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ORIGINAL ARTICLE

Widening Geographical Disparities in Cardiovascular Disease Mortality in the United States, 1969-2011

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ABSTRACT

Objectives: This study examined trends in geographical disparities in cardiovascular-disease (CVD) mortality in the United States between 1969 and 2011.

Methods: National vital statistics data and the National Longitudinal Mortality Study were used to estimate regional, state, and county-level disparities in CVD mortality over time. Log-linear, weighted least squares, and Cox regression were used to analyze mortality trends and differentials.

Results: During 1969-2011, CVD mortality rates declined fastest in New England and Mid-Atlantic regions and slowest in the Southeast and Southwestern regions. In 1969, the mortality rate was 9% higher in the Southeast than in New England, but the differential increased to 48% in 2011. In 2011, Southeastern states, Mississippi and Alabama, had the highest CVD mortality rates, nearly twice the rates for Minnesota and Hawaii. Controlling for individual-level covariates reduced state differentials. State- and county-level differentials in CVD mortality rates widened over time as geographical disparity in CVD mortality increased by 50% between 1969 and 2011. Area deprivation, smoking, obesity, physical inactivity, diabetes prevalence, urbanization, lack of health insurance, and lower access to primary medical care were all significant predictors of county-level CVD mortality rates and accounted for 52.7% of the county variance.

Conclusions and Global Health Implications: Although CVD mortality has declined for all geographical areas in the United States, geographical disparity has widened over time as certain regions and states, particularly those in the South, have lagged behind in mortality reduction. Geographical disparities in CVD mortality reflect inequalities in socioeconomic conditions and behavioral risk factors. With the global CVD burden on the rise, monitoring geographical disparities, particularly in low- and middle-income countries, could indicate the extent to which reductions in CVD mortality are achievable and may help identify effective policy strategies for CVD prevention and control.

Key words: CVD mortality • Geography • Deprivation • SES • Inequality • Trend • Longitudinal

Introduction

Reduction of health inequalities, including those between social groups and geographical areas, has been a major health policy goal in the United States (US) for the past 4 decades.[1-5] Cardiovascular diseases (CVD), including heart disease and stroke, have been the number one cause of death in the United States for the past eight decades, and contribute greatly to overall health inequalities for the nation.[6,7] While CVD mortality rates are widely reported by age, sex, and race/ethnicity, geographical disparities in CVD mortality are mostly limited to reporting differences by rural-urban or state of residence.[7-9] Analyses of geographical disparities in CVD mortality over time, especially by region or county of residence, and their socioeconomic and behavioral determinants are less common, although a few recent US studies have examined county-level variations in CVD mortality as a function of area-based deprivation or socioeconomic characteristics.[5,10-14]

Although US data have identified higher rates of CVD morbidity and mortality in several Southern states and the Southeastern region, research on whether the magnitude and patterns of geographical disparities in CVD mortality rates at various levels of geography (such as region, state, and county) have changed over time is either limited or lacking.[5,12-15] While national-level analyses are important in understanding overall social-group disparities in CVD, it is crucial to know from a policy standpoint as to how specific regions, states, or geographical areas are performing in reducing their CVD mortality rates and associated risk factors relative to each other or nation as a whole.[16] In the US, states and local communities such as counties are generally responsible for development and implementation of public policies to tackle public health problems, for collecting social, environmental, and health data, and for providing a broad range of social and health services to their residents.[5] Documenting disparities between geographical areas with the lowest and highest CVD rates can tell us the extent to which mortality reductions can be achieved.[16] Moreover, a spatial-temporal analysis should help identify geographical areas or regions which not only have high rates of CVD mortality but have also experienced slower mortality reductions, indicating the need for urgent action for CVD prevention and control.[5,13,14]

The aim of our study is to examine changes in the extent of geographical disparities in CVD mortality among 9 census regions, 50 states and the District of Columbia, and 3,141 counties of the United States between 1969 and 2011. Using small-area national vital statistics mortality and census data, we model variations in county-level CVD mortality rates as a function of area deprivation, urbanization, racial/ethnic composition, smoking, obesity, physical inactivity, diabetes, and health care access. Additionally, we use the National Longitudinal Mortality Study (NLMS) to model regional and state-level disparities in CVD mortality risks after adjusting for individual-level socioeconomic and demographic characteristics.

Methods

Use of National Vital Statistics and Census Databases to Analyze Trends in Regional, State and County-level Disparities

To analyze geographical disparities in CVD mortality over time, we used the national vital statistics mortality database, which has been the cornerstone of health and disease monitoring among sociodemograhic groups and geographical areas in the US for over a century.[3-9,17] The national mortality database is based on information from death certificates of every death occurring in the United States each year.[8,17,18] While the national mortality database provides the number of deaths (numerator data) by year, age, sex, race, geographic area, and cause of death, the corresponding population statistics developed by the US Census Bureau serve as the denominator for computing mortality rates.[6-9,17,18]

The mainland United States consists of 50 states and the District of Columbia, which are grouped into 9 census regions as shown in Figure 1. States are divided into counties, and the number of counties varies by state. In all, there are 3,143 counties in the United States. In our study, CVD mortality rates were computed annually for all 9 regions between 1969 and 2011. For smaller geographical areas such as states and counties, mortality trends are presented for three time periods due to data availability and space constraints. State-specific CVD mortality rates were computed for 1969, 1990, and 2011. CVD mortality rates were computed for 3,141 counties for the time periods: 1969-1974, 1990-1999, and 2003-2007. Mortality rates for all geographic areas were age-adjusted by the direct method using the age-composition of the 2000 US population as the standard.[4-9]

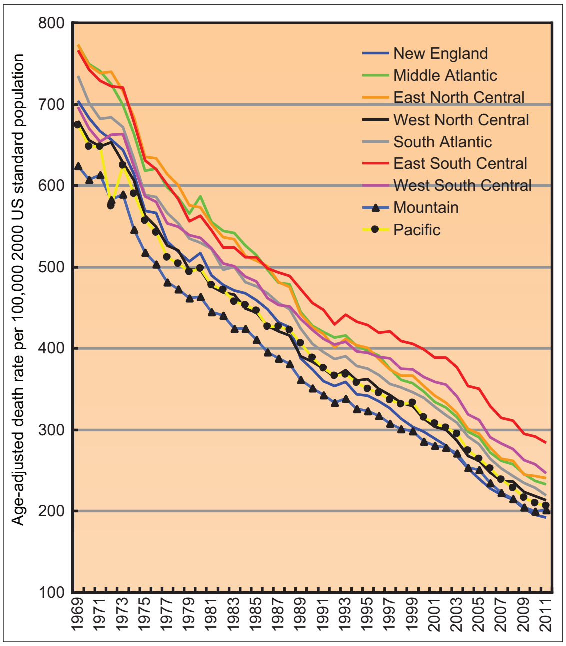

Figure 1. Trends in Cardiovascular Disease (CVD) Mortality by Geographic Region, United States, 1969-2011
New England = Maine + New Hampshire + Vermont + Massachusetts + Rhode Island + Connecticut
Middle Atlantic = New York + New Jersey + Pennsylvania
East North Central = Ohio + Indiana + Illinois + Michigan + Wisconsin
West North Central = Minnesota + Iowa + Missouri + North Dakota + South Dakota + Nebraska + Kansas
South Atlantic = Delaware + Maryland + District of Columbia + Virginia + West Virginia + North Carolina + South Carolina + Georgia + Florida
East South Central = Kentucky + Tennessee + Alabama + Mississippi
West South Central = Arkansas + Louisiana + Oklahoma + Texas
Mountain = Montana + Idaho + Wyoming + Colorado + New Mexico + Arizona + Utah + Nevada
Pacific = Washington + Oregon + California + Alaska + Hawaii

Log-linear regression models were used to estimate annual rates of decrease in CVD mortality for each census region.[4,5] Specifically, the logarithm of region-specific mortality rates were modeled as a linear function of time (calendar year), which yielded annual exponential rates of change in mortality rates.[4,5] In order to summarize state- and county-level disparities in mortality, we used various disparity measures such as the coefficient of variation (CV), interquartile range, quintile and percentile ratios, and absolute and relative mean deviation indices.[16] Moreover, disparities in mortality were described by rate ratios (relative risks) and rate differences (absolute inequalities), which were tested for statistical significance at the 0.05 level.

We used weighted least squares regression to model county-level variations in age-adjusted CVD mortality rates as a function of area deprivation, urbanization, racial/ethnic composition, smoking, obesity, physical inactivity, diabetes, and health uninsurance rates, and availability of primary care physicians. The data on county-level covariates were obtained from several sources such as the Census, Behavioral Risk Factor Surveillance System, and Area Resource File.[19-22] For area deprivation, we used a factor-based deprivation index from the 2000 decennial US census.[5,23] The deprivation index consisted of 22 socioeconomic indicators, which are viewed as broadly representing educational opportunities, labor force skills, economic, and housing conditions in a given county.[23] Selected indicators of education, occupation, wealth, income distribution, unemployment rate, poverty rate, and housing quality were used to construct the 2000 index.[23] Substantive and methodological details of the US deprivation index are provided elsewhere.[4,5,23]

Effects of both continuous and categorical measures of the deprivation index and smoking, obesity, and diabetes prevalence rates were estimated in the regression models. Cardiovascular deaths in each county were used as weights in the weighted regression models because the number of deaths is proportional to the inverse of the variance of mortality rates.[24]

National Longitudinal Mortality Study (NLMS)

To examine regional and state-level variations in CVD mortality, we also used the 1979-2002 NLMS, that allowed us to examine geographical differences in mortality after adjusting for individual-level socioeconomic and demographic characteristics. The NLMS is a longitudinal dataset for examining socioeconomic, occupational, and demographic factors associated with all-cause and cause-specific mortality in the United States.[25-28] The NLMS is conducted by the National Heart, Lung, and Blood Institute (National Institutes of Health [NIH]) in collaboration with the US Census Bureau, the National Cancer Institute (NIH), the National Institute on Aging (NIH), and the National Center for Health Statistics (Centers for Disease Control and Prevention).[25-28] The NLMS consists of 30 Current Population Survey (CPS) and census cohorts between 1973 and 2002 whose survival (mortality) experiences were studied between 1979 and 2002.[25] The CPS is a sample household and telephone interview survey of the civilian non-institutionalized population in the United States and is conducted by the US Census Bureau to produce monthly national statistics on unemployment and the labor force. Data from death certificates on the fact of death and the cause of death are combined with the socioeconomic and demographic characteristics of the NLMS cohorts by means of the National Death Index.[25-28] Detailed descriptions of the NLMS have been provided elsewhere.[25-27]

The full NLMS consists of approximately 3 million individuals drawn from 30 CPS and census cohorts whose mortality experience has been followed from 1979 through 2002, with the total number of deaths during the 23-year follow-up being 341,343.[25] However, our study uses the public-use micro-data sample that contains only selected population cohorts between 1979 and 1991, with a maximum mortality follow-up of 11 years.[25] State- and region-level differentials in mortality risks were adjusted by multivariate Cox proportional hazards regression for age and for additional covariates such as sex, race/ethnicity, marital status, metropolitan/non-metropolitan residence, education, income/poverty level, and occupation.[28] The public-use NLMS sample for 1979-2002 included 780,461 individuals aged ≥25 at the baseline and 50,430 CVD deaths during the 11-year mortality follow-up.[25] In estimating the mortality risk, all those surviving beyond the 11-year follow-up (i.e., 4,018 days of follow-up) and those dying from causes other than CVD during the follow-up period were treated as right-censored observations. The Cox models were estimated by the SAS PHREG procedure.[29]

Results

Regional Trends and Differentials in CVD Mortality

Figure 1 shows annual trends in CVD mortality among 9 census regions. During 1969-2011, CVD mortality rates declined at the fastest pace in New England and Mid-Atlantic regions and at the slowest rate in the Southeast and Southwestern regions of the United States. The average annual rates of decline in mortality during 1969-2011 were 2.94% for New England, 2.7% for Mid-Atlantic, 2.23% for Southwest, and 2.12% for Southeast. In 1969, the mortality rate was 9% higher in the Southeast than in New England, but this differential increased to 22% in 1990 and 48% in 2011. A similar increase in relative risk of CVD mortality was seen over time for the Southeast and Southwest regions when compared to New England and Mountain regions (Figure 1). Even after adjusting for individual-level socioeconomic and demographic characteristics in the NLMS, those in the Southeast and East Northcentral regions maintained 18-19% higher CVD mortality risks than their counterparts in the Mountain region (Table 1). The adjusted effects of other individual-level covariates on CVD mortality risks in the NLMS are worth noting (Table 1). Education and income were inversely associated with CVD mortality during 1979-2002. Individuals with low education and incomes had 32-40% higher CVD mortality risks than their counterparts with high education and income levels. Service workers and manual laborers had 17-19% higher CVD mortality risks than those employed in professional and managerial occupations. Divorced/separated and never married individuals had 29-32% higher CVD mortality risks than married individuals. Hispanics and Asian/Pacific Islanders had 35-41% lower CVD

Table 1. Age- and Covariate-Adjusted Relative Risks of Cardiovascular Disease (CVD) Mortality Among US Adults Aged 25+years According to Baseline Socioedemographic Characteristics and Region of Residence: The US National Longitudinal Mortaliy Study, 1979-2002 (N=780,461)

Baseline socio-demographic characteristics	Age-adjusted[1]			Covariate-adjusted[2]		
	Hazard ratio	95% confidence interval		Hazard ratio	95% confidence interval	
Age (years)	1.11	1.11	1.11	1.10	1.10	1.10
Sex						
Male	1.69	1.66	1.72	1.94	1.91	1.98
Female	1.00	Reference		1.00	Reference	
Race/ethnicity						
Non-Hispanic white	1.00	Reference		1.00	Reference	
Hispanic	0.75	0.71	0.79	0.65	0.62	0.69
Non-Hispanic black	1.24	1.20	1.28	1.03	1.00	1.07
American Indian/Alaska Native	1.00	0.88	1.14	0.88	0.77	1.01
Asian/Pacific Islander	0.61	0.55	0.68	0.59	0.53	0.66
Other	0.83	0.67	1.03	0.84	0.68	1.04
Maritalstatus						
Married	1.00	Reference		1.00	Reference	
Widowed	0.95	0.93	0.97	1.19	1.16	1.21
Divorced/separated	1.25	1.21	1.30	1.32	1.27	1.36
Single	1.19	1.15	1.23	1.29	1.24	1.34
Place of residence						
Metropolitan	1.00	Reference		1.00	Reference	
Non-metropolitan	1.02	1.01	1.04	0.98	0.96	1.00
Education (years)						
<12	1.53	1.48	1.58	1.32	1.27	1.37
12	1.24	1.20	1.29	1.21	1.17	1.26
13-15	1.15	1.11	1.20	1.14	1.10	1.19
16+	1.00	Reference		1.00	Reference	
Occupation						
Professional/managerial	1.00	Reference		1.00	Reference	
Sales/Clerical/Admin support	0.99	0.94	1.04	1.03	0.98	1.09
Service	1.34	1.27	1.42	1.17	1.11	1.24
Craftand repair	1.52	1.43	1.61	1.11	1.04	1.18
Laborer	1.53	1.45	1.62	1.19	1.12	1.27
Military	3.12	1.01	9.68	2.28	0.74	7.02
Unemployed/outside labor force	1.63	1.56	1.70	1.64	1.56	1.72
Poverty status (ratio of family income to poverty threshold)						
Below 100%	1.63	1.57	1.69	1.40	1.35	1.46
100-149%	1.54	1.48	1.60	1.31	1.26	1.37
150-199%	1.52	1.47	1.59	1.31	1.26	1.37
200-299%	1.39	1.34	1.44	1.22	1.17	1.27

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Table 1. *Contd...*

Baseline socio-demographic characteristics	Age-adjusted[1]			Covariate-adjusted[2]		
	Hazard ratio	95% confidence interval		Hazard ratio	95% confidence interval	
300-399%	1.29	1.24	1.34	1.17	1.12	1.22
400-599%	1.20	1.16	1.25	1.12	1.08	1.17
At or above 600%	1.00	Reference		1.00	Reference	
Geographic region						
New England	1.07	1.03	1.12	1.05	1.00	1.09
Middle Atlantic	1.17	1.13	1.22	1.13	1.09	1.17
East Northcentral	1.25	1.20	1.30	1.19	1.15	1.24
West Northcentral	1.08	1.04	1.12	1.05	1.00	1.09
South Atlantic	1.21	1.16	1.25	1.15	1.11	1.20
East Southcentral	1.31	1.25	1.37	1.18	1.13	1.24
West Southcentral	1.20	1.15	1.25	1.15	1.11	1.20
Mountain	1.00	Reference		1.00	Reference	
Pacific	1.04	1.00	1.09	1.08	1.04	1.13

Notes: Relative risks (hazard ratios) were derived from multivariate Cox proportional hazards regression models. [1]Adjusted for age only. [2]Adjusted for age, sex, race/ethnicity, marital status, metropolitan/non-metropolitan residence, educational attainment, occupation, income/poverty level, and geographic region

mortality risks than their non-Hispanic counterparts of equivalent socioeconomic backgrounds.

Trends and Differentials in State-Level Disparities in CVD Mortality

In 2011, Southeastern states such as Mississippi and Alabama had the highest CVD mortality rates, nearly two times higher than the rates for Minnesota and Hawaii (Table 2). State patterns were similar in 1969 and 1990, with substantially increased risks of CVD mortality for most Southern states. In 1990, Mississippi and Louisiana had the highest mortality rates, 51%, and 42% higher than the rate for Hawaii. In 1969, South Carolina had the highest mortality rate, 52% higher than the rate for Alaska (Table 2). Controlling for individual-level sociodemographic characteristics in the NLMS reduced state differentials; however, individuals in Indiana, Michigan, Louisiana, and Kentucky maintained 30-35% higher CVD mortality risks than their counterparts in New Mexico (Table 3).

Absolute disparities in state-level CVD mortality, as measured by interquartile range and absolute mean deviation, decreased over time. However, relative disparities in state-level CVD mortality rates, as measured by CV, relative mean deviation index, and quintile and percentile ratios, widened over time. The coefficient of variation in state-level CVD mortality increased by 48% from 10.0 in 1969 to 14.8 in 2011. The relative mean deviation index indicated a 43% increase in state-level disparity in CVD mortality between 1969 and 2011 (Table 4).

Trends and Differentials in County-Level Disparities in CVD Mortality

County-level variations in area deprivation and CVD mortality rates were closely related, with the weighted correlation being -0.53 (Figure 2 and Table 5). Consistent with high deprivation levels in the Southeast, individuals in this region had the highest CVD mortality rates (Figure 2). Area deprivation, smoking, obesity, physical inactivity, diabetes prevalence, urbanization, racial/ethnic composition, lack of health insurance, and lower access to primary medical care were all significant predictors of county-level CVD mortality rates (Table 5). In the multivariate models, these covariates (excluding health insurance and physician availability because of multicollinearity) accounted for 52.7% of the county variance. A 10-percentage-point increase in obesity prevalence was associated

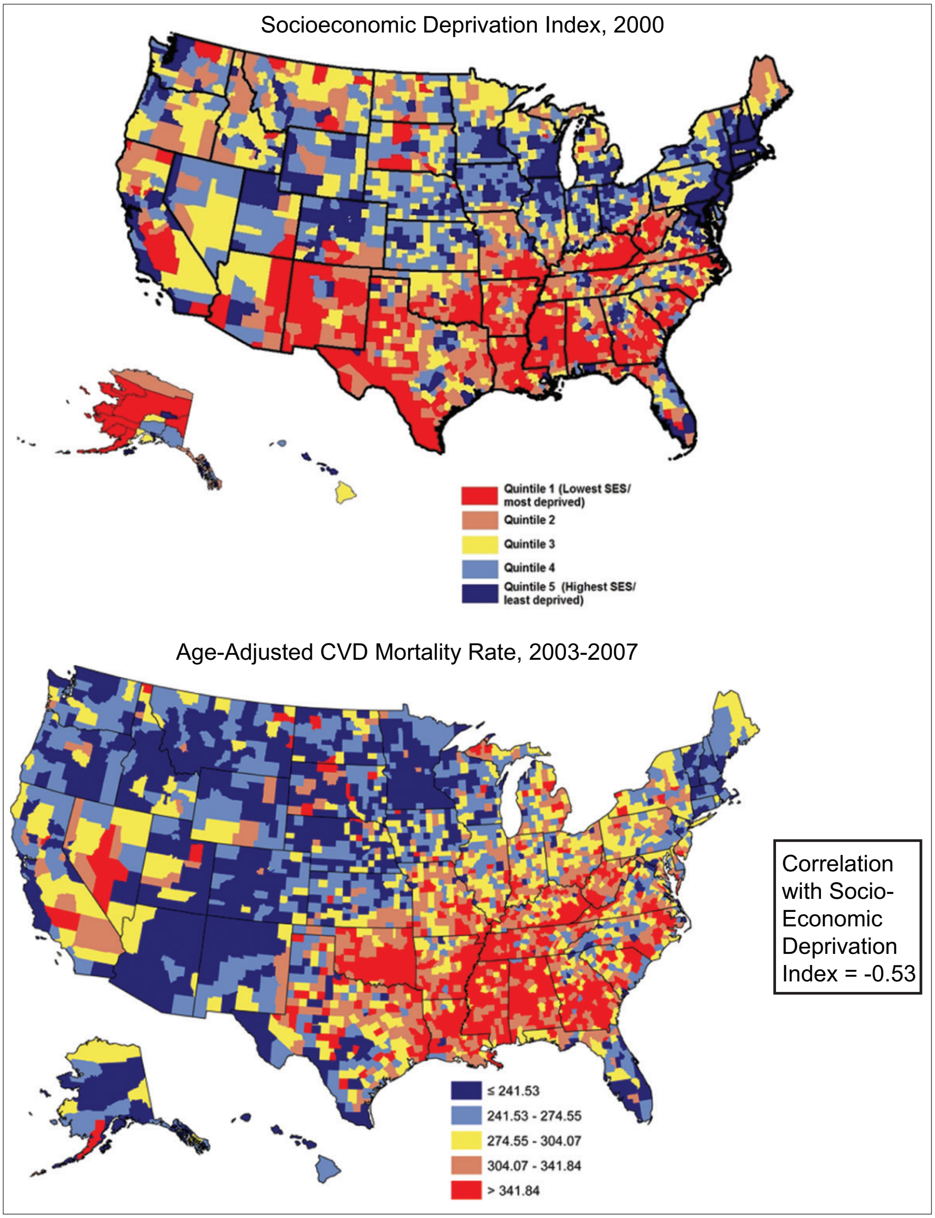

Figure 2. Area (County) Socioeconomic Deprivation Index and Age-Adjusted Cardiovascular Disease (CVD) Mortality Rates per 100,000 Population for the United States (2000 US Population Used as Standard; 3,141 Counties)

with a 32.2-point increase in the CVD mortality rate. Similarly, a 10-percentage-point increase in diabetes prevalence was associated with a 57.7-point increase in the CVD mortality rate. In multivariate categorical models, consistent gradients in CVD mortality were found by area deprivation and smoking, obesity and diabetes prevalence. Even after adjusting for behavioral risk factors, those in the most deprived counties had 15% higher CVD mortality than those in the most affluent counties. CVD mortality rates were 18% higher in areas with smoking rates ≥36%, compared with areas with smoking rates <12%.

Table 2. Age-Adjusted Cardiovascular Disease Mortality Rates by State: United States, 1969, 1990, and 2011

State	1969 Rate	1969 SE	1969 Deaths	1990 Rate	1990 SE	1990 Deaths	2011 Rate	2011 SE	2011 Deaths	% Decline in rate, 1969-2011
Alabama	737.06	6.01	16,747	446.41	3.49	16,714	296.10	2.40	15,496	59.83
Alaska	548.20	35.25	369	338.94	16.49	587	202.89	7.04	970	62.99
Arizona	595.18	8.42	6,043	350.55	3.39	11,192	198.35	1.68	14,043	66.67
Arkansas	690.41	6.79	11,120	424.96	4.16	10,633	279.13	2.91	9,345	59.57
California	672.40	2.43	84,185	396.75	1.35	88,293	211.91	0.76	79,859	68.48
Colorado	633.92	7.12	8,432	336.84	3.77	8,132	178.54	1.97	8,467	71.84
Connecticut	677.40	6.07	13,803	366.39	3.39	11,850	194.72	2.09	9,119	71.25
Delaware	781.07	16.53	2,504	417.74	8.79	2,343	226.44	4.72	2,342	71.01
District of Columbia	750.80	12.78	3,864	424.28	8.79	2,375	248.26	6.54	1,497	66.93
Florida	638.34	3.59	37,139	365.21	1.55	57,781	196.90	0.87	53,048	69.15
Georgia	771.66	5.70	20,919	449.20	3.13	21,359	244.30	1.72	20,938	68.34
Hawaii	554.29	14.70	1,756	325.02	6.37	2,743	178.12	3.26	3,128	67.87
Idaho	654.49	12.17	3,115	344.77	6.40	2,957	210.50	3.65	3,400	67.84
Illinois	816.74	3.43	62,961	424.76	2.03	44,380	230.35	1.29	32,457	71.80
Indiana	780.66	4.91	27,287	434.33	2.94	22,062	246.91	1.88	17,663	68.37
Iowa	676.38	5.34	16,686	377.54	3.41	12,483	216.38	2.35	8,862	68.01
Kansas	671.90	6.14	12,491	381.65	3.84	10,004	217.37	2.58	7,365	67.65
Kentucky	774.29	6.00	18,003	445.99	3.66	15,100	270.86	2.43	12,723	65.02
Louisiana	799.46	6.49	17,285	462.07	3.74	15,669	273.10	2.46	12,589	65.84
Maine	766.83	10.06	6,132	388.26	5.67	4,736	195.45	3.36	3,486	74.51
Maryland	767.09	6.47	16,446	406.60	3.38	14,978	222.58	1.92	13,750	70.98
Massachusetts	698.82	4.11	31,105	370.84	2.49	22,398	186.23	1.53	15,372	73.35
Michigan	748.22	4.01	39,639	437.92	2.37	34,754	253.89	1.49	29,776	66.07
Minnesota	652.43	4.94	18,550	345.55	2.86	14,687	166.52	1.66	10,328	74.48
Mississippi	774.46	7.49	11,711	491.02	4.62	11,485	311.88	3.22	9,562	59.73
Missouri	719.23	4.46	27,661	420.46	2.82	22,502	254.88	1.92	17,880	64.56
Montana	650.16	11.57	3,325	345.32	6.76	2,645	207.18	4.17	2,543	68.13
Nebraska	647.84	7.29	8,234	376.93	4.68	6,577	200.86	3.06	4,468	69.00
Nevada	732.48	20.98	1,606	431.82	7.79	3,578	248.13	3.19	6,308	66.12
New Hampshire	749.10	12.20	4,040	385.69	6.47	3,595	197.41	3.63	3,033	73.65
New Jersey	776.61	4.30	37,562	402.81	2.39	29,146	220.26	1.46	23,229	71.64
New Mexico	576.97	11.82	2,783	334.91	5.53	3,808	196.07	3.01	4,333	66.02
New York	758.58	2.56	100,650	441.80	1.61	75,829	234.67	1.02	54,292	69.06
North Carolina	781.98	5.57	22,991	426.92	2.79	24,272	225.21	1.51	22,749	71.20
North Dakota	643.25	12.07	3,001	364.42	7.26	2,554	194.39	4.76	1,755	69.78
Ohio	771.32	3.45	54,635	430.86	2.09	43,444	248.21	1.35	34,514	67.82
Oklahoma	680.49	5.97	13,872	443.08	3.78	13,883	292.34	2.69	11,957	57.04
Oregon	665.34	6.72	10,513	368.80	3.67	10,271	193.81	2.08	8,995	70.87
Pennsylvania	791.54	3.17	69,905	422.53	1.85	53,830	237.67	1.19	41,264	69.97
Rhode Island	715.24	10.55	5,088	394.62	6.10	4,258	207.05	3.93	2,944	71.05
South Carolina	832.66	8.34	11,889	452.36	4.17	12,471	246.39	2.25	12,349	70.41

Contd...

Table 2. *Contd....*

State	1969 Rate	1969 SE	1969 Deaths	1990 Rate	1990 SE	1990 Deaths	2011 Rate	2011 SE	2011 Deaths	% Decline in rate, 1969-2011
South Dakota	665.68	11.31	3,678	378.76	6.99	2,994	212.42	4.58	2,254	68.09
Tennessee	778.25	5.71	20,643	451.01	3.21	20,138	270.31	2.00	18,614	65.27
Texas	670.56	3.31	45,875	405.43	1.81	51,002	227.76	1.03	50,076	66.03
Utah	580.60	11.05	3,072	338.76	5.72	3,606	193.52	3.06	4,060	66.67
Vermont	693.80	14.74	2,323	371.26	8.65	1,854	193.68	5.06	1,520	72.08
Virginia	749.18	5.70	19,841	419.81	3.02	19,976	217.69	1.65	17,799	70.94
Washington	706.81	5.74	16,263	367.65	3.02	15,051	194.97	1.67	14,105	72.42
West Virginia	790.75	7.99	10,716	459.68	4.98	8,736	272.50	3.44	6,414	65.54
Wisconsin	705.43	4.84	22,951	387.57	2.83	18,915	214.06	1.78	14,825	69.66
Wyoming	630.66	18.27	1,340	368.01	10.51	1,254	206.71	6.05	1,205	67.22

Notes: Rates are per 100,000 population and are directly age-adjusted to the 2000 US standard population. SE=standard error.

Table 3. Relative Risks of Cardiovascular Disease (CVD) Mortality Among US Adults Aged ≥25 Years, According to State of Residence: The US National Longitudinal Mortaliy Study, 1979-2002 (N=780,461)

State of residence	Age-adjusted[1]			Covariate-adjusted[2]		
	Hazard ratio	95% confidence interval		Hazard ratio	95% confidence interval	
Alabama	1.44	1.29	1.61	1.20	1.07	1.35
Alaska	1.09	0.92	1.29	1.06	0.90	1.25
Arizona	1.13	1.00	1.27	1.06	0.94	1.19
Arkansas	1.38	1.23	1.54	1.16	1.04	1.30
California	1.22	1.11	1.34	1.18	1.07	1.30
Colorado	1.13	1.00	1.27	1.09	0.96	1.23
Connecticut	1.19	1.05	1.34	1.10	0.97	1.24
Delaware	1.43	1.26	1.62	1.28	1.13	1.45
District of Columbia	1.34	1.18	1.53	1.22	1.07	1.39
Florida	1.28	1.16	1.41	1.18	1.07	1.31
Georgia	1.35	1.20	1.51	1.17	1.05	1.32
Hawaii	0.99	0.86	1.14	1.28	1.10	1.50
Idaho	1.20	1.06	1.35	1.07	0.94	1.20
Illinois	1.41	1.27	1.55	1.28	1.16	1.42
Indiana	1.52	1.36	1.69	1.35	1.21	1.50
Iowa	1.22	1.10	1.37	1.12	1.00	1.25
Kansas	1.11	0.99	1.24	1.03	0.92	1.16
Kentucky	1.49	1.33	1.67	1.30	1.16	1.45
Louisiana	1.55	1.38	1.74	1.31	1.16	1.47
Maine	1.24	1.10	1.40	1.10	0.98	1.24
Maryland	1.28	1.14	1.43	1.15	1.03	1.29
Massachusetts	1.16	1.05	1.29	1.07	0.97	1.19
Michigan	1.52	1.38	1.68	1.33	1.20	1.47

Contd...

Table 3. *Contd...*

State of residence	Age-adjusted[1]			Covariate-adjusted[2]		
	Hazard ratio	95% confidence interval		Hazard ratio	95% confidence interval	
Minnesota	1.24	1.11	1.38	1.11	0.99	1.24
Mississippi	1.51	1.35	1.68	1.25	1.12	1.40
Missouri	1.38	1.25	1.54	1.21	1.09	1.35
Montana	1.13	1.00	1.28	1.02	0.90	1.15
Nebraska	1.24	1.11	1.39	1.16	1.03	1.30
Nevada	1.32	1.16	1.50	1.20	1.06	1.37
New Hampshire	1.28	1.13	1.45	1.18	1.04	1.34
New Jersey	1.27	1.15	1.41	1.20	1.08	1.33
New Mexico	1.00	Reference		1.00	Reference	
New York	1.28	1.17	1.41	1.17	1.06	1.28
North Carolina	1.47	1.32	1.62	1.29	1.16	1.44
North Dakota	1.13	1.00	1.27	1.00	0.89	1.12
Ohio	1.34	1.21	1.48	1.19	1.07	1.31
Oklahoma	1.38	1.24	1.55	1.23	1.10	1.37
Oregon	1.18	1.05	1.33	1.07	0.95	1.20
Pennsylvania	1.42	1.29	1.57	1.24	1.12	1.37
Rhode Island	1.25	1.11	1.42	1.10	0.97	1.24
South Carolina	1.48	1.31	1.67	1.27	1.12	1.43
South Dakota	1.18	1.05	1.32	1.06	0.94	1.18
Tennessee	1.49	1.33	1.67	1.26	1.12	1.41
Texas	1.29	1.17	1.43	1.21	1.10	1.34
Utah	1.11	0.98	1.25	1.04	0.92	1.17
Vermont	1.26	1.11	1.42	1.16	1.02	1.31
Virginia	1.41	1.26	1.57	1.27	1.13	1.42
Washington	1.12	1.00	1.27	1.03	0.91	1.16
West Virginia	1.48	1.32	1.66	1.24	1.10	1.39
Wisconsin	1.33	1.19	1.48	1.19	1.07	1.33
Wyoming	1.12	0.98	1.28	1.02	0.89	1.17

Notes: Estimated relative risks (hazard ratios) were derived from multivariate Cox proportional hazards regression models. [1]Adjusted for age only. [2]Adjusted for age, sex, race/ethnicity, marital status, metro/non-metro residence, educational attainment, occupation, and income/poverty level

Counties with obesity rates ≥40% had 54% higher CVD mortality than counties with an obesity rate <15%. Counties with a diabetes prevalence ≥14% had 19% higher CVD mortality than counties with a diabetes prevalence <6% (Table 5).

County-level differentials in CVD mortality rates, as measured by relative disparity indices, widened over time; the relative mean deviation index and coefficient of variation indicated, respectively, a 52% and 61% increase in county-level disparity in CVD mortality rates between 1969 and 2007. Absolute county-level disparities in CVD mortality, however, declined over time (Table 4).

Discussion

Cardiovascular disease mortality rates have decreased for all regions and states in the United States. Yet, geographical disparities in mortality, in relative terms, have widened over time as several

Table 4. Summary Measures of Geographical Disparities in Cardiovascular Disease (CVD) Mortality, United States, 1969-2011 (50 States and District of Columbia; 3,141 Counties)

Disparity measure	1969	1990	2011
State			
Coefficient of variation (%)	9.99	10.25	14.83
Interquartile range	111.58	7.87	7.53
Absolute mean deviation	59.63	16.04	21.60
Relative mean deviation index	8.43	8.86	12.09
Quintile ratio (Q4/Q1)	1.19	1.20	1.27
Percentile ratio (P90/P10)	1.24	1.30	1.41
Disparity measure	**1969-1974**	**1990-1999**	**2003-2007**
County			
Coefficient of variation (%)	13.79	16.49	22.14
Interquartile range	122.53	82.81	79.76
Absolute mean deviation	74.06	50.56	48.30
Relative mean deviation index	10.86	12.91	16.49
Quintile ratio (Q4/Q1)	1.26	1.31	1.42
Percentile ratio (P90/P10)	1.41	1.50	1.69

Interquartile range=3rd quartile - 1st quartile; Q1=First quintile; Q4=Fourth quintile. P10=10th Percentile; P90=90th Percentile

areas in the South experienced slower mortality declines than those in the Northeast and Western regions of the country. Geographical disparities are very marked, with several Southern states having nearly twice the risk of CVD mortality than states in the Northeastern and Western United States. Existence of such marked and growing geographical disparities in CVD mortality appears contrary to the goals of the national health initiative that calls for further reductions in cardiovascular disease inequalities in the United States by 2020.[1]

Our results are consistent with the previous studies that have shown historically higher rates of CVD mortality in the Southern region of the United States.[7,12-15] Because of the persistence of this geographical pattern, the "South" is often referred to as the "stroke or heart disease belt" of the United States.[14,15] Since behavioral risk factors such as smoking, unhealthy diet, physical inactivity, and obesity are known to account for about 80% of CVD deaths, geographical disparities in CVD mortality may be understood in terms of geographical distribution of these risk factors.[30] Our analysis confirms the significance of geographical distribution of smoking, obesity, physical inactivity, and diabetes prevalence in explaining county-level disparities in CVD mortality rates. Obesity and diabetes prevalence alone account for nearly 40% of the variance in CVD mortality, and geographical differences in smoking explain about 28% of the variance. Smoking, obesity, and physical inactivity rates are highest in the South, and increases in obesity rates have been more marked in the Southern states.[7,31,32] Moreover, smoking rates have declined more slowly in the South than elsewhere in the United States.[7,31,32]

Patterns and increasing geographical disparities in CVD mortality shown here are consistent with those observed previously for the United States and Europe.[5,13,33-35] A recent study showed widening rural-urban disparities in CVD mortality rates in the United States, with those in rural areas experiencing 16% and 26% higher mortality in 1990 and 2009 respectively than their urban counterparts.[33] Disparities in CVD mortality between most deprived non-metropolitan areas and most affluent metropolitan areas of the United States also increased markedly between 1990 and 2009 in both absolute and relative terms.[33] Coronary heart disease mortality rates have been found to be higher in inner-city areas and in local authority areas in the north of England than those in the south.[34] Another study showed a substantial, widening gap in coronary heart disease mortality between the "worst health" and "best health" areas of Britain over a 10-year period.[35]

Conclusions and Global Health Implications

With the prevalence of many chronic disease risk factors rising in the developing world due to urbanization, development, and globalization, the global burden of cardiovascular diseases is expected to increase further, especially in low- and middle-income countries which account for more than 80% of CVD deaths globally.[30,36-38] Cardiovascular disease is the leading cause of death not only in the

Table 5. Weighted Least Squares Regression Models Showing the Impacts of the Continuous and Categorical Socioeconomic Deprivation Index, Smoking, Obesity, Physical Activity, Diabetes Prevalence, Rural-Urban Continuum, and Racial/Ethnic Composition on County-Level Age-Adjusted Cardiovascular Disease (CVD) Mortality Rates: United States, 2003-2007 (N=3,141)

Covariate	Bivariate models					Multivariate model				
	b	*β*	t-stat	*P*-value	Adj. R^2	b	*β*	t-stat	*P*-value	Adj. R^2
Socioeconomic deprivation index[1]	−1.19	−0.53	−35.28	<0.001	28.58	−0.36	−0.16	−7.26	<0.001	52.7
Adult smoking prevalence (%)[2]	4.91	0.53	34.53	<0.001	27.71	1.76	0.19	8.10	<0.001	
Adult obesity prevalence (%)[3]	7.05	0.62	43.79	<0.001	38.13	3.22	0.28	13.52	<0.001	
Physical activity prevalence (%)[4]	−5.03	−0.39	−23.43	<0.001	15.00	−1.12	−0.09	−6.01	<0.001	
Adult diabetes prevalence (%)[3]	16.97	0.64	46.50	<0.001	40.79	5.77	0.22	10.27	<0.001	
Rural-urban continuuum[5]	5.35	0.21	11.97	<0.001	4.41	−1.83	−0.07	−4.34	<0.001	
Percentage minority population[6]	0.16	0.07	4.15	<0.001	0.55	0.32	0.15	6.90	<0.001	
Health uninsurance rate[7]	2.15	0.21	12.26	<0.001	4.61					
Availability of primary care doctors[8]	−0.23	−0.26	−14.76	<0.001	6.55					
	Age-adjusted CVD mortality					Covariate-adjusted CVD mortality[9]				
			Rate	SE				Rate	SE	
Socioeconomic deprivation, categorical										
Quintile 1 (lowest SES/most deprived)			321.04	1.61				322.60	4.20	
Quintile 2			291.97	1.45				304.69	4.14	
Quintile 3			277.71	1.53				294.69	4.14	
Quintile 4			253.55	1.50				282.13	4.11	
Quintile 1 (highest SES/least deprived)			247.24	1.50				281.56	4.12	
Adult smoking prevalence (%), categorical										
<12			213.73	8.05				269.85	7.70	
12-17.99			254.89	1.53				285.39	4.15	
18-23.99			264.70	1.06				284.89	3.84	
24-27.99			296.79	1.47				297.03	3.80	
28-31.99			323.23	2.18				309.63	4.05	
32-35.99			332.79	5.11				314.65	5.53	
≥36			351.73	9.66				318.47	8.58	
Adult obesity prevalence (%), categorical										
<15			192.72	14.30				253.61	12.37	
15-19.99			229.71	2.48				260.37	3.16	
20-24.99			256.55	1.19				270.61	2.64	
25-29.99			282.82	0.98				282.36	2.50	
30-34.99			324.83	1.76				299.11	2.65	
35-39.99			368.73	7.82				322.12	6.87	
≥40			444.03	25.20				391.74	21.74	
Adult diabetes prevalence (%), categorical										
<6			221.66	3.54				269.73	5.11	
6-7.99			250.32	1.15				282.82	4.46	
8-9.99			280.02	0.99				296.21	4.38	

Contd...

Table 5. Contd...

	Age-adjusted CVD mortality		Covariate-adjusted CVD mortality[9]	
	Rate	SE	Rate	SE
10-11.99	315.18	1.62	304.21	4.47
12-13.99	338.70	3.08	309.33	4.94
≥14	376.92	9.63	320.49	8.75

Notes: b=Unstandardized regression coefficient; β=Standardized regression coefficient; R^2=Percentage variance explained. β is also equal to the correlation coefficient in bivariate regression models. Health uninsurance and primary care physician availability rates were not used as covariates in the multivariate model because of estimation problems due to multicollinearity. [1]The 2000 census socioeconomic deprivation index is a continuous variable with a mean of 100 and a standard deviation of 20. Higher index scores denote higher levels of socioeconomic position and lower levels of deprivation. [2]Current smoking prevalence among adults aged 18+in 2000-2003. [3]Obesity or diabetes prevalence among adults aged 18+in 2006-2008. [4]Percentage of physically active adults aged 18+in 2007, where phyically active=at least 150 minutes of moderate physical activity per week, or 75 minutes of vigorous activity per week, or an equivalent comination of moderate and vigorous physical activity. [5]The 2003 rural-urban continuum is used a continuous variable, with code 1 being the most urbanized county and code 9 being the most rural county. [6]Percentage of black, American Indian/Alaska Native, Asian/Pacific Islander, and Hispanic populations in 2000. [7]Percentage of population without health insurance in 2000. [8]Number of primary care doctors per 100,000 population in 2005. [9]Adjusted for socioeconomic deprivation, smoking, obesity, and PA prevalence, rural-urban continuum, and minority concentration. Source: Based on the US National Vital Statistcs System, Behavioral Risk Factor Surveillance System, US Census, and Area Resource File

industrialized world, but also in low- and middle-income countries.[30,36-38] Globally, a major shift has been occurring in the distribution of disease burden as a number of low- and middle-income countries are experiencing an increasing proportion of deaths and years of life lost due to non-communicable diseases such as heart disease, stroke, and COPD.[30,36-38] Most of the CVD deaths are preventable through policy measures that are aimed at reducing behavioral risk factors such as smoking, physical inactivity, unhealthy diet, and heavy drinking that account for about 80% of cardiovascular diseases globally.[30,36]

Cardiovascular disease burden varies greatly across the world regions, with India and China accounting for >30% of all global CVD deaths.[30,36-38] Similar analyses of geographical disparities in cardiovascular disease prevalence and mortality rates in developing countries can highlight rural-urban, province-, or district-level disparities, thus indicating the need for targeted action and population-wide interventions to reduce cardiovascular disease incidence and associated behavioral risks. The following countries have the highest disease burden (in terms of number of heart disease deaths): US and Germany among high-income countries; China and Indonesia in the East Asia and Pacific region; Russia and Ukraine in Europe and Central Asia; Brazil and Mexico in Latin America and the Caribbean; India and Pakistan in South Asia; and Nigeria and Ethiopia in Sub-Saharan Africa.[30,36-38] Because of macro-societal forces, such as globalization and urbanization, people in developing countries are increasingly being exposed to such CVD risk factors as smoking, drinking, physical inactivity, and unhealthy diet. At the same time, they do not have similar access to public health education and prevention programs and access to primary care as their counterparts in the industrialized world.[30,36]

Geographical inequalities in the United States remain quite marked despite the impressive overall decline in CVD mortality over the past several decades. The growing geographical disparities in CVD mortality are a major public health concern. Because cardiovascular diseases are the leading cause of death and account for nearly one-third of all US deaths, the widening inequalities in CVD mortality contribute greatly to overall health and mortality inequalities in the United States.[1,7,8] These disparities in mortality may indicate significant geographical inequities in CVD prevention and control efforts. Population-wide interventions such as comprehensive tobacco control policies, smoking cessation programs, increased access to primary medical care, physical activity campaigns, and anti-obesity programs can be implemented to reduce CVD risks in the entire population while targeting those in the more disadvantaged areas of the country such as the South.[30] A broad course of policy action related to the wider social determinants can be a particularly effective strategy in reducing CVD inequalities.[5,30,34,35] Health and social policy interventions such as improved access to health services, and reductions in inequalities in education, poverty, unemployment, occupation, housing, and access to health-promoting physical or built environments are essential for tackling long-term inequalities in CVD mortality between geographical areas in the United States.[5,24,30,34,35]

Key Messages

- Previous research has identified higher risks of CVD mortality in the Southern region of the United States. Our study shows that, despite the substantial decline in overall mortality, regions, states, and counties in the Southeastern United States continue to show substantially increased risks of CVD mortality.
- County- and state-level inequalities in cardiovascular-disease mortality increased consistently between 1969 and 2011 as geographical areas in New England and Mid-Atlantic regions of the US experienced faster mortality declines than those in the South.
- Both area- and individual-level socioeconomic characteristics influence geographical disparities in CVD mortality in the United States. Additionally, preventable or modifiable risk factors such as smoking, obesity, physical inactivity, diabetes, and healthcare access account for much of the geographical inequality in CVD mortality.
- Widening geographical in US cardiovascular-disease mortality may be related to increasing temporal differences in material living conditions and health-risk behaviors such as smoking, obesity, physical inactivity, and unhealthy diet between geographical areas.
- From a policy standpoint, narrowing the socioeconomic gap and inequalities in smoking, obesity, and physical inactivity between affluent and disadvantaged areas has the greatest potential to reduce CVD and overall mortality rates in the United States.
- With the prevalence of many chronic disease risk factors rising in the developing world due to globalization and development, the global burden of cardiovascular diseases will likely increase further, especially in low- and middle-income countries, which account for more than 80% of CVD deaths globally.

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