Heterogeneity in national U.S. mortality trends within heart disease subgroups, 2000–2015

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Abstract

Background: The long-term downward national U.S. trend in heart disease-related mortality slowed substantially during 2011–2014 before turning upward in 2015. Examining mortality trends in the major subgroups of heart disease may provide insight into potentially more targeted and effective prevention and treatment approaches to promote favorable trajectories. We examined national trends between 2000 and 2015 in mortality attributed to major heart disease subgroups including ischemic heart disease, heart failure, and all other types of heart disease.

Methods: Using the Centers for Disease Control and Prevention Wide-ranging Online Data for Epidemiologic Research (WONDER) data system, we determined national trends in age-standardized mortality rates attributed to ischemic heart disease, heart failure, and other heart diseases from January 1, 2000, to December 31, 2011, and from January 1, 2011, to December 31, 2015. Annual rate of changes in mortality attributed to ischemic heart disease, heart failure, and other heart diseases for 2000–2011 and 2011–2015 were compared.

Results: Death attributed to ischemic heart disease declined from 2000 to 2015, but the rate of decline slowed from 4.96% (95% confidence interval 4.77%–5.15%) for 2000–2011 to 2.66% (2.00%–3.31%) for 2011–2015. In contrast, death attributed to heart failure and all other causes of heart disease declined from 2000 to 2011 at annual rates of 1.94% (1.77%–2.11%) and 0.64% (0.44%–0.82%) respectively, but increased from 2011 to 2015 at annual rates of 3.73% (3.21%–4.26%) and 1.89% (1.33%–2.46%). Differences in 2000–2011 and 2011–2015 decline rates were statistically significant for all 3 endpoints overall, by sex, and all race/ethnicity groups except Asian/Pacific Islanders (heart failure only significant) and American Indian/Alaskan Natives.

Conclusions: While the long-term decline in death attributed to heart disease slowed between 2011 and 2014 nationally before turning upward in 2015, heterogeneity existed in the trajectories attributed to heart disease subgroups, with ischemic heart disease mortality continuing to decline while death attributed to heart failure and other heart diseases switched from a downward to upward trend. While systematic efforts to prevent and treat ischemic heart disease continue to be effective, urgent attention is needed to address the challenge of heart failure.

Keywords: Mortality rate, Heart disease, Coronary heart disease, Heart failure, Epidemiology

Background

We recently reported that the rate of decline of death attributed to total cardiovascular disease (CVD) and to heart disease (HD) in the U.S. had decelerated substantially between 2011 and 2014 [1], with the annualized percent decline in CVD and HD mortality decreasing from 3.79% and 3.69% respectively for 2000–2011 to 0.65% and 0.76% for 2011–2014. We suggested that HD mortality might increase in 2015 [1] which was confirmed by the recent report of a 0.9% increase from 167.0 to 168.5 per 100,000 person-years from 2014 to 2015, the first year-to-year increase since 1992–93 [2, 3].

HD-related death encompasses a wide range of heart conditions. Thus, from both prevention and intervention perspectives, it is important to further delineate trends in subcategories of HD-related death. We studied
mortality trends in the two largest subgroups of HD (ischemic heart disease [IHD] and heart failure [HF]) and in all other HD combined.

**Methods**

Mortality rates between 2000 and 2015 were ascertained using the U.S. Centers for Disease Control and Prevention’s Wide-Ranging Online Data for Epidemiologic Research (CDC WONDER) dataset, which includes the assigned cause of death from all death certificates filed in the 50 states and the District of Columbia [3]. Categorization of the presumed cause of death used *International Statistical Classification of Diseases and Related Health Problems, Tenth Edition* codes as follows: HD (codes I00-I09, I11, I13, and I20-I51), IHD (I20-I25), HF (I50), and all other causes of HD (I00-I09, I11, I13, I26-I49, and I51).

This study did not require institutional review board approval because it analyzes government-issued public use data without individual identifiable information.

Age-standardized mortality rates (AAMR) were calculated using the direct method, with the 2000 U.S. Census as the standard population using the following age categorization: younger than 1 year, 1 to 4, 5 to 14, 15 to 24, 25 to 34, 35 to 44, 45 to 54, 55 to 64, 65 to 74, 75 to 84, and 85 years or older [4]. Poisson regression with allowance for overdispersion was used for point and interval estimation of age-adjusted annual rates of change for January 1, 2000, to December 31, 2011, and January 1, 2011, to December 31, 2015.

**Results**

Mortality rates from 2000 to 2015 for HD and HD subgroups are shown in Table 1, with the largest subgroup being IHD. Compared to 2014, in 2015, an increase in overall HD occurred in men (0.4%), women (1.4%), and in all racial-ethnic groups except NH Blacks in which HD mortality decreased by 0.3%. The 2015 mortality rate for each HD subgroup was higher in men than in women. By race-ethnicity, NH blacks had the highest mortality rate for each HD subcategory, followed by NH whites, NH American Indian/Alaskan Natives, Hispanics, and NH Asian/Pacific Islanders.

The rate of decline in death attributed to IHD slowed in 2011–2015, with mean annual rate of change of −2.66% compared to −4.96% for 2000–2011 (Table 2, Fig. 1). The difference in the rate of change between the two time periods was statistically significant overall, in each sex and, among NH whites, NH blacks, and Hispanics.

In sharp contrast, mortality rates attributed to HF and all other HD declined from 2000 to 2011, but then increased from 2011 to 2015 (Table 2, Fig. 1). These patterns were evident in both sexes (Tables 3 and 4 and Fig. 1) and in all race-ethnicity groups except NH American Indian/Alaskan Natives (Tables 5, Table 1

**Table 1** Age-adjusted mortality rates for all heart disease, ischemic heart disease, heart failure, and all other CHD, United States, 2000–2015

| Year | N = Population | Heart disease n = deaths | AAMRa | Ischemic HD n = deaths | AAMR | Heart failure n = deaths | AAMR | All other HD n = deaths | AAMR |
|------|----------------|--------------------------|-------|------------------------|------|-------------------------|------|------------------------|------|
| 2000 | 281,421,906    | 710,760                  | 257.6 | 515,204                | 186.8| 55,704                  | 20.3 | 139,852                | 50.6 |
| 2001 | 284,968,955    | 700,142                  | 249.5 | 502,189                | 179.0| 56,934                  | 20.4 | 141,019                | 50.2 |
| 2002 | 287,625,193    | 696,947                  | 244.6 | 494,382                | 173.5| 56,494                  | 19.9 | 146,071                | 51.2 |
| 2003 | 290,107,933    | 685,089                  | 236.3 | 480,028                | 165.6| 57,448                  | 19.9 | 147,613                | 50.9 |
| 2004 | 292,805,298    | 652,486                  | 221.6 | 451,326                | 153.2| 57,120                  | 19.5 | 144,040                | 48.9 |
| 2005 | 295,516,599    | 652,091                  | 216.8 | 445,687                | 148.2| 58,933                  | 19.7 | 147,471                | 49.0 |
| 2006 | 298,379,912    | 631,636                  | 205.5 | 425,425                | 138.3| 60,337                  | 19.7 | 145,874                | 47.5 |
| 2007 | 301,231,207    | 616,067                  | 196.1 | 406,351                | 129.2| 56,565                  | 18.0 | 153,151                | 48.8 |
| 2008 | 304,093,966    | 616,828                  | 192.1 | 405,309                | 126.1| 56,830                  | 17.7 | 154,689                | 48.3 |
| 2009 | 306,771,529    | 599,413                  | 182.8 | 386,324                | 117.7| 56,410                  | 17.2 | 156,679                | 47.9 |
| 2010 | 308,745,538    | 597,689                  | 179.1 | 379,559                | 113.6| 57,757                  | 17.3 | 160,373                | 48.2 |
| 2011 | 311,591,917    | 596,577                  | 173.7 | 375,295                | 109.2| 58,309                  | 16.9 | 162,973                | 47.7 |
| 2012 | 313,914,040    | 599,711                  | 170.5 | 371,469                | 105.4| 60,341                  | 17.1 | 167,901                | 48.0 |
| 2013 | 316,128,839    | 611,105                  | 169.8 | 370,213                | 102.6| 65,120                  | 18.0 | 175,772                | 49.1 |
| 2014 | 318,857,056    | 614,348                  | 167.0 | 364,593                | 98.8 | 68,626                  | 18.6 | 181,129                | 49.6 |
| 2015 | 321,418,820    | 633,842                  | 168.5 | 366,801                | 97.2 | 75,251                  | 19.9 | 191,790                | 51.4 |

Abbreviations: HD heart disease, AAMR age-adjusted mortality rate

*Age-adjusted mortality rate per 100,000 person-years, directly standardized to the 2000 U.S. population
Table 2 Age-adjusted mortality rates and annual rates of change for ischemic heart disease, heart failure, and other heart disease for time periods 2000–2011 and 2011–2015, United States

| Year(s) | AAMR 2000 | AAMR 2011 | AAMR 2015 | Annual rate of change (%)a | 2000–2011 | 2011–2015 | p-valueb |
|---------|-----------|-----------|-----------|-----------------------------|-----------|-----------|----------|
| Ischemic heart disease | | | | | | | |
| Total | 186.8 | 109.2 | 97.2 | –4.96 (–5.15 to –4.77) | –2.66 (–3.31 to –2.00) | <0.001 |
| Total male | 241.4 | 145.6 | 131.2 | –4.63 (–4.82 to –4.44) | –2.10 (–2.75 to –1.45) | <0.001 |
| Total female | 146.5 | 81.0 | 70.5 | –5.49 (–5.69 to –5.29) | –3.69 (–4.29 to –2.88) | <0.001 |
| NH White | 186.6 | 111.1 | 99.7 | –4.85 (–5.05 to –4.64) | –2.34 (–3.05 to –1.63) | <0.001 |
| NH Asian/PI | 109.7 | 63.2 | 55.1 | –4.71 (–5.03 to –4.43) | –3.75 (–4.64 to –2.85) | 0.08 |
| Hispanic | 153.2 | 84.2 | 74.5 | –5.38 (–5.64 to –5.12) | –3.39 (–4.21 to –2.58) | <0.001 |
| NH Black | 220.4 | 127.9 | 111.3 | –5.06 (–5.26 to –4.86) | –3.16 (–3.93 to –2.49) | 0.003 |
| NH AI/AN | 142.7 | 104.8 | 95.2 | –3.04 (–3.55 to –2.52) | –1.23 (–2.79 to 0.36) | 0.06 |
| Heart failure | | | | | | | |
| Total | 20.3 | 16.9 | 19.9 | –1.94 (–2.11 to –1.77) | 3.73 (3.21 to 4.26) | <0.001 |
| Total male | 21.5 | 18.7 | 22.5 | –1.51 (–1.70 to –1.31) | 4.58 (4.00 to 5.17) | <0.001 |
| Total female | 19.2 | 15.6 | 17.9 | –2.26 (–2.44 to –2.09) | 2.99 (2.43 to 3.56) | <0.001 |
| NH White | 20.7 | 17.5 | 20.8 | –1.86 (–2.02 to –1.70) | 4.10 (3.60 to 4.61) | <0.001 |
| NH Asian/PI | 7.8 | 6.4 | 7.3 | –0.95 (–1.68 to –0.22) | 4.14 (2.28 to 6.04) | <0.001 |
| Hispanic | 10.9 | 10.7 | 11.3 | –0.94 (–1.40 to –0.48) | 1.87 (0.65 to 3.11) | <0.001 |
| NH Black | 22.4 | 19.1 | 23.3 | –1.66 (–1.98 to –1.34) | 4.40 (3.43 to 5.37) | <0.001 |
| NH AI/AN | 16.7 | 14.9 | 15.0 | –1.12 (–2.14 to –0.09) | –2.08 (–4.95 to 0.89) | 0.60 |
| Other heart disease | | | | | | | |
| Total | 50.6 | 47.7 | 51.4 | –0.63 (–0.82 to –0.44) | 1.89 (1.33 to 2.46) | <0.001 |
| Total male | 57.1 | 53.9 | 58.1 | –0.59 (–0.79 to 0.39) | 2.04 (1.45 to 2.63) | <0.001 |
| Total female | 45.1 | 42.1 | 45.2 | –0.69 (–0.90 to –0.49) | 1.73 (1.11 to 2.36) | <0.001 |
| NH White | 48.1 | 47.1 | 51.5 | –0.34 (–0.55 to –0.22) | 2.52 (1.87 to 3.17) | <0.001 |
| NH Asian/PI | 28.6 | 24.2 | 24.2 | –1.70 (–2.06 to –1.33) | –0.38 (–1.37 to 0.61) | 0.04 |
| Hispanic | 31.9 | 31.4 | 31.9 | –0.93 (–1.19 to –0.66) | 0.78 (–0.06 to 1.51) | <0.001 |
| NH Black | 85.7 | 72.1 | 75.5 | –1.51 (–1.67 to –1.35) | 0.42 (–0.06 to 0.91) | <0.001 |
| NH AI/AN | 38.5 | 41.3 | 44.8 | 0.55 (–0.24 to 1.34) | 2.57 (0.41 to 4.78) | 0.14 |

Abbreviations: AAMR age-adjusted mortality rate, NH non-Hispanic, PI Pacific Islander, AI/AN American Indian/Alaskan Native
aAnnual rate of change age-adjusted by Poisson regression
b p-value for difference in annual rate of change between 2000 and 2011 and 2011–2015 time periods

6, 7, 8 and 9, Fig. 1). From 2011 to 2015, the mean annual rate of increase was 3.73% for HF-related mortality and 1.89% for all other HD mortality in the total population. The difference in the rate of change between the two time periods was statistically significant overall in each sex, and in all race-ethnicity groups except NH American Indian/Alaskan Natives for HF and other HD mortality as well as NH Asian/Pacific Islander for other HD mortality (Table 2). Trends in crude mortality rates (Table 10) for HD and each HD subgroup were similar to age-standardized mortality trends.

Five specific ICD-10 codes accounted for 63% of deaths attributed to other HD during 2011–2015. There was an increase in age-standardized mortality rates per 100,000 person-years from 9.7 to 11.1 for hypertensive HD (ICD-10 code I11), 5.2 to 6.3 (p < 0.001) for atrial fibrillation and flutter (ICD-10 code I18), and a decrease from 6.8 to 6.3 (p < 0.001) for cardiomyopathy (I42). Changes were not statistically significant for nonrheumatic aortic valve disorders (I13), 4.5 to 4.6 (p = 0.45); and cardiac arrest (I14), 4.4 to 4.3 (p = 0.48).

Discussion

The increase in death attributed to HD in 2015 represents a notable landmark denoting a time where the impact of prevention efforts has been at least temporarily stalled. HD mortality increased across both sexes and
most race-ethnicity groups. Although a slight decline was noted for NH blacks, HD-related death rates in this subgroup remain substantially higher than in other racial/ethnic groups.

While the continued decline in IHD mortality is encouraging, the rate of decline decreased by nearly 50% during the 2011–2015 period compared to 2000–2011. The decades-long epidemic of obesity and diabetes mellitus are likely important factors contributing the deceleration of the rate of decline of cardiovascular mortality nationally [1]. A recent study analyzing data from several cohort studies demonstrated a substantial decrease in the incidence of new-onset IHD between two time periods, with baseline exams conducted from 1983 to 1990 and 1996 to 2001, and showed that the fraction of CHD attributable to diabetes decreased over time [5]. However, the prevalence of diabetes has risen considerably from the time period that diabetes was assessed for these studies, [6] and populations now living with longer duration of diabetes have higher risk of CHD [7]. Additionally, follow-up ended in 2011, the year that the IHD mortality trend change occurred, so that the findings regarding the decreasing fraction of CHD attributable to diabetes are likely to not be as relevant to the current time period.

Several U.S.-based studies have shown decline in the incidence of acute myocardial infarction with follow-up through 2008–2011, [8–11] with one reporting additional
### Table 3 Males (age-adjusted)

Trends in mortality in United States from 2000 to 2015 by gender and race-ethnicity

| Year | (n = Population) | Heart disease (n = deaths) AAMR | Ischemic HD (n = deaths) AAMR | Heart failure (n = deaths) AAMR | All other HD (n = deaths) AAMR |
|------|------------------|---------------------------------|------------------------------|-------------------------------|-------------------------------|
| 2000 | 138,053,563 | 344,807 | 320.0 | 260,574 | 21.5 | 63,058 | 57.1 |
| 2001 | 139,891,492 | 339,095 | 307.8 | 254,005 | 241.4 | 21,632 | 21.4 | 63,458 | 56.1 |
| 2002 | 141,230,559 | 340,933 | 303.4 | 252,760 | 224.7 | 21,698 | 21.1 | 66,475 | 57.6 |
| 2003 | 142,428,897 | 336,095 | 292.3 | 246,342 | 213.9 | 22,427 | 21.3 | 67,326 | 57.1 |
| 2004 | 143,828,012 | 321,973 | 274.1 | 233,538 | 198.4 | 22,292 | 20.8 | 66,143 | 54.9 |
| 2005 | 145,197,078 | 322,841 | 268.2 | 232,115 | 192.3 | 23,026 | 20.8 | 67,700 | 55.0 |
| 2006 | 146,647,265 | 315,706 | 254.9 | 224,510 | 180.7 | 23,918 | 21.0 | 67,278 | 53.2 |
| 2007 | 148,064,854 | 309,821 | 243.7 | 216,050 | 169.2 | 24,385 | 19.2 | 70,857 | 55.0 |
| 2008 | 149,489,951 | 311,201 | 238.5 | 210,069 | 165.1 | 23,017 | 19.0 | 71,936 | 54.3 |
| 2009 | 150,807,454 | 307,225 | 229.4 | 210,069 | 160.7 | 23,563 | 18.9 | 73,593 | 54.2 |
| 2010 | 151,781,326 | 307,384 | 225.1 | 207,580 | 151.3 | 24,385 | 19.2 | 75,419 | 54.6 |
| 2011 | 153,290,819 | 308,398 | 218.1 | 206,908 | 145.6 | 24,609 | 18.7 | 76,881 | 53.9 |
| 2012 | 154,492,067 | 312,491 | 214.7 | 206,685 | 141.1 | 26,036 | 19.1 | 79,770 | 54.5 |
| 2013 | 155,651,602 | 321,347 | 214.5 | 208,515 | 138.2 | 28,513 | 20.2 | 84,319 | 56.1 |
| 2014 | 156,936,487 | 325,077 | 210.9 | 207,412 | 133.5 | 30,339 | 20.9 | 87,326 | 56.5 |
| 2015 | 158,229,297 | 335,002 | 211.8 | 209,298 | 131.2 | 33,667 | 22.5 | 92,037 | 58.1 |

Age-adjusted mortality rate per 100,000 person-years, directly standardized to the 2000 U.S. population

### Table 4 Female (age-adjusted)

Trends in mortality in United States from 2000 to 2015 by gender and race-ethnicity

| Year | (n = Population) | Heart disease (n = deaths) AAMR | Ischemic HD (n = deaths) AAMR | Heart failure (n = deaths) AAMR | All other HD (n = deaths) AAMR |
|------|------------------|---------------------------------|------------------------------|-------------------------------|-------------------------------|
| 2000 | 143,368,343 | 365,953 | 210.9 | 254,630 | 146.5 | 34,529 | 19.2 | 76,794 | 45.1 |
| 2001 | 145,077,463 | 361,047 | 205.4 | 241,622 | 135.7 | 34,796 | 19.0 | 79,596 | 45.6 |
| 2002 | 146,394,634 | 356,014 | 200.3 | 233,686 | 129.4 | 35,021 | 18.8 | 80,287 | 45.4 |
| 2003 | 147,679,036 | 348,994 | 193.7 | 224,686 | 119.4 | 34,828 | 18.6 | 77,897 | 43.5 |
| 2004 | 148,977,286 | 340,513 | 181.5 | 217,788 | 115.0 | 35,907 | 18.8 | 79,771 | 43.7 |
| 2005 | 150,319,521 | 329,250 | 177.5 | 213,572 | 110.5 | 36,419 | 18.6 | 78,596 | 42.3 |
| 2006 | 151,732,647 | 315,930 | 167.2 | 200,915 | 106.3 | 33,651 | 16.9 | 82,294 | 43.4 |
| 2007 | 153,166,353 | 306,246 | 159.0 | 190,301 | 98.8 | 33,813 | 16.6 | 82,753 | 42.9 |
| 2008 | 154,604,015 | 305,627 | 155.9 | 189,061 | 96.3 | 33,813 | 16.6 | 82,753 | 42.9 |
| 2009 | 155,964,075 | 292,188 | 146.6 | 176,255 | 88.4 | 32,847 | 15.9 | 83,086 | 42.3 |
| 2010 | 156,964,212 | 290,305 | 143.3 | 171,979 | 84.9 | 33,372 | 15.9 | 84,954 | 42.5 |
| 2011 | 158,301,521 | 288,179 | 138.7 | 168,387 | 81.0 | 33,700 | 15.6 | 86,092 | 42.1 |
| 2012 | 159,421,973 | 287,220 | 135.5 | 164,784 | 77.8 | 34,305 | 15.5 | 88,131 | 42.2 |
| 2013 | 160,477,237 | 289,758 | 134.3 | 161,698 | 74.9 | 36,607 | 16.3 | 91,453 | 43.0 |
| 2014 | 161,920,569 | 289,271 | 131.8 | 157,181 | 71.6 | 38,287 | 16.8 | 93,803 | 43.4 |
| 2015 | 163,189,523 | 298,840 | 133.6 | 157,503 | 70.5 | 41,584 | 17.9 | 99,753 | 45.2 |

Age-adjusted mortality rate per 100,000 person-years, directly standardized to the 2000 U.S. population
### Table 5 Non-Hispanic White (age-adjusted)

Trends in mortality in United States from 2000 to 2015 by gender and race-ethnicity

| Year (n = Population) | Heart disease (n = deaths) | AAMR | Ischemic HD (n = deaths) | AAMR | Heart failure (n = deaths) | AAMR | All other HD (n = deaths) | AAMR |
|-----------------------|---------------------------|------|--------------------------|------|---------------------------|------|---------------------------|------|
| 2000 197,324,684      | 594,465                   | 255.5| 434,505                  | 186.6| 48,782                    | 20.7 | 111,178                   | 48.1 |
| 2001 197,842,671      | 582,349                   | 247.2| 420,959                  | 178.5| 49,788                    | 20.8 | 111,602                   | 47.7 |
| 2002 198,101,982      | 577,761                   | 242.5| 413,230                  | 173.2| 49,162                    | 20.4 | 115,369                   | 48.8 |
| 2003 198,289,486      | 565,808                   | 234.2| 400,101                  | 165.5| 49,788                    | 20.3 | 115,919                   | 48.4 |
| 2004 198,619,903      | 537,512                   | 220.1| 374,900                  | 153.3| 49,628                    | 20   | 112,984                   | 46.7 |
| 2005 198,880,984      | 535,101                   | 215.6| 368,505                  | 148.3| 50,835                    | 20.1 | 115,761                   | 47.1 |
| 2006 199,200,396      | 516,883                   | 204.5| 350,356                  | 138.6| 52,125                    | 20.2 | 114,402                   | 45.8 |
| 2007 199,492,421      | 502,683                   | 195.5| 334,047                  | 129.9| 48,480                    | 18.4 | 120,156                   | 47.2 |
| 2008 199,783,797      | 482,979                   | 189.2| 333,378                  | 127.4| 48,518                    | 18.1 | 121,200                   | 46.8 |
| 2009 199,993,079      | 485,779                   | 182.5| 315,810                  | 118.9| 48,156                    | 17.7 | 121,813                   | 46.4 |
| 2010 200,127,372      | 483,973                   | 179.9| 309,492                  | 115.0| 49,253                    | 17.8 | 125,228                   | 47.0 |
| 2011 200,423,243      | 482,979                   | 175.6| 305,486                  | 111.1| 49,605                    | 17.5 | 127,888                   | 47.1 |
| 2012 200,698,847      | 481,991                   | 172.3| 300,439                  | 107.4| 50,922                    | 17.7 | 130,630                   | 47.2 |
| 2013 200,918,513      | 488,817                   | 171.8| 297,501                  | 104.6| 54,787                    | 18.7 | 136,529                   | 48.6 |
| 2014 201,048,793      | 489,926                   | 169.9| 291,879                  | 101.2| 57,522                    | 19.3 | 140,525                   | 49.4 |
| 2015 201,242,281      | 503,172                   | 171.9| 291,850                  | 99.7 | 62,649                    | 20.8 | 148,673                   | 51.5 |

Age-adjusted mortality rate per 100,000 person-years, directly standardized to the 2000 U.S. population

### Table 6 Non-Hispanic Asian/Pacific Islander (age-adjusted)

Trends in mortality in United States from 2000 to 2015 by gender and race-ethnicity

| Year (n = Population) | Heart disease (n = deaths) | AAMR | Ischemic HD (n = deaths) | AAMR | Heart failure (n = deaths) | AAMR | All other HD (n = deaths) | AAMR |
|-----------------------|---------------------------|------|--------------------------|------|---------------------------|------|---------------------------|------|
| 2000 11,355,553       | 8949                      | 146.1| 6689                     | 109.7| 418                       | 7.8  | 1842                      | 28.6 |
| 2001 11,983,178       | 9291                      | 139.5| 6916                     | 104.5| 392                       | 6.7  | 1983                      | 28.3 |
| 2002 12,472,384       | 9814                      | 139.2| 7159                     | 102.3| 445                       | 7.1  | 2210                      | 29.9 |
| 2003 12,942,337       | 9934                      | 132.5| 7221                     | 96.5 | 474                       | 7.1  | 2239                      | 28.9 |
| 2004 13,406,530       | 9756                      | 123.4| 6954                     | 88.2 | 475                       | 6.6  | 2327                      | 28.5 |
| 2005 13,888,295       | 10,281                    | 119.8| 7329                     | 85.7 | 519                       | 6.8  | 2433                      | 27.3 |
| 2006 14,375,996       | 10,457                    | 115.7| 7430                     | 82.3 | 556                       | 6.8  | 2471                      | 26.6 |
| 2007 14,854,701       | 10,394                    | 108.6| 7292                     | 76.1 | 504                       | 5.8  | 2598                      | 26.7 |
| 2008 15,336,181       | 10,951                    | 108.1| 7705                     | 76.1 | 606                       | 6.5  | 2640                      | 25.5 |
| 2009 15,793,995       | 11,134                    | 103.8| 7616                     | 70.9 | 638                       | 6.4  | 2880                      | 26.5 |
| 2010 16,133,872       | 11,254                    | 101.1| 7683                     | 69   | 694                       | 6.7  | 2877                      | 25.4 |
| 2011 16,579,709       | 11,406                    | 93.8 | 7712                     | 63.2 | 714                       | 6.4  | 2980                      | 24.2 |
| 2012 17,175,596       | 12,068                    | 92.7 | 7959                     | 61   | 825                       | 6.8  | 3284                      | 24.9 |
| 2013 17,693,870       | 13,064                    | 93.2 | 8477                     | 60.3 | 954                       | 7.1  | 3633                      | 25.7 |
| 2014 18,436,908       | 13,021                    | 86.4 | 8360                     | 55.3 | 1029                      | 7.2  | 3632                      | 23.8 |
| 2015 19,116,557       | 13,974                    | 86.6 | 8921                     | 55.1 | 1124                      | 7.3  | 3929                      | 24.2 |

Age-adjusted mortality rate per 100,000 person-years, directly standardized to the 2000 U.S. population
### Table 7 Hispanic (age-adjusted)

Trends in mortality in United States from 2000 to 2015 by gender and race-ethnicity

| Year  | (n = Population) | Heart disease (n = deaths) | AAMR | Ischemic HD (n = deaths) | AAMR | Heart failure (n = deaths) | AAMR | All other HD (n = deaths) | AAMR |
|-------|------------------|-----------------------------|------|--------------------------|------|---------------------------|------|---------------------------|------|
| 2000  | 35,305,818       | 25,819                      | 196  | 19,744                   | 153.2| 1270                      | 10.9 | 4805                      | 31.9 |
| 2001  | 37,144,096       | 27,090                      | 193.7| 20,664                   | 151.1| 1364                      | 10.8 | 5062                      | 31.9 |
| 2002  | 38,617,620       | 27,887                      | 188.8| 20,941                   | 144.7| 1412                      | 10.8 | 5534                      | 33.2 |
| 2003  | 40,049,429       | 28,298                      | 182.1| 20,783                   | 136.8| 1606                      | 11.5 | 5909                      | 33.8 |
| 2004  | 41,501,375       | 27,788                      | 169.1| 20,482                   | 127.4| 1545                      | 10.5 | 5761                      | 31.2 |
| 2005  | 43,023,614       | 29,555                      | 170.4| 21,774                   | 127.9| 1721                      | 11.3 | 6060                      | 31.3 |
| 2006  | 44,606,305       | 28,921                      | 157.8| 20,939                   | 116.4| 1830                      | 11.3 | 6152                      | 30.1 |
| 2007  | 46,196,853       | 29,021                      | 149.5| 20,326                   | 110.1| 1890                      | 10.9 | 6679                      | 31.1 |
| 2008  | 47,793,785       | 28,951                      | 141.4| 20,261                   | 100.8| 1966                      | 10.7 | 6724                      | 30.0 |
| 2009  | 49,327,489       | 29,611                      | 135.8| 20,939                   | 94.7 | 2013                      | 10.2 | 7370                      | 30.9 |
| 2010  | 50,477,594       | 30,006                      | 132.8| 20,494                   | 92.3 | 2024                      | 10   | 7488                      | 30.6 |
| 2011  | 52,045,277       | 30,385                      | 123.9| 20,326                   | 84.2 | 2233                      | 10.1 | 7826                      | 29.6 |
| 2012  | 53,027,708       | 31,595                      | 122  | 20,751                   | 81.1 | 2404                      | 10.2 | 8440                      | 30.7 |
| 2013  | 54,071,370       | 33,243                      | 121.2| 21,788                   | 80.3 | 2544                      | 10.1 | 8911                      | 30.7 |
| 2014  | 55,387,539       | 34,021                      | 116  | 21,871                   | 75.3 | 2742                      | 10.2 | 9408                      | 30.5 |
| 2015  | 56,592,793       | 36,401                      | 116.9| 23,055                   | 74.5 | 3239                      | 11.3 | 10,107                    | 31.9 |

Age-adjusted mortality rate per 100,000 person-years, directly standardized to the 2000 U.S. population

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### Table 8 Non-Hispanic Black (age-adjusted)

Trends in mortality in United States from 2000 to 2015 by gender and race-ethnicity

| Year  | (n = Population) | Heart disease (n = deaths) | AAMR | Ischemic HD (n = deaths) | AAMR | Heart failure (n = deaths) | AAMR | All other HD (n = deaths) | AAMR |
|-------|------------------|-----------------------------|------|--------------------------|------|---------------------------|------|---------------------------|------|
| 2000  | 35,091,809       | 76,706                      | 328.4| 50,659                   | 220.4| 4936                      | 22.4 | 21,111                    | 85.7 |
| 2001  | 35,638,389       | 76,794                      | 322.6| 50,295                   | 215.0| 5094                      | 22.7 | 21,405                    | 84.9 |
| 2002  | 36,049,904       | 76,694                      | 317.1| 49,522                   | 208.5| 5143                      | 22.7 | 22,029                    | 85.9 |
| 2003  | 36,422,205       | 76,452                      | 309.6| 48,617                   | 200.8| 5294                      | 22.9 | 22,541                    | 85.9 |
| 2004  | 36,848,991       | 73,373                      | 290.9| 46,064                   | 186.0| 5198                      | 22.2 | 22,111                    | 82.8 |
| 2005  | 37,270,736       | 73,302                      | 282.4| 45,435                   | 178.1| 5570                      | 23   | 22,297                    | 81.3 |
| 2006  | 37,719,495       | 71,461                      | 268.2| 43,992                   | 168.0| 5524                      | 22.2 | 21,945                    | 78.1 |
| 2007  | 38,184,699       | 70,443                      | 257.4| 42,152                   | 156.5| 5464                      | 21.4 | 22,827                    | 79.4 |
| 2008  | 38,651,733       | 69,918                      | 248.1| 41,373                   | 149.4| 5415                      | 20.6 | 23,130                    | 78.2 |
| 2009  | 39,104,815       | 68,811                      | 236.4| 39,956                   | 139.8| 5290                      | 19.3 | 23,565                    | 77.3 |
| 2010  | 39,437,133       | 68,215                      | 229.5| 39,047                   | 133.4| 5497                      | 19.8 | 23,671                    | 76.2 |
| 2011  | 39,944,896       | 67,595                      | 219.3| 38,928                   | 127.9| 5492                      | 19.1 | 23,175                    | 72.1 |
| 2012  | 40,391,388       | 69,147                      | 216.3| 39,005                   | 123.4| 5879                      | 19.6 | 24,263                    | 73.3 |
| 2013  | 40,802,086       | 71,102                      | 215.5| 39,199                   | 119.9| 6518                      | 21   | 25,385                    | 74.7 |
| 2014  | 41,316,519       | 71,894                      | 210.8| 38,843                   | 114.8| 6962                      | 21.6 | 26,089                    | 74.4 |
| 2015  | 41,777,483       | 74,093                      | 210.1| 39,054                   | 111.3| 7772                      | 23.3 | 27,267                    | 75.5 |

Age-adjusted mortality rate per 100,000 person-years, directly standardized to the 2000 U.S. population
follow-up showing continued decline through 2014 [12]. On the other hand, the prevalence of HF is on the rise [13]. The mortality trends for ischemic heart disease and HF since 2011 parallel these findings and are therefore plausible.

CVD remain a major cause of health loss internationally. Per the recent GBD (Global Burden of Disease) study, although dramatic declines in CVD occurred in regions with high socioeconomic status, only a gradual decrease or no change was noted in most other regions [14]. Of note, the data analyzed in our study used common groupings of ICD-10 codes to define heart disease and its subtypes such as IHD and all other HD in National Vital Statistics reports for the U.S. [15] that may be slightly different than codes used in GBD studies to define CVD and subtypes [16]. Therefore, the mortality numbers may vary. Similarly, in another study, trends in CHD and CVD mortality continue to be less favorable in Latin America than in Canada and in the U.S. [17].

The National Center for Health Statistics recently reported that deaths considered HF-related (i.e., HF reported anywhere on the death certification) declined from 2000 to 2012 but increased from 2012 to 2014 [18]. It is possible that HF is being inappropriately designated as the underlying cause of death in many instances [19]. This report noted that IHD was the underlying cause of death in 2014 for 23.9% of HF-related deaths in adults aged 45 years and older but did not report on the frequency of IHD as a listed cause of death when HF was recorded as the underlying cause of death. This might slightly attenuate the downward trend in the IHD mortality rate if HF is being designated as the underlying cause of death when it is due to IHD.

### Table 9 Non-Hispanic American Indian/Alaskan Native (age-adjusted) Trends in mortality in United States from 2000 to 2015 by gender and race-ethnicity

| Year   | Heart disease (n = Population) | Heart disease (n = deaths) | AAMR | Ischemic HD (n = deaths) | AAMR | Heart failure (n = deaths) | AAMR | All other HD (n = deaths) | AAMR |
|--------|--------------------------------|----------------------------|------|--------------------------|------|---------------------------|------|---------------------------|------|
| 2000   | 2,344,042                      | 2350                       | 197.8| 1688                     | 142.7| 171                       | 16.7 | 491                       | 38.5 |
| 2001   | 2,360,621                      | 2353                       | 190.6| 1672                     | 135.6| 163                       | 15.9 | 518                       | 39.1 |
| 2002   | 2,383,303                      | 2421                       | 195.7| 1744                     | 141.3| 182                       | 16.8 | 495                       | 37.6 |
| 2003   | 2,404,476                      | 2634                       | 201.6| 1855                     | 143.5| 176                       | 16.0 | 603                       | 42.2 |
| 2004   | 2,428,499                      | 2524                       | 192.8| 1795                     | 138.9| 187                       | 16.6 | 542                       | 37.2 |
| 2005   | 2,452,970                      | 2576                       | 185.7| 1738                     | 126.0| 216                       | 18.3 | 622                       | 41.4 |
| 2006   | 2,477,720                      | 2630                       | 182.7| 1810                     | 127.6| 208                       | 16.6 | 612                       | 38.4 |
| 2007   | 2,502,533                      | 2557                       | 171.6| 1719                     | 117.0| 180                       | 14.1 | 658                       | 40.6 |
| 2008   | 2,528,470                      | 2549                       | 163.6| 1671                     | 108.0| 230                       | 17.4 | 648                       | 38.2 |
| 2009   | 2,552,151                      | 2654                       | 164.2| 1878                     | 107.8| 230                       | 16.5 | 687                       | 39.9 |
| 2010   | 2,569,567                      | 2656                       | 161.6| 1747                     | 106.3| 217                       | 16.0 | 692                       | 39.3 |
| 2011   | 2,598,792                      | 2805                       | 161  | 1836                     | 104.8| 222                       | 14.9 | 747                       | 41.3 |
| 2012   | 2,620,501                      | 2823                       | 153.7| 1870                     | 101.7| 201                       | 12.7 | 744                       | 39.3 |
| 2013   | 2,643,000                      | 3002                       | 155.5| 1949                     | 100.4| 230                       | 13.8 | 823                       | 41.2 |
| 2014   | 2,667,297                      | 3118                       | 153.3| 2009                     | 97.8 | 233                       | 13.4 | 876                       | 42.2 |
| 2015   | 2,689,706                      | 3303                       | 154.9| 2044                     | 95.2 | 286                       | 15.0 | 973                       | 44.8 |

Age-adjusted mortality rate per 100,000 person-years, directly standardized to the 2000 U.S. population

### Table 10 Crude mortality rate, total population rates (per 100,000 person years)

| Year   | Heart disease | Ischemic HD | Heart failure | All other HD |
|--------|---------------|-------------|---------------|--------------|
| 2000   | 252.6         | 183.1       | 19.8          | 49.7         |
| 2001   | 245.7         | 176.2       | 20.0          | 49.5         |
| 2002   | 242.3         | 171.9       | 19.6          | 50.8         |
| 2003   | 236.1         | 165.5       | 19.8          | 50.9         |
| 2004   | 222.8         | 154.1       | 19.5          | 49.2         |
| 2005   | 220.7         | 150.8       | 19.9          | 49.9         |
| 2006   | 211.7         | 142.6       | 20.2          | 48.9         |
| 2007   | 204.5         | 134.9       | 18.8          | 50.8         |
| 2008   | 202.8         | 133.3       | 18.7          | 50.9         |
| 2009   | 195.4         | 125.9       | 18.4          | 51.1         |
| 2010   | 193.6         | 122.9       | 18.7          | 51.9         |
| 2011   | 191.5         | 120.4       | 18.7          | 52.3         |
| 2012   | 191.0         | 118.3       | 19.2          | 53.5         |
| 2013   | 193.3         | 117.1       | 20.6          | 55.6         |
| 2014   | 192.7         | 114.3       | 21.5          | 56.8         |
| 2015   | 197.2         | 114.1       | 23.4          | 59.7         |
Another potential cause of misclassification of HF-related mortality is competing mortality with a non-CVD cause. While it is possible that declining cancer related mortality is competing mortality with a non-CVD cause, it is unlikely since cancer mortality has been declining at a fairly stable rate of 1.5% per year since 2000 [1]. The most plausible sources for competing non-CVD mortality are diabetes (E10-E14) and chronic lower respiratory diseases (J40–J47) which have declined minimally from 2011 to 2015 (data not shown).

It is well-recognized that HF is a major and growing public health problem. Earlier estimates from projection models for the U.S. suggest that the prevalence of HF will increase by 46% from 2012 to 2030 [13]. It has been suggested that the absence of a national surveillance system significantly impedes the ability to track and manage this expected increase in HF [20]. Given this, present CDC mortality data becomes an important indicator for burden of HF. Another matter of importance is a rising proportion of patients having HF with preserved ejection fraction (HFpEF), accounting for more than 50% of incident HF cases, and no definitive treatment to so far, has been proven effective in reducing the morbidity and mortality of HFpEF [21]. Further concomitant multiple comorbid conditions are frequent in this patient population, [22] with a recent analysis from Denmark showing an increasing prevalence of comorbidities, including diabetes mellitus and hypertension, especially in younger patients with HF [23]. It is plausible that the increasing prevalence of these comorbidities and lower death rates after acute myocardial infarction are contributing to increased HF-related mortality rates. Whereas better risk factor control strategies to prevent HF may reduce the incidence, [24] more effective treatments for patients with established HF would be expected to reduce case-fatality.

Conclusions
While the mortality rate attributed to HD slowed substantially between 2011 and 2014 nationally before turning upward in 2015, trajectories among HD subgroups were heterogeneous, with IHD-related death continuing to decline while death attributed to HF and other causes of HD increased. While systematic efforts to prevent and treat IHD appear to be effective and require continued vigilance, an expanded focus on strategies to reduce deaths from HF and those attributed to other HD conditions appear needed. Finally, addressing the complex care of HF patients with multiple morbidities would likely need system-wide, multipronged health care interventions, with particularly urgent attention to developing more effective treatments for HFpEF [25].

Abbreviations
AAMR: Age-adjusted mortality rate; CVD: Cardiovascular disease; HD: Heart disease; HF: Heart failure; ICD-10: International Statistic Classification of Diseases and Related Health Problems, Tenth Edition; IHD: Ischemic heart disease

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Availability of data and materials
The source of data for determining all mortality rates for the study was the U.S. Centers for Disease Control and Prevention’s Wide-Ranging Online Data for Epidemiologic Research (CDC WONDER) dataset. CDC WONDER is a menu-driven system that makes the information resources of the Centers for Disease Control and Prevention (CDC) available to public health professionals and the public at large. For this study, the “Underlying Cause of Death, 1999–2015” section of CDC WONDER was accessed. For each cause of death noted in the paper, we entered an inquiry through the menu driven system for the number of deaths, crude death rate, and age-adjusted death rate for each of the years, 2000–2015. The link to the CDC “Underlying Cause of Death, 1999–2015” data system is https://wonder.cdc.gov/ucd-icd10.html.

Authors’ contributions
Dr. Sidney had full access to all of the data in the study and takes responsibility for the integrity of the data and the of the data analysis. Study concept and design: SS, JSR. Acquisition of data: SS, JSR. Analysis and interpretation of data: All authors. Drafting of the manuscript: SS, JSR. Critical revision of the manuscript: All authors. Statistical analysis: SS, CPQ, MES. Obtained funding: SS, ASG. Administrative, technical, or material support: SS. Study supervision: SS, JSR. All authors read and approved the final manuscript.

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