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ORIGINAL RESEARCH

# Geographic Variation in Trends and Disparities in Heart Failure Mortality in the United States, 1999 to 2017

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**BACKGROUND:** Cardiovascular disease mortality related to heart failure (HF) is rising in the United States. It is unknown whether trends in HF mortality are consistent across geographic areas and are associated with state-level variation in cardiovascular health (CVH). The goal of the present study was to assess regional and state-level trends in cardiovascular disease mortality related to HF and their association with variation in state-level CVH.

**METHODS AND RESULTS:** Age-adjusted mortality rates (AAMR) per 100 000 attributable to HF were ascertained using the Centers for Disease Control and Prevention's Wide-Ranging Online Data for Epidemiologic Research from 1999 to 2017. CVH at the state-level was quantified using the Behavioral Risk Factor Surveillance System. Linear regression was used to assess temporal trends in HF AAMR were examined by census region and state and to examine the association between state-level CVH and HF AAMR. AAMR attributable to HF declined from 1999 to 2011 and increased between 2011 and 2017 across all census regions. Annual increases after 2011 were greatest in the Midwest (β=1.14 [95% CI, 0.75, 1.53]) and South (β=0.96 [0.66, 1.26]). States in the South and Midwest consistently had the highest HF AAMR in all time periods, with Mississippi having the highest AAMR (109.6 [104.5, 114.6] in 2017). Within race–sex groups, consistent geographic patterns were observed. The variability in HF AAMR was associated with state-level CVH ($P<0.001$).

**CONCLUSIONS:** Wide geographic variation exists in HF mortality, with the highest rates and greatest recent increases observed in the South and Midwest. Higher levels of poor CVH in these states suggest the potential for interventions to promote CVH and reduce the burden of HF.

**Key Words:** geographic variation ■ health disparities ■ heart failure ■ prevention

Over the past several decades, advances in the management of cardiovascular disease (CVD) have led to substantial declines in CVD mortality in the United States. However, recent data have shown a significant slowing in this trend since 2011.[1,2] Among heart disease subtypes, ischemic heart disease mortality has continued to decline,[3] while heart failure (HF) mortality has experienced a significant reversal with increases in mortality related to HF since 2011.[4] Some of this increase may be driven by the rapid aging of the US population.[5] While HF mortality rates are increasing nationally, there is significant regional variation in HF prevalence,[6] HF hospitalization rates,[7,8] and outcomes after HF hospitalization.[7,9] It is therefore essential to understand how the burden of HF mortality is borne at regional and state levels, as well as the underpinnings of any observed variation. Prior studies that have looked at HF mortality rates by state have found that underlying risk factors such as obesity, diabetes mellitus, and hypertension are significantly associated with HF mortality rate.[10]

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## CLINICAL PERSPECTIVE

### What Is New?

- While increases in age-adjusted mortality rates for cardiovascular deaths related to heart failure have been observed in all census regions since 2011, increases are greatest in the Midwest and Southern United States.
- Large disparities between US states in cardiovascular health are associated with age-adjusted mortality rates for cardiovascular deaths related to heart failure.

### What Are the Clinical Implications?

- Differences in the burden of heart failure mortality are largely attributable to modifiable risk exposures and emphasize the need and potential for interventions to target cardiovascular health to minimize the burden of heart failure mortality.

### Nonstandard Abbreviations and Acronyms

**AAMR** age-adjusted mortality rate
**BRFSS** Behavior Risk Factor Surveillance System
**CVH** cardiovascular health

Cardiovascular health (CVH) incorporates both biological risk factors (total cholesterol, blood pressure, body mass index, and fasting plasma glucose) as well as behavioral risk factors (smoking, physical activity, and diet) into one comprehensive measure of CVH.[11] Prevalence of poor CVH increased nationally from 2003 to 2011, preceding the recent rise in HF mortality.[12] CVH also varies significantly by state, with higher rates of poor CVH clustered in Southern states.[13,14] These factors suggest that geographic variation in the distribution of HF mortality may be attributable to underlying geographic variation in CVH.

The present study seeks to (1) define geographic differences in contemporary trends in cardiovascular mortality related to HF (abbreviated throughout as HF mortality) and (2) examine the relationship between HF mortality and underlying risk factors, as measured by the American Heart Association's CVH score.

# METHODS

## Study Population and Data

We undertook a serial cross-sectional analysis of data from the 4 US census regions (Northeast, South, Midwest, West) as well as all 50 states and Washington DC using annual data from 1999 to 2017. The states and census regions included in this analysis were the Northeast (CT, MA, ME, NH, NJ, NY, PA, RI, VT), the Midwest (IA, IL, IN, KS, MI, MN, MO, NE, ND, OH, SD, WI), the South (AL, AR, DC, DE, FL, GA, KY, LA, MD, MS, NC, OK, SC, TN, TX, VA, WV), and the West (AZ, CA, CO, ID, MT, NM, NV, OR, UT, WA, WY). Within regions, age-adjusted mortality rates (AAMRs) were quantified for each race−sex group. Data were not available to calculate HF mortality among Black men in ID, ME, MT, ND, NE, NH, NM, RI, SD, UT, VT, WV, and WY and among Black women in ID, ME, MT, ND, NE, NH, NM, OR, RI, SD, UT, VT, and WY because of the small Black populations in these states.

Race-sex specific AAMRs for cardiovascular deaths with any mention of HF were calculated for states and census regions using the Centers for Disease Control and Prevention's Wide-Ranging Online Data for Epidemiologic Research (CDC WONDER), standardized to the 2000 US population.[15] We used the US Behavior Risk Factor Surveillance System (BRFSS) to calculate state-level CVH.[16] All data used in the study are de-identified and released publicly by the Centers for Disease Control and Prevention for researchers and therefore this study did not require review by the Institutional Review Board at Northwestern University.

## Outcome Ascertainment

HF AAMR were ascertained from 1999 to 2017 among US Black and White adults aged 35 to 84 years using the multiple cause of death files from CDC WONDER, which includes the underlying and contributing cause of death from all death certificates in the United States.[15] Because HF is considered an intermediate cause of, or mode of, death, the cause of death coding instructions from the International Classification of Disease suggest that other plausible heart conditions should be listed as the underlying cause of death instead of HF. In a study of death certificate data from the ARIC (Atherosclerotic Risk in Communities) Study, HF was >3.3 times likely to be listed as a multiple cause of death than the underlying cause of death.[17] Thus, measuring HF mortality by including any cardiovascular death in which HF is listed as a contributing cause helps to capture the broad burden of HF-related death without including non-CVD deaths that list HF where it less likely to be contributing (eg, neoplasm). Specifically, for the primary analysis, cardiovascular deaths related to HF were identified among those with CVD (I00–I78) listed as underlying cause of death and HF (I50) listed as contributing cause. This includes those who died with an underlying cause of death of coronary heart disease, myocardial infarction, and stroke, among other causes of CVD. We also examined 2 additional definitions whereby HF was listed as the underlying cause of death as well as all deaths with any mention of HF (as underlying or contributing cause) in sensitivity analyses.

## Assessment of Cardiovascular Health Exposure

CVH was estimated at the state-level using data from BRFSS[16] according to American Heart Association definitions and standards.[11] BRFSS is a telephone-based self-reported health surveillance system that collects sociodemographic data and tracks health status and behaviors in the United States. We used questions from the core component of the BRFSS on hypertension, high cholesterol, diabetes mellitus, body mass index, tobacco use, physical activity, consumption of fruits and vegetables, as well as demographic information including age, sex, and race/ethnicity. Data from the core component are available from every state. However, questions for several factors are not asked every year, therefore obtaining complete data to estimate CVH are only available in odd years (eg, 2015, 2017). Participants who reported a history of coronary heart disease, myocardial infarction, or stroke were excluded as tracking CVH at the population-level is intended for use in a primary prevention sample.

Ideal CVH for each metric was assessed included the following: responses of “no” when asked if a doctor has told a participant that he or she has high blood pressure, high cholesterol, or diabetes mellitus; reporting a body mass index of 18.5 to 25.0 kg/m$^2$; reporting <100 lifetime cigarettes smoked, or 100 lifetime cigarettes smoked but are not currently smoking; reporting ≥150 minutes a week of moderate-intensity activity, or ≥75 minutes of vigorous-intensity activity, or an equivalent combination of aerobic physical activity; and ≥5 daily servings of fruits or vegetables (Table 1). Though the American Heart Association’s healthy diet score consists of multiple more components than fruits and vegetables (intake of whole grains, sodium, sugar-sweetened beverages, and fish), fruits and vegetable intake were used as a proxy, as has been done previously.[13,18] CVH is considered “ideal” when an individual met criteria for “ideal” for 7 factors, and is considered “poor” for 2 or fewer factors as has been done previously.[13]

## Statistical Analysis

We performed Joinpoint trend analysis to identify inflection points in overall AAMR trends and linear regression to quantify annual rates of change in AAMR. We performed these analyses for the overall population and stratified by region, sex, and race/ethnicity subgroups. Separately for 2011 and 2017, linear regression was used to quantify the relationship between state CVH and HF mortality, with a state’s percentage of residents with poor CVH as the independent variable and HF AAMR as the dependent variable. All analyses were performed in SAS version 9.4 (SAS Institute, Cary, NC) and Joinpoint version 4.7.0.0.[19,20]

**Table 1. Quantification of State-Level American Heart Association Definition of Cardiovascular Health Using the Behavioral Risk Factor Surveillance System**

| Measure | BRFSS Question/Variable | Definition for Ideal Cardiovascular Health |
|---|---|---|
| BMI | About how much do you weigh without shoes?<br>About how tall are you without shoes? | BMI (kg/m$^2$)=18.5–24.9 |
| Diabetes mellitus | Have you ever been told by a doctor that you have diabetes? | Answered “no” |
| Cholesterol | Those who have been cholesterol screened—have you ever been told by a doctor, nurse, or other health professional that your blood cholesterol is high? | Answered “no” |
| Hypertension | Have you ever been told by a doctor, nurse, or other health professional that you have high blood pressure? | Answered “no” |
| Dietary Pattern | Not counting juice, how often do you eat fruit?<br>How often do you eat a green leafy or lettuce salad, with or without other vegetables?<br>During the past month, how many times did you eat dark green vegetables?<br>How often do you eat potatoes, not including French fries, fried potatoes, or potato chips?<br>How many times did you eat orange-colored vegetables such as sweet potatoes, pumpkin, winter squash, or carrots?<br>How many times did you eat other vegetables? | Consumed 5 or more servings of fruits and vegetables per day |
| Physical Activity | Respondents who reported doing 150+ min (or vigorous equivalent) of physical activity | 150+ min (or vigorous equivalent min) per week of physical activity. |
| Smoking Status | Have you smoked at least 100 cigarettes in your entire life?<br>Do you now smoke cigarettes every day, some days, or not at all? | Had not smoked at least 100 cigarettes in their lifetime; or reported smoking 100 cigarettes in their lifetime, but not currently smoking |

BMI indicates body mass index; and BRFSS, Behavioral Risk Factor Surveillance System.

## Role of the Funding Source

The funding sponsor did not contribute to design and conduct of the study, collection, management, analysis, or interpretation of the data or preparation, review, or approval of the article. The authors take responsibility for decision to submit the article for publication. Dr. Khan had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

# RESULTS

## Regional Differences in Cardiovascular Mortality Related to HF, 1999 to 2017

The South and Midwest regions had higher HF AAMRs than the Northeast or West across the study period (Table 2). AAMR for HF mortality experienced a significant inflection point in 2011, generally declining before and increasing after 2011 across all 4 regions (Tables 2 and 3, Figure 1). Annual increases in AAMR per 100 000 after 2011 were greatest in the Midwest (β=1.14 [95% CI, 0.75, 1.53]), indicating an increase of 1.14 deaths per 100 000 per year. In the South, annual AAMR increase was 0.96 per 100 000 per year (0.66, 1.26) followed by the West (0.72 [0.05, 1.39]) and Northeast (0.35 [0.03, 0.68]).

Geographic patterns were consistent for each race–sex group (Figure 2). Specifically, Black men and women had consistently higher AAMRs and steeper increases in AAMR than their White peers across all census regions. White women consistently had the lowest HF AAMRs across regions and White women in the Northeast were the only group to experience a negative rate of change (−0.05 [−0.36, 0.26]) between 2011 and 2017. In sensitivity analyses whereby HF was identified as either the underlying cause or any mention in all causes of death, similar regional patterns and race–sex differences were observed (Table S1).

## State-Level Differences in Cardiovascular Mortality Related to HF, 1999 to 2017

In 1999, 2011, and 2017, the states in the highest quintile of AAMRs came exclusively from the South and Midwest census regions (Table 4). Four states, all from the South region, consistently ranked among the 5 highest AAMRs in 1999, 2011, and 2017: Arkansas (5th, 4th, 3rd), Alabama (4th, 3rd, 4th), Oklahoma (3rd, 2nd, 5th), and Mississippi (1st, 1st, 1st). Only 3 states consistently ranked among the 10 lowest AAMRs during these years: Arizona (48th, 43rd, 44th), Connecticut (46th, 45th, 49th), and Florida (51st, 50th, 48th). A minority of states experienced a decrease in AAMR both between 1999 to 2011 and 2011 to 2017: Alaska, Mississippi, Nebraska, New Jersey, New York, North Dakota, Vermont, and West Virginia. All other states saw decreases between 1999 to 2011 and increases between 2011 to 2017. The ratio of the state with the highest AAMR to the state with lowest AAMR went from 2.5 in 1999 (Mississippi [133.8], Florida [54.6]), to 3.4 in 2011 (Mississippi [112.7], Hawaii [32.8]), to 2.8 in 2017 (Mississippi [109.6], Alaska [38.6]).

## Association of State-Level Differences in CVH and Cardiovascular Mortality Related to HF

The percentage of individuals meeting criteria for "poor" CVH (2 or fewer ideal factors) for each state in 2011 and 2017 is shown in Table S2. In 2011, the percentage of residents with poor CVH ranged from 8.4 (Colorado) to 22.4 (Mississippi). In 2017, poor CVH ranged from 6.5% (District of Columbia) to 19.7% (Kentucky). In 2011 and 2017, the percentage of state residents with poor CVH was significantly associated with HF mortality ($P$<0.001) (Figure 3). In 2017, the model β estimate was 3.13, indicating ≈3 additional deaths per 100 000 associated with every 1% higher in the prevalence of poor CVH at the state level.

# DISCUSSION

## Principal Findings

AAMR for HF mortality experienced an inflection point in 2011 nationally with similar trends across all 4 regions: generally declining before and increasing after 2011. Wide geographic variation exists in HF mortality rates. The South and Midwest experienced the highest rates and the largest increases observed since 2011. Black men in each region had the highest HF mortality rates and experienced the greatest increases between 2011 and 2017. Only 8 states saw decreases in their HF mortality rates between 2011 and 2017, while all others saw increases. No state from the West region saw decreases between 2011 and 2017. States from the South and Midwest census regions consistently comprised the 10 highest AAMR. A higher proportion of residents in a state with poor CVH was associated with higher rates of HF mortality in that state.

## Current Study in Context

The current study adds to this literature by demonstrating the significant geographic heterogeneity in the burden of HF mortality and highlights opportunities for targeted prevention efforts on a state and local level. HF AAMR in the South and Midwest are higher than other regions. The South has also seen the greatest increases in HF AAMR since 2011. This is consistent with historical work that has demonstrated geographic variation in HF and stroke mortality, with higher rates

**Table 2. Total Number of Cardiovascular Deaths Related to Heart Failure and Heart Failure Age-Adjusted Mortality Rate by US Census Region From 1999 to 2017 Among Black and White Adults Age 35 to 84 Years**

| Y | Northeast | | Midwest | | South | | West | |
|---|---|---|---|---|---|---|---|---|
| | No. of Deaths | AAMR (95% CI) | No. of Deaths | AAMR (95% CI) | No. of Deaths | AAMR (95% CI) | No. of Deaths | AAMR (95% CI) |
| 1999 | 20 052 | 71.2 (70.3–72.2) | 26 181 | 82.3 (81.3–83.3) | 38 955 | 82.1 (81.3–82.9) | 18 714 | 75.8 (74.7–76.9) |
| 2000 | 20 229 | 71.4 (70.4–72.4) | 25 727 | 80.6 (79.6–81.6) | 39 305 | 82.1 (81.3–82.9) | 18 177 | 72.7 (71.6–73.8) |
| 2001 | 19 589 | 68.6 (67.7–69.6) | 25 164 | 78.1 (77.1–79.1) | 39 223 | 80.4 (79.6–81.2) | 18 350 | 71.9 (70.9–73.0) |
| 2002 | 18 785 | 65.4 (64.4–66.3) | 24 297 | 74.8 (73.8–75.7) | 38 397 | 77.5 (76.7–78.2) | 18 489 | 71.2 (70.2–72.3) |
| 2003 | 18 146 | 62.9 (62.0–63.8) | 23 939 | 73.1 (72.1–74.0) | 38 281 | 75.9 (75.2–76.7) | 18 471 | 70.1 (69.1–71.1) |
| 2004 | 17 621 | 60.9 (60.0–61.8) | 22 994 | 69.7 (68.8–70.6) | 37 501 | 73.3 (72.5–74.0) | 17 693 | 66.2 (65.3–67.2) |
| 2005 | 17 129 | 59.3 (58.4–60.2) | 22 714 | 68.5 (67.6–69.4) | 37 956 | 72.9 (72.2–73.6) | 17 928 | 66.2 (65.2–67.2) |
| 2006 | 16 028 | 55.7 (54.9–56.6) | 21 464 | 64.4 (63.5–65.3) | 36 443 | 68.9 (68.2–69.6) | 17 199 | 62.8 (61.8–63.7) |
| 2007 | 15 104 | 52.5 (51.7–53.3) | 19 890 | 59.4 (58.6–60.3) | 35 215 | 65.6 (64.9–66.3) | 16 345 | 59.2 (58.2–60.1) |
| 2008 | 14 522 | 50.5 (49.7–51.3) | 19 991 | 59.3 (58.5–60.1) | 34 074 | 62.4 (61.7–63.0) | 16 142 | 57.6 (56.7–58.5) |
| 2009 | 13 883 | 48.5 (47.7–49.3) | 19 231 | 56.9 (56.1–57.7) | 33 558 | 60.5 (59.8–61.1) | 15 354 | 54.0 (53.2–54.9) |
| 2010 | 13 633 | 47.5 (46.7–48.3) | 18 951 | 55.9 (55.1–56.7) | 33 750 | 60.0 (59.4–60.7) | 14 918 | 51.9 (51.1–52.8) |
| 2011 | 13 780 | 48.0 (47.2–48.8) | 19 068 | 55.7 (54.9–56.5) | 32 953 | 57.3 (56.6–57.9) | 15 510 | 52.7 (51.8–53.5) |
| 2012 | 13 577 | 46.8 (46.0–47.6) | 19 202 | 55.3 (54.5–56.1) | 34 189 | 57.9 (57.3–58.5) | 15 266 | 50.3 (49.5–51.1) |
| 2013 | 14 023 | 48.0 (47.2–48.8) | 20 064 | 56.9 (56.1–57.7) | 36 447 | 60.1 (59.5–60.7) | 15 810 | 50.7 (49.9–51.6) |
| 2014 | 14 200 | 48.1 (47.3–48.9) | 20 716 | 57.8 (57.0–58.6) | 38 174 | 61.3 (60.6–61.9) | 16 368 | 50.8 (50.0–51.6) |
| 2015 | 14 729 | 49.3 (48.5–50.1) | 21 790 | 60.0 (59.2–60.8) | 40 935 | 63.9 (63.3–64.5) | 18 109 | 54.7 (53.9–55.5) |
| 2016 | 14 851 | 49.0 (48.2–49.8) | 22 454 | 60.6 (59.8–61.4) | 41 987 | 63.6 (63.0–64.2) | 19 190 | 56.1 (55.3–56.9) |
| 2017 | 15 278 | 48.9 (48.1–49.7) | 23 600 | 62.0 (61.2–62.8) | 43 793 | 64.4 (63.8–65.0) | 19 648 | 55.7 (55.0–56.5) |

AAMR indicates age-adjusted mortality rate.

**Table 3. Heart Failure Age-Adjusted Mortality Rate by Region Among Black and White Men and Women Age 35 to 84 Years Between 1999 and 2017**

| Region | Total Deaths, n | AAMR (95% CI) | | | Slope β (95% CI) | |
|---|---|---|---|---|---|---|
| | | 1999 | 2011 | 2017 | 1999–2011 | 2011–2017 |
| Northeast | 305 159 | | | | | |
| Black men | | 84.2 (77.9–90.5) | 61.4 (56.7–66.1) | 69.4 (64.9–73.9) | −2.35 (−2.95 to −1.74) | 1.29 (0.69–1.90) |
| Black women | | 62.7 (58.5–66.9) | 42.5 (39.3–45.6) | 43.1 (40.3–46.0) | −2.09 (−2.60 to −1.59) | 0.51 (−0.23 to 1.25) |
| White men | | 90.0 (88.2–91.8) | 59.9 (58.5–61.4) | 62.2 (60.8–63.6) | −2.79 (−3.08 to −2.51) | 0.51 (0.23 to 0.80) |
| White women | | 57.1 (55.9–58.3) | 37.8 (36.8–38.8) | 36.5 (35.5–37.4) | −1.94 (−2.16 to −1.72) | −0.05 (−0.36 to 0.26) |
| Midwest | 417 437 | | | | | |
| Black men | | 108.2 (101.2–115.2) | 91.4 (85.7–97.2) | 106.0 (100.3–111.7) | −1.79 (−2.36 to −1.22) | 2.45 (1.03–3.87) |
| Black women | | 88.0 (82.9–93.2) | 64.0 (60.0–67.9) | 74.0 (70.0–78.0) | −2.38 (−2.76 to −2.01) | 1.76 (0.21–3.31) |
| White men | | 102.0 (100.2–103.8) | 66.2 (64.9–67.6) | 75.1 (73.7–76.4) | −3.14 (−3.47 to −2.82) | 1.58 (1.20–1.96) |
| White women | | 65.5 (64.3–66.7) | 43.6 (42.7–44.6) | 46.4 (45.4–47.3) | −2.10 (−2.32 to −1.87) | 0.59 (0.28–0.91) |
| South | 711 136 | | | | | |
| Black men | | 119.6 (115.2–124.1) | 88.6 (85.4–91.9) | 110.3 (107.2–113.5) | −2.53 (−3.08 to −1.98) | 3.79 (2.61–4.96) |
| Black women | | 89.3 (86.3–92.3) | 62.0 (59.8–64.2) | 72.4 (70.2–74.6) | −2.62 (−3.01 to −2.22) | 1.85 (1.43–2.27) |
| White men | | 97.3 (95.9–98.8) | 67.0 (65.9–68.1) | 75.2 (74.2–76.3) | −2.73 (−2.96 to −2.51) | 1.51 (1.16–1.85) |
| White women | | 64.4 (63.4– 65.4) | 43.3 (42.5–44.0) | 45.5 (44.8–46.3) | −1.94 (−2.14 to −1.74) | 0.45 (0.06–0.85) |
| West | 327 681 | | | | | |
| Black men | | 120.7 (110.0–131.4) | 83.1 (75.8–90.3) | 106.4 (99.1–113.7) | −2.93 (−4.02 to −1.84) | 3.65 (2.41–4.88) |
| Black women | | 94.4 (86.3–102.5) | 63.8 (58.1–69.6) | 62.5 (57.5–67.5) | −2.26 (−2.99 to −1.53) | 0.48 (−1.26 to 2.21) |
| White men | | 92.0 (90.2–93.9) | 64.5 (63.1–65.9) | 69.1 (67.8–70.4) | −2.61 (−2.88 to −2.33) | 1.30 (0.23–2.38) |
| White women | | 60.3 (59.0–61.6) | 40.5 (39.4–41.5) | 41.0 (40.0–41.9) | −1.74 (−1.93 to −1.55) | 0.31 (−0.44 to 1.07) |

AAMR indicates age-adjusted mortality rate; and β, change in deaths per 100 000 per year.

clustered in Southern states leading to the region being labeled the "stroke belt".[8,10] Others have also demonstrated higher rates of HF-related morbidity reflected by hospitalization clustered in Southern and Midwest states.[7]

Our study also confirms significant disparities in HF mortality that are pervasive across regions and states and are consistent with prior data from population-based cohort studies, including the Multi-Ethnic Study of Atherosclerosis that demonstrated Black participants had higher rates of developing incident HF (4.6 per 1000 person-years) compared with Hispanic participants (3.5), White participants (2.4), and Chinese participants (1.0).[4,21] Multiple factors underlie these geographic and demographic trends. For instance, risk factors such as hypertension,[10,22] obesity, and diabetes mellitus[10,23] have previously been shown to cluster in Southern states, where HF mortality is high. Similarly, we found that state-level variation in poor CVH is significantly associated with HF mortality, which is consistent with prior publications demonstrating higher rates of poor CVH and CVD mortality in Southern states.[14] Ample epidemiologic evidence demonstrates that Black men and women have higher rates of poor CVH related to a variety of upstream social determinants of health, which include structural and systemic racism.[12,14] A separate study of county-level variation in total CVD mortality showed that demographic factors account for 36% of CVD mortality variation and economic/social conditions accounted for another 32%.[24] Combined, healthcare indicators, healthcare usage, and features of the environment accounted for 6%.

Given the rising rates of HF mortality as well as clear variation in rates across the United States, state-level policies and programs are needed to address the growing burden of HF. These programs must function on multiple levels. First, programs must target ideal CVH promotion and treat underlying CVD risk factors as they develop. Current estimates indicate that only 1% to 3.3% of the population meets criteria for ideal CVH,[13,25] and as re-demonstrated in this study, a high proportion of the population are classified as poor. If we are to stem the growing burden of HF morbidity and mortality, we must address

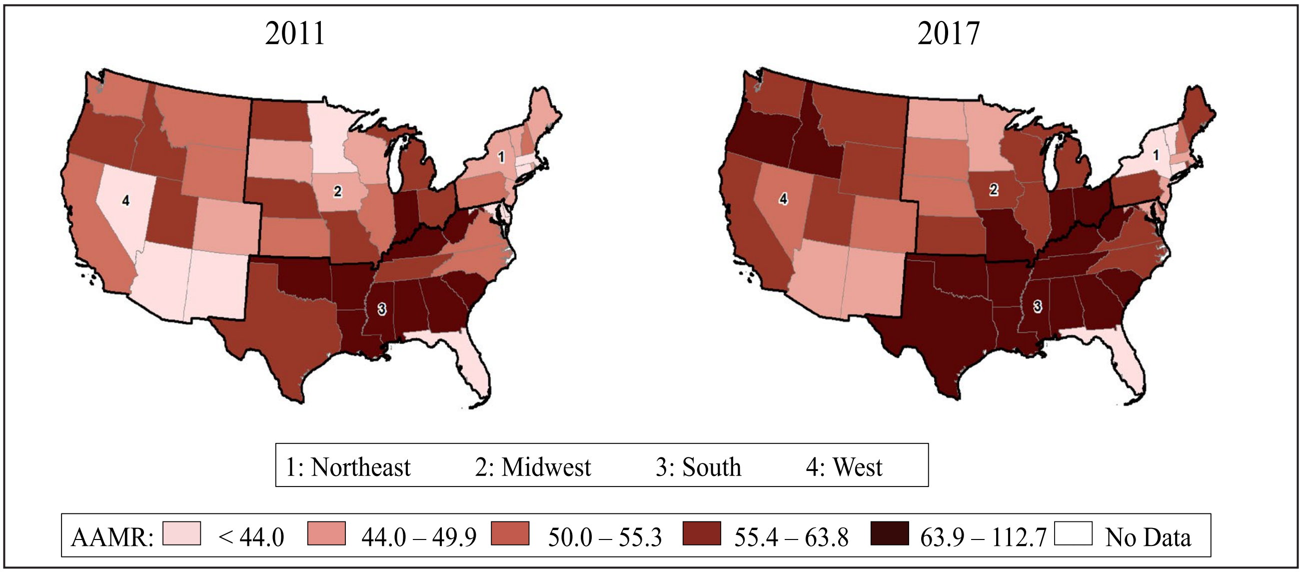


**Figure 1. Geographic variation in regional and state-level age-adjusted cardiovascular mortality rates related to heart failure in 2011 and 2017.**

States are color-coded according to their age-adjusted mortality rate (per 100 000). States represented in deeper red have higher age-adjusted mortality rates. Numbers in the map correspond to census region: 1 (Northeast), 2 (Midwest), 3 (South), 4 (West). AAMR indicates age-adjusted mortality rate.

the modifiable risk factors to improve CVH. Early identification and treatment of risk factors should be a priority, as should integrated programs focusing on the management of chronic conditions that lead to HF and other CVD.[26] In addition to focus on individual health behaviors are important, we must also

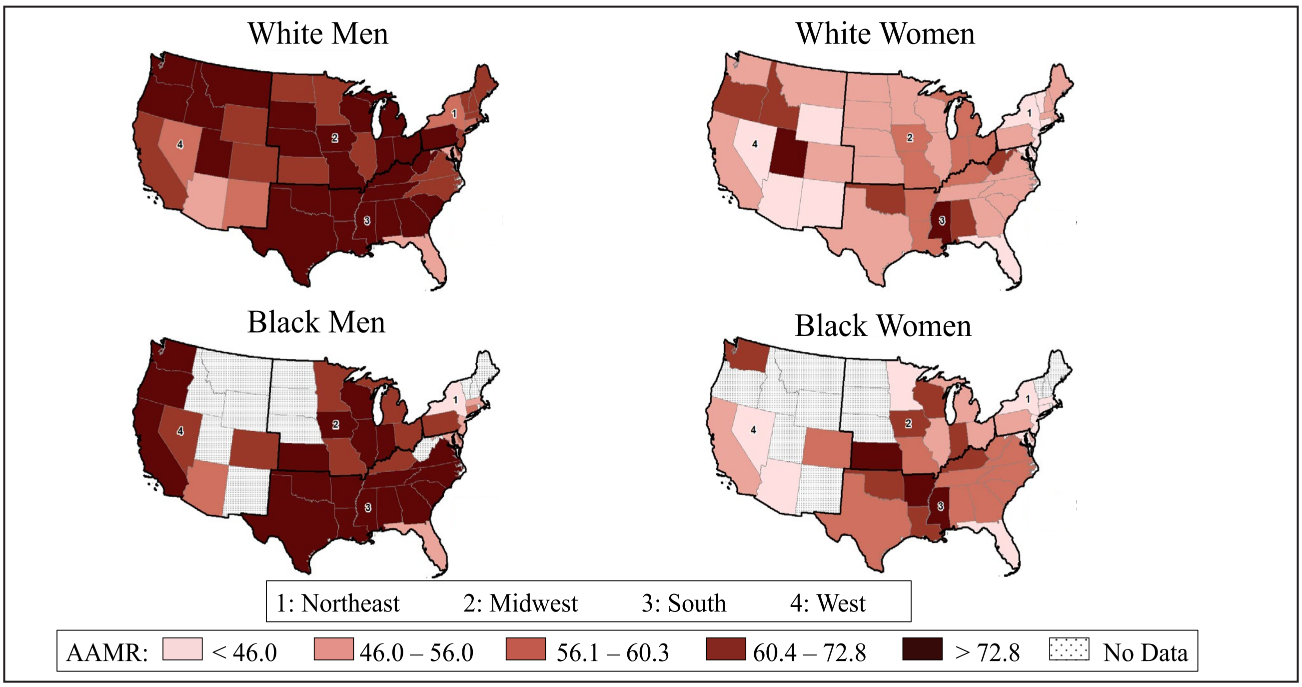


**Figure 2. Geographic variation in regional and state-level age-adjusted cardiovascular mortality related to heart failure by race-sex group in 2017.**

States are color-coded according to their corresponding race-sex age-adjusted mortality rate (age-adjusted mortality rate, per 100 000). States represented in deeper red have higher age-adjusted mortality rates. Numbers in the map correspond to census region: 1 (Northeast), 2 (Midwest), 3 (South), 4 (West). In several Mountain West and upper Great Plains states, there was insufficient data to calculate age-adjusted mortality rates for Black men and women attributable to small Black populations in those states. AAMR indicates age-adjusted mortality rate.

**Table 4. Total Number of Cardiovascular Deaths Related to Heart Failure and Heart Failure Age-Adjusted Mortality Rate by US State in 1999, 2011, and 2017**

| State | 1999 | | 2011 | | 2017 | |
|---|---|---|---|---|---|---|
| | No. of Deaths | AAMR (95% CI) | No. of Deaths | AAMR (95% CI) | No. of Deaths | AAMR (95% CI) |
| Alabama | 2360 | 106.6 (102.3–110.9) | 2044 | 79.5 (76.0–82.9) | 2044 | 81.9 (78.6–85.3) |
| Alaska | 72 | 62.2 (48.1–79.1) | 89 | 49.9 (39.5–62.2) | 89 | 38.6 (30.9–47.6) |
| Arizona | 1466 | 58.9 (55.8–61.9) | 1394 | 42.5 (40.2–44.7) | 1394 | 45.4 (43.3–47.5) |
| Arkansas | 1457 | 102.6 (97.3–107.8) | 1219 | 75.9 (71.6–80.2) | 1219 | 82.8 (78.5–87.1) |
| California | 10 379 | 82.4 (80.8–84.0) | 7782 | 55.3 (54.0–56.5) | 7782 | 56.7 (55.6–57.9) |
| Colorado | 1118 | 70.1 (66.0–74.2) | 1066 | 49.3 (46.2–52.3) | 1066 | 51.7 (48.9–54.5) |
| Connecticut | 1112 | 60.5 (56.9–64.1) | 762 | 41.1 (38.1–44.0) | 762 | 41.1 (38.2–43.9) |
| Delaware | 354 | 91.8 (82.2–101.4) | 210 | 43.3 (37.4–49.2) | 210 | 52.5 (46.6–58.4) |
| District of Columbia | 158 | 58.8 (49.6–68.0) | 104 | 40.4 (32.5–48.2) | 104 | 54.3 (45.8–62.8) |
| Florida | 5796 | 54.6 (53.2–56.0) | 4267 | 34.8 (33.7–35.8) | 4267 | 41.5 (40.5–42.6) |
| Georgia | 2917 | 94.6 (91.2–98.1) | 2734 | 65.9 (63.4–68.4) | 2734 | 74.7 (72.2–77.1) |
| Hawaii | 107 | 66.3 (53.7–78.9) | 70 | 32.8 (25.3–41.7) | 70 | 44.3 (35.8–52.8) |
| Idaho | 387 | 68.8 (61.9–75.6) | 420 | 57.5 (51.9–63.0) | 420 | 68.9 (63.5–74.4) |
| Illinois | 4587 | 79.7 (77.4–82.0) | 3269 | 54.3 (52.4–56.2) | 3269 | 61 (59.1–63.0) |
| Indiana | 2797 | 95.7 (92.1–99.2) | 2181 | 67.4 (64.6–70.3) | 2181 | 72.8 (70.0–75.6) |
| Iowa | 1079 | 64.0 (60.2–67.9) | 823 | 48.0 (44.7–51.3) | 823 | 60.1 (56.5–63.7) |
| Kansas | 1034 | 75.9 (71.2–80.5) | 763 | 53.4 (49.6–57.2) | 763 | 58.6 (54.7–62.4) |
| Kentucky | 1946 | 99.8 (95.3–104.2) | 1525 | 67.5 (64.1–70.9) | 1525 | 74.4 (71.1–77.8) |
| Louisiana | 1694 | 85.4 (81.4–89.5) | 1490 | 67.2 (63.8–70.7) | 1490 | 88.3 (84.6–92.1) |
| Maine | 514 | 73.7 (67.3–80.1) | 375 | 46.2 (41.5–50.9) | 375 | 56.1 (51.2–61.1) |
| Maryland | 1561 | 67.7 (64.3–71.0) | 978 | 37.1 (34.7–39.4) | 978 | 44 (41.6–46.4) |
| Massachusetts | 2085 | 62.9 (60.2–65.6) | 1411 | 42.3 (40.1–44.6) | 1411 | 48.5 (46.2–50.8) |
| Michigan | 3881 | 81.9 (79.4–84.5) | 2902 | 56.2 (54.2–58.3) | 2902 | 62.6 (60.5–64.7) |
| Minnesota | 1469 | 64.3 (61.0–67.6) | 1037 | 40.6 (38.1–43.0) | 1037 | 45.8 (43.3–48.3) |
| Mississippi | 1749 | 133.8 (127.5–140.1) | 1690 | 112.7 (107.2–118.1) | 1690 | 109.6 (104.5–114.6) |
| Missouri | 2527 | 87.7 (84.3–91.1) | 1864 | 58.2 (55.5–60.8) | 1864 | 69.2 (66.5–72.0) |
| Montana | 338 | 73.5 (65.7–81.4) | 275 | 51.8 (45.6–58.0) | 275 | 59.1 (53.0–65.2) |
| Nebraska | 723 | 82.1 (76.2–88.1) | 530 | 56.3 (51.4–61.1) | 530 | 54.7 (50.1–59.3) |
| Nevada | 632 | 78.6 (72.4–84.8) | 442 | 37.8 (34.2–41.4) | 442 | 50.3 (46.6–53.9) |
| New Hampshire | 335 | 59.0 (52.7–65.3) | 352 | 51.6 (46.2–57.1) | 352 | 55.3 (50.0–60.6) |
| New Jersey | 2943 | 69.2 (66.7–71.7) | 2008 | 46.9 (44.9–49.0) | 2008 | 45.7 (43.8–47.7) |
| New Mexico | 440 | 57.7 (52.3–63.0) | 435 | 43.9 (39.7–48.0) | 435 | 48.1 (44.0–52.1) |
| New York | 6543 | 71.8 (70.1–73.5) | 4450 | 47.2 (45.8–48.6) | 4450 | 42.9 (41.6–44.2) |
| North Carolina | 2831 | 76.3 (73.5–79.1) | 2584 | 54.1 (52.0–56.2) | 2584 | 63.8 (61.7–65.9) |
| North Dakota | 272 | 76.4 (67.3–85.5) | 202 | 55.5 (47.8–63.2) | 202 | 45.9 (39.0–52.7) |
| Ohio | 5505 | 93.8 (91.3–96.3) | 3838 | 61.7 (59.8–63.7) | 3838 | 67.2 (65.2–69.2) |
| Oklahoma | 1764 | 107.2 (102.2–112.2) | 1484 | 80.5 (76.4–84.6) | 1484 | 79.9 (76.0–83.9) |

(*Continued*)

**Table 4. Continued**

| State | 1999 | | 2011 | | 2017 | |
|---|---|---|---|---|---|---|
| | No. of Deaths | AAMR (95% CI) | No. of Deaths | AAMR (95% CI) | No. of Deaths | AAMR (95% CI) |
| Oregon | 1390 | 81.9 (77.6–86.2) | 1239 | 63.8 (60.2–67.4) | 1239 | 72.2 (68.7–75.7) |
| Pennsylvania | 5954 | 79.5 (77.5–81.6) | 3991 | 53.9 (52.2–55.5) | 3991 | 59.2 (57.5–60.9) |
| Rhode Island | 373 | 62.5 (56.2–68.9) | 259 | 46.6 (40.9–52.3) | 259 | 57.5 (51.4–63.7) |
| South Carolina | 1750 | 93.1 (88.8–97.5) | 1640 | 66.5 (63.3–69.8) | 1640 | 74.5 (71.4–77.7) |
| South Dakota | 266 | 66.2 (58.2–74.2) | 192 | 44.5 (38.2–50.8) | 192 | 51.1 (44.5–57.6) |
| Tennessee | 2422 | 89.4 (85.8–92.9) | 2001 | 60.2 (57.5–62.9) | 2001 | 73.2 (70.5–75.9) |
| Texas | 6538 | 83.2 (81.2–85.2) | 6153 | 60.2 (58.7–61.7) | 6153 | 66.8 (65.3–68.3) |
| Utah | 524 | 72.3 (66.1–78.5) | 577 | 60.6 (55.6–65.6) | 577 | 62 (57.4–66.6) |
| Vermont | 193 | 65.3 (56.1–74.5) | 172 | 49.7 (42.2–57.2) | 172 | 40.1 (33.8–46.5) |
| Virginia | 2461 | 80.9 (77.7–84.1) | 1975 | 53.7 (51.3–56.0) | 1975 | 60.3 (58.0–62.7) |
| Washington | 1679 | 67.0 (63.8–70.2) | 1578 | 53.3 (50.6–56.0) | 1578 | 56 (53.5–58.5) |
| West Virginia | 1197 | 112.2 (105.8–118.5) | 855 | 74.7 (69.6–79.7) | 855 | 73.3 (68.4–78.1) |
| Wisconsin | 2041 | 75.4 (72.2–78.7) | 1467 | 49.4 (46.9–52.0) | 1467 | 56 (53.4–58.6) |
| Wyoming | 182 | 83.3 (71.2–95.4) | 143 | 53.6 (44.7–62.6) | 143 | 56.3 (47.9–64.7) |

AAMR indicates age-adjusted mortality rate.

examine regional socioeconomic and political/policy infrastructures that underlie these trends to enact structural and environmental changes.[26,27] For example, local policy measures such as taxation of tobacco products or sugary beverages and availability of healthy foods may affect health risk behaviors and ultimately CVH.[28–30] Local infrastructure, such as the structure of state and local boards of health, may influence public health expenditures and indirectly health outcomes.[31] However, interventions that focus

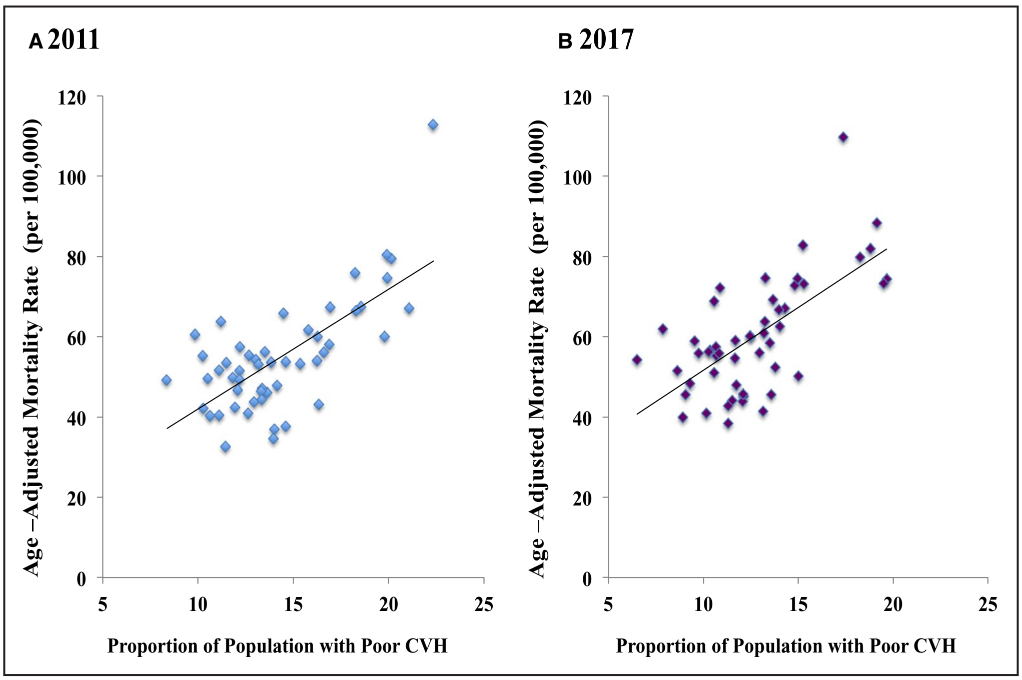


**Figure 3. Correlation of state-level prevalence of poor cardiovascular health score with cardiovascular mortality related to heart failure in (A) 2011 and (B) 2017.**
Poor cardiovascular health was calculated according to American Heart Association criteria with state-level data from the Behavior Risk Factor Surveillance System. CVH indicates cardiovascular health.

on proximate causes alone are unlikely to mitigate the increasing Black-White HF mortality disparities that reflect structural and systemic barriers to access to high quality care.

Crucially, we must consider the role that social determinants of health play in these health disparities as well. In this regard, state-level policies are vitally important. One illustrative example of this is the different approaches states have taken to Medicaid expansion. When the Affordable Care Act went into effect, it included provisions for the expansion of Medicaid to all adults with a family income <138% of the federal poverty level; however, a Supreme Court ruling in 2012 essentially made the expansion optional to individual states.[32] As of May 2020, 36 states (including the District of Columbia) have implemented the expansion, 1 state (Nebraska) has adopted but not yet implemented, while 14 states have not adopted expansion.[33] Subsequent research has demonstrated that implementation of the Affordable Care Act not only increased the overall rate of insurance coverage in the United States, but it also reduced race and ethnicity related disparities in health insurance. Coverage gains and disparity improvements were greater in states that implemented Medicaid expansion compared with states that did not expand Medicaid.[32] Unfortunately, ≈46% of Black working-aged adults live in non-expansion states and have thus been disproportionately impacted by non-expansion.[34] The states that have not expanded are clustered predominantly in the South and Midwest where rates of HF mortality are also highest.

## Strengths and Limitations

The current nationwide study builds on the literature by highlighting geographic trends specifically of cardiovascular mortality related to HF (abbreviated here as HF mortality) over time in the US population. By measuring HF mortality in this way, we capture all cardiovascular deaths in which HF is listed as a contributing cause. This is significant because HF is more likely to be listed as a contributing cause of death than an underlying cause of death.[17] While prior studies have published geographic trends in HF mortality previously,[10,35] we were able to more fully capture the burden of HF mortality using this approach.

Our study has several limitations. First, our findings are based on death certificate data. Therefore, there is the possibility for misclassification of deaths because of poorly defined underlying cause of death and/or lack of inclusion of HF as a contributing cause of death. While it is possible that miscoding may affect race–sex groups disparately, this alone does not likely completely explain the disparities observed.[17] To address the potential role for alternate coding of HF on the findings, we performed sensitivity analyses examining alternate definitions (HF as the underlying cause or HF as any contributing cause to all causes of death) and regardless of which definition used, the race−sex and geographic patterns described above persisted. Additionally, leveraging national death certificate data provides the most comprehensive evaluation of state and regional burden of HF mortality. Second, limited numbers across states in other key race/ethnic groups (eg, Asian Americans, Hispanic/Latino Americans) and concern for misclassification of race/ethnicity led to our focus on only Black–White differences. Even so, in several states the number of deaths among Black men and women was so small that AAMRs could not be reliably calculated. This limits our ability to infer about HF mortality rates among Black men and women in these states. Third, data on type, severity, and treatment of HF, such as left ventricular ejection fraction, presence of comorbidities (eg, diabetes mellitus), and guideline-directed medical therapy use are unavailable in the CDC WONDER data set. Fourth, quantification of CVH using BRFSS may be subject to under-estimation given reliance on self-report. However, this likely biased our results towards the null. As CVH is a tool in the primary prevention of CVD, we excluded individuals with a known history of coronary heart disease, myocardial infarction, or stroke from the CVH calculations. BRFSS does not ask about other chronic CVD (such as heart failure, peripheral arterial disease, or history of revascularization), so we are unable to exclude those individuals. Finally, increasing awareness of HF could contribute to increases in reporting of HF as a contributing cause of death, in which case, recent data better reflect true burden of HF mortality in the United States.

# CONCLUSIONS

In summary, we demonstrate that there is significant geographic variation in HF mortality, which is associated with state-level CVH. Highest rates of HF mortality and greatest increases occurred in the South and Midwest. Black men are disproportionately affected by HF mortality and are experiencing the most rapidly increasing rates. Interventions at the regional and state level, particularly those equitably targeting CVH and HF prevention, are urgently needed.

## ARTICLE INFORMATION

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## Disclosures

None.

## Supplementary Material

**Tables S1–S2**

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# Supplemental Material

**Table S1. Age-Adjusted Mortality Rates for HF mortality Comparing Different Death Certificate Definitions by Region among Black and White Men and Women Age 35-84 years in 2017.**

| Region | UCD: HF | UCD: CVD with HF as contributing cause (primary definition) | UCD: all causes with HF any mention |
|---|---|---|---|
| **Northeast** | | **AAMR (95% CI)** | |
| Black Men | 24.3 (21.6, 27.0) | 69.4 (64.9, 73.9) | 110.6 (104.9, 116.2) |
| Black Women | 14.3 (12.6, 16.0) | 43.1 (40.3, 46.0) | 71.8 (68.1, 75.5) |
| White Men | 20.2 (19.4, 21.0) | 62.2 (60.8,63.6) | 101.3 (99.5, 103.1) |
| White Women | 13.6 (13.0, 14.2) | 36.5 (35.5,37.4) | 64 (62.7, 65.3) |
| **Midwest** | | | |
| Black Men | 41.0 (37.4, 44.6) | 106.0 (100.3,111.7) | 170.4 (163.2, 177.7) |
| Black Women | 31.3 (28.7, 33.9) | 74.0 (70.0, 78.0) | 120.5 (115.4, 125.6) |
| White Men | 25.4 (24.6, 26.2) | 75.1 (73.7, 76.4) | 126.8 (125, 128.6) |
| White Women | 17.5 (16.9, 18.1) | 46.4 (45.4, 47.3) | 82.3 (81, 83.6) |
| **South** | | | |
| Black Men | 43.6 (41.6, 45.6) | 110.3 (107.2, 113.5) | 177.6 (173.6, 181.6) |
| Black Women | 29.0 (27.6, 30.3) | 72.4 (70.2, 74.6) | 120.8 (118, 123.6) |
| White Men | 26.4 (25.8, 27) | 75.2 (74.2, 76.3) | 124.1 (122.7, 125.4) |
| White Women | 17.4 (17, 17.9) | 45.5 (44.8, 46.3) | 80.8 (79.8, 81.8) |
| **West** | | | |
| Black Men | 28.6 (24.8, 32.4) | 106.4 (99.1, 113.7) | 169.6 (160.4, 178.8) |
| Black Women | 19.9 (17.1, 22.8) | 62.5 (57.5, 67.5) | 106.2 (99.7, 112.8) |
| White Men | 16.8 (16.2, 17.5) | 69.1 (67.8, 70.4) | 113.5 (111.8, 115.2) |
| White Women | 11.7 (11.2, 12.2) | 41.0 (40.0, 41.9) | 70.7 (69.5, 72) |

*****AAMR = Age-Adjusted Mortality Rate, UCD = underlying cause of death, CVD = cardiovascular death, HF = Heart Failure

**Table S2. Assessment of Prevalence of Poor Cardiovascular Health* by US State in 2011 and 2017.**

| State | Prevalence of Poor Health based on CVH | |
|---|---|---|
| | 2011 % (SE) | 2017 % (SE) |
| Alabama | 20 (2) | 19 (2) |
| Alaska | 12 (6) | 11 (4) |
| Arizona | 12 (1) | 12 (1) |
| Arkansas | 18 (2) | 15 (2) |
| California | 10 (1) | 10 (1) |
| Colorado | 8 (2) | 9 (1) |
| Connecticut | 13 (2) | 10 (1) |
| Delaware | 16 (3) | 14 (3) |
| D.C. | 11 (4) | 7 (4) |
| Florida | 14 (1) | 13 (1) |
| Georgia | 15 (1) | 13 (1) |
| Hawaii | 11 (4) | 12 (4) |
| Idaho | 12 (3) | 11 (3) |
| Illinois | 13 (1) | 13 (1) |
| Indiana | 17 (2) | 15 (1) |
| Iowa | 14 (2) | 12 (2) |
| Kansas | 15 (2) | 14 (2) |
| Kentucky | 19 (2) | 20 (2) |
| Louisiana | 21 (2) | 19 (2) |
| Maine | 14 (2) | 13 (3) |
| Maryland | 14 (1) | 12 (1) |
| Massachusetts | 10 (1) | 9 (1) |
| Michigan | 17 (1) | 14 (1) |
| Minnesota | 11 (1) | 9 (1) |
| Mississippi | 22 (3) | 17 (3) |
| Missouri | 17 (1) | 14 (1) |

| | | |
|---|---|---|
| Montana | 11 (3) | 10 (3) |
| Nebraska | 14 (3) | 12 (2) |
| Nevada | 15 (2) | 15 (2) |
| New Hampshire | 12 (3) | 11 (3) |
| New Jersey | 12 (1) | 14 (1) |
| New Mexico | 13 (2) | 12 (2) |
| New York | 13 (1) | 11 (1) |
| North Carolina | 16 (1) | 13 (1) |
| North Dakota | 13 (4) | 12 (4) |
| Ohio | 16 (1) | 14 (1) |
| Oklahoma | 20 (2) | 18 (2) |
| Oregon | 11 (2) | 11 (2) |
| Pennsylvania | 15 (1) | 12 (1) |
| Rhode Island | 13 (3) | 11 (3) |
| South Carolina | 18 (2) | 15 (2) |
| South Dakota | 13 (3) | 11 (3) |
| Tennessee | 20 (1) | 15 (1) |
| Texas | 16 (1) | 14 (1) |
| Utah | 10 (3) | 8 (2) |
| Vermont | 11 (4) | 9 (3) |
| Virginia | 14 (1) | 12 (1) |
| Washington | 13 (1) | 10 (1) |
| West Virginia | 20 (3) | 19 (3) |
| Wisconsin | 12 (1) | 11 (1) |
| Wyoming | 12 (5) | 10 (4) |

[*]CVH was defined as “poor” when only two or fewer of the following criteria were met: responses of “no” when asked if a doctor has told a participant that he or she has high blood pressure, high cholesterol, or diabetes; BMI 18.5 to 24.9; less than 100 cigarettes smoked lifetime; ≥150 minutes a week of moderate-intensity activity, ≥75 minutes of vigorous-intensity activity, or an equivalent combination of aerobic physical activity; and 5 or more daily servings of fruits or vegetables.