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Research paper

Heart disease and heart failure: Trends and disparities in mortality rates in the United States from 2000 to 2020

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ABSTRACT

Study objective: To describe the age, sex and racial disparities in mortality rates for heart disease (HD) and heart failure (HF) in the United States (US) between 2000 and 2020.
Design: This was an ecological study with trend analysis of mortality rates.
Setting: United States.
Participants: Adults aged 18 years and above.
Main outcomes measures: Mortality rates per 100,000 for HD and HF.
Results: There was a significant decrease in the age-standardized mortality rate for HD over the past two decades (from 343.5 per 100,000 cases to 215.1 per 100,000 cases, $p < 0.001$). HD mortality rates were significantly higher in males ($p < 0.001$), non-Hispanic blacks ($p < 0.001$) and in adults aged 65+ ($p < 0.001$) and 75+ ($p < 0.001$). There was no significant change in the age-standardized mortality rate for HF (from 26.9 per 100,000 cases to 25.7 per 100,000 cases ($p = 0.706$)) due to a reversal in the trend beyond 2011. Though the HF mortality rates were significantly lower in males ($p = 0.001$), and not significantly different in non-Hispanic blacks and non-Hispanic whites, there were shifts in trends beyond 2016, with higher rates in males and in non-Hispanic blacks compared to non-Hispanic whites.
Conclusions: In summary, this study underscores significant reductions in heart disease mortality rates over the past two decades, alongside persistent disparities among different demographic groups. It also highlights emerging trends in heart failure mortality rates in particular population subgroups in recent years, necessitating further exploration to inform targeted interventions and policies.

1. Introduction

Heart disease (HD), a term encompassing various heart-related conditions, remains the leading cause of death for both men and women in the United States (US) [1]. In 2021 alone, nearly 700,000 people died from heart disease, accounting for 1 in every 5 deaths [1]. Heart diseases also pose a significant economic burden on the healthcare system [1,2]. Among the different types of heart disease, coronary artery disease is the most prevalent, affecting approximately 7.2 % of US adults [1]. In addition, according to the National Centers for Disease Control and Prevention (CDC), approximately 6.2 million adults in the US suffer from heart failure [3]. In fact, heart failure was listed as the cause of death on 13.4 % of all death certificates in 2018, underscoring its substantial impact on healthcare [3].

Fortunately there has been a remarkable decline in the overall prevalence and mortality rates of cardiovascular diseases (CVD) in the US over the past few decades [4,5]. This encouraging trend can be attributed to a reduction in major risk factors and significant advancements in treatment options for these conditions. However, this decline in mortality rates has not been consistent across all age groups, sexes, races, and types of cardiovascular diseases. There are increasing concerns about a deceleration or even a reversal of this positive trend in certain population groups. Various studies examining different cohorts have reported conflicting findings regarding mortality rates among

Abbreviations: CDC, Centers for Disease Control and Prevention; CVD, cardiovascular diseases; HD, heart disease; HF, heart failure; ICD, The International Classification of Diseases; NVVS, National Vital Statistics System; US, United States.

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distinct population groups. For instance, some studies have identified Black adults as having the highest risk of death and/or hospitalization from heart failure, while Hispanic patients have a higher risk of hospitalization compared to White patients [6–8]. On the other hand, some studies have actually found lower rates of death from heart failure in Black and Hispanic patients compared to their White counterparts [9]. However, these studies were conducted in different populations with different characteristics, locations and sizes and over different time periods, highlighting the need for larger studies on the actual national trends over longer time periods. At the national level, the study by Sidney *et al* highlighted the increased number of heart disease deaths in adults aged 65 years and above between 2011 and 2017, as opposed to the declining heart disease mortality rate in the general population, despite the substantial increased population growth rate in the 65+ years age group [10]. Identifying actual disparities in health outcomes across different population demographics is therefore important and sets the foundation to explore factors which may contribute to these differing outcomes.

Given the conflicting results from these diverse study cohorts and observed trends in prior studies, this study aimed to address these reported discrepancies in mortality rates for heart disease and heart failure across age groups, sexes and races by presenting overall national data over a significantly longer period. We therefore comprehensively analyzed and presented the actual national trends and disparities in heart disease and heart failure mortality across these specific subpopulations over the past two decades. This study specifically sought to describe the trends in heart disease and heart failure mortality in the US from 2000 to 2020, specifically focusing on age, sex, and race.

2. Materials and methods

2.1. Study design and data sources

This was an ecological study with trend analysis of the mortality from heart disease and heart failure in the US between 2000 and 2020. Mortality data on CVD was obtained from the National Vital Statistics System (NVSS) surveillance database of the National Centers for Disease Control and Prevention (CDC). The mortality data produced by the NVSS are collected and provided by state registries. This data are county-level national mortality and population data over several years. The data are based on death certificates of US residents which contain both demographic data and a single underlying cause of death (with ICD-10 codes) and up to twenty additional multiple causes. According to the CDC, race and ethnicity are collected by self-report, which in the case of deaths is recorded by funeral directors "based on information provided by an informant or by observation" [11]. Heart disease and heart failure were defined according to indicator definitions of the division for heart disease and stroke prevention of the CDC [12]. Heart disease was defined according to the ICD-10, I00-I78 codes. Heart failure was defined according to the ICD-10: I50 code.

2.2. Data management and analysis

Data was exported from the database source to an excel sheet. The exported data included information on mortality of heart disease and heart failure, categorized by age groups, sex, and race. Races were grouped into Hispanic, non-Hispanic blacks, non-Hispanic whites and other races. The data was exported to STATA 17 (STATA Corp, College Station, TX) for analysis. The two main outcomes of interest were the age-standardized mortality rate per 100,000 cases for heart disease and heart failure respectively. Mortality rates for heart disease were calculated as the number of adults aged 18+ who died with heart disease listed as the underlying cause of death, divided by the number of adults (18+) per 100,000. Likewise, Mortality rates for heart failure were calculated as the number of adults aged 18+ who died with heart failure listed as the underlying cause of death, divided by the number of adults aged 18+, per 100,000.

To visualize the trends in mortality rates over time for these two outcomes, graphs were plotted. To evaluate the trends in mortality rates over time for both heart disease and heart failure, linear-by-linear trends test and negative binomial regression models we used. Within these models, groups were compared using likelihood ratios and the Wald-Chi [2] test. The goodness of fit of the models was assessed using the pseudo-R [2]. Additionally, the Mann-Kendall test for trends was applied to evaluate non-linear trends, and the corresponding Kendall's tau-b correlation coefficient was reported. Linear regression analyses were conducted to assess significant linear trends and associations and generate regression equations. Statistical significance was considered for p-values <0.05.

2.3. Ethical considerations and reporting

This was an analysis of publicly available disease surveillance data and ethical approval was therefore not required. The 'Strengthening the Reporting of Observational studies in Epidemiology' (STROBE) guidelines were used for the reporting of this study (Supplemental file 1).

3. Results

Table 1 summarizes the age-standardized mortality rates per 100,000 cases for the two outcomes, heart disease and heart failure. There was a general downtrend in the age-standardized mortality for heart disease over the past two decades, but not so for heart failure (Fig. 1).

3.1. Heart disease

Mortality from HD significantly decreased from 343.5 per 100,000 cases in 2000 to 215.1 per 100,000 cases in 2020 ($p < 0.001$, K tau-b correlation coefficient $= -0.95$) (Table 1).

Across sexes, there was a significant reduction in mortality rates from 2000 to 2020. Mortality rates decreased from 381.3 to 259.1 per

Table 1
Age-standardized mortality rates per 100,000 for heart disease and heart failure in the United States from 2000 to 2020.

Year	Age-standardized mortality per 100,000 cases	
	Heart disease	Heart failure
2000	343.5	26.9
2001	334.3	27.2
2002	327.9	26.7
2003	316	26.6
2004	295.9	26
2005	290.6	26.3
2006	276.7	26.5
2007	261.7	24
2008	255.3	23.5
2009	241.9	22.7
2010	233.8	22.4
2011	227.5	22
2012	223	22.2
2013	221.7	23.3
2014	217.4	23.8
2015	218.6	25.4
2016	214	25.8
2017	212.7	25.8
2018	210.5	26.1
2019	207	26.3
2020	215.1	25.7
P linear	<0.001	0.276
NB p value	<0.001	0.706
(Pseudo R2)	0.2336	0.0013
K tau-b	−0.9524	−0.2775
p value	<0.001	0.085

NB – negative binomial.

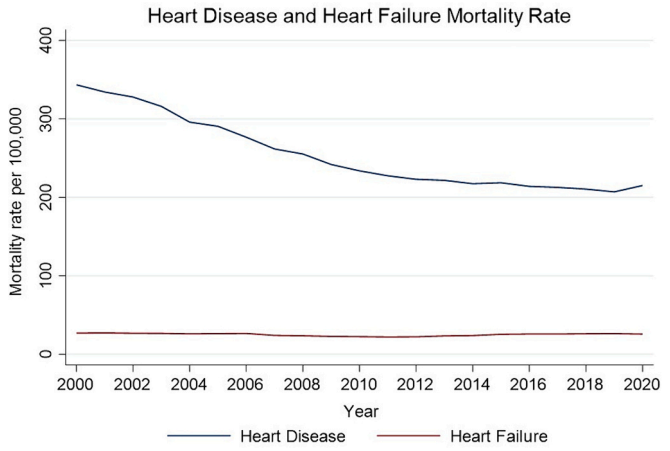

Fig. 1. Age-standardized mortality rate per 100,000 for heart disease and heart failure in the United States from 2000 to 2020.

100,000 cases in males ($p < 0.001$, K tau-b = −0.90) and from 311.4 to 176.1 per 100,000 cases in females ($p < 0.001$, K tau-b = −0.97) (Table 2). Mortality rates were significantly higher in males compared to females ($p < 0.001$, $R^2 = 0.92$) (Tables 2 & 3) (Fig. 2).

Across races, there was a significant decrease in mortality rates from 2000 to 2020, with mortality rates decreasing from 231.5 to 142.8 per 100,000 cases in Hispanics ($p < 0.001$, K tau-b = −0.88), from 409.4 to 278.9 per 100,000 cases in non-Hispanic blacks ($p < 0.001$, K tau-b = −0.88), from 350.7 to 223.2 in non-Hispanic whites ($p < 0.001$, K tau-b = −0.97) and from 162.9 to 117.9 per 100,000 cases in other races ($p < 0.001$, K tau-b = −0.84) (Table 4; Fig. 3). Mortality rates were significantly higher in non-Hispanic blacks ($p < 0.001$), but significantly lower in Hispanics ($p < 0.001$) and other races ($p < 0.001$), compared to non-Hispanic whites (Tables 3 & 4).

With regards to age groups, between 2000 and 2020, mortality rates significantly decreased from 494.8 to 383.3 per 100,000 cases in the 35+ years age group ($p < 0.001$, K tau-b = −0.59), from 158.5 to 148.3 per 100,000 cases in the 45–64 years age group ($p = 0.032$, K tau-b = −0.37), from 1692.9 to 1000.1 per 100,000 cases in the 65+ years age group ($p < 0.001$, K tau-b = −0.98), and 2823 to 1825.4 per 100,000 cases in the 75+ years age group ($p < 0.001$, K tau-b = −0.97) (Table 5). Mortality rates were significantly higher in the 35+ years age group ($p < 0.001$), 65+ years age group ($p < 0.001$) and 75+ years age group ($p < 0.001$), compared to the 45–64 years age group (Fig. 4) (Table 3). Comparisons with other age groups as reference group are presented in Supplementary file 2.

Table 2
Age-standardized mortality rates per 100,000 by sex for heart disease and heart failure in the United States from 2000 to 2020.

Year	Age-standardized mortality per 100,000 cases			
	Heart disease		Heart failure	
	Male	Female	Male	Female
2000	381.3	311.4	23.8	29.3
2001	369	304.5	23.9	29.7
2002	364	297	23.6	28.9
2003	350.4	286.4	23.8	28.6
2004	328.6	267.5	23.1	28.1
2005	322.6	262.7	23.4	28.5
2006	308.9	248.5	23.8	28.5
2007	293.1	234.1	21.9	25.6
2008	286	228.1	21.3	25.1
2009	274.7	213.1	21.2	23.8
2010	265.5	205.8	21.1	23.4
2011	259.4	199.4	20.7	23.1
2012	255.9	193.9	21.2	22.9
2013	256.5	191	22.6	23.8
2014	252.8	186.1	23.3	24.2
2015	253.8	187.4	25.1	25.6
2016	251	181.3	25.7	25.7
2017	250.9	179.1	26	25.5
2018	249.8	175.7	26.4	25.7
2019	246.5	171.9	26.9	25.7
2020	259.1	176.1	26.9	24.5
P linear	<0.001	<0.001	0.030	0.002
NB p value	<0.001	<0.001	0.376	0.184
(Pseudo R2)	0.1969	0.2675	0.0072	0.0159
K tau-b	−0.9048	−0.9714	0.2238	−0.4058
p value	<0.001	<0.001	0.164	0.012

NB – negative binomial.

Table 3
Linear regression coefficients for the association between heart disease, heart failure and sex, race, and age groups.

Outcome	Demographic		Coefficients (95 % CI)	p value	Adjusted R^2
Heart disease	Sex	Female	Reference	–	0.92
		Male	65.7 (55 – 76)	<0.001	
		Year	−7 (−7.8 – 6.2)		
		Constant	14,289 (12,635 – 15,943)		
	Race	Non-Hispanic Whites	Reference	–	0.94
		Non-Hispanic Blacks	42.7 (30.3–55.1)	<0.001	
		Hispanics	−100.1 (−112.5 to −87.7)	<0.001	
		Other	−136.2 (−148.6 to −123.8)	<0.001	
		Year	−5.7 (−6.5 to −5.0)		
		Constant	11,816.2 (10,362.0–13,270.4)		
	Age group	18–24 years	−135.6 (−216.3 to −54.9)	<0.001	0.97
		25–44 years	−120.7(−201.4 to −40)	<0.001	
		35+ years	257.7 (776.1–937.5)	<0.001	
		45–64 years	Reference	–	
		65+ years	1114.4 (1033.7–1195.1)	<0.001	
		75+ years	2044.9 (1964.1–2125.6)	<0.001	
		Year	−15.5 (−19.3 to −11.7)		
		Constant	31,296 (23,820.2–39,287.4)		
Heart failure	Sex	Female	Reference	–	0.23
		Male	−2.4 (−3.7 to −1.1)	0.001	
		Year	−0.04 (−0.15–0.06)		
		Constant	115 (−102.8–333.9)		
	Race	Non-Hispanic Whites	Reference	–	0.96
		Non-Hispanic Blacks	−0.5 (−1.5 to −0.5)	0.342	
		Hispanics	−14.9 (−16.0 to −13.9)	<0.001	
		Other	−18.3 (−19.3 to −17.3)	<0.001	
		Year	0.06 (0.00–0.12)		
		Constant	−95.8 (−214.4–22.8)		
	Age group	18–24 years	−5.8 (−10.7–0.8)	0.023	0.99
		25–44 years	−5.3 (−10.2 to −0.3)	0.037	
		35+ years	34.1 (29.2–39.1)	<0.001	
		45–64 years	Reference	–	
		65+ years	135.7 (130.8–140.7)	<0.001	
		75+ years	268.1 (263.1–273.0)	<0.001	
		Year	0.3 (0.08–0.55)		
		Constant	−621 (−1097.0 to −146.5)		

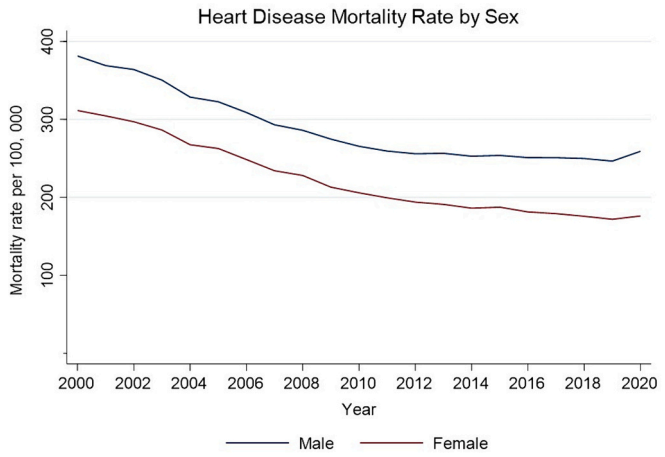

Fig. 2. Heart disease mortality rate per 100,000 by sex in the United States from 2000 to 2020.

3.2. *Heart failure*

There was no significant change in the age-standardized mortality rates of heart failure from 26.9 per 100,000 cases in 2000 to 25.7 per 100,000 cases in 2020 (p = 0.706, K tau-b correlation coefficient = −0.28) (Table 1). There was, however, a significant linear trend from 2000 to 2011 (p = 0.002) and from 2012 to 2020 (p = 0.013). Nevertheless, the change in mortality rates from 2000 to 2011 (p = 0.222, K tau-b = −0.88) and from 2012 to 2020 (p = 0.469, K tau-b = 0.75) were both non-significant.

With regards to sexes, from 2000 and 2020, there was no significant change in mortality rates in both males (23.8 to 26.9 per 100,000 cases, p = 0.376, K tau-b = 0.22) and females (29.3 to 24.5 per 100,000 cases, p = 0.184, K tau-b = −0.41) (Table 2) (Fig. 5). Mortality rates were significantly lower in males compared to females (p = 0.001, R^2 = 0.27) (Tables 2 & 3).

With regards to races, there was no significant change in mortality rates from 2000 to 2020 in Hispanics (12 to 13.5 per 100,000 cases, p = 0.516, K tau-b = 0.20), non-Hispanic blacks (27.1 to 31.3 per 100,000 cases, p = 0.573, K tau-b = 0.15), non-Hispanic whites (28.6 to 27.5 per 100,000 cases, p = 0.808, K tau-b = −0.18) and other races (8.9 to 10.6 per 100,000 cases, p = 0.324, K tau-b = 0.42) (Table 4) (Fig. 6). There was no significant difference in mortality rates between non-Hispanic whites and non-Hispanic blacks (p = 0.342), but mortality rates were significantly lower in Hispanics (p < 0.001) and other races (p < 0.001), compared to non-Hispanic whites (Table 3).

Mortality rates were significantly higher in non-Hispanic blacks (p < 0.001) but significantly lower in other races (p < 0.001) compared Hispanics (Supplementary file 2).

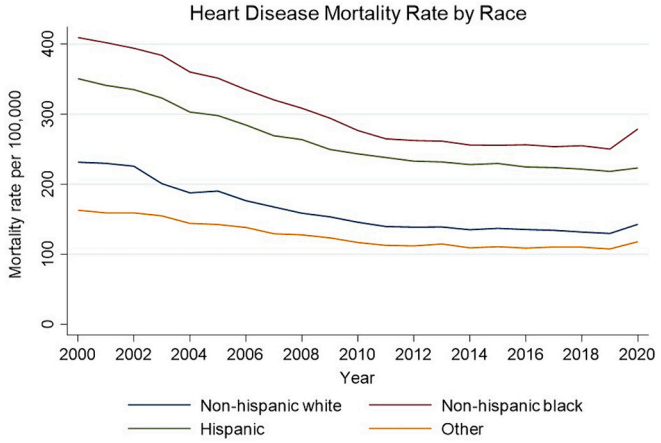

Fig. 3. Heart disease mortality rate per 100,000 by race in the United States from 2000 to 2020.

Table 4
Mortality rates per 100,000 by race for heart disease and heart failure in the United States from 2000 to 2020.

Year	Age-standardized mortality per 100,000 cases							
	Heart disease				Heart failure			
	H	NHB	NHW	O	H	NHB	NHW	O
2000	231.5	409.4	350.7	162.9	12	27.1	28.6	8.9
2001	229.8	402.1	341.1	159.1	12.1	27.5	29	7.9
2002	225.7	394.1	335	159.1	12.3	27.3	28.3	8.4
2003	200.8	383.9	323	154.8	11.9	27.4	28.2	8.3
2004	187.7	360.2	303	144.1	10.9	26.3	27.8	8
2005	190.2	351.4	298	142.5	11.7	27.6	28.1	8.4
2006	176.5	335	284.5	138.3	11.7	26.7	28.5	8.3
2007	167.5	320.4	269.2	129.3	11.5	25.6	25.7	7
2008	158.6	308.5	263.7	127.7	11.3	24.6	25.1	8
2009	153.4	294.3	249.6	123.4	10.9	23.2	24.3	7.9
2010	145.7	276.6	243.3	116.8	10.3	22.8	24.3	7.8
2011	139.6	264.8	238.1	112.7	10.8	22	23.9	7.6
2012	138.7	262.4	232.9	111.9	11.1	22.7	24	7.9
2013	139	261.5	231.8	114.7	11.1	24.3	25.2	8.5
2014	135	256	228	109.1	11.3	25.1	25.9	8.6
2015	137	255.6	229.6	110.8	12.7	27	27.6	9.1
2016	135.3	256.3	224.6	108.8	13.4	28	27.9	9.4
2017	134.2	253.6	223.8	110.3	13.2	28.4	27.9	10
2018	131.7	254.9	221.5	110.1	13.3	29.3	28.3	10.1
2019	129.7	250.2	218.3	107.6	13.6	30.1	28.4	10.2
2020	142.8	278.9	223.2	117.9	13.5	31.3	27.5	10.6
P linear	<0.001	<0.001	<0.001	<0.001	0.025	0.246	0.476	0.003
NB p value	<0.001	<0.001	<0.001	<0.001	0.516	0.573	0.808	0.324
(Pseudo R2)	0.2057	0.1897	0.2289	0.1860	0.0046	0.0028	0.0005	0.0113
K tau-b	−0.8762	−0.8762	−0.9714	−0.8353	0.2019	0.1524	−0.1762	0.4252
p value	<0.001	<0.001	<0.001	<0.001	0.215	0.349	0.2763	0.008

H – Hispanic, HF – Heart failure, MCVD – Major cardiovascular disease, NB- Negative Binomial, NHB – Non-Hispanic white, NHB – Non-Hispanic black, O - Other.

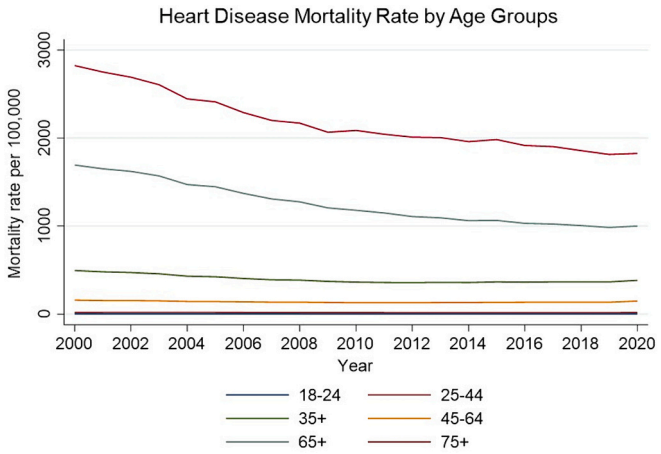

Fig. 4. Heart disease mortality rate per 100,000 by age groups in the United States from 2000 to 2020.

With regards to age groups, increases in mortality rates were only significant in the 35+ years age group (from 38.9 to 47.4 per 100,000 cases, p = 0.037), and the 75+ years age group (from 274.7 to 283.6 per 100,000 cases, p = 0.008). There was no significant change in mortality rate in the 45–64 years age group (4.8 to 9 per 100, 000 cases, p = 0.05) and 65+ years age group (149 to 139.1 per 100,000 cases, p = 0.381) (Table 5). Mortality rates were significantly higher in the 75+ years age groups (p < 0.001), 65+ years age group (p < 0.001), 35+ years age group (p < 0.001), compared to the 45–64 years age group (Table 3) (Fig. 7).

4. Discussion

This study aimed to describe the national trends and disparities in mortality rates associated with heart disease and heart failure over the preceding two decades. By presenting both outcomes, we aimed to elucidate commonalities, divergences, and potential interrelationships in their temporal trends. Our findings reveal a statistically significant decrease in overall heart disease mortality rates in the US from 2000 to 2020. However, the overall decrease in heart failure mortality rates over the same period was not statistical significance, primarily due to a reversal in the trend for heart failure from 2012 to 2019 subsequent to the initial decline from 2000 to 2011.

The observed decline in heart disease mortality rates have been attributed to improved preventive measures and control of risk factors, better diagnosis, and improved medical and surgical management options [4,5]. There have been significant advances in secondary prevention strategies following acute coronary events and also improved revascularization strategies over the years. Similarly, better control of risk factors, such as the reduction in the prevalence of smoking [4] and the management of hypertension and dyslipidemia through initiatives like the Healthy People Initiative (HPI) overseen by the US Department

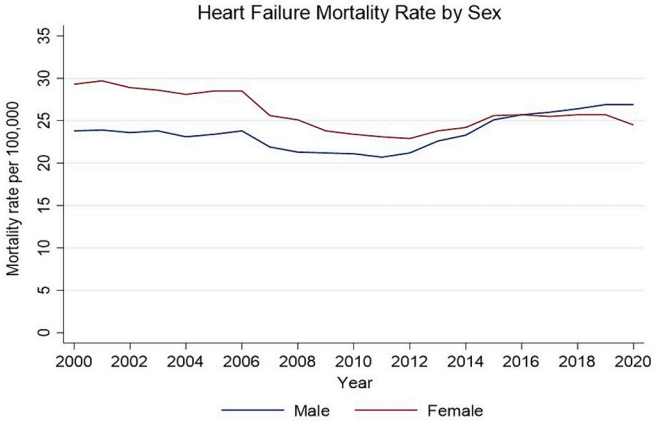

Fig. 5. Heart failure mortality rate per 100,000 by sex in the United States from 2000 to 2020.

Table 5
Mortality rates per 100,000 by age groups for heart disease and heart failure in the United States from 2000 to 2020.

Year	Crude mortality per 100,000 cases											
	Heart disease						Heart failure					
	18–24	25–44	35+	45–64	65+	75+	18–24	25–44	35+	45–64	65+	75+
2000	3	19	494.8	158.5	1692.9	2823	0.1	0.4	38.9	4.8	149	274.7
2001	2.9	19.5	480.2	153.6	1650.6	2750.1	0.1	0.5	39.2	5.2	150.5	276.2
2002	2.9	20	471.8	153.2	1621.2	2691.3	0.1	0.5	38.4	5	148.3	270.1
2003	3.2	20.2	457.7	150.1	1569.3	2605.5	0.1	0.5	38.6	5	149	270.5
2004	2.9	19.3	430.2	143.5	1471.1	2444.4	0.1	0.5	37.8	4.9	146.6	266.3
2005	3.1	19.2	423.7	142.4	1446.2	2411.1	0.1	0.5	38.5	5.1	149.1	271.3
2006	3	18.9	404.5	139.1	1371.1	2289.2	0.1	0.5	38.9	5.4	149.9	273.2
2007	3.1	18.2	389.4	135.1	1308.1	2199.9	0.1	0.5	35.9	5	137.7	251.6
2008	2.9	17.6	385.7	134.8	1274.9	2169.2	0.1	0.5	35.7	5.1	134.8	250.5
2009	2.9	17.2	371.2	131.7	1206.2	2065.4	0.1	0.5	35.1	5.1	130.6	244.7
2010	2.8	16.8	363.1	128.2	1179.2	2086.2	0.1	0.5	35.3	4.9	131.5	254.4
2011	2.7	16.9	359	127.8	1148.9	2042.9	0.1	0.5	35.3	4.9	130.1	254.4
2012	2.6	16.6	357.3	128.6	1107.8	2010	0.1	0.5	36.1	5.1	129	257.4
2013	2.5	16.3	360.6	129.8	1093.7	2005	0.1	0.5	38.6	5.7	134.2	271.2
2014	2.6	16.3	358.7	131.1	1060.9	1959.2	0.1	0.6	40.3	6.1	136.4	279.1
2015	2.7	16.5	365.8	132.7	1064.2	1982.6	0.1	0.6	43.7	6.6	145.1	299.5
2016	2.6	16.3	362.7	134	1030.6	1914.9	0.1	0.6	45	7	146	302.6
2017	2.5	16.4	365.7	134.1	1022.6	1902.6	0.1	0.7	45.7	7.2	145.2	301.6
2018	2.6	16.2	366.6	135.2	1005.7	1857	0.1	0.7	47	7.7	146	301
2019	2.4	16	365.4	134.5	983.8	1813.3	0.1	0.8	48	8.1	145.5	298.8
2020	2.4	18.3	383	148.3	1000.1	1825.4	0.1	1	47.4	9	139.1	283.6
P linear	<0.001	<0.001	<0.001	0.007	<0.001	<0.001	–	<0.001	0.002	<0.001	0.165	0.017
NB p value	0.577	0.213	<0.001	0.032	<0.001	<0.001	1.000	0.529	0.037	0.054	0.381	0.008
(Pseudo R2)	0.0051	0.0153	0.1208	0.0297	0.2416	0.1944	0.0	0.0122	0.0349	0.0464	0.0051	0.0376
K tau-b	−0.7278	−0.7286	−0.5905	−0.3714	−0.9810	−0.9714	–	0.7807	0.3667	0.6476	−0.2679	0.3007
p value	<0.001	<0.001	<0.001	0.020	<0.001	<0.001	1	<0.001	0.022	<0.001	0.096	0.061

NB – negative binomial.

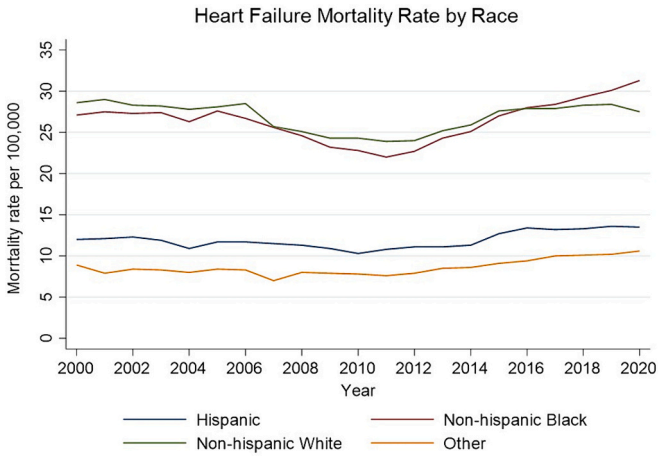

Fig. 6. Heart failure mortality rate per 100,000 by race in the United States from 2000 to 2020.

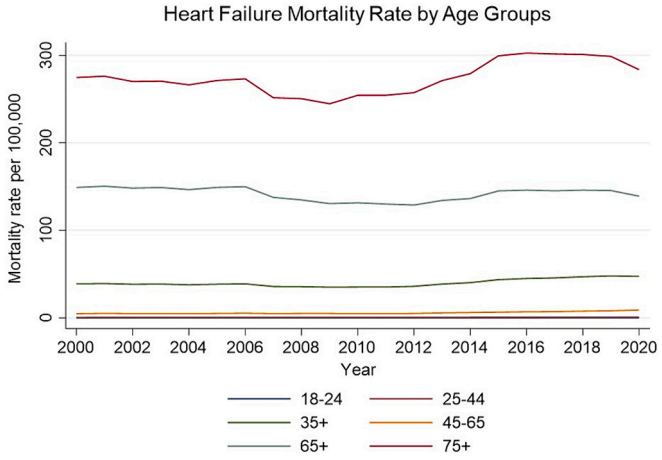

Fig. 7. Heart failure mortality rate per 100,000 by age groups in the United States from 2000 to 2020.

of Health and Human Services [13] have contributed positively to improving mortality rates. Advancements in heart disease management, particularly in coronary artery disease and acute myocardial infarction, have predominantly influenced heart disease mortality rates compared to heart failure, whose overall mortality rates have stagnated in recent decades, as observed in our study. Despite numerous therapeutic and procedural innovations, heart failure mortality rates have shown a rising trend in recent years, contrary to expectations. Some authors predict a dramatic increase in the number heart failure new diagnosis, nearing 50 % by 2030 [14]. The management of heart failure has historically focused on improving symptoms, quality of life, survival and reducing hospital admissions [15]. The past three decades have been marked by the introduction and continued evolution of guideline-directed medical therapy for heart failure [16–18]. Advances in devices for both acute and chronic heart failure including implantable cardioverter-defibrillators, cardiac resynchronization therapy, left ventricular assist devices and transvalvular pumps significantly enhanced heart failure management [18,19]. Newer devices such as the transvalvular pumps, the valve therapies, cardiac contractility modulation and splanchnic nerve modulation devices among others are gradually introduced in current clinical practice [20,21]. However, despite these advancements, the reasons for the sustained mortality rates and recent up-trends in heart failure remain unclear and warrant further investigation.

The increasing prevalence of diabetes mellitus and obesity, significant risk factors for heart failure, are believed to be the principal drivers of the worsening heart failure numbers [14,22,23]. Additionally, the improvement in survival rates of patients with other heart diseases, such as coronary artery disease and acute myocardial infarction, certainly contributes to the growing pool of patients at risk of developing heart failure in the long term.

Furthermore, demographic shifts, including the role of an aging population in the increasing prevalence and mortality rates of heart failure have been documented, with a notable increase of nearly 10 million people aged 65 and above in the US between 2011 and 2017 [10]. And as our study does show, in contrast to heart disease mortality rates which have significantly reduced in most age groups including the 65+ and 75+ years age groups, heart failure mortality rates have stagnated in the 65+ year age group, and rather been on the rise in the 75+ years age group.

Beyond these overall trends, this study also highlights the persistent disparities in these health outcomes among various population groups. Heart disease mortality rates have consistently been higher in males compared to females over the past two decades, in alignment with the concept of the male sex being an important risk factor for cardiovascular disease [24,25]. Also, the percentage reduction of heart disease mortality rates over this time period has been much lower in males compared to females. This could, at the same time, be a reflection of the positive strides of the multiple initiatives over the past decades rolled out by several stakeholders to raise awareness around cardiovascular diseases in women [26,27]. It is, nevertheless, worth noting that despite this reported higher mortality rate of heart disease in males compared to females over the preceding two decades, the absolute number of annual deaths from cardiovascular disease in females exceeded that in males since the mid-1980s [26]. This has been attributed to multiple factors including the slightly higher prevalence of CVD risk factors such as hypertension and diabetes in females [26].

In contrast to heart disease, overall heart failure mortality rates were significantly higher in females compared to males, despite the male sex being a traditional risk factor for heart failure as established from the Framingham study [28]. At the same time, it is worth noting that the mortality rate in males surpassed that in females beyond 2016, indicating a shift in trend. The reasons for this shift in trend are amenable to exploration. These differences in mortality rates between both sexes could lie in the type and etiology of the heart failure, the associated ventricular remodeling and the response to treatment among others [29,30].

Even though the overall change in heart failure mortality rates in both sexes over the past two decades was non-significant, an important finding of this study is the upward trend in heart failure mortality rates beyond 2011, which could eventually become significant with time.

Non-Hispanic blacks experienced the highest mortalities from heart disease in the US over this time, followed by non-Hispanic whites, Hispanics and then other races. Despite the significant reduction in mortality rates across all races, the percentage decline in heart disease mortality rate was the least among other races and the non-Hispanic blacks. Disparities in access to healthcare and variations in risk factors such as hypertension contribute to these differences. It is well known that the prevalence of hypertension in non-Hispanics blacks in the US is higher than in other races [31]. This discrepancy is rooted in a multitude of factors including genetic predispositions, inherent variable responses to treatment, and socio-economic factors among others [31]. Beyond the traditional risk factors for heart disease, the impact of emerging concepts such as the social determinants of health and zip code poverty are increasingly being studied [8,32].

With regards to heart failure, No significant changes in mortality rates were found among races. Even though, non-Hispanics whites had the highest overall mortality rates, no significant disparities were found between non-Hispanic whites and non-Hispanic blacks. However, heart failure mortality rates in non-Hispanic blacks have surpassed those of non-Hispanic whites since 2016, indicating a shifting trend.

Exploring disparities among states with varying healthcare coverage,

income levels, and urban and rural areas may provide further insights. However, it's important to note that individual-level inferences cannot be drawn from grouped population data. The trends observed in this study may not apply to different geographical settings. Also, the data source does not mention any changes in the definition of the outcomes, heart disease and heart failure over time, which could also affect the reported mortality rates. Despite limitations, this study provides valuable insights into national trends in heart disease and heart failure outcomes, suggesting areas for future research to better understand observed reversals in trends.

5. Conclusion

In summary, this study underscores significant reductions in heart disease mortality rates over the past two decades, alongside persistent disparities among different demographic groups. It also highlights emerging trends in heart failure mortality rates among particular population subgroups, necessitating further exploration to inform targeted interventions and policies.

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Ethical considerations and reporting

This was an analysis of publicly available disease surveillance data and ethical approval was therefore not required.

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CRediT authorship contribution statement

C.A. Dimala: Writing – review & editing, Writing – original draft, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **C. Reggio:** Writing – review & editing, Writing – original draft, Methodology, Conceptualization. **W. Khalife:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation. **A. Donato:** Writing – review & editing, Writing – original draft, Visualization, Project administration, Methodology, Conceptualization.

Declaration of competing interest

The 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.

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