

National Trends and Disparities in Cardiomyopathy-Related Mortality Among Individuals with Diabetes Mellitus in the United States: A Retrospective Observational Study from 1999 to 2019

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Abstract

Background

The global prevalence of DM and Cardiomyopathy is increasing. This study offers a longitudinal analysis of mortality patterns due to these two diseases, along with regional and demographic insights that highlight disparities in mortality rates in the US from 1999 to 2019.

Methods

The CDC WONDER mortality database was used to determine crude death rates (CR) and age-adjusted mortality rates (AAMRs) per 1000,000 individuals, 25 years and above. Joinpoint Regression was used to examine annual percent change (APC), average APC (AAPC), and parallelism. Stata analysis was done to assess the significance of the association between mortality trends and different variables.

Results

From 1999 to 2019, there were 141,167 deaths with an AAPC of -3.26. Males (43.11) had higher AAMR than females (22.31). The Blacks had the highest AAMR (56.37) while non-Hispanic Asians experienced the lowest (22.62). AAMRs varied by region (Midwest: 33.56, South: 32.00, West: 31.61, Northeast: 27.14). States with the highest AAMR were Hawaii and Ohio; Colorado had the lowest AAMR. Non-metropolitan areas showed a higher AAMR (32.37) than metropolitan areas (31.11). Crude mortality rate was highest for the 85 + age group.

Conclusions

Mortality due to cardiomyopathy in people with DM decreased in the US. Males, Blacks, the Midwestern region, and non-urban areas had higher mortality, highlighting the need for targeted interventions to mitigate the mortality burden.

INTRODUCTION

Cardiomyopathies, a group of diseases causing structural and functional changes in the heart,¹ are a significant cause of cardiovascular-related mortality worldwide. Various types of cardiomyopathies include dilated cardiomyopathy, hypertrophic cardiomyopathy, restrictive cardiomyopathy, takotsubo cardiomyopathy, arrhythmogenic cardiomyopathy, and diabetic cardiomyopathy. Cardiomyopathy damages heart muscles and can lead to heart failure.¹ With the rising prevalence of Diabetes Mellitus worldwide, the incidence of Diabetic Cardiomyopathy (DM) is also rising. Moreover, people with DM are 2–5 times more likely to develop heart failure than age-matched non-diabetic patients.

The Centers for Disease Control and Prevention (CDC) reports that over 34 million Americans have diabetes, with an additional 88 million adults having prediabetes.² DM can lead to various cardiovascular complications like coronary artery disease, heart failure, stroke, atherosclerosis, and cardiomyopathies. Globally, DM is the ninth leading cause of mortality, and two-thirds of these deaths occur due to cardiovascular complications.³ Myocardial dysfunction in people with DM without coronary artery disease and hypertension is called Diabetic Cardiomyopathy (DCM).⁴ DM can lead to cardiomyopathy because of effects on calcium transport,⁵ prolonged action potential duration, impaired ATP production due to suppressed glucose metabolism, increased fatty acid metabolism, mitochondrial dysfunction, increased oxidative stress, production of Advanced-glycation End Products that reduce collagen turnover, fibrosis, microangiopathy, endothelial dysfunction, modification of intracellular signaling, and increased susceptibility of myocardium to ischemia.^{6–10}

Despite the significant disease burden of DM and associated cardiomyopathy, a critical research gap persists in identifying the progression of DCM, particularly its contribution to DM-associated mortality. Moreover, the current management options focus on symptomatic management only, rather than placing the underlying mechanisms and preventive methods. Current medications like ACE inhibitors, beta blockers, and insulin do not treat the root cause of DCM. There is a significant knowledge vacuum about the onset and course of DCM in patients, as well as how early intervention may lessen its impact on overall mortality.

The increasing prevalence of DM and the fact that cardiovascular diseases are the leading cause of death in people with DM make it imperative to gain a deeper understanding of how DCM affects survival.¹¹ Our study provides a deep insight into the mortality trends due to DCM, along with the disparities across different epidemiological groups from 1999 to 2019 in the United States. By exploring the complex interplay between these two conditions, we seek to inform strategies for prevention, early detection, and management of diabetic cardiomyopathy, ultimately reducing the burden of cardiovascular disease among individuals with diabetes.

METHODS

Study Design

Mortality data were obtained from the Centers for Disease Control and Prevention Wide-Ranging Online Data for Epidemiological Research (CDC-WONDER) database, a comprehensive repository of death certificate records from all U.S. states and the District of Columbia.¹² Multiple causes of death data were utilized to identify death certificates that included any mention of mortality related to cardiomyopathy in patients with diabetes mellitus. Data extraction was performed using the International Classification of Diseases, Tenth Revision (MCD- ICD-10) codes. DM patients were identified with ICD-10 codes E10-E14, and Cardiomyopathy patients were identified with ICD-10 codes I42.0 (Dilated cardiomyopathy); I42.1 (Obstructive hypertrophic cardiomyopathy); I42.2 (Other hypertrophic cardiomyopathy); I42.3

(Endomyocardial (eosinophilic) disease); I42.4 (Endocardial fibroelastosis); I42.5 (Other restrictive cardiomyopathy); I42.6 (Alcoholic cardiomyopathy); I42.7 (Cardiomyopathy due to drugs and other external agents); I42.8 (Other cardiomyopathies); I42.9 (Cardiomyopathy, unspecified). Institutional review board (IRB) approval was not required, as the data were de-identified and publicly accessible. This study was conducted in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.¹³

Data Extraction

All the data was extracted on the 10th of March 2025 from the CDC WONDER database.¹² Data was stratified by population characteristics, including gender, race/ethnicity, age group, urban-rural classification, census region, and state. Race/ethnicity was categorized as Non-Hispanic (NH) Asian or Pacific Islander, NH American Indian or Alaska Native, NH Black or African American, and NH White. Age groups were segmented into 10-year intervals, ranging from 25 years to 85 years and older. Census regions were defined as the Northeast, Midwest, South, and West. Urban-rural classification followed the 2013 U.S. Census Bureau definition,¹⁴ with urban areas designated as having a population of 500,000 or more, and the rural regions defined as those with populations below 500,000.

Statistical Analysis

The data were presented as age-adjusted mortality rates (AAMRs) and crude death rates (CRs). AAMRs were calculated by applying age-specific mortality rates to the 2000 U.S. standard population, producing a weighted average that facilitates equitable comparisons of mortality rates across different populations or time periods.¹⁵ CRs were determined by dividing the number of deaths from cardiomyopathy in people with DM by the total population for each respective year. AAMRs were employed to analyze mortality trends by gender, race/ethnicity, census region, urban-rural classification, and state, while CRs were utilized for age-group analyses.

Trend analyses were performed using the Join Point Regression Program version 5.0.3 to estimate Annual Percentage Changes (APCs) and Average Annual Percentage Changes (AAPCs), along with their corresponding 95% Confidence Intervals (CIs).¹⁶ The Join Point software identifies the simplest join point model by starting with the fewest join points and sequentially assessing the statistical significance of adding additional join points up to a predefined maximum, using Monte Carlo permutation tests.¹⁷ To determine whether APCs represented increasing or decreasing trends, the slope of mortality rate changes was evaluated for significant deviation from zero using a two-tailed t-test. A pairwise comparison between groups was conducted to assess the parallelism of trends. Statistical significance was defined as a p-value less than 0.05. Stata analysis was done to assess the z value, which indicates the significance between mortality trends and the following variables: age groups, gender, urbanization, states, races, and census regions. The association was considered significant if the p-value was less than 0.05.

RESULTS

Annual Trends:

The total death toll due to Diabetic Cardiomyopathy from 1999 to 2019 was recorded as 141,167 in the United States alone, resulting in an Average Annual Percentage Change (AAPC) of -3.26 (95% CI: -3.5 to -3.05, $p < 0.000001$). The average AAMR per 1,000,000 individuals was reported as 31.32 (95% CI: 31.155 to 31.484) (Table 1). In 1999, the AAMR was recorded at 43.01 (95% CI: 42.044 to 43.975), and this rate decreased to 22.586 (95% CI: 22.002 to 23.171) by 2019. Join point analysis revealed three different trends, a gradual increase was observed from 1999 to 2001 with the Annual Percentage Change (APC) of 0.35 (95% CI: -2.46 to 3.02), followed by a decreasing trend with an APC of -4.00 (95% CI: -5.23 to -3.86) from 2001 to 2016, and again a decreasing trend from 2016 to 2019 with an APC of -1.88 (95% CI: -3.68 to 0.32) (Fig. 1). Thus, there was an overall mortality decrease recorded from 1999 to 2019. The absolute number of deaths across the demographics and regions is presented in **Supplementary Tables S1 through S5**.

Table 1

Absolute Number of Deaths, Age-adjusted Mortality Rates (AAMRs) per 1,000,000, and Average Annual Percentage Change (AAPCs) due to Cardiomyopathy and Diabetes Mellitus in Adults in the United States from 1999–2019

Variable	Number of Deaths	AAMRs (95% CI)	AAPCs (95% CI)
Overall	141,167 (100%)	31.32 (31.16–31.48)	-3.26* (-3.5 – -3.05)
Sex			
Female	57,247 (40.55%)	22.31 (22.12–22.49)	-4.36* (-4.6 – -4.1)
Male	83,920 (59.45%)	43.11 (42.82–43.41)	-2.84* (-3.28 – -2.45)
Census Region			
Northeast	23,884 (16.92%)	27.14 (26.79–27.48)	-4.04* (-4.37 – -3.72)
Midwest	33,971 (24.06%)	33.56 (33.20–33.92)	-2.78* (-3.04 – -2.52)
South	52,703 (37.33%)	32.00 (31.73–32.28)	-3.68* (-3.96 – -3.35)
West	30,609 (21.68%)	31.61 (31.26–31.97)	-3.2* (-3.52 – -2.9)
Urbanization			
Metropolitan	115,679 (81.94%)	31.11 (30.93–31.29)	-3.56* (-3.84 – -3.36)
Non – Metropolitan	25,488 (18.06%)	32.37 (31.97–32.77)	-2.66* (-3.1 – -2.24)
Race and Ethnicity			
American Indian or Alaska Native	1,253 (0.89%)	36.96 (34.78–39.14)	-3.83* (-5.05 – -2.62)
Asian or Pacific Islander	4,002 (2.83%)	22.62 (21.90–23.33)	-4.77* (-5.32 – -4.23)
Black or African American	25,015 (17.72%)	56.37 (55.66–57.09)	-3.65* (-4.28 – -3.11)
AAMR: Age-adjusted mortality rate; AAPC: Average annual percentage change; NA: Not available			
^a Crude mortality rates were used for age groups.			
* AAPC is significantly different from zero at alpha = 0.05			

Variable	Number of Deaths	AAMRs (95% CI)	AAPCs (95% CI)
White	110,897 (78.56%)	28.65 (28.48–28.82)	-3.27* (-3.64 – -2.96)
Age Groups ^a			
25–34 Years	1,024 (0.73%)	0.12 (0.11–0.12)	-1.52 (-3.09–0.01)
35–44 Years	3,658 (2.59%)	0.41 (0.40–0.42)	-1.15* (-1.85 – -0.52)
45–54 Years	11,126 (7.88%)	1.25 (1.23–1.28)	-1.86* (-2.44 – -1.41)
55–64 Years	23,890 (16.92%)	3.30 (3.26–3.34)	-4.04* (-4.27 – -3.82)
65–74 Years	36,381 (25.77%)	7.61 (7.53–7.69)	-4.46* (-4.72 – -4.17)
75–84 Years	41,330 (29.28%)	14.65 (14.51–14.79)	-3.78* (-4.12 – -3.45)
85 + Years	23,758 (16.83%)	21.05 (20.78–21.32)	-1.82* (-2.14 – -1.5)
AAMR: Age-adjusted mortality rate; AAPC: Average annual percentage change; NA: Not available			
^a Crude mortality rates were used for age groups.			
* AAPC is significantly different from zero at alpha = 0.05			

The Stata analysis revealed a z-value of -4.45 with a p-value of < 0.001, indicating that the overall trend is significant. This strongly suggests that the observed trend cannot be attributed to random variation.

Demographic Variations in Mortality Trends:

Sex-wise Analysis: Males had more deaths than females throughout the study period. The total number of deaths for males was 83,920, as compared to female deaths, which were 57,427. The average age-adjusted mortality rate (AAMR) in males was reported as 43.112 (95% CI: 42.816 to 43.408), and in females, it was 22.309 (95% CI: 22.125 to 22.493), representing a difference of just under two times. The AAMR for males decreased from 55.247 (95% CI: 53.535 to 56.958) in 1999 to 32.384 (95% CI: 31.334 to 33.435) in 2019, and for females, it declined from 34.025 (95% CI: 32.892 to 35.158) in 1999 to 14.656 (95% CI: 14.02 to 15.293) in 2019 (**Supplementary Table S6**).

The AAPCs recorded for females and males were – 4.36 (95% CI: -4.88 to -3.84) and – 2.84 (95% CI: -3.47 to -2.21), respectively (Table 1). Join point analysis revealed three segments for females and two for males. From 1999 to 2001, the Average Percentage Change (APC) rate for males reported an incline of 1.83 (95% CI: -2.89 to 6.43). It was followed by a gradual decline from 2001 to 2019 with an APC of -3.35

(95% CI: -4.12 to -3.14). On the other hand, females experienced an APC of -3.2 (95% CI: -4.44 to -0.46) from 1999 to 2003, with further decrease until 2014 represented by an APC of -5.288 (95% CI: -7.04 to -4.99), followed by a slower decrease until 2019, with an APC value of -3.22 (95% CI: -4.44 to -0.067) (Fig. 2).

The pairwise tests rejected parallelism for gender with a p-value of 0.000271, revealing non-parallel trends between males and females from 1999 to 2019. The AAPC comparison showed a difference of -1.51 (95% CI: -2.34 to -0.70). The value of z after Stata analysis was reported as 5.30 with a p-value of < 0.001, thus marking the difference in the mortality trends between genders as significant. This strongly suggests that the observed trend cannot be attributed to random variation.

Race Analysis: Black or African American individuals had the highest AAMR at 56.37 (95% CI: 55.66 to 57.09) with 25,015 deaths, followed by American Indian or Alaska Native individuals with an AAMR of 36.96 (95% CI: 34.78 to 39.14). White individuals had an AAMR of 28.65 (95% CI: 28.48 to 28.82) but accounted for 78.56% of the deaths with a total of 110,897 deaths, while Asian or Pacific Islander individuals had the lowest AAMR at 22.62 (95% CI: 21.90 to 23.33) with 4002 deaths (Table 1). From 1999 to 2019, there was an overall decline in AAMR across all racial/ethnic groups. For Black or African Americans, the AAMR dropped from 76.07 in 1999 to 56.37 in 2019, representing an overall AAPC of -3.65 (95% CI: -4.28 to -3.11). Asian or Pacific Islander individuals represented the greatest drop in AAMR, going from 36.50 in 1999 to 15.25 in 2019 (AAPC: -4.77, 95% CI: -5.32 to -4.23). The AAMR for White individuals went from 39.51 in 1999 to 20.87 in 2019 (AAPC: -3.27, 95% CI: -3.64 to -2.96), while American Indian or Alaska Native individuals saw a decline from 59.66 in 1999 to 27.88 in 2019 (AAPC: -3.83, 95% CI: -5.05 to -2.62) (**Supplementary Table S7**) (Table 1).

The American Indians, the Blacks, and the Whites exhibited varying trends over all these years. The American Indians showed a gradual rise from 1999 to 2003 (APC: 1.69; 95% CI, -6.95 to 18.48), then a huge drop up to 2007 (APC: -14.58; 95% CI, -22.16 to 1.13) followed by a gradual decline up to 2019 (APC: -1.8; 95% CI, -5.23 to 1.4). The Blacks exhibited a declining trend from 1999 to 2004 (APC: -1.85; 95% CI, -3.64 to 4.43), followed by a more significant drop up to 2019 (APC: -4.24; 95% CI, -7.57 to -3.84). In the Whites, a declining trend was observed from 1999 to 2002 (APC: -1.49; 95% CI, -3.6 to 2.78) followed by a significant drop up to 2017 (APC: -4.01; 95% CI, -7.0 to -3.82) and then up to 2019, mortality rate decreased at a lower rate (APC: -0.26; 95% CI, -3.89 to 2.55) (Fig. 3).

The pairwise comparison for American Indian or Alaska Native individuals was significant when compared with Asian or Pacific Islander individuals with a p-value of 0.0253, and when compared with Black or African American Individuals with a p-value of 0.0031, representing non-parallel trends. Additionally, the pairwise comparison for Asian or Pacific Islander individuals was significant when compared with Black or African American individuals, with a p-value of 0.0087, exhibiting non-parallel trends.

The reported z-value after Stata analysis was -0.10, with a p-value of 0.924, which indicates that the association between mortality trends and races can be attributed to random variation.

Regional Variations in Mortality Trends: From 1999 to 2019, the South region experienced the highest number of deaths (52,703), followed by the Midwest (33,971), the West (30,609), and the North (23,884) (**Supplementary Table S3**). However, the AAMR was highest in the Midwest region (AAMR = 33.56, 95% CI: 33.20 to 33.92), followed by the South region with an AAMR of 32.00 (95% CI: 31.73 to 32.28). The AAMR exhibited by the West region was 31.61 (95% CI: 31.26 to 31.97), and that by the Northeast region was 27.14 (95% CI: 26.79 to 27.48), which was significantly lower than the rest of the regions. The Northeast region also experienced the highest decrease in AAMR with an AAPC of -4.04 (95% CI: -4.37 to -3.72) from 1999 to 2019. The South region followed it with an AAPC of -3.68 (95% CI: -3.96 to -3.35) and the West region with an AAPC of -3.2 (95% CI: -3.52 to -2.9). The Midwest region experienced the least decrease with an AAPC of -2.78 (95% CI: -3.04 to -2.52) (Table 1). The Midwest and the South regions exhibited varying trends over these years. In the Midwest region, mortality rate declined from 1999 to 2003 (APC: -1.77, 95% CI, -3.09 to 1.0) followed by a more pronounced decline from 2003 to 2016 (APC: -3.96, 95% CI, -5.0 to -3.71) and then a gradual rise till 2019 (APC: 1.13, 95% CI, -1.4 to 4.91). The South region exhibited an increasing trend from 1999 to 2001 (APC: 2.49, 95% CI, -1.84 to 6.36) and then a significant decline in the mortality rate till 2019 (APC: -4.34, 95% CI, -4.64 to -4.14) (**Supplementary Figure S1**).

The pairwise comparisons for the Midwest census region revealed non-parallel trends when compared to the South region ($p = 0.02$) and the West region ($p = 0.001$). Similarly, the pairwise comparisons for the South census region revealed non-parallel trends when compared with the West region, with a p -value of 0.0002. The value of z after Stata analysis was reported as 1.76 with a p -value of 0.076, showing a non-significant association between mortality trends and census region.

Urban-Rural Analysis: The AAMR was slightly higher in Nonmetropolitan areas (32.37, 95% CI: 31.97–32.77) as compared to Metropolitan areas (31.11, 95% CI: 30.93–31.29). Metropolitan areas reported a greater decrease with an AAPC of -3.56 (95% CI: -3.84 to -3.36) as compared to non-Metropolitan areas having an AAPC of -2.66 (95% CI: -3.1 to -2.24) (Table 1).

From 1999 to 2001, the AAMR for metropolitan areas declined slowly (APC = -0.5265, 95% CI: -3.57 to 1.70), followed by a greater decline from 2001 to 2019 (APC = -3.89, 95% CI: -4.3 to -3.7). Meanwhile, the AAMR for non-metropolitan areas increased initially from 1999 to 2001 with an APC of 2.52 (95% CI: -2.78 to 7.15), followed by a decline from 2001 to 2015 (APC = -3.89, 95% CI: -6.78 to -3.60), and then a much slower decline from 2015 to 2019 with an APC of -0.81 (95% CI: -3.19 to -4.21) (**Supplementary Figure S2**).

Stata analysis revealed a non-significant association between mortality trends and metropolitan and non-metropolitan status with a z -value of 0.44, and a p -value of 0.66.

Age-Groups Analysis

Overall, 125,359 of the deaths were reported in people aged 55 or older, representing around 88.8% of the total deaths with the highest number of deaths occurring in the age group 75–84 years (41,330). In

contrast, 15,808 deaths were reported in people aged 54 or younger, representing 11.2% of the total deaths. The lowest number of deaths were reported in the age group 25–34 years, with only 1024 deaths (**Supplementary Table S5**).

The highest mortality rate per 1,000,000 individuals was observed in the age group 85 years or older, with a Crude Rate (CR) of 21.05 (95% CI: 20.78 to 21.32) whereas the lowest AAMR was observed in the age group 25–34 years, with a CR of 0.12 (95% CI: 0.11 to 0.12) (**Supplementary Table S10**). The AAPCs for all age groups decreased from 1999–2020, with the greatest decrease occurring in the age group of 65–74 years of -4.46 (95% CI: -4.72 to -4.17) (Table 1).

The pairwise comparisons for age group 25–34 years revealed non-parallel trends when compared with age groups 55–64 years ($p = 0.0047$), 65–74 years ($p = 0.0016$), 75–84 years ($p = 0.0096$), and 85 + years ($p = 0.0024$). Similarly, the pairwise comparisons for age group 35–44 years revealed non-parallel trends when compared with age groups 45–54 years ($p = 0.01$), 55–64 years ($p = 0.0002$) 65–74 years ($p = 0.0002$), 75–84 years ($p = 0.0002$), and 85 + years ($p = 0.0002$). The 45–54 years age group also revealed non-parallel trends when compared with age groups 55–64 years ($p = 0.0007$) 65–74 years ($p = 0.0004$), 75–84 years ($p = 0.0004$) and 85 + years ($p = 0.0002$). Trends for 55–64 years age groups were also non-parallel when compared with 65–74 years ($p = 0.0002$) and 75–84 years age groups ($p = 0.0004$).

The value of z after Stata analysis was reported as 11.88 with a p -value of < 0.001 , thus marking the difference in mortality trends by age group stratification as significant. This strongly suggests that the observed trend cannot be attributed to random variation.

State-wise Analysis: There was a notable difference in AAMRs among states. Hawaii had the highest AAMR of 59.71 (95% CI: 56.39 to 63.02) with 1269 deaths, followed by Ohio with an AAMR of 45.65 (95% CI: 44.66 to 46.64) and 8248 deaths, and Delaware with 40.72 (95% CI: 37.33 to 44.11) and 563 deaths. The highest number of deaths was reported in California, with 19,244 deaths recorded from 1999 to 2019, followed by Florida with 10,843 deaths. The state of Colorado had the lowest AAMR of 15.71 (95% CI: 14.72 to 16.69) with 1,005 deaths. States in the top 90th percentile include Hawaii, Ohio, Delaware, Maryland, North Carolina, and West Virginia, while those in the lowest 10th percentile are New York, Massachusetts, Nevada, Wyoming, Utah, and Colorado (**Supplementary Table S11**). A heatmap depicting AAMRs across US states is provided in Fig. 4.

The z -value of 0.45 was found from Stata analysis with a p -value of 0.656, showing a non-significant association between mortality trends and States.

DISCUSSION

The analysis of diabetic cardiomyopathy-related deaths from 1999 to 2019 in the United States provides valuable insights into the changing landscape of this major public health issue, as both diabetes and cardiomyopathy are significant contributors to cardiovascular morbidity and mortality. DM affects 537 million people globally, and this figure is expected to climb to 643 million by 2030 and to 643 million

by 2045, according to the International Diabetes Federation, 2021.¹⁸ Moreover, the high disease burden of cardiomyopathy is alarming. It is compounded by the anticipated rise in key risk factors, including type II diabetes and high blood pressure, both of which are strongly associated with the development of cardiomyopathy.¹⁹ Diabetes increases the risk of cardiovascular diseases, which lead to increased morbidity and mortality.²⁰ Diabetic cardiomyopathy is the cardiac dysfunction that occurs without coronary artery disease, hypertension, or valvular disease.²¹ Diabetics have an increased risk of developing cardiomyopathy as diabetes-induced hyperglycemia and hyperinsulinemia lead to capillary damage, myocardial fibrosis and hypertrophy, mitochondrial dysfunction, excessive fat accumulation in cardiomyocytes, increased oxidative stress, and inflammation.²¹ This study is based on an in-depth search of the CDC Wonder database and shows a significant overall decrease in DCM-related mortality during the study period, with notable variations observed across racial/ethnic groups, census regions, age groups, gender, urbanization status, and states.

With 141,167 documented fatalities in two decades, DCM had a significant overall mortality burden in the United States. Our results show a consistent drop in death rates with varying trends. There was a rise in mortality from 1999 to 2001, but then a drop up to 2019, which is attributed to the overall reduction in cardiovascular disease mortality rates in the late 20th century and early 2000s, which was primarily driven by advancements in evidence-based medical and surgical treatments, alongside global prevention strategies aimed at reducing cardiovascular risk factors. William R Rowley mentions in his paper that the prevalence of diabetes (both type 1 and type 2) is projected to increase by 54%, reaching over 54.9 million Americans between 2015 and 2030, and the prevalence of cardiomyopathy is also growing.^{22,23} Despite the consistent increase in prevalence of both diabetes and cardiomyopathy, the mortality rate due to DCM is decreasing, which marks improvements in diabetes treatment, heart disease prevention, medical interventions, advancements in cardiovascular care, increased public awareness, better healthcare access, and lifestyle modifications.

While evaluating gender stratification, a gender gap was observed in DCM-associated mortality. Gender disparities play a crucial role in determining the trajectory of DM, its complications, and treatment. Our study revealed that the mortality rate (AAMR) of males was double that of females, which is in line with the previous studies, according to which the burden of comorbidities is generally higher in males.^{24,25} Moreover, males exhibited less pronounced decline in mortality than females, indicating that women might have benefited more from medical improvements. This is in line with Lori Mosca's study, which states that males are more likely to die from cardiovascular diseases than females.²⁶ Our results are also consistent with the National Diabetes Statistics Report, according to which the prevalence of diabetes (both diagnosed and undiagnosed) is higher in males than in females.² Moreover, Alexandra Kautzky-Willer states in a paper that men are diagnosed with diabetes slightly more often than women, but at a younger age and with a lower BMI. Due to hormonal factors, women have a higher risk burden and have a greater risk of developing cardiovascular diseases, but still, the absolute risk of cardiovascular events is greater in men.²⁷ Gender differences in health outcomes, like diabetic cardiomyopathy, come from a mix of biological, lifestyle, and hormonal factors, with testosterone

affecting men's cardiovascular health and estrogen offering some protection to women. On top of this, lifestyle choices such as diet, exercise, stress levels, and health habits often vary between the genders, influencing disease development and outcomes. Men and women may approach the following treatment plans differently, all of which contribute to differences in how diabetes and its complications progress and impact each gender. This contributes to the notable gender-based inequalities in death trends in our study. This underscores the development of targeted interventions and public health measures to lessen these disparities.

All the age groups also exhibited a decline in DCM-associated mortality, aligning with previous studies reporting similar trends in diabetes-related cardiovascular mortality.²⁸ People 55 years of age or older accounted for most DCM-related deaths (88.8%), with the highest mortality rate seen in those 75–84 years old. This result is in line with earlier studies that indicate higher DCM-related death rates among senior citizens.²⁹ The 65–74 years age group had the greatest significant drop, suggesting improvements in DCM prevention and management. Increased mortality among older individuals is due to the decreased impact of healthcare therapies in older persons due to their diminished physiological resilience, various comorbidities, and extended disease duration.²⁹ On the other hand, younger populations might gain better management techniques, lifestyle changes, and early diagnosis.²⁸ Our results are in line with another study, according to which in economically advanced countries, the elderly population (≥ 75 years) is expanding over the years with a corresponding increase in the burden of chronic illnesses and morbidity (especially DM) and higher rates of hospitalization.³⁰

In addition to age-related disparities, geographic differences were also evident. Non-urban areas had a greater death burden than urban areas. A worrying discrepancy in mortality trends was highlighted by the fact that, although mortality decreased in both settings between 1999 and 2019, the fall was less pronounced in non-urban areas compared to urban areas. This may be due to a lack of medical facilities and limited insurance coverage in rural regions.³¹ This discrepancy is influenced by socioeconomic factors, healthcare disparities, the limited availability of primary care physicians and cardiac specialists in rural areas, less access to specialized tertiary care in rural areas, delays in implementing strategies to prevent and manage risk factors, and a high number of uninsured persons in rural areas.^{32–37} Our results are also in line with another study, according to which the percentage of the elderly in non-urban areas (18%) is greater than that of urban areas (12%), hinting at a greater mortality rate in non-urban areas.³² These factors all contribute to higher mortality rates in non-urban areas and underscore the need for the development of targeted interventions, public health measure initiatives, improved access to healthcare and health insurance, health education, community health programs, and government-level policies to address the socioeconomic determinants of health.

The regional trends further indicate the influence of socioeconomic and geographic factors on mortality outcomes. The Midwest has the highest mortality burden, followed by the South and the West. The Northwest had the lowest AAMR, which is in line with another study on heart disease in diabetics.³⁸ This is due to socioeconomic factors, inadequate access to healthcare, and a higher prevalence of diabetes,

hypertension, and obesity in some regions as compared to others. The Northeast exhibited the largest drop in mortality, indicating notable progress over time. These results are consistent with a previous study by Peter A Glynn, which suggests that the public health in the Northeast region improved as a result of improved access to healthcare and prevention, whereas the Midwest's mortality rates remained high.³⁹ These notable regional differences may result from various factors, such as inconsistent use of evidence-based medications, state Medicaid policies, insurance coverage, disparities in ambulatory cardiology practices, and the increasing prevalence of comorbidities. To minimize these differences, improving access to healthcare, standardizing evidence-based practices, increasing public health education, decreasing economic barriers, and addressing healthcare infrastructure disparities are essential.

AAMRs across the states of the US indicated a clear geographic variation. The AAMR was highest for Hawaii (59.71), followed by Ohio (45.65) and Delaware (40.72), while the lowest was for Colorado (15.71). State-specific differences and mortality trends did not reach statistical significance ($p = 0.656$), indicating more extensive regional or socioeconomic implications. This disparity can be caused due to interplay of several factors like racial distribution, genetic predisposition, poor healthcare, socioeconomic hurdles, a lack of awareness about health education, Medicaid expansion, funding for public health programs and state-specific healthcare policies and access to medications as stated by a study by Vardhmaan Jain that although newer treatments like sodium-glucose cotransporter-2 (SGLT2) inhibitors and glucagon-like peptide-1 (GLP-1) receptor agonists show promise in reducing diabetes and cardiovascular disease-related morbidity and mortality, their high cost remains a barrier for many. Federal and state-level policies play a pivotal role in making these therapies more accessible to help reduce the growing mortality burden.⁴⁰ This underscores the need to lessen disparity among various states by collaborative efforts of the government and the public, along with appropriate community health measures.

Significant racial differences in DCM-related mortality were found in our investigation. Due to impediments to healthcare access, Black people had the highest AAMR (56.37 per 100,000), followed by American Indians (36.96 per 100,000). Asians showed the biggest drop (AAPC: -4.77%) and the lowest AAMR (22.62 per 100,000) which is in line with a previous study indicating that the mortality burden due to diabetes related cardiovascular disease is lowest in the Asians and highest in the Blacks (almost double as compared to the Whites).⁴⁰ Our findings are in line with previous literature which mentions that the mortality due to Diabetes and Cardiovascular diseases is significantly higher in the Black people due to ecological and economical barriers, less access to healthcare and higher prevalence of cardiovascular diseases-associated risk factors like increased Low-density lipids (LDL), lipoprotein oxidation, adiponectin, increased prevalence of homocysteinemia and inflammatory conditions.⁴¹ Moreover, studies indicate that hospitals serving predominantly African American and American Indian communities receive less funding and provide lower-quality healthcare.^{42,43} Moreover, factors like unemployment, poverty, inadequate education, and lack of health insurance also contribute to these disparities. Anh L. Bui also mentions in his study that Black people are more prone to develop comorbid

health conditions like diabetes, hypertension, and coronary artery disease.⁴⁴ All of these factors interplay and contribute to this concerning disparity that prevails across the racial groups. Asians have a lower mortality rate, along with the most pronounced decrease in mortality, which may be attributed to genetic, behavioral, socioeconomic factors, and an improvement in the provision of healthcare facilities. But to reduce racial disparity, we need to improve quality healthcare access, increase investment in health education, and provide early detection and prompt treatment for Black populations. Additionally, policy changes addressing healthcare funding and resources for hospitals serving minority communities are crucial.

Strengths and limitations

Using solid population-level data from the CDC Wonder Database (1999–2019), this study offers a longitudinal analysis of DCM-associated mortality patterns over time, while also enabling regional and demographic insights, which can highlight disparities in mortality rates. Moreover, access to a large and reliable dataset ensures the generalizability and credibility of the findings. These findings can play a pivotal role in evidence-based policy recommendations and healthcare strategies, especially for high-risk populations.

The limitations of this study include the absence of individual-level risk factors such as socioeconomic status, obesity, and healthcare access, as well as misclassification bias brought on by differences in cause-of-death reporting.^{45,46} Data from a multi-center diabetes care study, the Translating Research into Action for Diabetes (TRIAD) study, indicates that the reporting rates of diabetes mellitus on death certificates have improved in recent years. This improvement could potentially obscure the national trends in diabetes-related mortality rates. In other words, trends in death certificate reporting may not reliably reflect the true trends in diabetes-related mortality.⁴⁷ Moreover, the CDC database does not include data on disease characteristics such as vital signs, laboratory results, and echocardiographic findings, or genetic testing and it does not provide information on social determinants of health, which could affect access to care and, in turn, contribute to racial and ethnic disparities in DCM-related mortality.

CONCLUSION

Even though DCM-related mortality has significantly decreased over the past 20 years, differences still exist by gender, age, location, and race. A higher mortality burden was experienced by males, older persons, non-urban groups, and specific geographic areas. Targeted public health initiatives, better access to healthcare, and early screening are essential to mitigate these disparities and lower the mortality burden even more. Better results and equitable healthcare for all communities require a multidisciplinary approach, government policies, and community health initiatives.

Declarations

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Author contributions

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Author declaration:

All authors have read and approved the final version of the manuscript. Mahnoor Fatima and Faiza Fatima have full access to all of the data in this study and takes complete responsibility for the integrity of the data and the accuracy of the data analysis.

Transparency statement:

Faiza Fatima affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned have been explained.

Ethics approval and consent to participate

The research is based on de-identified human death certificate data from the CDC WONDER database. Therefore, ethical approval was not required and consent of the participants was not applicable.

Consent for publication

Not applicable.

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Conflict of interest

All authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The datasets generated during and analyzed during the current study are available in the CDC WONDER Database, <https://wonder.cdc.gov/mcd.html>

Declaration of Generative AI and AI-assisted Technologies in the Writing Process:

The authors did not use any generative AI and AI-assisted technologies in the writing process.

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Not applicable.

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Figures

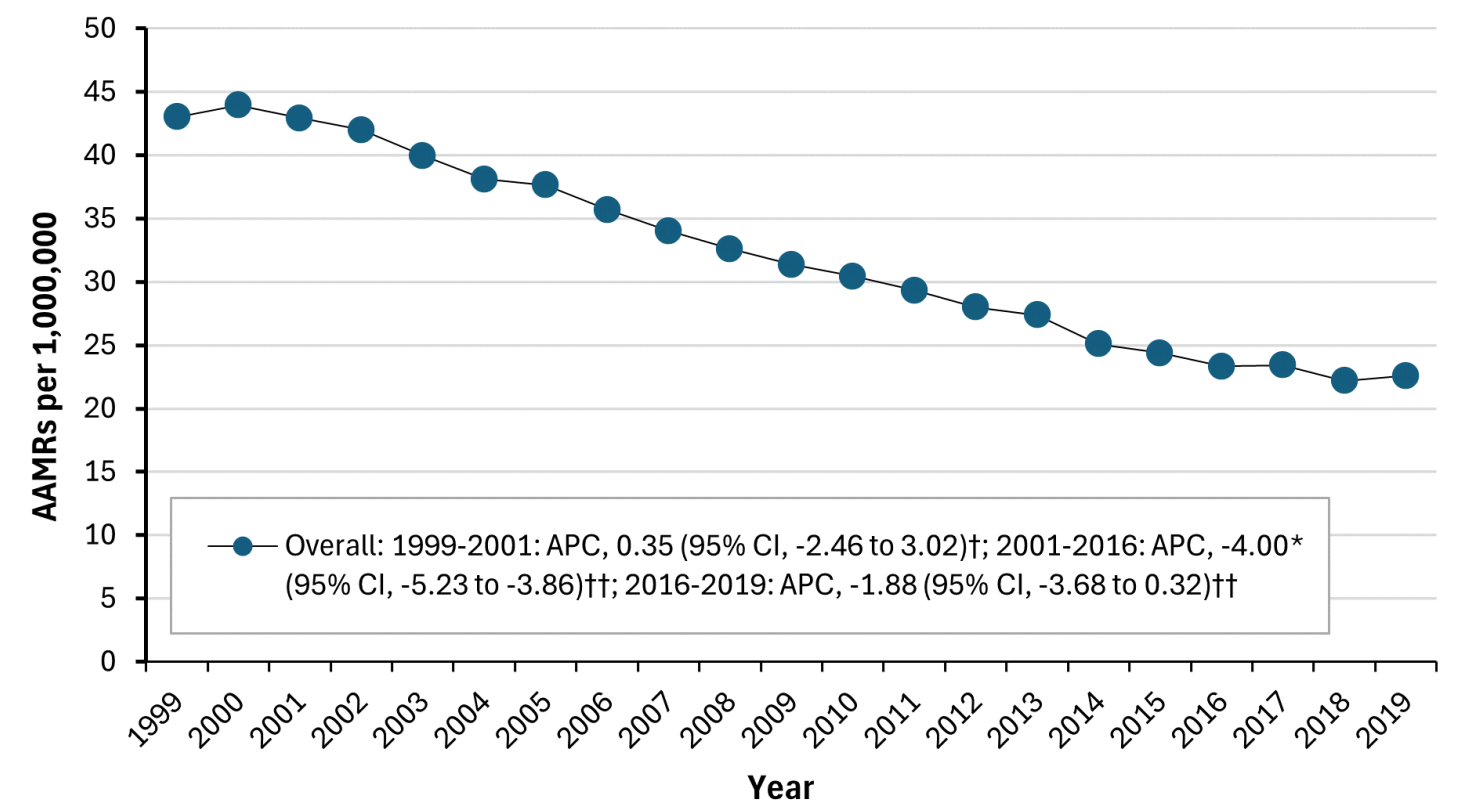


Figure 1

Overall Trend in Age-adjusted Mortality Rates per 1,000,000 for Cardiomyopathy and Diabetes Mellitus in Adults in the United States, 1999 to 2019; † indicates an increasing trend in mortality; †† indicates a decreasing trend in mortality; * indicates the value significantly differs from zero at alpha = 0.05

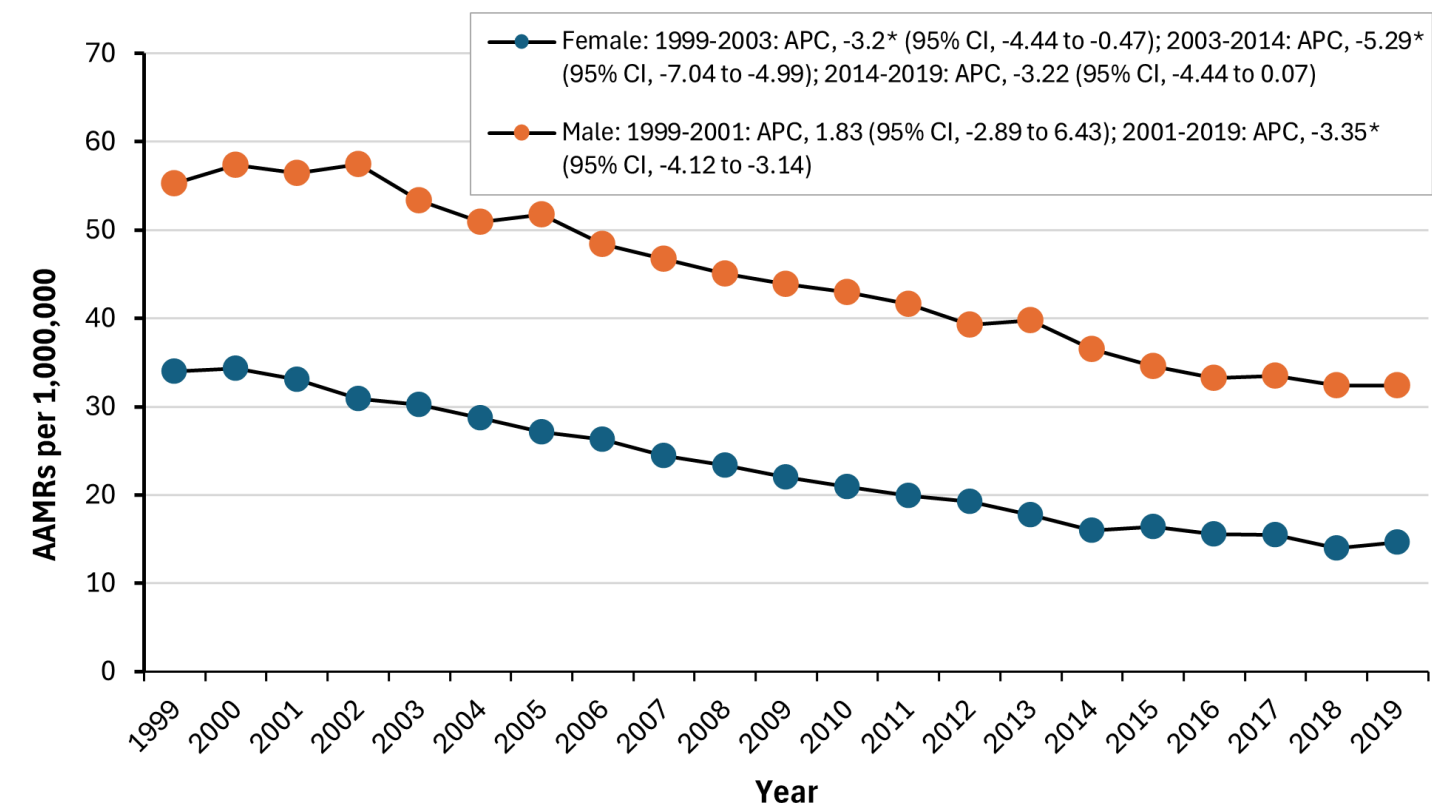


Figure 2

Sex-stratified Trends in Age-adjusted Mortality Rates per 1,000,000 for Cardiomyopathy and Diabetes Mellitus in Adults in the United States, 1999 to 2019; † indicates an increasing trend in mortality; †† indicates a decreasing trend in mortality; * indicates the value significantly differs from zero at alpha = 0.05

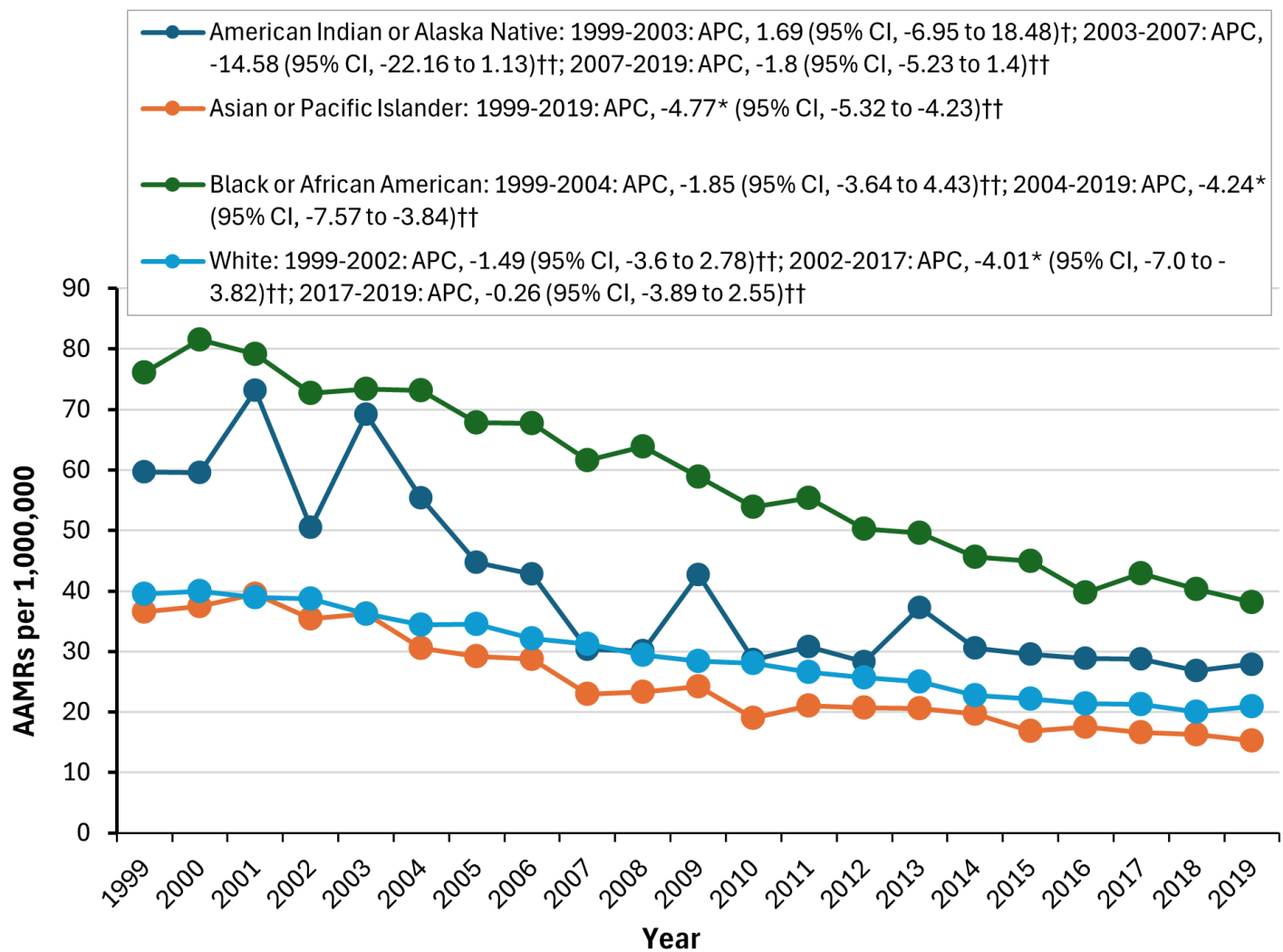


Figure 3

Race-stratified Trends in Age-Adjusted Mortality Rates per 1,000,000 for Cardiomyopathy and Diabetes Mellitus in Adults in the United States, 1999 to 2019; † indicates an increasing trend in mortality; †† indicates a decreasing trend in mortality; * indicates the value significantly differs from zero at alpha = 0.05

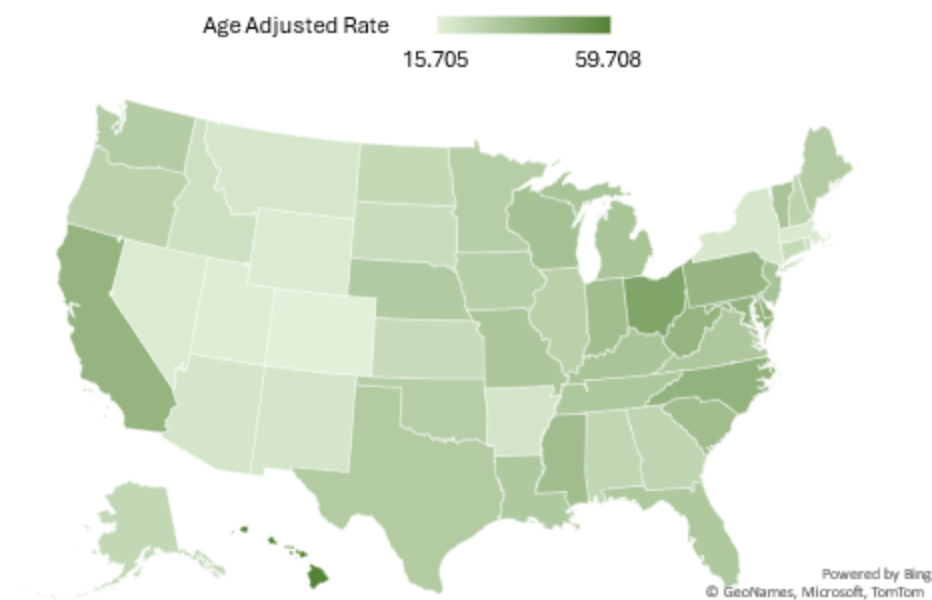


Figure 4

Heatmap depicting Age-adjusted Mortality Rates per 1,000,000 for Cardiomyopathy and Diabetes Mellitus in Adults in the United States, 1999-2019

Supplementary Files

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