationships are summarized in Table 3 and Fig. 3. Use of these models is supported by Leung tests (Leung et al., 2000), which showed that there is statistically significant spatial non-stationarity in the relationships between the two social vulnerability indices and the four causes of deaths (See Appendix D).

The GWR models estimated relationships between the predictors and the four causes of death for each county, which generated 3142 coefficients for each model variable. We then conduced *t*-test to determine whether coefficients were statistically significant ($p < 0.05$). We also checked for multicollinearity, and removed results in which any variable had a VIF score higher than 5. Summaries for significant coefficients (average, minimum, and maximum regression coefficient values for the relationships between the vulnerability indices and the four causes of death) are shown in Table 3, along with the percentage of counties for which each vulnerability index was significantly associated with each type of mortality ($p < 0.05$). In addition to presenting the summary GWR regression results, we also present maps (Fig. 3) that show *where* in the U.S. each type of vulnerability is significantly associated with the four mortality rates ($p < 0.05$). The maps classify counties using the following categories: 1) association was not statistically significant (white), 2) significant weak positive association (bottom 25th percentile; yellow), 3) significant moderate positive association (25th-50th percentile, orange), 4) significant strong positive association (50th-75th percentile; bright red), and 5) significant very strong positive association (top 25th percentile; dark red). Negative associations are classified with various shades of blue, but the specific scheme differs across the maps where there are negative associations. In cases where there were a lot of counties with negative associations and wide variation across the negative values (Fig. 3A2 and 3B2), we used quantile classification similar to that described above for the position associations. In cases where there were few counties with negative associations and small ranges, we either dichotomized the classification (Fig. 3A1) or used a single shade of blue to denote negative associations (Fig. 3C2 and 3D2). In all cases, the legends show the range of coefficient values in each category.

Socioeconomic vulnerability was significantly associated with drug poisoning mortality in 937 (29.8%) counties. Among these counties, a one-unit increase in socioeconomic vulnerability was associated with an average of 9.2 more drug poisoning deaths per 100,000 population. The places where higher socioeconomic vulnerability was associated with significantly higher drug poisoning mortality rates (Fig. 3A1) included the mid-Atlantic coastal area, parts of eastern Appalachia, Ohio, parts of Southern Mississippi and Louisiana, Illinois, Wisconsin, northwest Minnesota, eastern North Dakota, southeastern Kansas, northern Oklahoma, a cluster of counties embedded within South Dakota, Colorado, Wyoming, Utah, and Hawaii. There were also significant (though lower magnitude) relationships throughout much of California and Nevada. However, there were also small clusters of counties where higher socioeconomic vulnerability was associated with lower mortality rates, specifically eastern Kentucky and southeastern Missouri.

Socioeconomic vulnerability was associated with suicide in 1953 (62.2%) counties. In these counties, a one-unit increase in socioeconomic vulnerability was associated with an average of 4.6 more suicides per 100,000 population. These counties are overwhelmingly concentrated in the western half of the U.S., with additional clusters in Missouri and eastern Michigan (Fig. 3B1). In the 951 (30.3%) counties where socioeconomic vulnerability was significantly associated with alcohol-induced deaths, a one-unit increase in socioeconomic vulnerability was associated with an average of 6.9 more alcohol-induced deaths per 100,000 population. These geographically-specific associations were largely similar to those for suicide, with significant clusters throughout the Western U.S., Wisconsin, Alaska, and Hawaii (Fig. 3C1). In the 1796 (57.2%) counties where socioeconomic vulnerability was significantly associated with homicide, a one-unit increase in socioeconomic vulnerability was associated with an average of 2.5 more homicides per 100,000 population. Clusters with significant associations between socioeconomic vulnerability and homicide are located in central Appalachia, the mid-central and northern plains, the mountain west, the Pacific coast, and Alaska and Hawaii (Fig. 3D1). Finally, there were clusters of counties where socioeconomic vulnerability was associated with significantly higher rates of all four causes of death – western Minnesota, eastern North Dakota, western South Dakota, and the tri-state borders of Wyoming, Utah, and Colorado. There were also several additional clusters that had significant positive associations for two or three of the four causes of death.

Turning to household vulnerability, in counties where relationships were statistically significant, the coefficients for the household

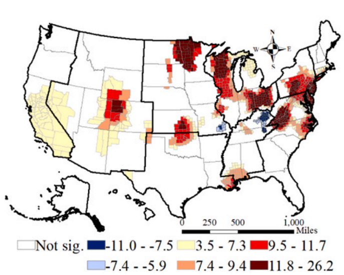


Fig. 3A1. Relationship between socioeconomic vulnerability and drug poisoning mortality rates

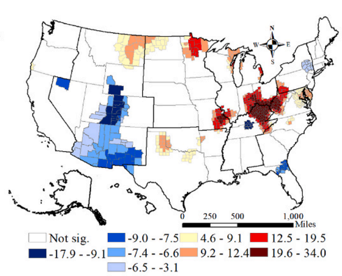


Fig. 3A2. Relationship between household vulnerability and drug poisoning mortality rates

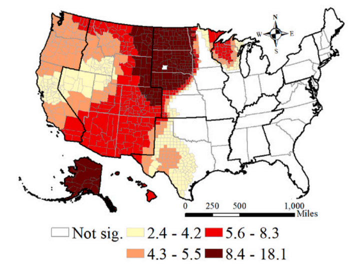


Fig. 3C1. Relationship between socioeconomic vulnerability and alcohol-induced mortality rates

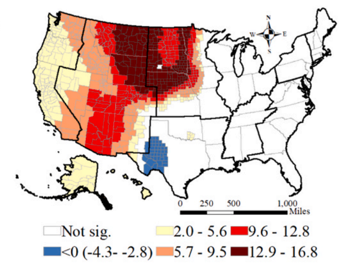


Fig. 3C2. Relationship between household vulnerability and alcohol-induced mortality rates

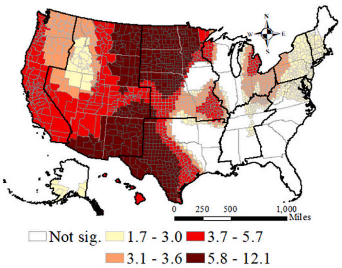


Fig. 3B1. Relationship between socioeconomic vulnerability and suicide mortality rates

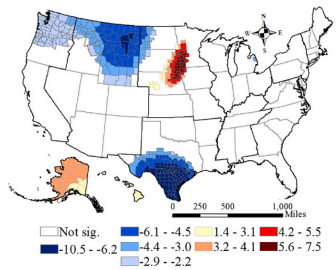


Fig. 3B2. Relationship between household vulnerability and suicide mortality rates

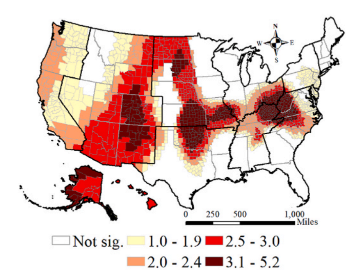


Fig. 3D1. Relationship between socioeconomic vulnerability and homicide mortality rates

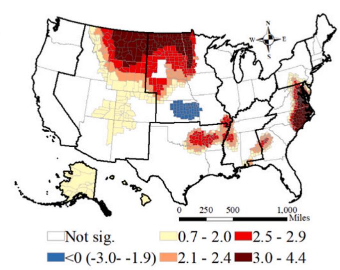


Fig. 3D2. Relationship between household vulnerability and homicide mortality rates

Fig. 3. Results from geographically weighted regression models identifying factors significantly related to mortality from drug poisonings, sucides, alcohol-induced deaths, and homicides, 2014-19.

Note: Mortality rates are age adjusted. Significance is based on an alpha <.05, and a VIF score lower than 5. Quantile classification is used to categorize relationships between social vulnerability and each cause of death in most maps. In cases where there were a small number of counties with negative associations and where the range of negative values were small, we either dichotomized the negative coefficients (Fig. 3A1 or used only one category to show the counties with negative coefficients).

vulnerability index were positive on average (except for suicide, for which the mean was negative), but included both negative and positive relationships. In the 590 (18.8%) counties where household vulnerability was significantly associated with drug poisoning mortality, a one-unit increase in household vulnerability was associated with an average of 10.8 more drug poisoning deaths per 100,000 population. Clusters with large positive associations are in Central Appalachia, northern Minnesota, and eastern Montana. Counties that had a negative association with household vulnerability and drug poisoning rates are in the southwest and along the borders of Utah, Colorado, and Wyoming, as well as pockets in southern New York and northern Florida. (Fig. 3A2.). In the 411 (13.1%) counties where household vulnerability was significantly associated with suicide, a one-unit increase in household vulnerability was associated with an average of 2.3 *fewer* suicides per 100,000 population. This included the northern Mountain division, Washington, southern Oregon, and southern Texas. However, there is a pocket of counties where there was the expected positive association between household vulnerability and suicide, covering the four state border region of Minnesota, South Dakota, Nebraska, and Iowa. There was also a significant positive association in Alaska (Fig. 3B2.). In the 842 (26.8%) counties where household vulnerability was significantly associated with alcohol-induced deaths, a one-unit increase in household vulnerability was associated with an average of 8.6 more alcohol-induced deaths per 100,000 population. These counties are all in the western half of the U.S. There was also a pocket of counties in western Texas where household vulnerability was associated with lower alcohol-induced mortality rates (Fig. 3C2). In the 845 (26.9%) counties where household vulnerability was significantly associated with homicide, a one-unit increase in household vulnerability was associated with an average of 2.1 more homicides per 100,000 population. Homicide rates were higher in counties with greater household vulnerability in the northern Great Plains, Rocky Mountains, Ozarks, and mid-Atlantic coast. There was a small pocket with negative associations between household vulnerability and homicide in eastern Kansas (Fig. 3D2).

There was less geographic overlap in relationships between household vulnerability and the four causes of death than there was for socioeconomic vulnerability, but the upper Great Plains is a noteworthy region where household vulnerability was associated with both alcohol-induced mortality and homicide rates.

4. Discussion

Drug poisoning, suicide, alcohol, and homicide are “fatal social problems” (Feldmeyer et al., 2022) among U.S. working-age adults (ages 25–64), but mortality rates from these causes vary substantially across the country. Various measures of place-level socioeconomic and household distress have been found to contribute to geographic variation in one or more of these causes of death (Altekruse et al., 2020; Blake-Gonzalez et al., 2021; Cano et al., 2023; DeBastiani, Norris, & Kerr, 2019; Feldmeyer et al., 2022; Frankenfeld & Leslie, 2019; Frey & Cerel, 2015; Mobley & Taasoobshirazi, 2022; Monnat, 2018; Monnat et al., 2019; Peters et al., 2020; Shaw, Warren, & Johnson, 2019). However, this is the first national study to consider localized (spatially specific) relationships between county-level socioeconomic and household distress and mortality rates from these four causes. There are several important takeaways, with implications for interventions to reduce both mortality rates overall and geographic disparities in mortality from these causes.

Consistent with prior research, we found that at a national level, higher levels of county socioeconomic vulnerability predicted higher rates of drug poisoning mortality, suicide, alcohol-induced deaths, and homicide for the years 2014–2019. Higher levels of household vulnerability predicted higher rates of drug poisoning, alcohol-induced deaths, and homicide. Socioeconomic vulnerability was more strongly associated with drug poisoning and homicide than was household vulnerability, whereas household vulnerability was more strongly associated with alcohol-induced deaths compared to socioeconomic vulnerability. Though useful for understanding the overall (average) relationships between place-level distress and these four causes of death, the findings from these national analyses mask the considerable geographic heterogeneity in the contribution of place-level distress to the four causes of death.

The novelty of our study is in going beyond estimating national associations to identify localized relationships (spatial non-stationarity) between place-level distress and the four causes of death. Consistent with the subnational spatial inequality framework (Lobao, 2004; Lobao et al., 2007), we found that relationships between place-level distress and mortality vary widely across the country. Whereas both socioeconomic and household distress were associated with significantly higher rates of drug poisoning mortality, suicide, alcohol-induced deaths, and homicide in some parts of the U.S., they were associated with significantly lower rates in other parts of the U.S., and did not have any significant associations in yet other parts.

Specifically, findings from GWR models suggested that socioeconomic vulnerability was associated with higher rates of drug poisoning in small pockets in the mid-Atlantic, Appalachia, the Industrial Midwest, and central Plains; suicide throughout most of the northeastern and Western U.S.; alcohol-induced mortality throughout the West and Alaska, and homicide throughout pockets of the central U.S., Appalachia, the West, and Alaska. Household vulnerability was associated with higher rates of drug poisoning mortality in Appalachia and pockets of the northern Plains; suicide only in Alaska and the four corners of South Dakota, Minnesota, Nebraska, and Iowa; alcohol-induced mortality throughout most of the West; and homicide in the mid-Atlantic, parts of the deep South, and northern Plains. However, there were also several pockets (notably in the Mississippi Delta and Gulf Coast) where, although socioeconomic and household distress were comparatively high, they were not significantly associated with drug, suicide, alcohol, or homicide rates. It is possible that place-level distress manifests in higher rates of other causes of mortality (e.g., those related to diet and/or smoking) in these places. We encourage future research to apply the GWR techniques used in this study to estimate rates from other causes of death.

We also found places where one or both types of distress were associated with multiple types of mortality (i.e., either or both socioeconomic distress and household distress were associated with higher rates of more than one type of mortality), suggesting compounding or concentrated disadvantage or the presence of features that exacerbate the consequences of place-level socioeconomic and household distress. These areas included central Appalachia, the northern Plains, the desert Southwest, and Alaska.

There were places where socioeconomic vulnerability was associated with *lower* rates of drug poisoning and household vulnerability was associated with *lower* rates of all four causes of death. There are at least two potential explanations for these findings. On the one hand, these findings could be an artifact of the GWR approach, which uses neighboring counties to estimate regression coefficients. For example, in the case of regions where we observe negative associations between socioeconomic vulnerability and drug poisoning, socioeconomic vulnerability is overwhelmingly high among most counties in those regions (see Appendix Fig. A1). Household vulnerability is also overwhelmingly low in the northern Mountain division where there is a negative association between household vulnerability and suicide, and in eastern Kansas where there is a negative association between household vulnerability and homicide (see Appendix Fig. A2). Therefore, it may be that there is too little variability (too much homogeneity) in socioeconomic and household vulnerability in these places, thereby making it appear as though socioeconomic vulnerability and household vulnerability are protective against mortality. On the other hand, if the findings are not an artifact of the GWR approach, the negative association could suggest the presence of buffering factors that may mitigate against the consequences of economic and household distress, such as shared norms, social capital, availability of health resources, policies and other contextual features. Exploring potential buffering or exacerbating factors was beyond the scope of this study. We encourage future research to consider the roles of potential buffering factors that may explain why some places appear to be resilient to household distress and why some places appear to be more vulnerable to socioeconomic and household distress than others.

Our findings have implications for geographically tailored interventions directed at reducing socioeconomic and household distress. Targeting such interventions is likely to be more cost efficient and effective than attempting broad-brush national approaches that do not consider subnational spatial inequality (Lobao, 2004). In the places where socioeconomic distress is associated with higher mortality rates, implementing policies aimed at increasing access to employment with livable wages and benefits (especially for those without a four-year college degree), providing more robust income supports, and expanding Medicaid could be instrumental in preventing mortality from these four causes. In places where household vulnerabilities are associated with one or more of these causes, enhancing supports for single-parent families, investing in quality and affordable housing infrastructure that might reduce housing instability, and enhancing the public transportation infrastructure might help reduce mortality rates. In places with compounded disadvantages like Appalachia, the Northern Great Plains, and Alaska, where there is significant physical and social isolation that increase risk of fatal social problems (Hirsch & Cukrowicz, 2014), interventions aimed reducing social isolation, improving availability and access to mental health services, and reducing access to lethal means may be effective in reducing mortality rates in this region. Reducing mortality rates in these places will likely require multi-sector collaborations between institutions involved in employment, social services, education, health, housing, and transportation.

4.1. Limitations

Results should be considered in light of some limitations. First, our analyses were ecological and cannot account for decedents' characteristics, including duration of exposure to county conditions. Related, associations between place-level vulnerabilities and mortality rates likely play out over an extended period, but these analyses considered only relatively recent conditions and did not consider changes in environments over a longer period. Future research should examine the roles of changing labor market, family, and housing conditions over time and the relationships between those changes and the three causes of death. Second, death certificates may misclassify causes of death, and results may be biased by geographic heterogeneity in cause-of-death reporting (Rockett et al., 2022). Third, we cannot account for within-county heterogeneity in these analyses. Fourth, although our social vulnerability measures capture a multi-dimensional set of place-level characteristics, other unobserved factors likely play additional important roles in explaining, exacerbating, and/other buffering geographic variation in each of the causes of death, such as drug supply for drug poisoning (Ruhm, 2019) and access to firearms for suicide and homicide (Martínez-Alés, Jiang, Keyes, & Gradus, 2022). Fourth, GWR results need to be interpreted with limitations. GWR can help make inferences about local spatial relationships but is not useful for global (e.g., national) inference (Wheeler & Páez, 2009). GWR assumes smooth spatial variation (Nakaya, 2015), but real-world relationships are complicated, rather than smooth. Interpreting GWR results is challenging due to numerous local models, demanding careful examination of parameters and spatial patterns, which can lead to bias. Moreover, although we tested for multicollinearity and removed cases with high VIFs, correlations between the two indices in some places could have resulted in coefficient sign reversal in GWR (Wheeler & Páez, 2009). Most counties where we observed a negative relationship between household vulnerability and mortality tended to be counties where socioeconomic vulnerability was associated with higher mortality rates. This suggests that in some places, socioeconomic and household vulnerability may be proxying similar underlying constructs. We encourage research using case studies based on GWR findings to a gain deeper understanding for the explanations behind the observed local trends. Fifth, we intentionally restricted our analysis to the pre-COVID years to avoid complications in the factors that drove mortality rates since the onset of the pandemic. It will be important for research to assess how rates of mortality from these causes changed, where they changed, and the factors associated with those changes during the pandemic. Sixth, although our definition of working age (ages 25–64) is consistent with many other studies, including a recent NASEM report on working-age mortality rates (NASEM 2021), and our sensitivity analyses showed similar results when we included deaths among ages 15–24 in the analyses (which encapsulates the OECD definition) (OECD, 2023), we acknowledge that individuals' own definitions of working age vary. In addition, the ability to continue working past age 64 or even up to age 64 varies depending on many factors, including type of employment (e.g., manual labor vs. intellectual labor), financial wellbeing, and caretaking obligations. To the extent that these factors vary across the U.S., our analyses would differentially under- or over-count true "working age" deaths across places. Finally, we did not stratify our analyses by ethnoracial group. To do so would have required limiting our analyses to counties that had sufficient populations of each group to be able to calculate stable mortality rates. While this is possible within a traditional non-spatial approach, it would not be possible within the GWR framework, which requires information from neighboring counties. We encourage future research that examines how different types of place-level vulnerabilities are associated with these and other causes of death across different ethnoracial groups.

5. Conclusion

Overall, we show that place-level socioeconomic and household distress were significant and substantial predictors of drug poisoning mortality, suicide, alcohol-induced deaths and homicide in some parts of the U.S. in 2014–19, but these associations were not universal. National associations that are observed between different types of place-level distress and these four causes of death mask considerable heterogeneity in localized associations. Understanding where specific place-level factors contribute to these fatal social problems among working-age adults could guide tailored interventions to not only reduce geographic disparities in rates from these causes, but also reduce overall national rates from these causes that are driving troubling mortality trends in this population.

Ethical statement for Solid State Ionics

1) This material is the authors' own original work, which has not been previously published elsewhere.
2) The paper is not currently being considered for publication elsewhere.
3) The paper reflects the authors' own research and analysis in a truthful and complete manner.
4) The paper properly credits the meaningful contributions of co-authors and co-researchers.
5) The results are appropriately placed in the context of prior and existing research.
6) All sources used are properly disclosed (correct citation). Literally copying of text must be indicated as such by using quotation marks and giving proper reference.
7) All authors have been personally and actively involved in substantial work leading to the paper, and will take public responsibility for its content.
   The violation of the Ethical Statement rules may result in severe consequences.

I agree with the above statements and declare that this submission follows the policies of Solid State Ionics as outlined in the Guide for Authors and in the Ethical Statement.

CRediT authorship contribution statement

Xue Zhang: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Software, Validation, Visualization, Writing – original draft, Writing – review & editing, Project administration, Resources. **Shannon M. Monnat:** Conceptualization, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Writing – original draft, Writing – review & editing, Validation.

Declarations of competing interests

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.

Data availability

The authors do not have permission to share data.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ssmph.2023.101595.

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