

JAMA | Original Investigation

# Trends and Patterns of Geographic Variation in Mortality From Substance Use Disorders and Intentional Injuries Among US Counties, 1980-2014

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 Supplemental content

**IMPORTANCE** Substance use disorders, including alcohol use disorders and drug use disorders, and intentional injuries, including self-harm and interpersonal violence, are important causes of early death and disability in the United States.

**OBJECTIVE** To estimate age-standardized mortality rates by county from alcohol use disorders, drug use disorders, self-harm, and interpersonal violence in the United States.

**DESIGN AND SETTING** Validated small-area estimation models were applied to deidentified death records from the National Center for Health Statistics (NCHS) and population counts from the US Census Bureau, NCHS, and the Human Mortality Database to estimate county-level mortality rates from 1980 to 2014 for alcohol use disorders, drug use disorders, self-harm, and interpersonal violence.

**EXPOSURES** County of residence.

**MAIN OUTCOMES AND MEASURES** Age-standardized mortality rates by US county (N = 3110), year, sex, and cause.

**RESULTS** Between 1980 and 2014, there were 2 848 768 deaths due to substance use disorders and intentional injuries recorded in the United States. Mortality rates from alcohol use disorders (n = 256 432), drug use disorders (n = 542 501), self-harm (n = 1 289 086), and interpersonal violence (n = 760 749) varied widely among counties. Mortality rates decreased for alcohol use disorders, self-harm, and interpersonal violence at the national level between 1980 and 2014; however, over the same period, the percentage of counties in which mortality rates increased for these causes was 65.4% for alcohol use disorders, 74.6% for self-harm, and 6.6% for interpersonal violence. Mortality rates from drug use disorders increased nationally and in every county between 1980 and 2014, but the relative increase varied from 8.2% to 8369.7%. Relative and absolute geographic inequalities in mortality, as measured by comparing the 90th and 10th percentile among counties, decreased for alcohol use disorders and interpersonal violence but increased substantially for drug use disorders and self-harm between 1980 and 2014.

**CONCLUSIONS AND RELEVANCE** Mortality due to alcohol use disorders, drug use disorders, self-harm, and interpersonal violence varied widely among US counties, both in terms of levels of mortality and trends. These estimates may be useful to inform efforts to target prevention, diagnosis, and treatment to improve health and reduce inequalities.

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Substance use disorders (ie, drug use disorders and alcohol use disorders) and intentional injuries (ie, self-harm and interpersonal violence) impose a significant health and financial burden in the United States. In 2015, substance use disorders and intentional injuries comprised 3.9% of all deaths.<sup>1</sup> Because substance use disorders and intentional injuries disproportionately impact young and middle-aged adults, nearly 10% of all years of life lost were due to these causes.<sup>1</sup> Moreover, recent research has implicated so-called deaths of despair, including substance use disorders and self-harm, in contributing to the increasing rates of midlife mortality among certain demographic groups.<sup>2,3</sup>

A number of studies have previously documented significant geographic variation in mortality rates from self-harm,<sup>4-6</sup> interpersonal violence,<sup>4-7</sup> and drug poisoning.<sup>8,9</sup> Information on how mortality rates vary spatially at a local level is an important input for developing an effective public health and policy response. However, existing studies<sup>4-7</sup> of spatial patterns in mortality from self-harm and interpersonal violence are primarily from the 1980s and 1990s, and more timely data on local-level trends are unavailable. Additionally, studies<sup>8,9</sup> of drug poisoning have failed to distinguish between accidental and intentional overdoses (ie, overdoses intended to self-inflict harm or to harm others), despite important differences in the underlying etiology of unintentional and intentional overdoses.

More recently, a new small-area methodology was used to estimate county-level trends in mortality from 21 major causes of death.<sup>10</sup> Among these 21 categories were mental and substance use disorders (which combines both drug use disorders and alcohol use disorders as well as deaths due to several mental health disorders) and intentional injuries (which combines self-harm and interpersonal violence).

This study utilizes the same small-area estimation method to describe county-level trends in mortality rates separately for 4 causes: alcohol use disorders, drug use disorders, self-harm, and interpersonal violence from 1980 to 2014.

## Methods

This study used previously reported methods<sup>10</sup> that are described briefly in this section. This research received institutional review board approval from the University of Washington. Informed consent was not required because the study used deidentified data and was retrospective.

### Data

This analysis used deidentified death records from the National Center for Health Statistics (NCHS)<sup>11</sup> and population counts from the US Census Bureau,<sup>12</sup> NCHS,<sup>13-15</sup> and the Human Mortality Database.<sup>16</sup> Deaths and population were tabulated by county of residence, age group (0, 1-4, 5-9, ..., 70-74, 75-79, and ≥80 years), sex, year, and (for deaths only) underlying cause. County-level covariates, including levels of education, income, race/ethnicity, Native American reservations, and population density were derived from

## Key Points

**Question** What are the spatial and temporal trends in mortality due to alcohol use disorders, drug use disorders, self-harm, and interpersonal violence among US counties from 1980 to 2014?

**Findings** In this study of 2 848 768 deaths in the United States from 1980 to 2014, mortality rates varied widely among counties and increased by 618.3% for drug use disorders but decreased by 8.1% for alcohol use disorders, 6.0% for self-harm, and 44.9% for interpersonal violence. Mortality rates due to drug use disorders increased in every county, while mortality rates due to alcohol use disorders, self-harm, and interpersonal violence increased in some counties and decreased in others.

**Meaning** Between 1980 and 2014, there were important differences among US counties in the level and trend in mortality rates due to alcohol use disorders, drug use disorders, self-harm, and interpersonal violence.

data provided by the US Census Bureau and NCHS (eTable 1 in the [Supplement](#)). Counties were combined as needed to ensure historically stable units of analysis (eTable 2 in the [Supplement](#)).

### Cause List and Garbage Redistribution

The Global Burden of Diseases, Injuries, and Risk Factors Study (GBD) cause list was used for this analysis.<sup>1</sup> This cause list is arranged hierarchically in 4 levels, and within each level, the list is exhaustive and mutually exclusive. eTable 3 (in the [Supplement](#)) lists all causes in the GBD cause list and the *International Classification of Diseases, Ninth Revision (ICD-9)* and *ICD-10* codes that correspond to each cause. The focus of this study was on substance use disorders and intentional injuries, specifically: alcohol use disorders (*ICD-9* codes 291-291.9, 303-303.93, 305.0-305.03, 357.5, 790.3, E860-E860.19; *ICD-10* codes F10-F10.99, G31.2, G72.1, P04.3, Q86.0, R78.0, X45-X45.9), drug use disorders (*ICD-9* codes 292-292.9, 304.0-304.83, 305, 305.1-305.93, 760.7-760.79, E850-E850.29; *ICD-10* codes F11-F16.99, F18-F19.99, P04.4-P04.49, P96.1, R78.1-R78.5), self-harm (*ICD-9* codes E950-E959; *ICD-10* codes X60-X84.9, Y87.0), and interpersonal violence (*ICD-9* codes E960-E969; *ICD-10* codes X85-Y08.9, Y87.1). However, all causes of death in the GBD cause list were analyzed concurrently.

Previous studies have documented the existence of “garbage codes”—insufficiently specific or implausible cause of death codes used in death registration data that may lead to misleading geographic and temporal patterns.<sup>17</sup> Algorithms developed for the GBD (and described in detail elsewhere<sup>1,10</sup>) were used to reallocate deaths assigned one of these garbage codes to plausible alternatives. First, plausible target causes were assigned to each garbage code or group of garbage codes. Second, deaths were reassigned to specified target codes according to proportions derived in 1 of 4 ways: (1) published literature or expert opinion; (2) regression models; (3) according to the proportions initially observed among targets; and (4) for HIV/AIDS

specifically, by comparison to years before HIV/AIDS became widespread.

### Small-Area Models

Bayesian, spatially explicit mixed-effects regression models were estimated separately for each cause and for males and females. The model was specified as

$$\log(m_{j,t,a}) = \beta_0 + \beta_1 X_{j,t} + \gamma_{1,a,t} + \gamma_{2,j} + (\gamma_{3,j} \cdot t + \gamma_{4,j,t}) + (\gamma_{5,j} \cdot a + \gamma_{6,j,a})$$

in which  $D_{j,t,a}$  indicates the number of deaths,  $P_{j,t,a}$  indicates the population, and  $m_{j,t,a}$  indicates the underlying mortality rate for a given county ( $j$ ), year ( $t$ ), and age group ( $a$ ). The model for  $m_{j,t,a}$  contained 6 components: an intercept ( $\beta_0$ ); fixed covariate effects ( $\beta_1$ ); random age-time effects ( $\gamma_{1,a,t}$ ); random spatial effects ( $\gamma_{2,j}$ ); random space-time effects ( $\gamma_{3,j}$  and  $\gamma_{4,j,t}$ ); and random space-age effects ( $\gamma_{5,j}$  and  $\gamma_{6,j,a}$ ). The model incorporated 7 covariates: the proportion of the adult population who graduated from high school, the proportion of the population that is Hispanic (regardless of race), the proportion of the population that is black (regardless of Hispanic ethnicity), the proportion of the population that is a race other than black or white (regardless of Hispanic ethnicity), the proportion of a county that is contained within a state or federal Native American reservation, the median household income, and the population density. The random effects  $\gamma_1$ ,  $\gamma_2$ ,  $\gamma_3$ , and  $\gamma_5$  were assumed to follow conditional autoregressive distributions, which allow for smoothing over adjacent age groups and years ( $\gamma_1$ ) or counties ( $\gamma_2$ ,  $\gamma_3$ , and  $\gamma_5$ ).<sup>18,19</sup> The random effects  $\gamma_4$  and  $\gamma_6$  were assumed to follow independent mean-zero normal distributions.

Models were fit using the Template Model Builder Package<sup>20</sup> in the R statistical software (version 3.2.4). One thousand draws of  $m_{j,t,a}$  were taken from the posterior distribution and then raked (ie, scaled along multiple dimensions) by cause and by county to ensure consistency between levels of the cause hierarchy as well as with national estimates from the GBD.<sup>1,10,21</sup> Mortality rates for both sexes combined were calculated from the population-weighted average of the male and female mortality rates. Age-standardized mortality rates were calculated using the US 2010 census population as the standard. Years of life lost were calculated by multiplying the mortality rate by population by age-specific life expectancy from the reference life table used in the GBD<sup>1</sup> and then summing across all ages. Point estimates were calculated from the mean of all draws, and 95% uncertainty intervals (UIs) were calculated from the 2.5th and 97.5th percentiles. Changes over time were considered statistically significant if the posterior probability of an increase (or decrease) was at least 95% (ie, if there was an increase (or decrease) in more than 95% of the 1000 posterior draws). Changes over the full time range (1980-2014) were the primary focus; however, changes between 1980 and 2000, as well as changes between 2000 and 2014, were also considered because preliminary results indicated a reversal in trends from 2000 to 2014 compared with 1980 to 2000 for self-harm.

No explicit correction for multiple testing (ie, across multiple counties) was applied; however, the risk of spuriously detecting changes due to multiple testing was mitigated by modeling all counties simultaneously. County-level inequality in mortality rates was quantified by comparing the 10th and 90th percentile rates among counties: the difference between the 10th and 90th percentile was used as a measure of absolute geographic inequality and the ratio between the 10th and 90th percentile was used as a measure of relative geographic inequality.

## Results

A total of 2 848 768 deaths due to substance use disorders and intentional injuries were recorded in the United States between 1980 and 2014. Of these deaths, 73.9% were originally assigned ICD codes that map exclusively to 1 of these 4 causes, including 91.1% of deaths due to alcohol use disorders, 15.0% of deaths due to drug use disorders, 87.6% of deaths due to self-harm, and 88.6% of deaths due to interpersonal violence. ICD codes related to accidental poisonings (ICD-9: E850.3-E854.3, E854.8, E855-E855.6, E855.8-E855.9, E858-E858.9, E866-E866.9; ICD-10: X40-X44.9, X49-X49.9), which were redistributed primarily to substance use disorders among individuals aged 15 years and older and to unintentional poisonings among individuals younger than age 15 years, contributed 5.2% of deaths due to alcohol use disorders and 80.0% of deaths due to drug use disorders. ICD codes related to injury deaths for which intent was undetermined (ICD-9: E980-E989; ICD-10: Y10-Y34.9, Y86-87, Y87.2, Y89, Y89.9, Y90-Y99.9) contributed a further 1.2% of deaths due to alcohol use disorders, 1.4% of deaths due to drug use disorders, 6.7% of deaths due to self-harm, and 5.3% of deaths due to interpersonal violence. In addition, other garbage codes contributed 2.4% of deaths due to alcohol use disorders, 3.6% of deaths due to drug use disorders, 5.6% of deaths due to self-harm, and 6.1% of deaths due to interpersonal violence.

### Alcohol Use Disorders

Between 1980 and 2014, there were 256 432 deaths due to alcohol use disorders recorded in the United States. In 2014, the age-standardized national mortality rate due to alcohol use disorders was 2.8 (95% UI, 2.7-3.0) deaths per 100 000 persons but varied among counties from 0.6 deaths per 100 000 to 38.8 deaths per 100 000 persons (Table 1). The distribution of counties, according to the mortality rate from alcohol use disorders, was highly skewed: in 2014, the 90th percentile among counties was 4.7 deaths per 100 000, compared with the maximum rate of 38.8 deaths per 100 000 persons (Table 1). Western counties generally experienced higher levels of mortality than counties in the East, and counties with especially high mortality rates, compared with the rest of United States (>12.9 deaths per 100 000 persons [top 1%]), were found in parts of Wisconsin, North Dakota, South Dakota, Nebraska, Montana, New Mexico, Arizona, Utah, and Alaska (Figure 1).

**Table 1. National-Level Deaths, Years of Life Lost, and Age-Standardized Mortality Rates; and County-Level Distribution of Age-Standardized Mortality Rates in 1980, 2000, and 2014 Due to Alcohol Use Disorders, Drug Use Disorders, Self-harm, and Interpersonal Violence**

Cause of Death	National Level			US County-Level Mortality Rates						
	Deaths, No. in Thousands (95% Uncertainty Interval)	Years of Life Lost, No. in Thousands (95% Uncertainty Interval)	Age-Standardized Mortality Rate, No. of Deaths/100 000 Population (95% Uncertainty Interval)	No. of Deaths/100 000 Population						
				Minimum	10th Percentile	Median	90th Percentile	Maximum	90th Minus 10th Percentile <sup>a</sup>	90th/10th Percentile Ratio <sup>b</sup>
<b>Alcohol Use Disorders</b>										
1980	5.8 (5.4-6.3)	202.8 (189.1-217.7)	3.1 (2.9-3.3)	0.5	1.1	2.2	5.0	49.4	3.8	4.3
2000	7.2 (6.9-7.5)	247.7 (238.0-256.8)	2.8 (2.7-2.9)	0.7	1.3	2.3	4.4	36.0	3.0	3.2
2014	9.4 (8.8-9.9)	307.4 (289.7-324.5)	2.8 (2.7-3.0)	0.6	1.5	2.5	4.7	38.8	3.2	3.2
<b>Drug Use Disorders</b>										
1980	3.3 (3.1-3.5)	162.9 (154.0-174.8)	1.4 (1.4-1.5)	0.2	0.4	0.6	1.1	9.3	0.7	3.0
2000	14.3 (13.7-14.9)	647.9 (621.2-676.8)	4.9 (4.7-5.1)	0.8	1.7	3.2	6.1	27.0	4.5	3.6
2014	33.1 (30.9-34.6)	1455.5 (1359.6-1524.0)	10.4 (9.7-10.9)	1.6	4.1	8.6	17.0	57.1	12.9	4.2
<b>Self-harm</b>										
1980	31.9 (30.6-33.1)	1416.2 (1359.0-1473.9)	14.7 (14.2-15.3)	6.6	11.2	14.3	18.9	46.0	7.6	1.7
2000	34.7 (33.8-35.6)	1458.0 (1418.9-1496.1)	12.5 (12.2-12.8)	5.6	10.4	13.7	18.7	66.2	8.3	1.8
2014	44.8 (43.2-46.4)	1785.4 (1721.7-1847.8)	13.9 (13.3-14.4)	5.9	11.6	16.1	23.0	98.7	11.5	2.0
<b>Interpersonal Violence</b>										
1980	24.7 (23.5-25.5)	1322.1 (1257.9-1370.8)	10.4 (9.9-10.8)	1.5	2.5	6.0	15.5	50.4	13.0	6.1
2000	19.5 (19.0-20.1)	1047.6 (1018.8-1076.9)	6.8 (6.6-7.0)	1.1	2.0	4.2	9.9	40.9	8.0	5.0
2014	18.3 (17.6-19.1)	942.0 (905.8-982.3)	5.7 (5.5-6.0)	1.0	1.9	3.9	9.0	35.7	7.1	4.7

<sup>a</sup> Measure of absolute geographic inequality.

<sup>b</sup> Measure of relative geographic inequality.

Nationally, the age-standardized mortality rate from alcohol use disorders decreased by 8.1% (95% UI, -0.5% to 21.1%) between 1980 and 2014 due to a decrease of 11.0% (95% UI, 3.9% to 18.8%) between 1980 and 2000 and an increase of 3.2% (95% UI, -3.9% to 10.0%) between 2000 and 2014 (Table 2). Despite the national decrease in alcohol use mortality between 1980 and 2014, more counties experienced increases in the mortality rate (65.4%; statistically significant in 26.8% of counties) than decreases (34.6%; statistically significant in 12.5% of counties). Counties with above average increases were located predominantly in the northern and western United States. In contrast, counties with particularly large decreases (>67.8% [top 1%]) were found in South Carolina, North Carolina, Virginia, Georgia, Florida, and Alaska (Figure 1). The degree of absolute and relative inequality among counties in mortality from alcohol use disorders decreased from 1980 to 2014 (Table 1; 99.7% posterior probability of decrease in absolute inequality; >99.9% posterior probability of decrease in relative inequality); in 1980, the mortality rate in counties in the 10th percentile was 1.1 deaths per 100 000 persons and the mortality rate in counties in the 90th percentile was 5.0 deaths per 100 000 persons (absolute difference, 3.8 deaths per 100 000 persons; relative difference, 4.3-fold), compared to a 2014 mortality rate of 1.5 deaths per 100 000 persons in counties in the 10th percentile and a mortality rate of 4.7 deaths per 100 000 persons in counties in the 90th percentile (absolute difference, 3.2 deaths per 100 000 persons; relative difference, 3.2-fold).

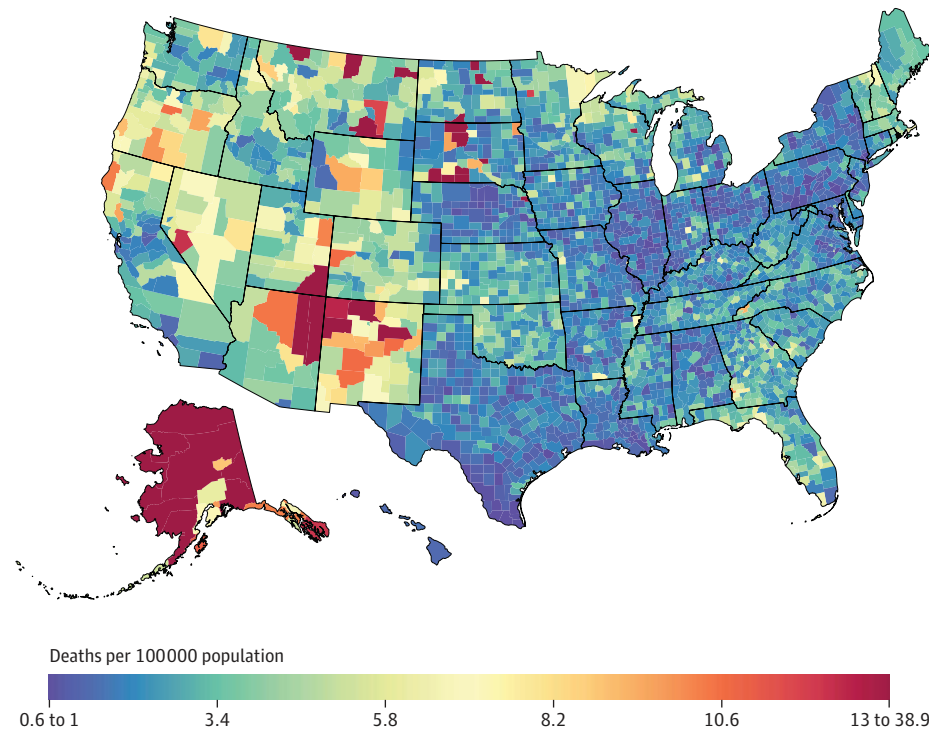
### Drug Use Disorders

Between 1980 and 2014, there were 542 501 deaths due to drug use disorders recorded in the United States. Nationally, the age-standardized mortality rate from drug use disorders was 10.4 (95% UI, 9.7 to 10.9) deaths per 100 000 persons in 2014, while at the county level, mortality rates varied from 1.6 deaths per 100 000 to 57.1 deaths per 100 000 persons (Table 1). The distribution of counties by mortality rate was highly skewed: the 90th percentile among counties was 17.0 deaths per 100 000 persons, compared to the maximum rate of 57.1 deaths per 100 000 persons (Table 1). Counties near the border of Kentucky and West Virginia, as well as individual counties in New Mexico, Alabama, Indiana, Tennessee, and Virginia had very high mortality rates relative to the rest of the United States (>32.3 deaths per 100 000 persons [top 1%]) (Figure 2).

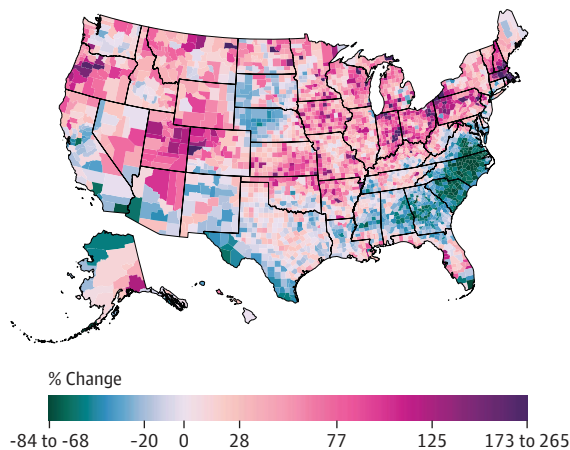
Nationally, the age-standardized mortality rate due to drug use disorders increased by 238.2% (95% UI, 211.8% to 261.5%) from 1980 to 2000 and by 112.4% (95% UI, 98.4% to 125.7%) from 2000 to 2014, for an overall increase of 618.3% (95% UI, 526.8% to 648.3%) between 1980 and 2014 (Table 2). Mortality rates increased in every county between 1980 and 2014 (statistically significant in 99.8% of counties), although the magnitude of this increase varied regionally. Counties located in Kentucky, West Virginia, Ohio, Indiana, and eastern Oklahoma experienced the largest increases (>5000%) over this period (Figure 2). As a result of this variability, there was a marked increase in both absolute and

Figure 1. County-Level Mortality From Alcohol Use Disorders

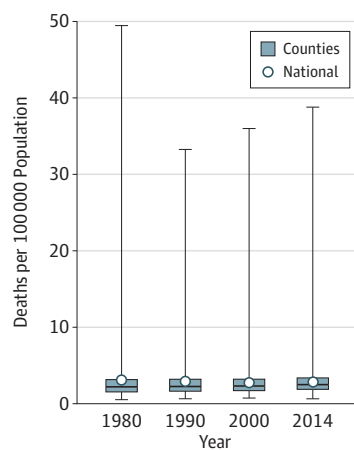
A Age-standardized mortality rate from alcohol use disorders, both sexes, 2014



B Percent change in age-standardized mortality rate from alcohol use disorders between 1980 and 2014, both sexes



C Age-standardized mortality rate from alcohol use disorders over time



A, Age-standardized mortality rate for both sexes combined in 2014.

B, Relative change in the age-standardized mortality rate for both sexes combined between 1980 and 2014. A and B, the color scale is truncated at approximately the first and 99th percentile as indicated by the range given in the color scale.

C, Age-standardized mortality rate for both sexes combined in 1980, 1990, 2000, and 2014. The bottom border of the boxes indicates the 25th percentile; middle line, the 50th percentile; and top border indicates the 75th percentile across all counties; whiskers indicate the full range across counties; and the circles indicate the national-level rate.

relative inequality (Table 1; >99.9% posterior probability of increase); in 1980, the mortality rate in counties in the 10th percentile was 0.4 deaths per 100 000 persons and in counties in the 90th percentile was 1.1 deaths per 100 000 persons (absolute difference, 0.7 deaths per 100 000 persons; relative difference, 3.0-fold), compared to a 2014 mortality rate of 4.1 deaths per 100 000 persons in counties in the 10th percentile and a rate of 17.0 deaths per 100 000 persons in counties in the 90th percentile (absolute difference, 12.9 deaths per 100 000 persons; relative difference, 4.2-fold).

### Self-harm

Between 1980 and 2014, there were 1 289 086 deaths due to self-harm recorded in the United States. In 2014, the national age-standardized mortality rate due to self-harm was 13.9 (95% UI, 13.3 to 14.4) deaths per 100 000 persons, while among counties, the mortality rate due to self-harm varied from 5.9 deaths per 100 000 to 98.7 deaths per 100 000 persons with an 11.5 deaths per 100 000-persons gap between counties in the 10th and 90th percentiles (Table 1). Counties with very high mortality rates (>34.2 deaths per 100 000

**Table 2. Change in the Age-Standardized Mortality Rate Due to Alcohol Use Disorders, Drug Use Disorders, Self-harm, and Interpersonal Violence, 1980-2000, 2000-2014, and 1980-2014**

Cause of Death by Year	National Change in Mortality Rate, % (95% Uncertainty Interval)	No. (%) of US Counties			
		Increases in Mortality Rate		Decreases in Mortality Rate	
		Total	Statistically Significant Increase <sup>a</sup>	Total	Statistically Significant Decrease <sup>b</sup>
<b>Alcohol Use Disorders</b>					
1980-2000	-11.0 (-18.8 to -3.9)	1854 (59.61)	527 (16.95)	1256 (40.39)	328 (10.55)
2000-2014	3.2 (-3.9 to 10.0)	2135 (68.65)	520 (16.72)	975 (31.35)	223 (7.17)
1980-2014	-8.1 (-21.1 to 0.5)	2033 (65.37)	832 (26.75)	1077 (34.63)	388 (12.48)
<b>Drug Use Disorders</b>					
1980-2000	238.2 (211.8 to 261.5)	3109 (99.97)	3099 (99.65)	1 (0.03)	0
2000-2014	112.4 (98.4 to 125.7)	3107 (99.90)	3087 (99.26)	3 (0.10)	0
1980-2014	618.3 (526.8 to 648.3)	3110 (100.00)	3105 (99.84)	0	0
<b>Self-harm</b>					
1980-2000	-15.3 (-19.1 to -11.3)	1096 (35.24)	387 (12.44)	2014 (64.76)	960 (30.87)
2000-2014	11.0 (6.4 to 15.7)	3016 (96.98)	2611 (83.95)	94 (3.02)	21 (0.68)
1980-2014	-6.0 (-11.2 to -1.0)	2320 (74.60)	1558 (50.10)	790 (25.40)	342 (11.00)
<b>Interpersonal Violence</b>					
1980-2000	-34.6 (-37.4 to -31.0)	71 (2.28)	5 (0.16)	3039 (97.72)	1529 (49.16)
2000-2014	-15.6 (-19.0 to -11.7)	1044 (33.57)	29 (0.93)	2066 (66.43)	274 (8.81)
1980-2014	-44.9 (-47.7 to -41.0)	204 (6.56)	14 (0.45)	2906 (93.44)	1375 (44.21)

<sup>a</sup> Posterior probability of an increase equal to or greater than 95%.

<sup>b</sup> Posterior probability of a decrease equal to or greater than 95%.

persons [top 1%]) were found primarily in states in the Western United States, including Alaska, Nevada, South Dakota, Utah, New Mexico, Arizona, Montana, North Dakota, Oregon, and Wyoming, as well as 1 county in Maryland (Figure 3).

The age-standardized mortality rate due to self-harm decreased by 6.0% (95% UI, 1.0% to 11.2%) overall between 1980 and 2014 (Table 1) due to a decrease of 15.3% (95% UI, 11.3% to 19.1%) between 1980 and 2000 and an increase of 11.0% (95% UI, 6.4% to 15.7%) from 2000 to 2014 (Table 2). Most counties experienced an increase in self-harm mortality from 1980 to 2014 (74.6%; statistically significant in 50.1% of counties). Counties with particularly large increases (>74.4% [top 1%]) in mortality from self-harm were found in Alaska, Utah, Arkansas, Montana, North Dakota, Oklahoma, Tennessee, Colorado, Indiana, Kentucky, Maryland, Michigan, South Dakota, and Texas (Figure 3). Absolute and relative inequality among counties in mortality from self-harm also increased over this period (Table 1; posterior probability of increase >99.9%): in 1980 the mortality rate in counties in the 10th percentile was 11.2 deaths per 100 000 persons and for counties in the 90th percentile was 18.9 deaths per 100 000 persons (absolute difference, 7.6 deaths per 100 000 persons; relative difference, 1.7-fold), compared to a 2014 mortality rate of 11.6 deaths per 100 000 persons for counties in the 10th percentile and 23.0 deaths per 100 000 persons for counties in the 90th percentile (absolute difference, 11.5 deaths per 100 000 persons; relative difference, 2.0-fold).

### Interpersonal Violence

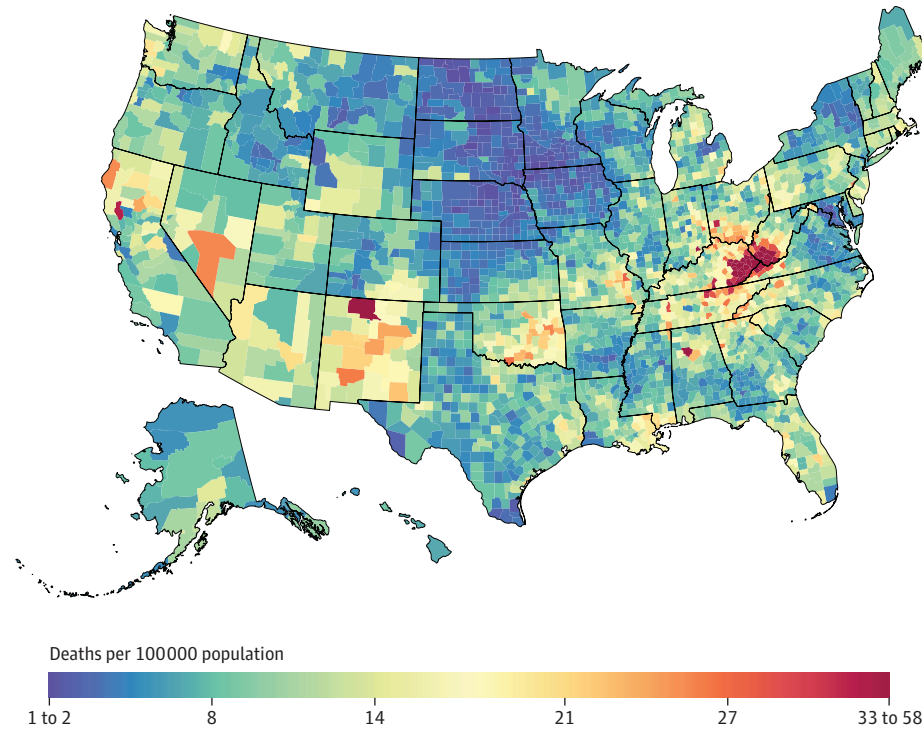
Between 1980 and 2014, there were 760 749 deaths due to interpersonal violence recorded in the United States. The

national age-standardized mortality rate due to interpersonal violence was 5.7 (95% UI, 5.5 to 6.0) deaths per 100 000 persons in 2014. Among counties, the mortality rate from interpersonal violence varied from 1.0 deaths per 100 000 to 35.7 deaths per 100 000 persons, with a 7.1 deaths per 100 000-persons gap between the 10th and 90th percentile (Table 1). Counties with very high mortality rates from interpersonal violence (>19.1 deaths per 100 000 persons [top 1%]) were found along the southern half of the Mississippi River and in Alabama, as well as in Alaska, Montana, North Dakota, South Dakota, Kansas, Michigan, Maryland, Virginia, and North Carolina (Figure 4).

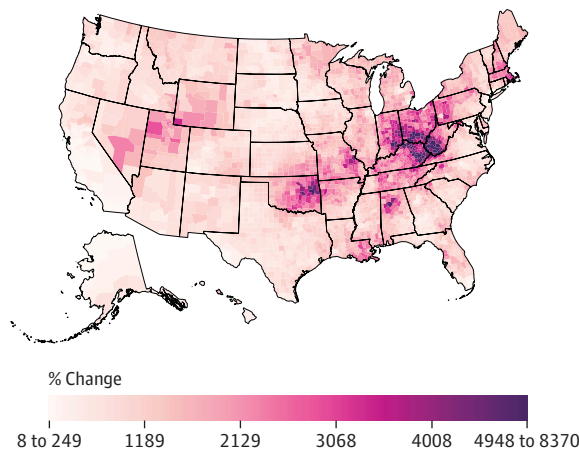
Nationally, the age-standardized mortality rate due to interpersonal violence decreased by 34.6% (95% UI, 31.0% to 37.4%) from 1980 to 2000 and by 15.6% (95% UI, 11.7% to 19.0%) from 2000 to 2014, for an overall decrease of 44.9% (95% UI, 41.0% to 47.7%) between 1980 and 2014 (Table 2). Most counties also experienced a decrease between 1980 and 2014 (93.4%; statistically significant in 44.2% of counties), although increases in the mortality rate due to interpersonal violence were observed in 6.6% of counties (statistically significant in 0.5%). Counties with increases were concentrated in northern Midwestern and Atlantic states, while counties with the largest decreases (>70.6% [top 1%]) were found in Virginia, Georgia, Florida, Texas, California, and New York (Figure 4). Despite these differences, both absolute and relative inequality among counties in mortality from interpersonal violence decreased substantially over this period (Table 1; posterior probability of decrease >99.9%); in 1980, the mortality rate in counties in the 10th percentile was 2.5 deaths per 100 000 persons and for counties in the 90th percentile, it was 15.5 deaths per 100 000 persons (absolute

Figure 2. County-Level Mortality From Drug Use Disorders

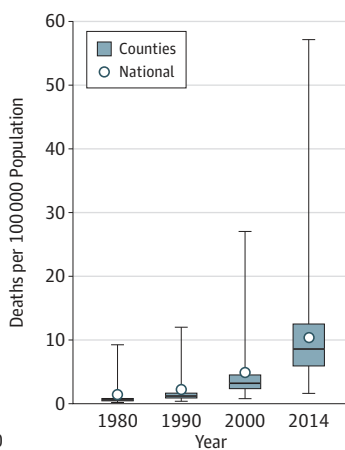
A Age-standardized mortality rate from drug use disorders, both sexes, 2014



B Percent change in age-standardized mortality rate from drug use disorders between 1980 and 2014, both sexes



C Age-standardized mortality rate from drug use disorders over time



A, Age-standardized mortality rate for both sexes combined in 2014.

B, Relative change in the age-standardized mortality rate for both sexes combined between 1980 and 2014. A and B, the color scale is truncated at approximately the first and 99th percentile as indicated by the range given in the color scale.

C, Age-standardized mortality rate for both sexes combined in 1980, 1990, 2000, and 2014. The bottom border of the boxes indicates the 25th percentile; middle line, the 50th percentile; and top border indicates the 75th percentile across all counties; whiskers indicate the full range across counties; and the circles indicate the national-level rate.

difference, 13.0 deaths per 100 000 persons; relative difference, 6.1-fold), compared to a 2014 mortality rate of 1.9 deaths per 100 000 persons for counties in the 10th percentile and 9.0 deaths per 100 000 persons for counties in the 90th percentile (absolute difference, 7.1 deaths per 100 000 persons; relative difference, 4.7-fold).

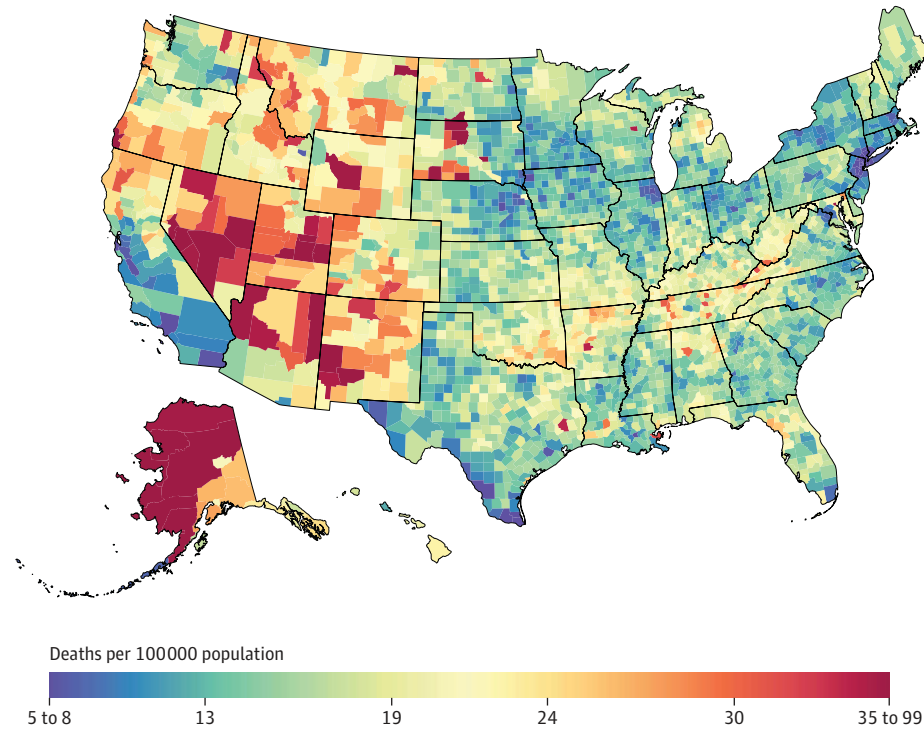
All results by county, year, and sex are available in an online visualization tool.<sup>22</sup> Selected sex-specific results are also presented in eTables 4 and 5 and eFigures 1 through 8 in the Supplement.

## Discussion

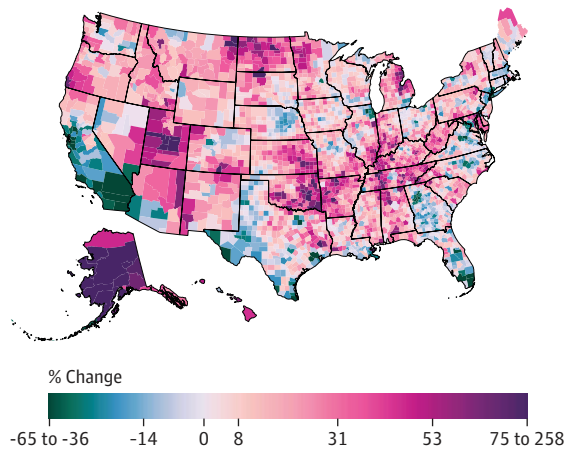
This study documents spatial and temporal variation in mortality rates from 4 causes of death: alcohol use disorders, drug use disorders, self-harm, and interpersonal violence. For all 4 causes, there were substantial differences in mortality rates among counties. Moreover, for drug use disorders and self-harm, these differences have increased over time. The findings in this study may help clinicians,

Figure 3. County-Level Mortality From Self-harm

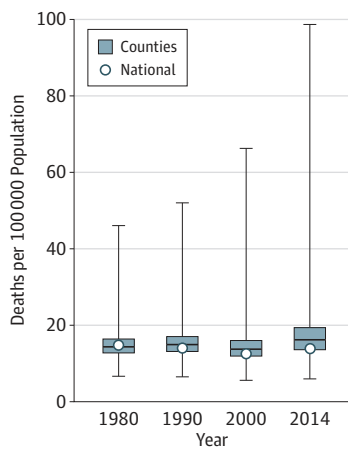
A Age-standardized mortality rate from self-harm, both sexes, 2014



B Percent change in age-standardized mortality rate from self-harm between 1980 and 2014, both sexes



C Age-standardized mortality rate from self-harm over time



A, Age-standardized mortality rate for both sexes combined in 2014.  
 B, Relative change in the age-standardized mortality rate for both sexes combined between 1980 and 2014. A and B, the color scale is truncated at approximately the first and 99th percentile as indicated by the range given in the color scale.  
 C, Age-standardized mortality rate for both sexes combined in 1980, 1990, 2000, and 2014. The bottom border of the boxes indicates the 25th percentile; middle line, the 50th percentile; and top border indicates the 75th percentile across all counties; whiskers indicate the full range across counties; and the circles indicate the national-level rate.

local health authorities, and policymakers address the burden of substance use disorders and intentional injuries in their communities.

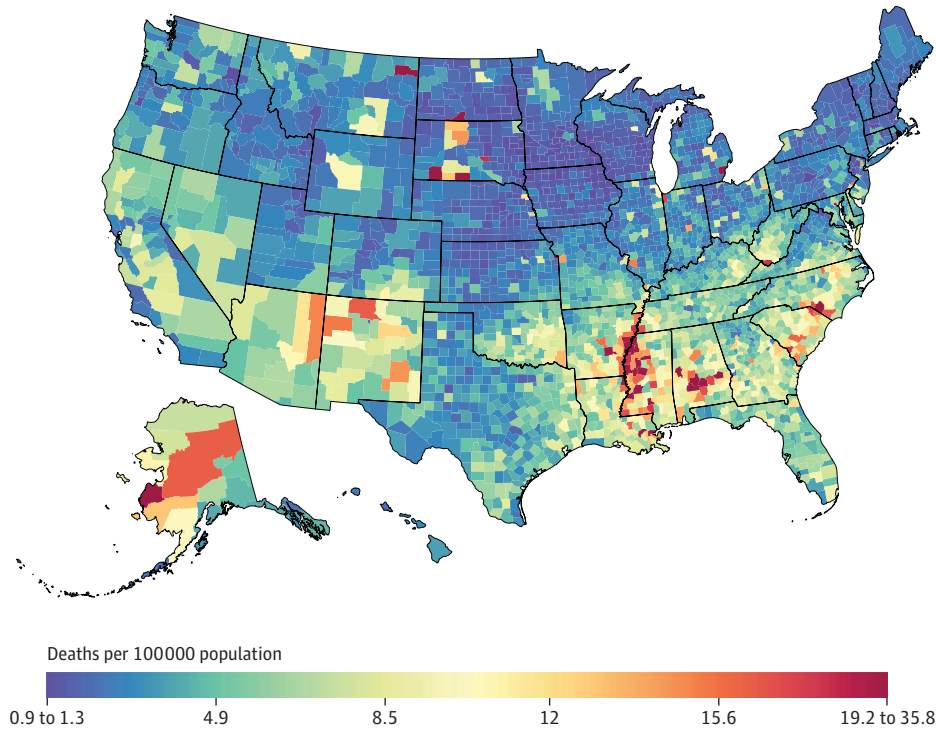
The results of this study are consistent with earlier reports, based on data from the 1980s and early 1990s, of large regional differences in mortality rates from self-harm and interpersonal violence.<sup>4-6</sup> This study improves on these earlier efforts by using small-area estimation methods that do not require pooling multiple years of data or combining counties into larger areas, and it also updates these analyses to include data from more recent decades. A number of pre-

vious studies have also considered regional differences in unintentional poisonings<sup>5,23</sup> or all drug use overdoses,<sup>8,9</sup> but in the former case, they do not distinguish between drug- and alcohol-related poisonings and other types of poisoning, and in the latter case do not distinguish between intentional overdoses (ie, as a means of self-harm or interpersonal violence) and unintentional overdoses. To our knowledge, this study is the first to consider alcohol and drug use disorders, apart from other types of unintentional poisonings and distinct from intentional overdoses, at the county level in the United States.

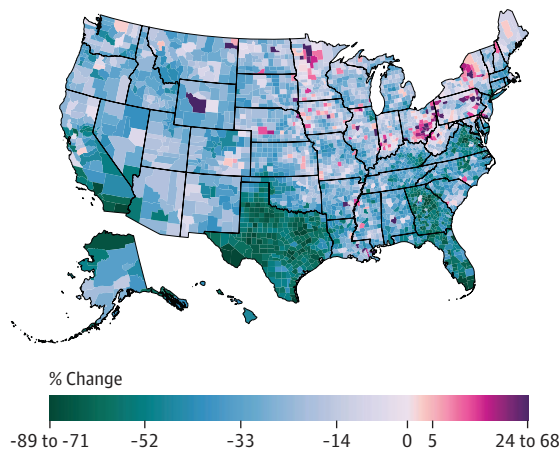


Figure 4. County-Level Mortality From Interpersonal Violence

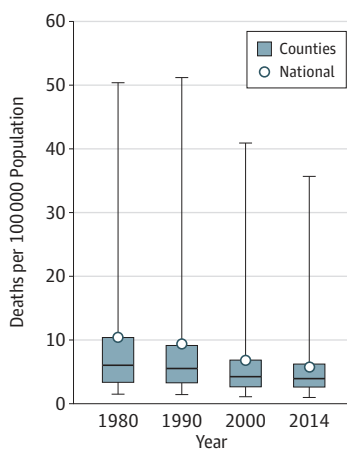
A Age-standardized mortality rate from interpersonal violence, both sexes, 2014



B Percent change in age-standardized mortality rate from interpersonal violence between 1980 and 2014, both sexes



C Age-standardized mortality rate from interpersonal violence over time



A, Age-standardized mortality rate for both sexes combined in 2014.  
 B, Relative change in the age-standardized mortality rate for both sexes combined between 1980 and 2014. A and B, the color scale is truncated at approximately the first and 99th percentile as indicated by the range given in the color scale.  
 C, Age-standardized mortality rate for both sexes combined in 1980, 1990, 2000, and 2014. The bottom border of the boxes indicates the 25th percentile; middle line, the 50th percentile; and top border indicates the 75th percentile across all counties; whiskers indicate the full range across counties; and the circles indicate the national-level rate.

Substance use disorders and intentional injury are responsible for a significant health burden in the United States, particularly among young and middle-aged adults. Indeed, among people aged 15 to 49 years in the United States, self-harm, drug use disorders, and interpersonal violence are the first, second, and fifth leading causes of death; combined, substance use disorders and intentional injuries are responsible for nearly one-third of all deaths in this age group.<sup>1</sup>

Overall, there was a slight decrease in mortality from alcohol use disorders between 1980 and 2014, although there were geographic areas, such as Alaska and the region in

which the 4 Southwest states of Utah, Colorado, Arizona, and New Mexico meet, that had very high mortality rates relative to rest of the country, and many counties experienced an increase in the mortality rate due to alcohol use disorders over the same period. However, mortality rates from drug use disorders increased by more than 600% between 1980 and 2014, largely due to increasing numbers of deaths from both prescription and nonprescription opioid overdoses.<sup>24</sup> Every county experienced an increase in deaths from drug use disorders, but that the burden of drug use overdoses was particularly acute in certain communities,

with more than a 4-fold variation from counties in the 10th percentile to counties in the 90th percentile. These findings highlight the need for a multipronged public health response focusing on prevention, harm-reduction, treatment, and recovery support.<sup>25</sup> Potentially beneficial strategies for each of these dimensions have been described, including fully implementing safer prescribing practices for opioid analgesics,<sup>26</sup> increasing availability of the opioid antagonist Naloxone,<sup>27</sup> and expanding access to treatment (including behavioral therapies and medication-assisted treatment).<sup>25</sup> Moreover, fuller integration of substance use disorder screening and treatment into primary care and other health care settings is required to promote earlier identification of at-risk or affected individuals and increase access to and utilization of appropriate services.<sup>25</sup>

Mortality rates from self-harm decreased overall between 1980 and 2014, but despite this overall decrease, mortality rates from self-harm increased between 2000 and 2014. In terms of geographic variation, deaths from self-harm were particularly high in regions of the Western United States with high rates of firearm availability and relatively low population density. Further action is required to reverse these recent increases and reduce the substantial health and social burden imposed by self-harm. In particular, improved access to effective mental health services,<sup>28</sup> and structural approaches such as means reduction<sup>29,30</sup> should be considered. In contrast to self-harm, mortality rates due to interpersonal violence decreased substantially between 1980 and 2014. Nonetheless, there was still significant inequality among counties with certain regions experiencing much higher rates of mortality due to interpersonal violence than the nation as a whole. In general, these counties were not located in regions typically noted for high rates of gun ownership (eg, the Western United States), nor were they primarily in more urban areas as might be expected. Substance use disorders increase the risk of suicide and intentional injuries, and efforts to reduce exposure to drugs and alcohol through prevention and treatment for at-risk individuals may also help to reduce mortality rates from self-harm and interpersonal violence in addition to mortality rates from substance use disorders; in 2015, 23% of deaths due to self-harm and

18% of deaths due to interpersonal violence were attributable to substance use.<sup>31</sup>

Relative geographic inequality in mortality rates from the conditions discussed in this article (a ratio of 4.2 for drug use disorders and 4.7 for interpersonal violence between counties in the 90th and the 10th percentile in 2014) was high compared to most other causes (eg, this ratio ranges from 1.2 to 2.2 among different cancers)<sup>32</sup> This suggests that there are important opportunities to more closely examine counties and communities with notably high or low mortality rates or particularly substantial increases or decreases in the mortality rate over time. Such research could facilitate identifying potential solutions to these problems that might include social, cultural, legal, policy, or health service-related approaches.

### Limitations

This study has several limitations. First, the population, deaths, and covariates data used are all subject to error. Second, the garbage code redistribution algorithms used to redistribute deaths assigned implausible or nonspecific causes to likely true causes of death have not been validated because appropriate criterion standard data are unavailable. Third, although these redistribution methods are likely associated with nontrivial uncertainty, this uncertainty is difficult to quantify and consequently has not been included in the uncertainty intervals associated with the estimated mortality rates. Fourth, the small-area models used in this analysis smooth mortality rates over time, space, and age groups, and may in some cases attenuate unusually low or high mortality rates, underestimating true geographic variability.

### Conclusions

Mortality due to alcohol use disorders, drug use disorders, self-harm, and interpersonal violence varied widely among US counties, both in terms of levels of mortality and trends. These estimates may be useful to inform efforts to target prevention, diagnosis, and treatment efforts to improve health and reduce inequalities.

#### ARTICLE INFORMATION

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**Author Contributions:** Dr Murray had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

**Concept and design:** Dwyer-Lindgren, Bertozzi-Villa, Shirude, Mokdad, Murray.

**Acquisition, analysis, or interpretation of data:** Dwyer-Lindgren, Bertozzi-Villa, Stubbs, Morozoff, Unützer, Naghavi, Mokdad.

**Drafting of the manuscript:** Dwyer-Lindgren.

**Critical revision of the manuscript for important intellectual content:** All authors.

**Statistical analysis:** Dwyer-Lindgren, Bertozzi-Villa, Stubbs, Naghavi.

**Obtained funding:** Mokdad.

**Administrative, technical, or material support:**

Morozoff, Unützer, Mokdad, Murray.

**Supervision:** Shirude, Mokdad, Murray.

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