JAMA | Original Investigation

Trends and Patterns of Differences in Chronic Respiratory Disease Mortality Among US Counties, 1980-2014

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IMPORTANCE Chronic respiratory diseases are an important cause of death and disability in the United States.

OBJECTIVE To estimate age-standardized mortality rates by county from chronic respiratory diseases.

DESIGN, SETTING, AND PARTICIPANTS Validated small area estimation models were applied to deidentified death records from the National Center for Health Statistics and population counts from the US Census Bureau, National Center for Health Statistics, and Human Mortality Database to estimate county-level mortality rates from 1980 to 2014 for chronic respiratory diseases.

EXPOSURE County of residence.

MAIN OUTCOMES AND MEASURES Age-standardized mortality rates by county, year, sex, and cause.

RESULTS A total of 4 616 711 deaths due to chronic respiratory diseases were recorded in the United States from January 1, 1980, through December 31, 2014. Nationally, the mortality rate from chronic respiratory diseases increased from 40.8 (95% uncertainty interval [UI], 39.8-41.8) deaths per 100 000 population in 1980 to a peak of 55.4 (95% UI, 54.1-56.5) deaths per 100 000 population in 2002 and then declined to 52.9 (95% UI, 51.6-54.4) deaths per 100 000 population in 2014. This overall 29.7% (95% UI, 25.5%-33.8%) increase in chronic respiratory disease mortality from 1980 to 2014 reflected increases in the mortality rate from chronic obstructive pulmonary disease (by 30.8% [95% UI, 25.2%-39.0%], from 34.5 [95% UI, 33.0-35.5] to 45.1 [95% UI, 43.7-46.9] deaths per 100 000 population), interstitial lung disease and pulmonary sarcoidosis (by 100.5% [95% UI, 5.8%-155.2%], from 2.7 [95% UI, 2.3-4.2] to 5.5 [95% UI, 3.5-6.1] deaths per 100 000 population), and all other chronic respiratory diseases (by 42.3% [95% UI, 32.4%-63.8%], from 0.51 [95% UI, 0.48-0.54] to 0.73 [95% UI, 0.69-0.78] deaths per 100 000 population). There were substantial differences in mortality rates and changes in mortality rates over time among counties, and geographic patterns differed by cause. Counties with the highest mortality rates were found primarily in central Appalachia for chronic obstructive pulmonary disease and pneumoconiosis; widely dispersed throughout the Southwest, northern Great Plains, New England, and South Atlantic for interstitial lung disease; along the southern half of the Mississippi River and in Georgia and South Carolina for asthma; and in southern states from Mississippi to South Carolina for other chronic respiratory diseases.

CONCLUSIONS AND RELEVANCE Despite recent declines in mortality from chronic respiratory diseases, mortality rates in 2014 remained significantly higher than in 1980. Between 1980 and 2014, there were important differences in mortality rates and changes in mortality by county, sex, and particular chronic respiratory disease type. These estimates may be helpful for informing efforts to improve prevention, diagnosis, and treatment.

JAMA. 2017;318(12):1136-1149. doi:10.1001/jama.2017.11747

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Supplemental content

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Chronic respiratory diseases, including chronic obstructive pulmonary disease (COPD), interstitial lung disease and pulmonary sarcoidosis, asthma, and pneumoconiosis, are responsible for substantial health and financial burden in the United States each year. In 2015, 6.7% of all deaths were due to chronic respiratory diseases, which were the fifth leading cause of death and the eighth leading cause of health burden overall as measured by disability-adjusted life-years.[1,2] Costs due to chronic respiratory diseases increased by 3.7% per year between 1996 and 2013, resulting in an estimated $132 billion in personal health expenditures in 2013.[3]

Significant variation in levels and trends in mortality rates due to chronic respiratory diseases among states has previously been documented.[4-6] More geographically granular information on temporal trends in mortality rates from chronic respiratory diseases is not widely available, but previous analyses of levels of COPD mortality at the county and health service area level have found substantial variation even within state borders.[7-9] Moreover, analyses of chronic respiratory disease prevalence and hospitalizations have also found significant variation both across and within states.[10,11] Geographically precise annual estimates of chronic respiratory disease mortality by type would facilitate a more complete understanding of regional and temporal variation in chronic respiratory disease mortality rates and may be useful for clinicians and policy makers interested in reducing geographic disparities and the health and financial burdens of chronic respiratory diseases overall.

Key Points

Question What are the spatial and temporal trends in chronic respiratory disease mortality among US counties from 1980 to 2014?

Findings Mortality rates due to chronic respiratory diseases varied substantially among counties in all years. Between 1980 and 2014, chronic respiratory disease mortality increased by 29.7% (95% uncertainty interval, 25.5%-33.8%) overall, but this trend varied by county, sex, and chronic respiratory disease type.

Meaning Between 1980 and 2014, there were important differences in chronic respiratory disease mortality among US counties.

Methods

The methods used for this analysis were previously reported in detail elsewhere and are described briefly here.[12] 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[13] and population counts from the US Census Bureau,[14] National Center for Health Statistics,[15-17] and Human Mortality Database.[18] Deaths and population in the United States from January 1, 1980, through December 31, 2014, were tabulated by county, age group (0, 1-4, 5-9, ..., 75-79, and ≥80 years), sex, year, and cause. County-level information on levels of education, income, race/ethnicity, Native American reservations, and population density derived from data provided by the US Census Bureau and the National Center for Health Statistics was also used (eTable 1 in the Supplement). Where needed, counties were combined to ensure historically stable units of analysis (eTable 2 in the Supplement).

Cause List and Garbage Code Redistribution

This study used the cause list developed for the Global Burden of Diseases, Injuries, and Risk Factors Study (GBD).[1] This cause list is arranged hierarchically in 4 levels; 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 *Tenth Revision* (*ICD-10*) codes that correspond to each cause. The focus of this study was on chronic respiratory diseases, specifically chronic obstructive pulmonary disease, interstitial lung disease and pulmonary sarcoidosis, asthma, pneumoconiosis (further subdivided into asbestosis, coal workers' pneumoconiosis, silicosis, and other pneumoconiosis), and the combination of all other respiratory diseases. Although the focus of this study was chronic respiratory diseases, all causes of death in the GBD cause list were analyzed concurrently.

Previous studies have identified "garbage codes" used in death registration data, that is, insufficiently specific or implausible cause-of-death codes. The use of these codes may vary over time and place, resulting in misleading geographic and temporal patterns.[19] Algorithms developed for the GBD were used to reallocate deaths assigned one of these garbage codes to plausible alternatives.[1] 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 with years before HIV/AIDS became widespread.

Statistical Analysis

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

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

where $D_{j,t,a}$, $P_{j,t,a}$, and $m_{j,t,a}$ are the number of deaths, the population, and the underlying mortality rate, respectively, for county j, year t, and age group a. The model for $m_{j,t,a}$ contained 6 components: an intercept (β_0), fixed covariate effects (β_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 $\gamma_{6,j,a}$).

Table. National-Level Deaths, YLLs, and Age-Standardized Mortality Rates and County-Level Distribution of Age-Standardized Mortality Rates Due to Chronic Respiratory Diseases in 2014

Chronic Respiratory Diseases	Deaths, No. in Thousands (95% UI)	YLLs, No. in Thousands (95% UI)	Age-Standardized Mortality Rate, No. of Deaths/100 000 Population (95% UI)	County-Level Mortality Rates: No. of Deaths/100 000 Population, Minimum	10th Percentile	Median	90th Percentile	Maximum	90th Minus 10th Percentile[a]	Ratio of 90th to 10th Percentile[b]
Chronic respiratory diseases, total	177.3 (172.8-182.2)	2522.2 (2466.8-2582.7)	52.9 (51.6-54.4)	14.3	44.1	62.5	85.2	161.0	41.1	1.9
Chronic obstructive pulmonary disease	151.2 (146.4-157.3)	2062.0 (2004.5-2138.2)	45.1 (43.7-46.9)	9.9	36.7	54.1	76.5	152.3	39.8	2.1
Interstitial lung disease and pulmonary sarcoidosis	18.2 (11.9-20.5)	275.1 (191.9-303.5)	5.5 (3.5-6.1)	2.7	4.4	5.4	6.9	14.9	2.6	1.6
Asthma	3.9 (3.6-4.3)	107.7 (101.7-115.1)	1.2 (1.1-1.3)	0.5	0.9	1.2	1.7	4.1	0.8	1.9
Pneumoconiosis	1.5 (1.4-1.7)	17.0 (16.0-18.7)	0.46 (0.43-0.51)	0.1	0.3	0.5	1.0	43.5	0.7	3.2
Asbestosis	0.58 (0.49-0.65)	6.9 (6.1-7.7)	0.17 (0.15-0.19)	0.0	0.1	0.1	0.4	10.8	0.3	6.1
Coal workers' pneumoconiosis	0.27 (0.23-0.35)	3.2 (2.8-3.9)	0.08 (0.07-0.10)	0.0	0.0	0.0	0.2	42.4	0.2	23.7
Silicosis	0.07 (0.06-0.10)	1.1 (0.9-1.4)	0.022 (0.019-0.031)	0.0	0.0	0.0	0.1	4.1	0.1	6.7
Other pneumoconiosis	0.61 (0.55-0.73)	5.9 (5.4-6.9)	0.18 (0.16-0.22)	0.1	0.2	0.2	0.3	0.7	0.2	2.1
Other chronic respiratory diseases[c]	2.4 (2.3-2.6)	60.3 (57.1-63.9)	0.73 (0.69-0.78)	0.3	0.7	0.9	1.1	2.2	0.4	1.6

Abbreviations: UI, uncertainty interval; YLLs, years of life lost.

[a] Measure of absolute geographic inequality.

[b] Measure of relative geographic inequality.

[c] Combination of all chronic respiratory diseases except chronic obstructive pulmonary disease, interstitial lung disease and pulmonary sarcoidosis, asthma, asbestosis, coal workers' pneumoconiosis, silicosis, and other pneumoconiosis.

The model incorporated 7 covariates ($X_{j,t}$): the proportion of the adult population who graduated high school, the proportion of the population that is Hispanic, the proportion of the population that is black, the proportion of the population that is a race other than black or white, the proportion of a county that is contained within a state or federal Native American reservation, the median household income, and the population density. γ_1, γ_2, γ_3, and γ_5 were assumed to follow conditional autoregressive distributions, which allow for smoothing over adjacent age groups and years (γ_1) or counties (γ_2, γ_3, and γ_5).[20,21] γ_4 and γ_6 were assumed to follow independent mean-zero normal distributions.

Models were fit using the Template Model Builder Package[22] in R version 3.2.4 statistical software (R Foundation for Statistical Computing). One thousand draws of $m_{j,t,a}$ were taken from the posterior distribution. These draws were raked[23] (ie, scaled along multiple dimensions) to ensure consistency between levels of the cause hierarchy and to ensure consistency with national estimates from the GBD.[1] Mortality rates for both sexes combined were calculated from the population-weighted average of the sex-specific mortality rates. Age-standardized mortality rates were calculated using the US 2010 census population as the standard. Years of life lost (YLLs) were calculated by multiplying the mortality rate by population by age-specific life expectancy from the reference life table used in the GBD[1] 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%. No explicit correction for multiple testing (ie, across multiple counties) was applied; however, modeling all counties simultaneously is expected to mitigate the risk of spuriously detecting changes due to multiple testing.

Results

Chronic Respiratory Diseases

Between 1980 and 2014, 4 616 711 deaths due to chronic respiratory diseases were recorded in the United States. Among all deaths due to chronic respiratory diseases, 9.4% had been assigned garbage codes and were reassigned via garbage code redistribution; at the county level, this ranged from 0% to 58.5% (interquartile range, 8.1%-12.6%) of deaths due to chronic respiratory diseases. In 2014, there were 177.3 (95% UI, 172.8-182.2) thousand deaths (6.7% of all deaths) and 2522.2 (95% UI, 2466.8-2582.7) thousand YLLs (5.5% of all YLLs) from chronic respiratory diseases (**Table**). Within chronic respiratory diseases, COPD accounted for the largest number of deaths in 2014

(151.2 [95% UI, 146.4-157.3] thousand deaths; 85.3%), followed by interstitial lung disease and pulmonary sarcoidosis (18.2 [95% UI, 11.9-20.5] thousand deaths; 10.3%), asthma (3.9 [95% UI, 3.6-4.3] thousand deaths; 2.2%), other chronic respiratory diseases (2.4 [95% UI, 2.3-2.6] thousand deaths; 1.4%), and pneumoconiosis (1.5 [95% UI, 1.4-1.7] thousand deaths; 0.9%).

Mortality rates from chronic respiratory diseases varied widely among counties (eFigure 1 in the Supplement), ranging from 14.3 to 161.0 deaths per 100 000 population and with a gap of 41.1 deaths per 100 000 population between counties in the 10th and 90th percentiles in 2014. Nationally, the mortality rate from chronic respiratory diseases increased from 40.8 (95% UI, 39.8-41.8) deaths per 100 000 population in 1980 to a peak of 55.4 (95% UI, 54.1-56.5) deaths per 100 000 population in 2002 and then declined to 52.9 (95% UI, 51.6-54.4) deaths per 100 000 population in 2014. Overall, this corresponds to a 29.7% (95% UI, 25.5%-33.8%) increase in the national mortality rate between 1980 and 2014. During this same period, the mortality rate from chronic respiratory diseases similarly increased in 93.2% of counties (statistically significant in 88.3%), but changes ranged from a 52.9% decline to a 224.0% increase. From 1980 to 2014, the difference between the mortality rate in counties in the 90th and 10th percentiles nearly doubled, increasing from 21.7 to 41.1 deaths per 100 000 population (posterior probability of increase >99.9%).

Results for all chronic respiratory diseases by county and year, including estimates for males and females separately, are available in an online visualization tool.[24]

Chronic Obstructive Pulmonary Disease

A total of 3 942 450 deaths due to COPD were recorded in the United States between 1980 and 2014. Mortality rates due to COPD varied widely among counties in 2014, ranging from 9.9 to 152.3 deaths per 100 000 population, with a difference of 39.8 deaths per 100 000 population between counties in the 10th and 90th percentiles. Counties with the highest rates of COPD in 2014 were concentrated in central Appalachia, but could also be found in other states in the southern half of the United States as far west as Colorado (**Figure 1**). Counties with the lowest rates of COPD in 2014 were found near Washington, DC; New York, New York; and San Francisco, California; along the Texas-Mexico border; in central Colorado; and in northern Utah.

Mortality from COPD increased between 1980 and 2014, with the mortality rate increasing 30.8% (95% UI, 25.2%-39.0%) overall from 34.5 (95% UI, 33.0-35.5) to 45.1 (95% UI, 43.7-46.9) deaths per 100 000 population. The mortality rate similarly increased in a majority of counties (91.9%; statistically significant in 86.1%) during this period, but changes in the mortality rate nonetheless varied widely among counties, ranging from a 60.5% decline to a 263.7% increase. Large increases were observed in counties throughout the South, particularly in a band stretching from northern Texas to North Carolina and South Carolina. Counties where COPD declined were concentrated in the Washington, DC, area, along the Texas-Mexico border, along the Pacific coast in California, and in parts of Alaska, Colorado, Wyoming, and Montana.

Temporal trends in COPD mortality rates differed considerably between males and females (eFigure 2 and eFigure 3 in the Supplement). Nationally, COPD mortality rates among males declined by 10.9% (95% UI, 3.9%-15.4%) between 1980 and 2014, with most of this decline occurring between 2000 and 2014. In contrast, national COPD mortality rates among females increased by 107.4% (95% UI, 92.1%-125.2%) between 1980 and 2014, with most of the increase occurring prior to 2003 and relatively steady rates from 2003 to 2014. At the county level between 1980 and 2014, COPD mortality among males declined in 40.7% of counties (statistically significant in 23.6%), whereas COPD mortality among females increased in most counties (98.9%; statistically significant in 97.4%).

Interstitial Lung Disease and Pulmonary Sarcoidosis

Between 1980 and 2014, 403 168 deaths due to interstitial lung disease and pulmonary sarcoidosis were recorded in the United States. In 2014, mortality rates from interstitial lung disease and pulmonary sarcoidosis varied among counties, ranging from 2.7 to 14.9 deaths per 100 000 population and with a gap of 2.6 deaths per 100 000 population between counties in the 10th and 90th percentiles. Counties with very high mortality rates relative to other counties were dispersed throughout several regions, including the Southwest, northern Great Plains, New England, and South Atlantic (**Figure 2**). Counties with very low mortality rates relative to other counties were also found in many parts of the United States, including parts of Nevada, Colorado, Texas, North Dakota, South Dakota, and Florida.

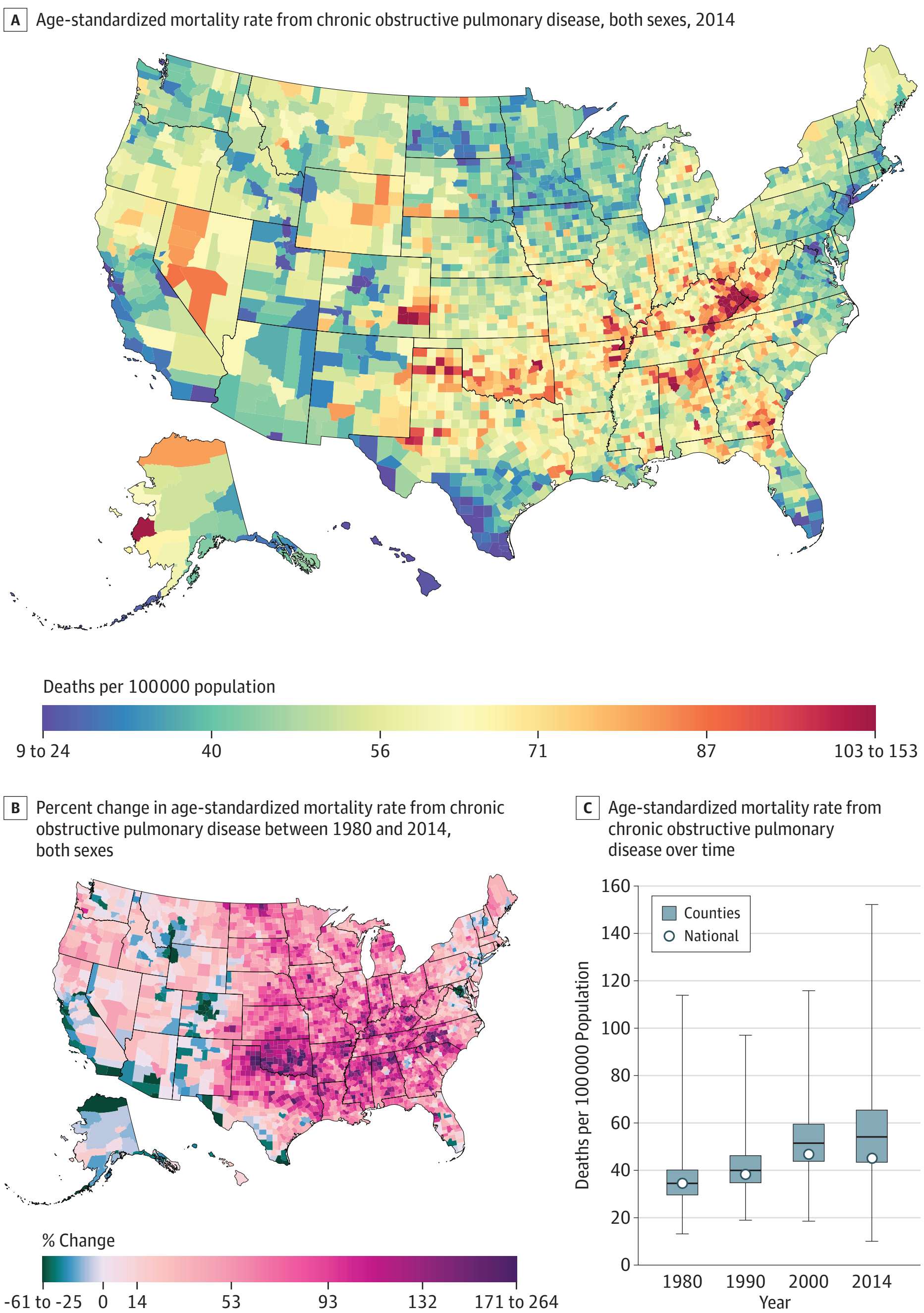
The mortality rate from interstitial lung disease and pulmonary sarcoidosis increased nationally by 100.5% (95% UI, 5.8%-155.2%), from 2.7 (95% UI, 2.3-4.2) deaths per 100 000 population in 1980 to 5.5 (95% UI, 3.5-6.1) deaths per 100 000 population in 2014. The mortality rate likewise increased in nearly every county (statistically significant in 86.1% of counties) during this period. Counties with the largest increases in mortality during this period were located primarily in New England, whereas counties with the smallest increases were found chiefly in Alaska, Nevada, southern Florida, and near the US-Mexico border.

Asthma

A total of 157 066 deaths due to asthma were recorded in the United States between 1980 and 2014. In 2014, mortality rates due to asthma ranged from 0.5 to 4.1 deaths per 100 000 population, and the difference between counties in the 10th and 90th percentiles was 0.8 death per 100 000 population. The counties with the highest mortality rates from asthma were located along the southern half of the Mississippi River and in Georgia and South Carolina (**Figure 3**).

The asthma mortality rate declined by 46.5% (95% UI, 27.0%-51.8%) between 1980 and 2014, from 2.2 (95% UI, 2.0-2.3) to 1.2 (95% UI, 1.1-1.3) deaths per 100 000 population. The mortality rate similarly declined in nearly every county

Figure 1. County-Level Mortality From Chronic Obstructive Pulmonary Disease



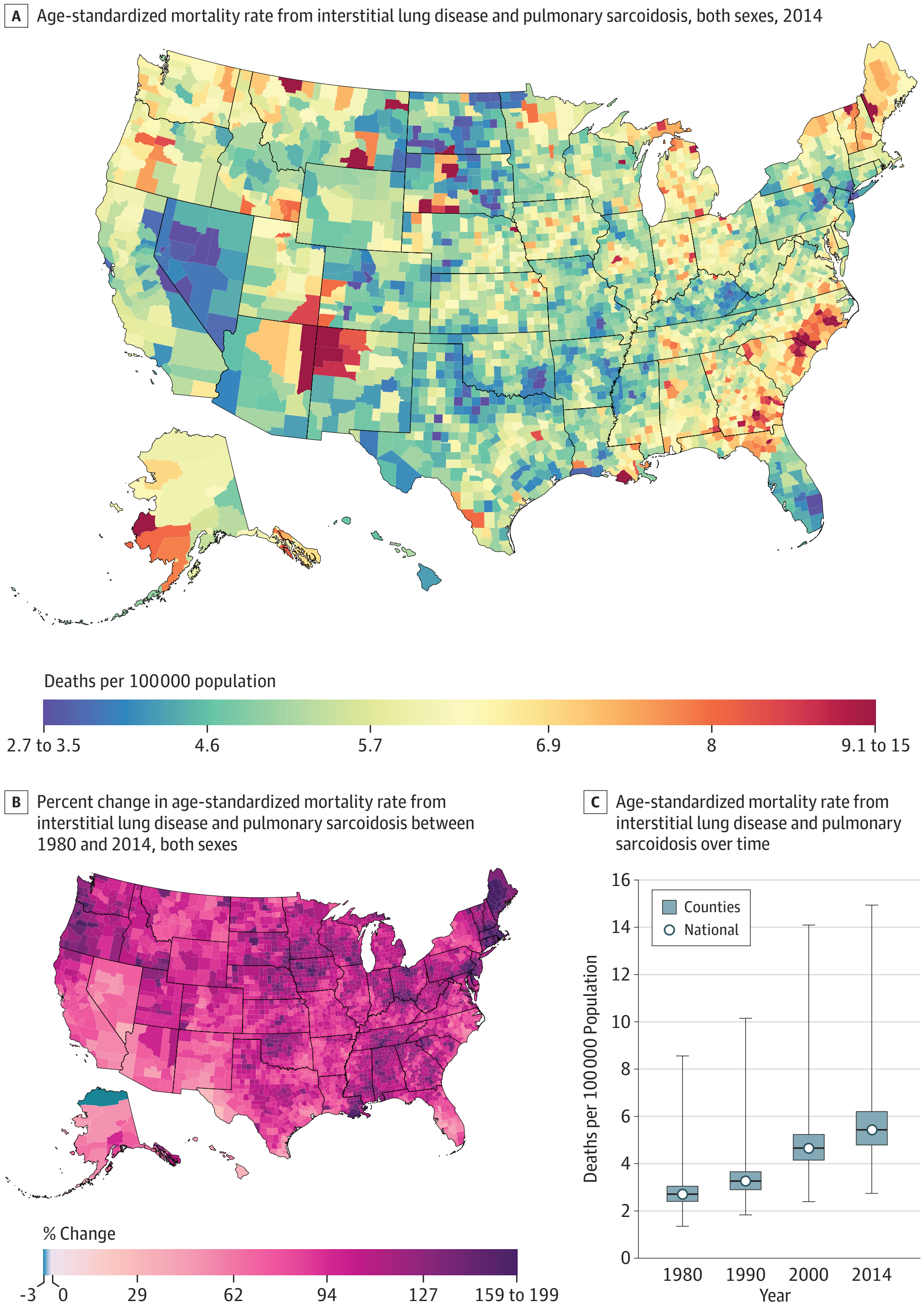
A, Age-standardized mortality rate for both sexes combined in 2014. B, Relative change in the age-standardized mortality rate for both sexes combined between 1980 and 2014. A and B, The color scale is truncated at approximately the first and 99th percentiles as indicated by the range given in the color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

(99.6%; statistically significant in 92.1%) during this period. However, changes in the mortality rate still varied widely among counties, ranging from a 15.3% increase to a 75.5% decline. Counties with the largest declines were located primarily in western and southwestern states, particularly southern Arizona, northern New Mexico, central Colorado, and western Montana. Counties with the smallest declines (or even increases) were found in the same regions with elevated mortality in 2014.

Pneumoconiosis

Between 1980 and 2014, 57 033 deaths due to pneumoconiosis were recorded in the United States. These included 15 163 deaths due to asbestosis, 21 592 due to coal workers' pneumoconiosis, 4529 due to silicosis, and 15 749 due to other pneumoconiosis. Large differences in the mortality rate were observed among counties, with mortality rates ranging from 0.1 to 43.5 deaths per 100 000 population in 2014. Most counties had very low pneumoconiosis mortality

Figure 2. County-Level Mortality From Interstitial Lung Disease and Pulmonary Sarcoidosis



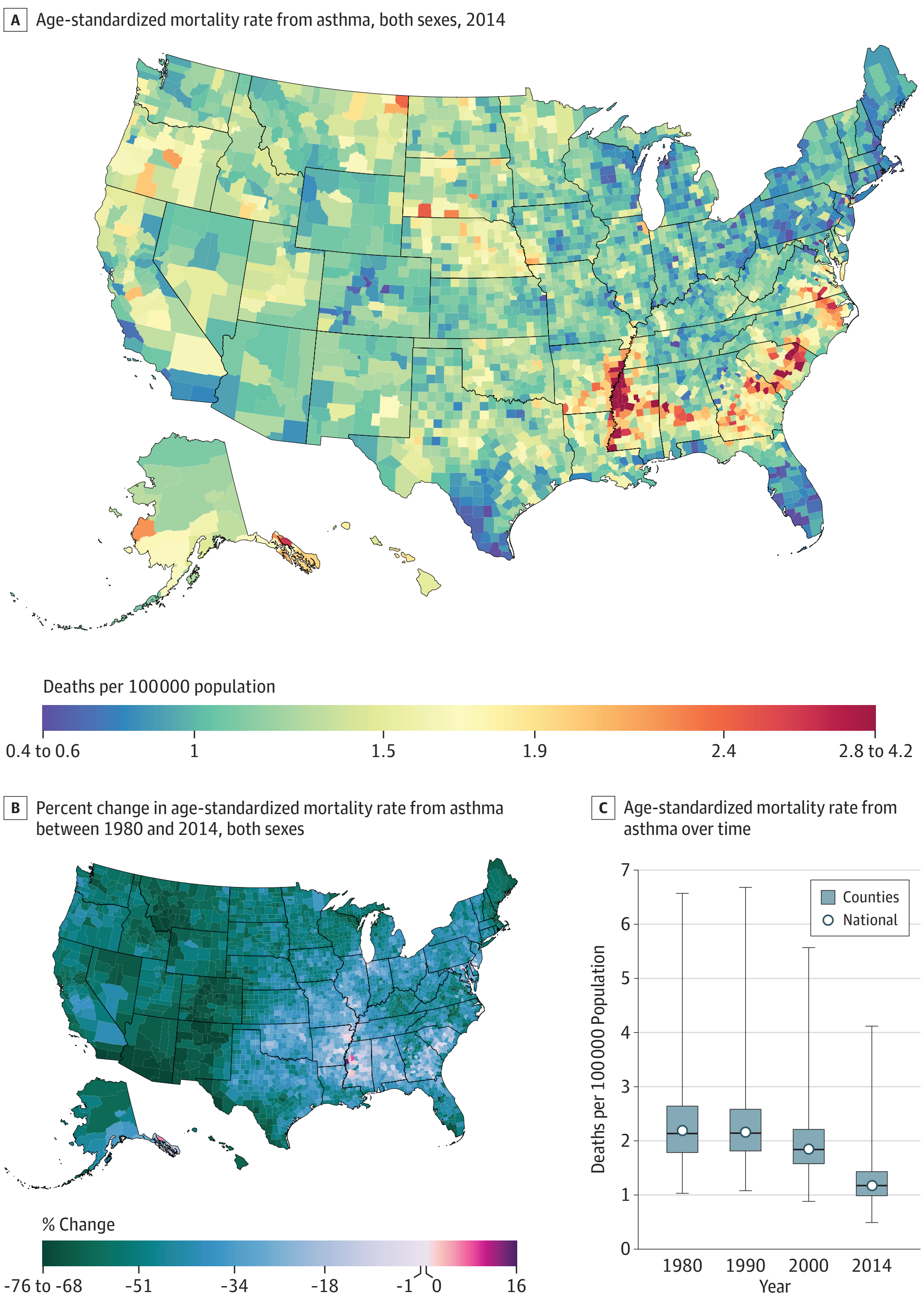
A, Age-standardized mortality rate for both sexes combined in 2014. The color scale is truncated at approximately the first and 99th percentiles as indicated by the range given in the color scale. B, Relative change in the age-standardized mortality rate for both sexes combined between 1980 and 2014. The color scale is truncated at approximately the 99th percentile but not at the first percentile, to avoid combining counties where the mortality rate increased with counties where the mortality rate decreased in the same group. C, Age-standardized mortality rate in 1980, 1990, 2000, and 2014. The bottom border, middle line, and top border of the boxes indicate the 25th, 50th, and 75th percentiles, respectively, across all counties; whiskers, the full range across counties; and circles, the national-level rate.

rates: 91.0% of counties experience mortality rates of less than 1 death per 100 000 in 2014. A small subset of counties experienced substantially higher mortality rates from pneumoconiosis; these counties were concentrated in central Appalachia, but there were also individual counties with relatively high pneumoconiosis mortality rates in Mississippi, Colorado, Utah, and Montana (**Figure 4**).

Among 1530 deaths due to pneumoconiosis in 2014, 38.0% (582 [95% UI, 493-648]) were due to asbestosis, 17.4% (266 [95% UI, 229-349]) were due to coal workers' pneumoconiosis, 4.8% (74 [95% UI, 62-105]) were due to silicosis, and 39.7% (608 [95% UI, 552-734]) were due to other pneumoconiosis. As with pneumoconiosis overall, most counties had very low mortality rates from asbestosis, coal workers' pneumoconiosis, and silicosis, whereas a small subset of counties experienced substantially elevated mortality rates (**Figure 5**, **Figure 6**, and **Figure 7**). In contrast, the mortality rates due to other pneumoconiosis were low (<0.7 death per 100 000 population) in all counties in 2014 (eFigure 4 in the Supplement).

The mortality rate from pneumoconiosis declined by 48.5% (95% UI, 38.7%-53.7%) overall between 1980 and

Figure 3. County-Level Mortality From Asthma



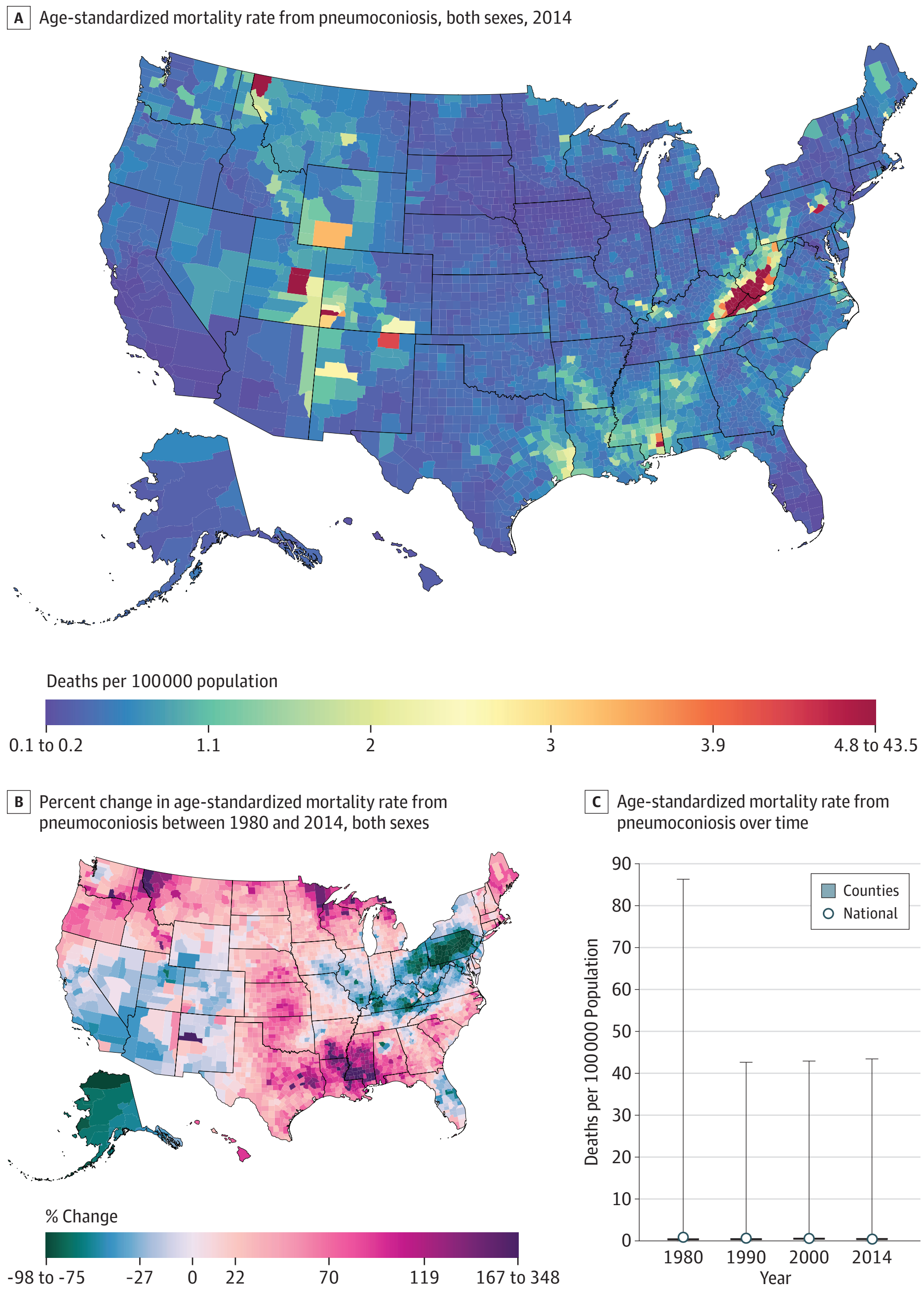
A, Age-standardized mortality rate for both sexes combined in 2014. The color scale is truncated at approximately the first and 99th percentiles as indicated by the range given in the color scale. B, Relative change in the age-standardized mortality rate for both sexes combined between 1980 and 2014. The color scale is truncated at approximately the first percentile but not at the 99th percentile, to avoid combining counties where the mortality rate increased with counties where the mortality rate decreased in the same group. C, Age-standardized mortality rate in 1980, 1990, 2000, and 2014. The bottom border, middle line, and top border of the boxes indicate the 25th, 50th, and 75th percentiles, respectively, across all counties; whiskers, the full range across counties; and circles, the national-level rate.

2014, from 0.9 (95% UI, 0.8-1.0) to 0.46 (95% UI, 0.43-0.51) death per 100 000 population. This was primarily due to a decrease in coal workers' pneumoconiosis, which declined 85.0% (95% UI, 79.8%-87.4%), and silicosis, which declined 80.1% (95% UI, 70.7%-83.7%); in contrast, asbestosis increased by 129.5% (95% UI, 44.3%-177.3%) during this period.

Other Chronic Respiratory Diseases

A total of 56 994 deaths due to other chronic respiratory diseases were recorded in the United States between 1980 and 2014. The mortality rate due to other chronic respiratory diseases was generally low but still varied among counties, ranging from 0.3 to 2.2 deaths per 100 000 population in 2014. Mortality rates from this group of diseases were generally highest in southern counties stretching from Mississippi to South Carolina, and were also elevated in counties in northern Maine and western counties stretching from Wyoming and Utah to California and Oregon (**Figure 8**). Mortality rates from other chronic respiratory diseases were lowest in counties near New York City and in southern Florida and California.

Figure 4. County-Level Mortality From Pneumoconiosis



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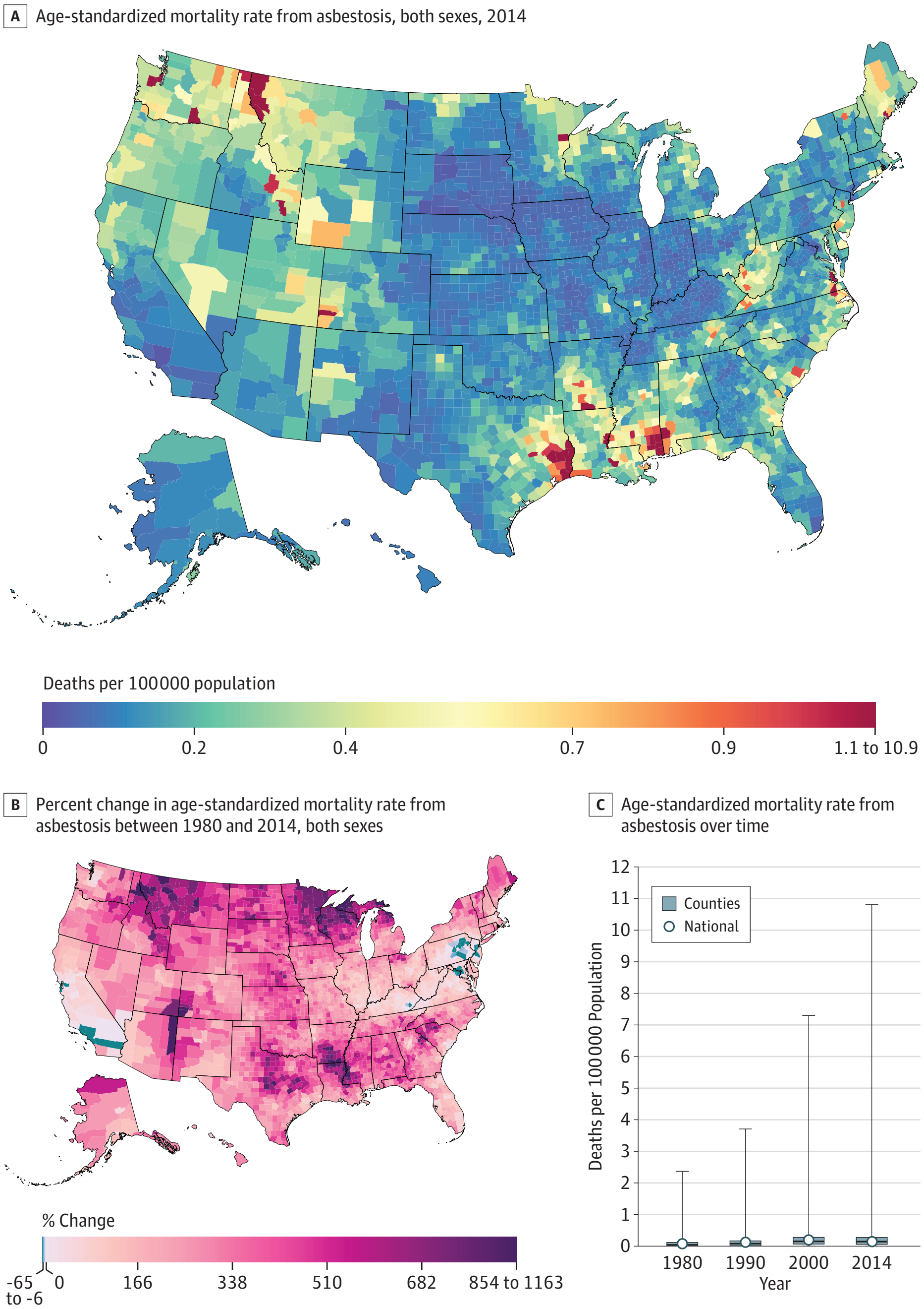
Between 1980 and 2014, the mortality rate from other chronic respiratory diseases increased by 42.3% (95% UI, 32.4%-63.8%) nationally, from 0.51 (95% UI, 0.48-0.54) to 0.73 (95% UI, 0.69-0.78) death per 100 000 population. The mortality rate from other chronic respiratory diseases similarly increased in most counties (99.6%; statistically significant in 94.5%) during this period, although the magnitude of change was variable. The counties with the largest increases in chronic respiratory disease mortality were found predominantly in western Oregon and northwestern California, southern Idaho and northern Utah, and northern Maine.

Discussion

Between 1980 and 2014, the mortality rate due to chronic respiratory diseases increased nationally. However, the results of this analysis show that this national trend does not demonstrate the significant diversity among counties, among different types of chronic respiratory diseases, and between males and females. This analysis expands the amount of information available on chronic respiratory diseases at local levels in several important ways and provides

Figure 5. County-Level Mortality From Asbestosis



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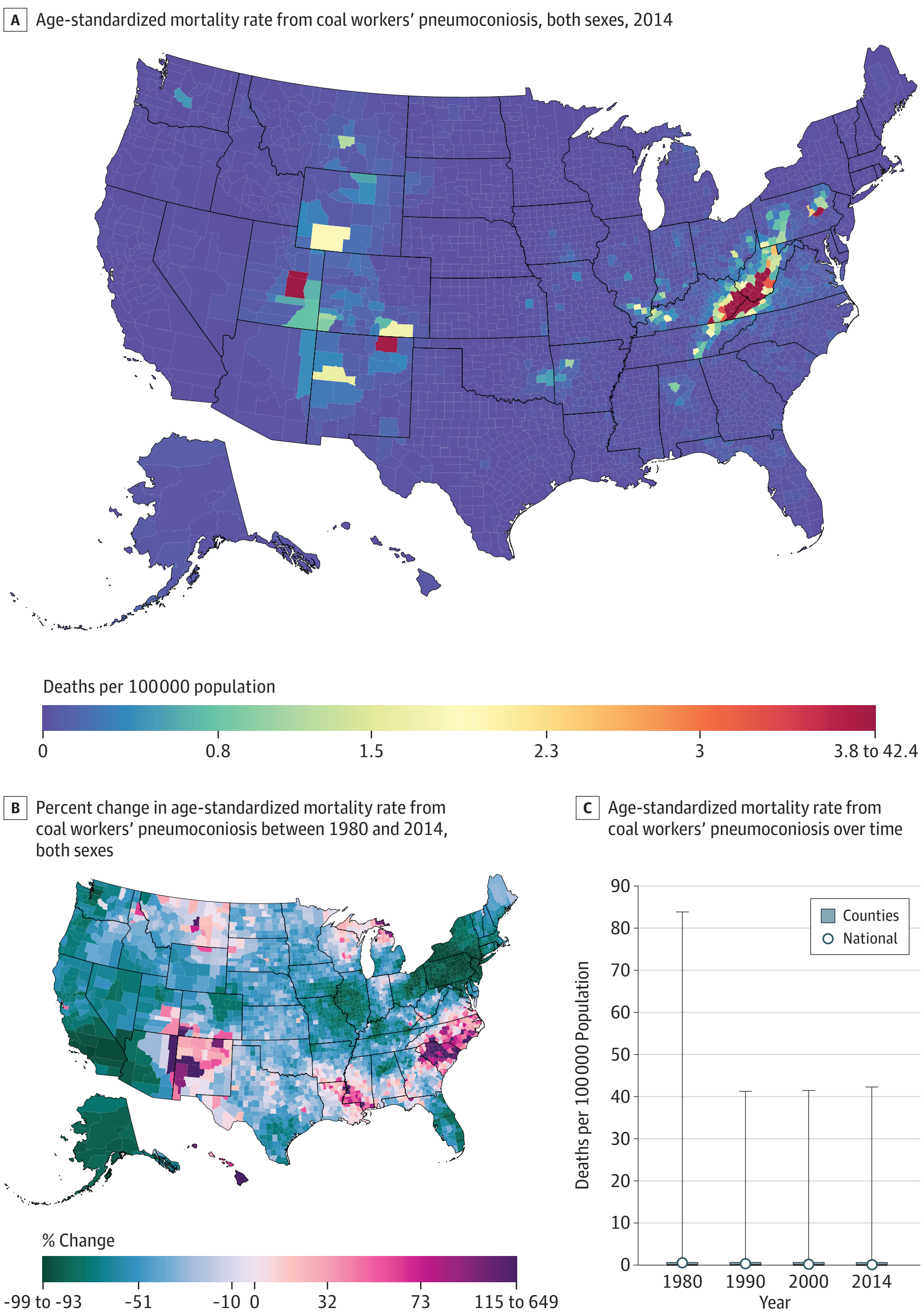
local health authorities and health care professionals with needed information to address the burden of chronic respiratory diseases in their communities.

This study confirmed earlier reports[9] of large variation among counties in mortality rates from COPD and also revealed substantial variation among counties in mortality rates from other chronic respiratory diseases. Additionally, this study found markedly different geographic patterns for different chronic respiratory diseases: counties with the highest mortality rates were found primarily in central Appalachia for COPD and pneumoconiosis; along the southern half of the Mississippi River and in Georgia and South Carolina for asthma; widely dispersed throughout the Southwest, northern Great Plains, New England, and South Atlantic for interstitial lung disease and pulmonary sarcoidosis; and in southern states from Mississippi to South Carolina for other chronic respiratory diseases.

This study is also the first, to our knowledge, to estimate mortality rates on an annual basis during an extended period for any chronic respiratory disease, enabling comparison of temporal trends among counties and examination of changes in geographic disparities over time. For all chronic respiratory

Figure 6. County-Level Mortality From Coal Workers' Pneumoconiosis

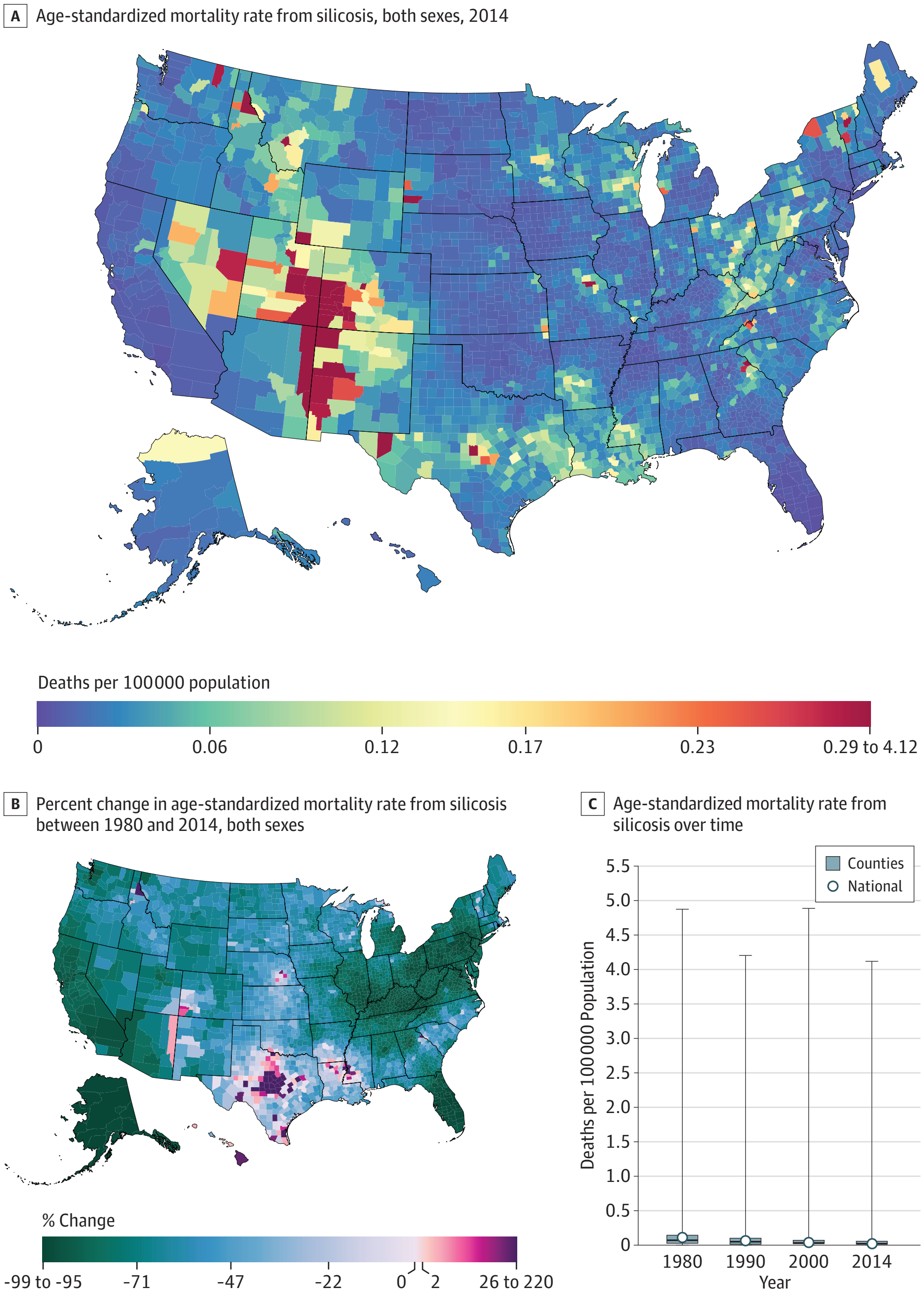


A, Age-standardized mortality rate for both sexes combined in 2014. B, Relative change in the age-standardized mortality rate for both sexes combined between 1980 and 2014. A and B, The color scale is truncated at approximately the first and 99th percentiles as indicated by the range given in the color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

diseases, there was considerable variation among counties in the change in the mortality rate between 1980 and 2014; for example, county-level changes in the mortality rate from COPD ranged from a 60.5% decline to a 263.7% increase. Moreover, for chronic respiratory diseases as a group, this study found evidence of increasing geographic disparities during this same period, with the gap between counties in the 10th and 90th percentiles almost doubling between 1980 and 2014.

There are a number of potential explanations for the geographic and temporal variation documented in this study. Nearly three-quarters (73.4%) of deaths due to chronic respiratory disease in the United States have been attributed to tobacco smoke, including 81.8% of deaths due to COPD.[25] Smoking prevalence varies widely among counties and there is considerable overlap between regions with high smoking prevalence and regions with high chronic respiratory disease mortality.[26] Differences in COPD mortality trends between males and females may also be partially attributed to historical trends in smoking: smoking prevalence and intensity increased less rapidly among females compared with males but peaked later, a pattern that is reflected in COPD mortality rates decades later.[27,28]

Figure 7. County-Level Mortality From Silicosis

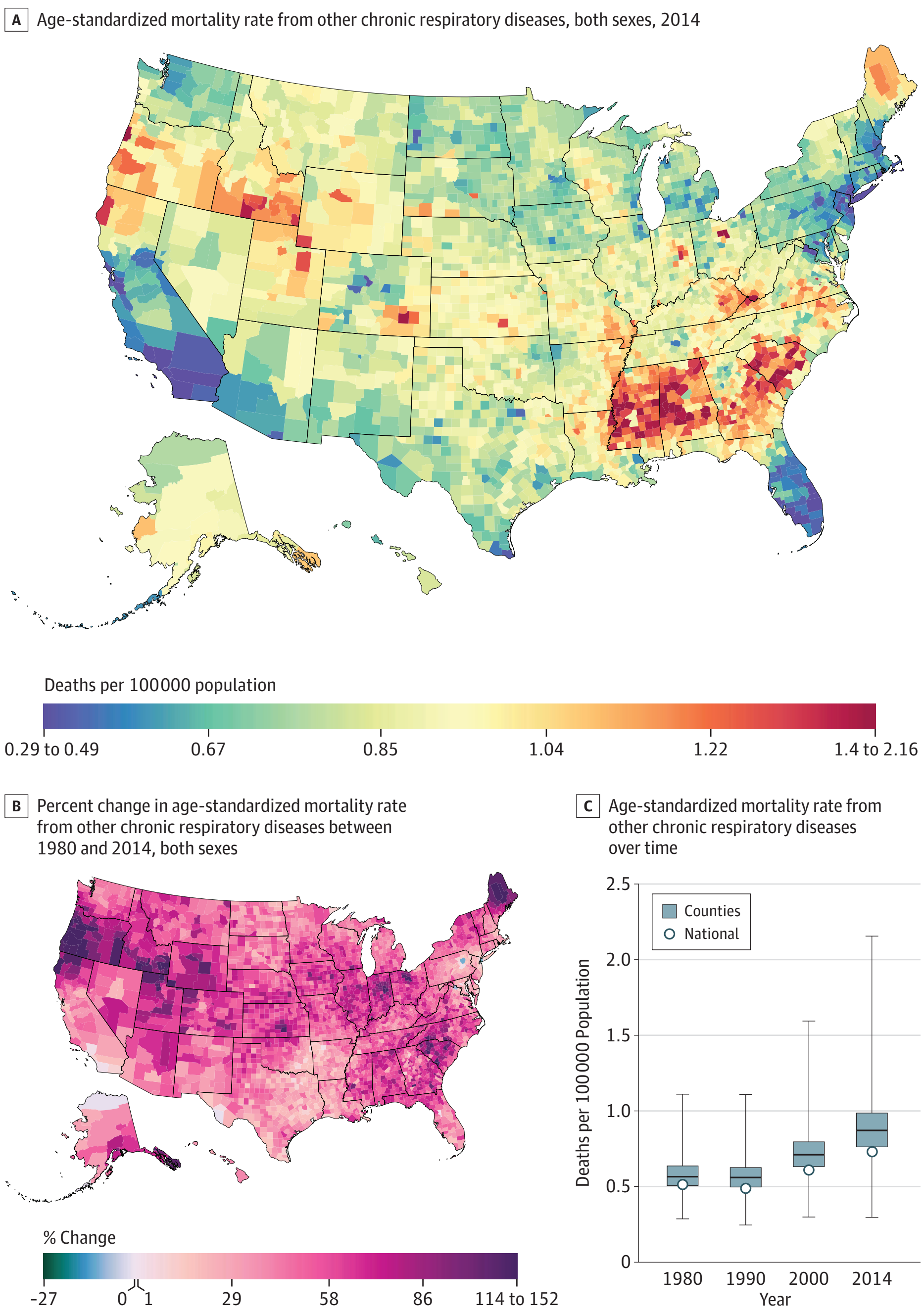


A, Age-standardized mortality rate for both sexes combined in 2014. B, Relative change in the age-standardized mortality rate for both sexes combined between 1980 and 2014. A and B, The color scale is truncated at approximately the first and 99th percentiles as indicated by the range given in the color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

Occupational exposure to certain dusts has been implicated as a risk factor for mortality from chronic respiratory diseases, particularly pneumoconiosis.[25] The long-term declines in mortality rates due to silicosis and coal workers' pneumoconiosis documented in this study have previously been attributed to declines in exposure to silica and coal dust, respectively, following establishment and enforcement of exposure limits in the 1960s and 1970s, as well as declining participation in occupations associated with exposure.[4,29] Although exposure to asbestos has also declined, mortality rates increased during the period of our analysis, likely due to the long lag between asbestos exposure and onset of asbestosis.[30] Much of the variation in mortality rates due to pneumoconiosis among counties is likely due to regional differences in industry; this can be seen particularly for coal workers' pneumoconiosis, with high mortality rates concentrated in regions with coal mines. Differences in compliance with exposure limits, average job tenure, and geology may further contribute to the variability in mortality rates among counties.[31]

Air pollution is also a well-documented risk factor for chronic respiratory disease mortality.[25] County-level

Figure 8. County-Level Mortality From Other Chronic Respiratory Diseases



"Other chronic respiratory diseases" is defined as the combination of all chronic respiratory diseases except chronic obstructive pulmonary disease, interstitial lung disease and pulmonary sarcoidosis, asthma, asbestosis, coal workers' pneumoconiosis, silicosis, and other pneumoconiosis. A, Age-standardized mortality rate for both sexes combined in 2014. The color scale is truncated at approximately the first and 99th percentiles as indicated by the range given in the color scale. B, Relative change in the age-standardized mortality rate for both sexes combined between 1980 and 2014. The color scale is truncated at approximately the 99th percentile but not at the first percentile, to avoid combining counties where the mortality rate increased with counties where the mortality rate decreased in the same group. C, Age-standardized mortality rate in 1980, 1990, 2000, and 2014. The bottom border, middle line, and top border of the boxes indicate the 25th, 50th, and 75th percentiles, respectively, across all counties; whiskers, the full range across counties; and circles, the national-level rate.

variation in exposure to air pollution has previously been linked to county-level variation in life expectancy,[32] a relationship that may be partially mediated via chronic respiratory diseases.

County-level differences in diagnosis and treatment of chronic respiratory diseases may also explain part of the variation in chronic respiratory disease mortality documented in this study. Deaths due to COPD make up the majority of deaths due to all chronic respiratory diseases in the United States, and appropriate treatment can often prolong and improve quality of life among individuals with COPD.[33] Previous research has suggested that many individuals with COPD are undiagnosed[34] and that recommended treatments are underused even among individuals who have been diagnosed.[35] Although county-level information on rates of diagnosis and treatment of COPD and other chronic respiratory diseases is unavailable, large differences have been documented for other chronic conditions,[36,37] suggesting that similar differences may exist with respect to chronic respiratory diseases.

This analysis has several important limitations. First, this analysis made use of population, deaths, and covariates data from a number of different sources, all of which are subject to error. Second, 2 different versions of the *ICD* were in use during the period considered, and changes to cause-of-death coding corresponding to changes in the *ICD* may lead to spurious trends, although we have attempted to mitigate the effects of this change by using a consistent mapping of *ICD* codes to chronic respiratory disease causes. Third, this analysis used garbage code redistribution algorithms to redistribute deaths assigned implausible or nonspecific causes to likely true causes of death; however, these methods have not been validated because appropriate gold-standard data are unavailable. Fourth, the uncertainty that arises from applying these garbage code redistribution algorithms is difficult to quantify and consequently has not been accounted for in the UIs associated with all estimated mortality rates. Fifth, this analysis used small area estimation models that smooth mortality rates over time, space, and age groups, which may in some cases attenuate unusually low or high mortality rates and underestimate true geographic variability.

Chronic respiratory diseases are a leading cause of death in the United States and are associated with significant morbidity and financial costs. Chronic respiratory disease mortality has previously been linked with a number of exposures—smoking, occupational exposures, air pollution—that are potentially amenable to intervention. Moreover, for some chronic respiratory diseases, treatments exist that can improve quality of life and prevent or delay death, underscoring the importance of promoting prompt diagnosis and utilization of recommended treatments. The local information on chronic respiratory disease mortality from this study should be used to galvanize support for action and to better target and customize efforts to reduce the burden of chronic respiratory diseases.

Conclusions

Despite recent declines in mortality from chronic respiratory diseases, mortality rates in 2014 remained significantly higher than in 1980. Between 1980 and 2014, there were important differences in mortality rates and changes in mortality by county, sex, and particular chronic respiratory disease type. These estimates may be helpful for informing efforts to improve prevention, diagnosis, and treatment.

ARTICLE INFORMATION

Accepted for Publication: August 16, 2017.

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.
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Obtained funding: Murray.
Administrative, technical, or material support: Morozoff, Shirude, Naghavi, Murray.
Supervision: Shirude, Naghavi, Murray.

Conflict of Interest Disclosures: All authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest and none were reported.

Funding/Support: Research reported in this publication was supported by the Robert Wood Johnson Foundation (grant 72305), the National Institute on Aging of the National Institutes of Health (grant 5P30AG047845), and John W. Stanton and Theresa E. Gillespie.

Role of the Funder/Sponsor: The funders had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

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