Exploring Heart Failure Mortality Trends and Disparities in Women: A Retrospective Cohort Analysis

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Heart failure (HF) remains a significant cause of morbidity and mortality in women. Population-level analyses shed light on existing disparities and promote targeted interventions. We evaluated HF-related mortality data in women in the United States to identify disparities based on race/ethnicity, urbanization level, and geographic region. We conducted a retrospective cohort analysis utilizing the Centers for Disease Control and Prevention Wide-ranging Online Data for Epidemiologic Research database to identify HF-related mortality in the death files from 1999 to 2020. Age-adjusted HF mortality rates were standardized to the 2000 US population. We fit log-linear regression models to analyze mortality trends. Age-adjusted HF mortality rates in women have decreased significantly over time, from 97.95 in 1999 to 89.19 in 2020. Mortality mainly downtrended from 1999 to 2012, followed by a significant increase from 2012 to 2020. Our findings revealed disparities in mortality rates based on race and ethnicity, with the most affected population being non-Hispanic Black (age-adjusted mortality rates [AAMR] 90.36), followed by non-Hispanic White (AAMR 83.25), American Indian/Alaska Native (AAMR 64.27), and Asian/Pacific Islander populations (AAMR 37.46). We also observed that nonmetropolitan (AAMR 103.36) and Midwestern (AAMR 90.45) regions had higher age-adjusted mortality rates compared with metropolitan (AAMR 78.43) regions and other US census regions. In conclusion, significant differences in HF mortality rates were observed based on race/ethnicity, urbanization level, and geographic region. Disparities in HF outcomes persist and efforts to reduce HF-related mortality rates should focus on targeted interventions that address social determinants of health, including access to care and socioeconomic status. **(Am J Cardiol 2023;209:42−51)**

Keywords: disparities, heart failure, population, women

Heart failure (HF) is a complex and multifactorial disease that continues to pose significant therapeutic challenges for healthcare providers, despite remarkable advancements in cardiovascular disease treatment. It is a major cause of morbidity and mortality, and its burden is particularly high in women, with gender differences in incidence, prevalence, response to therapy, and clinical outcomes across the spectrum of HF subtypes and etiologies.[1,2] Some of these differences can be attributed to gender hormone fluctuations and differences, endothelial response to injury, left ventricular remodeling and hypertrophy, vascular aging, and risk factors such as aging, hypertension, obesity, and diabetes mellitus. Unfortunately, implicit bias, undertreatment, underrepresentation of women in clinical trials, and social determinants of health such as limited access to care and low socioeconomic status likely also contribute to persistent disparities in HF outcomes in women.[1,3−5] Furthermore, women of older age have a higher risk of developing HF compared with men of the same age, and advancements in therapy have led to significant survival gains that are more prominent in men and younger patients.[6,7] However, little is known about disparities and outcomes in female subpopulations. In this study, we describe trends in HF-related mortality in women in the United States from 1999 to 2020, identifying variation in HF-related mortality rates by sociodemographic factors including race/ethnicity, urbanization level, and geographic region.

Methods

We used the Centers for Disease Control and Prevention (CDC) Wide-ranging Online Data for Epidemiologic Research (WONDER) database to identify HF-related mortality in women within the United States between 1999 and 2020.[8] Specifically, we queried the database to identify death certificates with International Classification of Diseases, Tenth Revision codes I50.0 (congestive HF), 150.1 (left ventricular failure), 150.9 (HF, unspecified), I11.0 (hypertensive heart disease with congestive HF), I13.0 (hypertensive heart and renal disease with congestive HF), and I13.2 (hypertensive heart and renal disease with both

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congestive HF and renal failure) within the multiple causes of death files, similarly done by Pham et al.[9] Utilizing death certificate information offers a dependable measure of mortality counts in the United States, as the CDC WONDER database sources its data from the National Vital Statistics System. This is particularly reliable because federal law mandates the collection and publication of these statistics, resulting in the registration of over 99% of deaths in the United States in this database in 2018. Consequently, our analyses excluded any deaths that were not registered.[10]

Our objective was to investigate HF-related mortality rates in women, aiming to identify any disparities and patterns. To gather the required data, death certificates were examined for demographic information such as gender, race/ethnicity, and location of residence. The funeral director usually reported the race/ethnicity information through an informant, typically the next of kin. However, if this information was not available, it was determined based on observation. Additionally, the residence area was divided into 4 regions based on the US census regions, namely the Northeast, Midwest, South, and West. Furthermore, the metropolitan (urban) and nonmetropolitan (rural) classifications were determined according to the 2013 National Center for Health Statistics Urban-Rural Classification Scheme. This scheme classifies counties into metropolitan and nonmetropolitan areas based on population size. The metropolitan areas include large central metropolitan, large fringe metropolitan, medium metropolitan, and small metropolitan counties, whereas nonmetropolitan areas include micropolitan and noncore regions. Counties with a population of more than 50,000 are considered urban, whereas rural regions include counties with a population size lower than that. Large central metropolitan counties are those with a metropolitan statistical area (MSA) of 1 million or more people containing the entire population of a large principal city of the MSA or at least 250,000 people of any principal city of the MSA. Large fringe metropolitan are counties in MSAs that contain at least 1 million people that do not qualify as a large central metropolitan county. Medium metropolitan counties include MSAs of populations between 250,000 and 999,999, whereas small metropolitan counties have populations under 250,000. Micropolitan counties have at least one urban cluster of 10,000 to 49,999 people, and noncore counties include <10,000 residents.

We estimated crude mortality rates (CMRs) and age-adjusted mortality rates (AAMRs) per 100,000 population to determine HF-related mortality rates. The age-adjustment was standardized to the US population in the year 2000 using the direct method. We estimated 95% confidence intervals (CIs) for both CMR and AAMR. To analyze yearly mortality trends, we used Joinpoint Regression Program (Version 4.7.0.0; National Cancer Institute, Bethesda, Maryland) to identify significant changes in age-adjusted mortality over time.[11] The program fits log-linear regression models to identify joinpoints, or inflection points, in the mortality trends.[11–16] We calculated the annual percentage change using the Monte Carlo permutation test and calculated weight averages of the annual percentage change to estimate the average annual percentage change (AAPC).[12–15] We also used this method to identify up to 4 inflection points in the mortality trends from 1999 to 2020, as recommended by National Cancer Institute.[11] We used two-tailed *t* test statistics to estimate significance in the AAPCs, with a p value of less than 0.05 considered statistically significant. Data visualization was completed using Stata Statistical Software (StataCorp 2019; Release 16.1; StataCorp LLC, College Station, Texas). Institutional board review was not required for this study as the data were publicly available and deidentified.

Results

Our analysis uncovered 3,774,809 deaths related to HF in women in the United States between 1999 and 2020. The CMR increased from 120.28 (95% CI 119.71 to 120.85) in 1999 to 130.85 (95% CI 130.85 to 131.40) in 2020 with a cumulative CMR measuring 110.08 (95% CI 109.97 to 110.20). Supplementary Table 1 lists population sizes, death counts, CMR, AAMR, and corresponding 95% CIs. Figure 1 displays cumulative AAMR across US counties. Over the same period, the AAMR decreased from 97.95 to 89.19 (AAPC −0.5, 95% CI −1.1 to 0.1, p = 0.121). The cumulative AAMR from 1999 to 2020 was 82.79 (Figure 2). Inflection points are included in Supplementary Table 2.

In Hispanic populations, there were a total of 157,964 deaths. The CMR in this group increased from 29.64 in 1999 to 43.12 in 2020. However, the AAMR decreased from 70.1 in 1999 to 60.69 in 2020, resulting in an overall AAMR of 54.78 (AAPC −0.8, 95% CI −1.4 to −0.2, p = 0.009) (Figure 3). In non-Hispanic populations, there were a total of 3,610,392 deaths. The CMR in this group increased from 131.84 in 1999 to 150.15 in 2020. The AAMR decreased from 98.88 in 1999 to 91.95 in 2020, resulting in an overall AAMR of 84.55 (AAPC −0.4, 95% CI −1.0 to 0.2, p = 0.207). In Black populations, there were a total of 368,175 HF-related deaths between 1999 and 2020. The CMR increased from 80.68 in 1999 to 107.11 in 2020, whereas the AAMR decreased from 106.77 in 1999 to 105.66 in 2020 (AAPC −0.2, 95% CI −0.7 to 0.3, p = 0.377). The cumulative AAMR in Black populations was 90.36 (Figure 4). For White populations, the total death rate from 1999 to 2020 was 3,333,408, with a CMR increase from 132.52 in 1999 to 144.87 in 2020. The AAMR decreased from 97.59 in 1999 to 89.53 in 2020, with an overall AAMR of 83.25 (AAPC −0.7, 95% CI −0.9 to −0.4, p <0.001). Asian/Pacific Islander populations had a total death rate of 56,845. The CMR increased from 25.63 in 1999 to 42.16 in 2020, whereas the AAMR decreased from 49.41 in 1999 to 39.53 in 2020, with an overall AAMR of 37.46 (AAPC −1.0, 95% CI −1.5 to −0.6, p <0.001). For American Indian/Alaska Native populations, there were a total of 16,381 deaths. The CMR increased from 38.75 in 1999 to 53.28 in 2020. The AAMR decreased from 84.81 in 1999 to 67.24 in 2020, with an overall AAMR of 64.27 (AAPC −1.1, 95% CI −1.9 to −0.3, p = 0.008).

Between 1999 and 2020, a total of 2,948,670 deaths occurred in metropolitan regions. The CMR in metropolitan regions increased from 109.71 in 1999 to 121.08 in 2020, whereas the AAMR decreased from 93.23 in 1999 to 84.83 in 2020, resulting in an overall AAMR of 78.43 (AAPC −0.7, 95% CI −1.0 to −0.4, p <0.001) (Figure 5). In

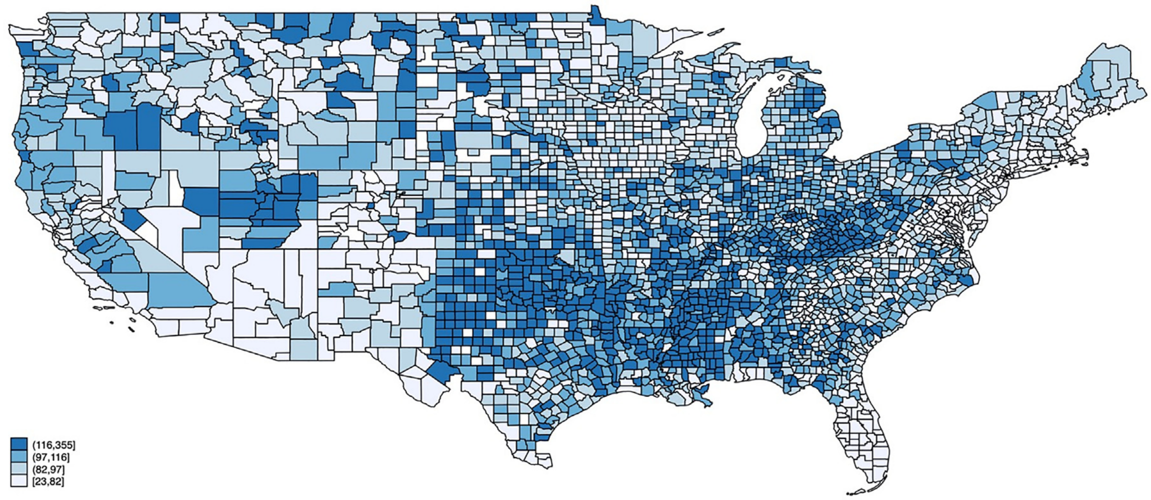

Figure 1. Chloropleth Map of AAMR in US counties. Overall US county AAMR per 100,000 population in included US counties between 1999 and 2020.

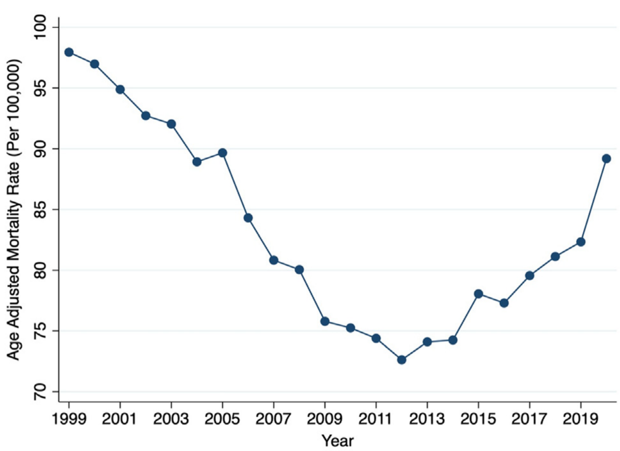

Figure 2. HF-related AAMR in the United States. Yearly connected plot of overall AAMR per 100,000 population between 1999 and 2020.

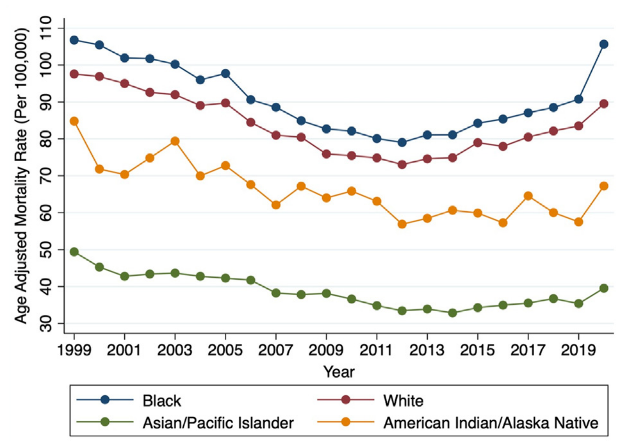

Figure 4. HF-related AAMR in the United States by race. Yearly connected plot of overall AAMR per 100,000 population between 1999 and 2020, stratified by race.

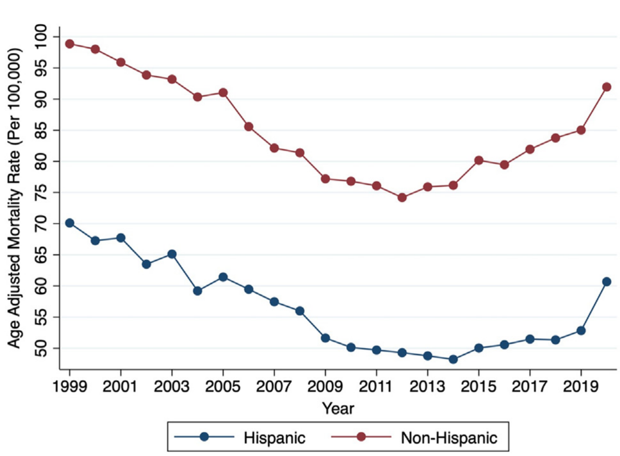

Figure 3. HF-related AAMR in the United States by ethnicity. Yearly connected plot of overall AAMR per 100,000 population between 1999 and 2020, stratified by ethnicity,

nonmetropolitan regions, there were 826,139 deaths identified between 1999 and 2020, with a CMR increase from 176.35 in 1999 to 192.20 in 2020. The AAMR decreased from 117.81 in 1999 to 112.07 in 2020, resulting in an overall AAMR of 103.36 (AAPC −0.4, 95% CI −0.8 to 0.0, p = 0.051).

Between 1999 and 2020, there were 716,759 deaths identified in the Northeast. The CMR in the Northeast increased from 125.57 in 1999 to 129.14 in 2020, whereas the AAMR decreased from 89.51 in 1999 to 75.71 in 2020, resulting in an overall AAMR of 74.14 (AAPC −1.1, 95% CI −1.4 to −0.8, p <0.001) (Figure 6). In the Midwest, a total of 968,146 deaths were identified between 1999 and 2020. The CMR in the Midwest increased from 140.36 in 1999 to 158.26 in 2020, whereas the AAMR decreased from 105.76 in 1999 to 101.82 in 2020, resulting in an overall AAMR of 90.45 (AAPC −0.5, 95% CI −0.8 to −0.1, p = 0.009). Between 1999 and 2020, there were 1,368,713 deaths identified in the South. The CMR in the South increased from 119.08 in 1999 to 129.64 in 2020, whereas

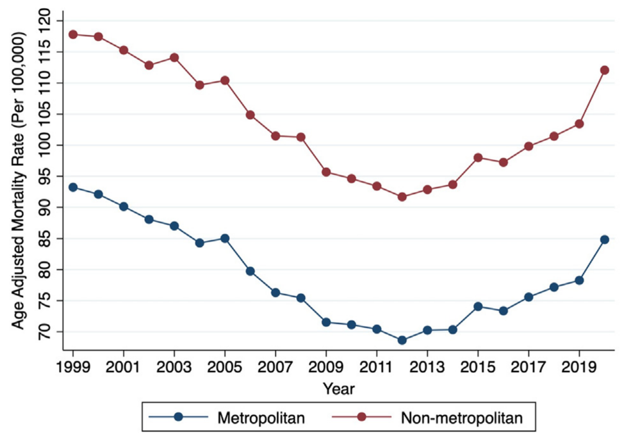

Figure 5. HF-related AAMR in the United States by urbanization. Yearly connected plot of overall AAMR per 100,000 population between 1999 and 2020, stratified by urbanization.

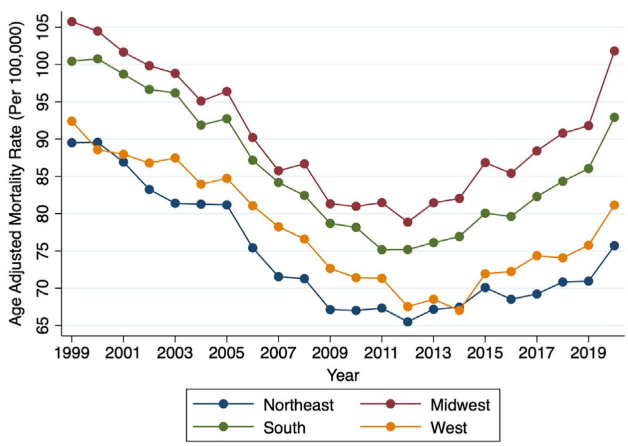

Figure 6. HF-related AAMR in the United States by census regions. Yearly connected plot of overall AAMR per 100,000 population between 1999 and 2020, stratified by US census regions.

the AAMR decreased from 100.44 in 1999 to 92.92 in 2020, resulting in an overall AAMR of 85.63 (AAPC −0.4, 95% CI −0.9 to 0.0, p = 0.065). In the West, a total of 721,191 deaths were identified between 1999 and 2020. The CMR in the West increased from 96.53 in 1999 to 110.01 in 2020, whereas the AAMR decreased from 92.40 in 1999 to 81.15 in 2020, resulting in an overall AAMR of 77.18 (AAPC −0.8, 95% CI −1.1 to −0.5, p <0.001).

Discussion

The present study aimed to investigate HF-related mortality rates and disparities in women in the United States from 1999 to 2020. Our findings revealed that the AAMR decreased from 97.95 in 1999 to 89.19 in 2020, with a cumulative AAMR of 82.79. We identified disparities in mortality rates based on race and ethnicity, with non-Hispanic Black populations most affected by the highest AAMR, followed by non-Hispanic White, American Indian/Alaska Native, and Asian/Pacific Islander populations. Nonmetropolitan and Midwestern regions were disproportionately impacted by the highest age-adjusted mortality as opposed to metropolitan regions and the other US census regions (Figure 7).

HF mortality rates have decreased overall in the past 2 decades because of advancements in pharmacologic and nonpharmacologic management. The implementation of guideline-directed medical therapy and the increased use of implantable cardioverter-defibrillator and cardiac resynchronization therapy have significantly improved overall survival and reduced the risk of sudden cardiac death.[17] However, many of these interventions are less commonly implemented in the care of women, including a less aggressive treatment approach.[7] The exact causes for the reduced implementation of therapy remain uncertain; however, they may be associated with clinical inertia, provider knowledge gaps, and affordability issues.[18] For instance, lower-income populations tend to use guideline-directed medical therapy less frequently and have a higher burden of co-morbidities. Medication costs, such as those for sodium/glucose cotransporter 2 inhibitors and sacubitril-valsartan, remain prohibitive and could be unaffordable for patients without a suitable prescription plan.[18,19] Furthermore, even for those with healthcare coverage, the additional financial barriers posed by cost-sharing may affect affordability. These challenges may result in decreased adherence to pharmacological therapy, increased morbidity, and an increase in cardiovascular events and may ultimately worsen existing disparities.[20−22]

For example, physician adherence to guideline-indicated use of inhibitors of the renin-angiotensin system, when treating women with HF is less stringent and leads to undertreatment.[1] Gender-specific susceptibilities and disparities in evidence-generation and the appropriate implementation of HF therapies are also likely to be contributing to differences in incidence, prevalence, and therapeutic response in women with HF. For example, in studies that involve patients with coronary artery disease, HF prevalence is approximately double the rate in women as compared with men.[23,24] Moreover, in the SOLVD (Studies of Left Ventricular Dysfunction) study, despite greater thromboembolic risk being independently associated with ejection fraction in women, women were less likely to be on anticoagulation.[25] Another example includes the use of implantable cardioverter-defibrillators, in which eligible women are less likely than men to receive one.[26−29] Additionally, women are underrepresented in many of the landmark clinical trials pertaining to evidence-based therapies for HF, even when these medications have been shown to be beneficial for women.[30−39]

Our study findings align with recent research that indicates no significant change in HF-related mortality rates in the early 2000s.[40] However, we found an increase in HF-related deaths since 2012, with similar trends observed in our included subpopulations. This comes amidst an upsurge in HF incidence and younger adults being hospitalized for HF.[41] Various factors could contribute to this increase in HF mortality, including an increase in cardiac and metabolic risk factors and expanded use of electronic health records to diagnose HF.[42] Since the implementation of the Affordable Care Act in 2010, notable changes have been observed in the care of HF patients. The Affordable Care Act has not only expanded healthcare access but also

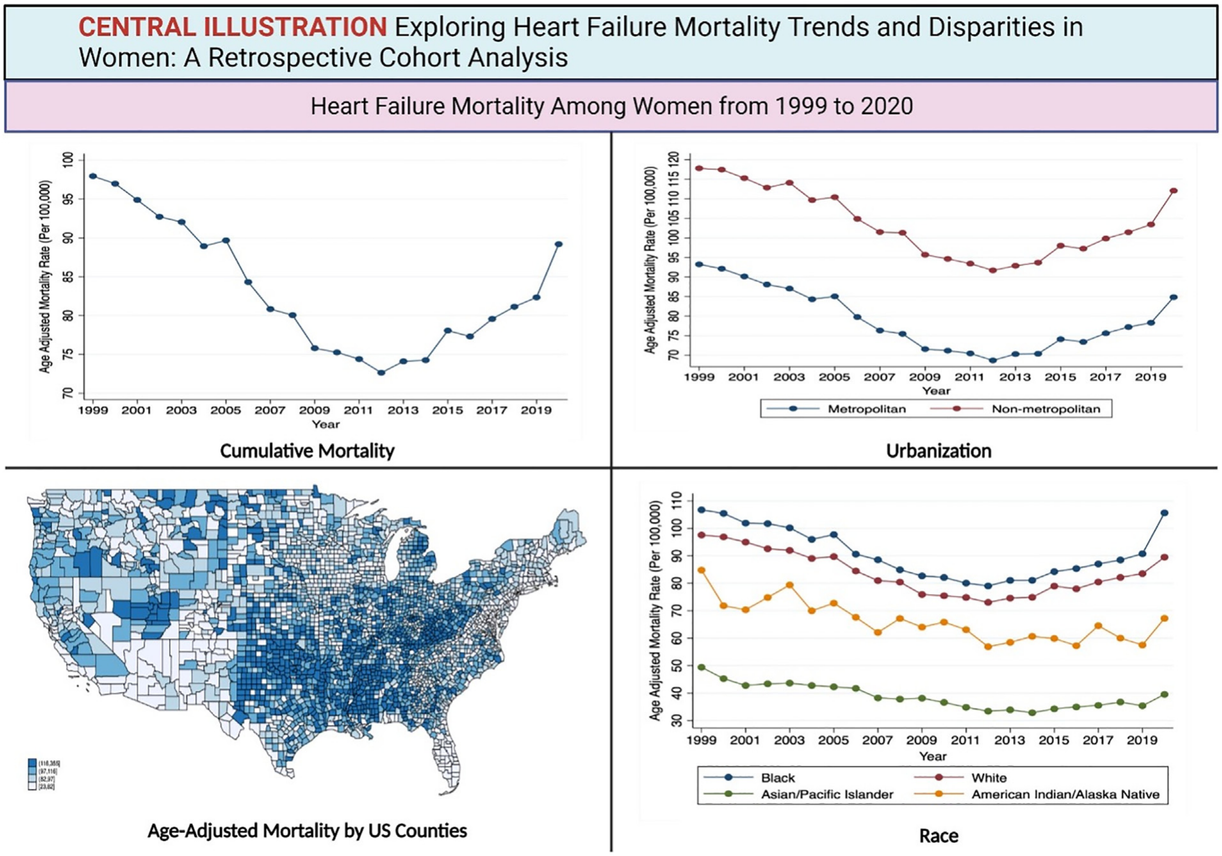

Figure 7. Central illustration.

introduced the controversial Hospital Readmissions Reduction Program.[43] There is some evidence that the implementation of Hospital Readmissions Reduction Program may have led to an unintended increase in HF mortality.[44,45] Factors such as changes in HF coding and increased use of observation units and emergency room care might also contribute to these findings.[46] Despite progress in targeted health policy interventions and better management of clinical risk during the first decade of the 2000s, our data suggest contemporary challenges in implementing these strategies.

The spike in HF mortality observed in 2020 compared with recent years may be attributed to the COVID-19 pandemic, which has profoundly disrupted cardiovascular care through various mechanisms, affecting both routine and emergency services. For instance, an international survey involving multiple countries revealed a decrease in cardiac diagnostic testing during the pandemic.[47] Moreover, lockdown measures and a general hesitancy to seek medical attention may have also contributed to the elevated mortality rates.[48] This is evidenced by a decrease in acute coronary syndrome hospitalizations, an increase in out-of-hospital cardiac arrests, longer wait times for appropriate management, and an increase in infarct size, rates of intramyocardial hemorrhage, and the extent of microvascular obstruction.[49−52]

The prevalence of cardiovascular risk factors is different in women of various races and ethnicities, with non-Hispanic Black women having the highest rates of hypertension, obesity, and diabetes mellitus.[53] This disparity is attributed to a combination of psychosocial factors. Although Asian women have the lowest prevalence of cardiovascular risk factors, South Asian women have a higher incidence of risk factors such as obesity and diabetes mellitus, which puts them at increased risk for HF.[54] Therefore, further research stratifying Asian women into subgroups may reveal different outcomes and warrant targeted interventions. Social determinants of cardiovascular disease also play a significant role in racial disparities in cardiovascular disease mortality outcomes. The CARDIA (Coronary Artery Risk Development in Young Adults Study) cohort revealed that Black populations had lower cardiovascular health scores compared with White populations, with a higher prevalence of tobacco use, less physical activity, and a less healthy diet contributing to this disparity.[55] Furthermore, a report by the American Heart Association discussed the persistently low levels of physical activity in the Black population compared with White and Asian populations. Interestingly, women of all races had lower levels of physical activity compared with men.[56]

Our findings also indicate that there are notable regional disparities in HF-related mortality, and a geographical perspective can provide insight into the impact of health policy measures. The observed differences in mortality rates across different regions could be influenced by a range of factors, such as variation in provider availability, co-

Table 1
Heart failure disparities and outcomes

Study	Year of Publication	Databases Utilized	Research Objective
Trends in Heart Failure-Related Mortality Among Older Adults in the United States From 1999-2019	2022	CDC WONDER	Assessing trends and regional differences in HF mortality among older adults
Trends in heart failure-related cardiovascular mortality in rural versus urban United States counties, 2011−2018: A cross-sectional study	2021	CDC WONDER	Quantify nationwide HF mortality trends by urbanization of residence
Mortality From Heart Failure and Dementia in the United States: CDC WONDER 1999−2016	2019	CDC WONDER	Estimate burden of mortality from HF and dementia
Epidemiology of geographic disparities in heart failure among US older adults: a Medicare-based analysis	2022	CDC WONDER	Geographic disparities in HF outcomes between US states with different life expectancies (leading/lagging states)
The contemporary trends and geographic variation in premature mortality due to heart failure from 1999 to 2018 in the United States	2021	CDC WONDER	Contemporary trends and regional variations in premature mortality due to HF
Trends and Disparities in Palliative Care Encounters in Acute Heart Failure Admissions; Insight From National Inpatient Sample	2021	National Inpatient Sample	Use of palliative care in acute HF admissions
National Differences in Trends for Heart Failure Hospitalizations by Sex and Race/Ethnicity	2017	National Inpatient Sample	Disparities in HF burden and hospital utilization by sex and race/ethnicity
Methamphetamine-Associated Heart Failure Hospitalizations Across the United States: Geographic and Social Disparities	2021	National Inpatient Sample	Characterization of methamphetamine induced HF hospitalizations
20-year trends in cause-specific heart failure outcomes by sex, socioeconomic status, and place of diagnosis: a population-based study	2019	UK Clinical Practice Research Datalink	Differences in cause specific outcomes and trends among groups with HF by various demographics
Demographic and Regional Trends of Heart Failure-Related Mortality in Young Adults in the US, 1999-2019	2022	CDC WONDER	Trends in HF mortality in young adults
Trends in Place of Death for Cardiovascular Mortality Related to Heart Failure in the United States From 2003 to 2017	2020	CDC WONDER	Trends in location of death for HF related deaths
Trends in HF Hospitalizations Among Young Adults in the United States From 2004 to 2018	2022	National Inpatient Sample	Trends in HF hospitalizations among young adults
Mortality Among Patients Hospitalized With Heart Failure and Diabetes Mellitus: Results From the National Inpatient Sample 2000 to 2010	2016	National Inpatient Sample	Trends in hospitalizations and in-hospital mortality among patients with HF and DM
Trends in Characteristics and Outcomes in Primary Heart Failure Hospitalizations Among Older Population in the United States, 2004 to 2018	2022	National Inpatient Sample	Trends in clinical outcomes and economic burden of HF hospitalizations in older patients
Trends in hospitalizations for heart failure, acute myocardial infarction, and stroke in the United States from 2004 to 2018	2022	National Inpatient Sample	Trends in hospitalizations for HF, acute myocardial infarction, and stroke
Trends in 30- and 90-day Readmission Rates for Heart Failure	2021	National Readmission Database	Temporal trends of HF readmission rates
Trends and Characteristics of Hospitalization for Heart Failure in the United States from 2004 to 2018	2022	National Inpatient Sample	Trends and characteristics of HF related hospitalizations
Trends in Heart Failure Hospitalizations in the US from 2008 to 2018	2022	National Inpatient Sample	Trends in HF related hospitalizations
Characteristics, trends, outcomes, and costs of stimulant-related acute heart failure hospitalizations in the United States	2021	National Inpatient Sample	Trends of stimulant related HF hospitalizations and associated outcomes
Trends of Clinical Outcomes and Health Care Resource Use in Heart Failure in the United States	2020	National Inpatient Sample	Trends of comorbidities, inpatient mortality, and healthcare resource use in patients admitted with acute HF
Trends in Hospital Admissions for Systolic and Diastolic Heart Failure in the United States Between 2004 and 2017	2022	National Inpatient Sample	Trends in outcomes and costs regarding hospitalizations for systolic and diastolic HF

(*continued*)

Table 1 (***Continued***)

Study	Year of Publication	Databases Utilized	Research Objective
National Trends in Incidence and Outcomes of Patients With Heart Failure Requiring Respiratory Support	2019	National Inpatient Sample	Exploring respiratory support strategies among patients with HF
Heterogeneity in national U.S. mortality trends within heart disease subgroups, 2000-2015	2017	CDC WONDER	Trends in mortality attributed to major heart diseases (ischemic heart disease, HF, and others)
Trends and Predictors of Palliative Care Consultation Among Patients Admitted for LVAD: A Retrospective Analysis From the Nationwide Inpatient Sample Database From 2006-2014	2022	National Inpatient Sample	Assess the incidence, trends, and predictors of palliative care consultation in LVAD recipients
Trends in Heart Failure Hospitalizations in the US from 2008 to 2018	2022	National Inpatient Sample	Trends in hospitalization related to heart failure with reduced and preserved ejection fractions
National Trends in Admission and In−Hospital Mortality of Patients With Heart Failure in the United States (2001−2014)	2017	National Inpatient Sample	Change in trends of HF hospitalizations after publication of management guidelines
National Trends in Heart Failure Hospital Stay Rates, 2001 to 2009	2013	National Inpatient Sample	Trends in HF related hospitalization length of stay and in-hospital mortality

Recent heart failure studies evaluating disparities in prevalence, outcomes, and management using nationally representative data samples.
HF=heart failure.

morbidity burden, and individual state policies. For example, the higher mortality rates from HF in the Southern and Midwest regions as compared with the West and Northeast regions can be attributed to multiple risk factors. Higher prevalence of smoking has been observed in the Midwest and Southern states, which has been linked to coronary artery disease and higher brain natriuretic peptide levels and left ventricular mass, leading to increased left ventricular stress and thereby increasing the risk for HF.[57] Additionally, the Southern region exhibited the greatest physical inactivity followed by the Midwest.[58] Physical inactivity, particularly when linked with obesity, is associated with hemodynamic and myocardial changes that can lead to cardiac dysfunction.[59] Moreover, it can contribute to an increased predisposition to other risk factors for HF such as coronary artery disease, diabetes mellitus, hypertension, dyslipidemia, and obstructive sleep apnea.[59]

Our study has significant implications. Although previous analyses have evaluated HF mortality trends and outcome disparities using nationally representative data (Table 1), to the best of our knowledge, this is the first retrospective cohort analysis that utilizes the CDC WONDER database to evaluate HF mortality trends in only women, cumulatively and in racial, ethnic, and regional subpopulations.[41,60−85] Our results shed light on the intricacies of year-to-year variation of mortality trends in women, and overall mortality rates in certain subpopulations, and demonstrate population-level insight into the current understanding of HF mortality. Despite the overall decrease in HF mortality rates, significant disparities still exist in women based on race, ethnicity, and geography. To address this issue, future cardiovascular research needs to be more inclusive of diverse populations. It is important to note that in major HF studies, women only represented approximately a quarter of the enrolled subjects.[1] Additionally, there is a lack of prospective HF studies that only involve women.[1] Another concern is the predominance of men in heart transplant recipients, and even in the women who undergo heart transplant, mortality was higher compared with men at the 1-year period.[86] Conducting studies with a more inclusive approach to all HF participants will enable a better understanding of why HF remains a leading cause of death in women and how the subgroup differences found in this study can be minimized for equitable cardiovascular disease health outcomes.

This study is not without limitations. First, this is a retrospective cohort analysis that utilizes data from a publicly available database. Our data query included information received from death certificates across the United States, which are subjected to misclassification. Secondly, given the design of our study, although we can determine mortality trends and compare age-adjusted mortality in subpopulations, we cannot determine causality. Thirdly, our study did not take into account other possible covariates that may have an impact on HF mortality, and the results may possibly be influenced by confounders. However, despite these limitations, the sample size and the robust capture of mortality data across the United States strengthens the validity of our study.

In conclusion, HF-related mortality rates in women in the United States remain a significant public health challenge despite notable advances in cardiovascular disease treatment. Our analysis showed that HF disproportionately affects women of certain racial and ethnic populations, with higher mortality rates in nonmetropolitan regions. The identification of such disparities highlights the need for targeted interventions to address the underlying factors contributing to persistent disparities in HF outcomes.

Declaration of Competing Interest

Dr. Martyn serves as an advisor or receives consulting fees from Recora Health, Cleveland Clinic/American Well Joint Venture, Synkopi Inc., and receives grant support from Ionis Therapeutics/AstraZeneca related to amyloidosis. The remaining authors have no competing interests to declare.

Supplementary materials

Supplementary material associated with this article can be found in the online version at https://doi.org/10.1016/j.amjcard.2023.09.087.

1. Bozkurt B, Khalaf S. Heart failure in women. *Methodist Debakey CardioVasc J* 2017;13:216–223.
2. DeFilippis EM, Beale A, Martyn T, Agarwal A, Elkayam U, Lam CSP, Hsich E. Heart failure subtypes and cardiomyopathies in women. *Circ Res* 2022;130:436–454.
3. He J, Ogden LG, Bazzano LA, Vupputuri S, Loria C, Whelton PK. Risk factors for congestive heart failure in US men and women: NHANES I epidemiologic follow-up study. *Arch Intern Med* 2001;161:996–1002.
4. Masoudi FA, Havranek EP, Smith G, Fish RH, Steiner JF, Ordin DL, Krumholz HM. Gender, age, and heart failure with preserved left ventricular systolic function. *J Am Coll Cardiol* 2003;41:217–223.
5. Hogg K, Swedberg K, McMurray J. Heart failure with preserved left ventricular systolic function; epidemiology, clinical characteristics, and prognosis. *J Am Coll Cardiol* 2004;43:317–327.
6. Writing Group Members, Mozaffarian D, Benjamin EJ, Go AS, Arnett DK, Blaha MJ, Cushman M, Das SR, de Ferranti S, Després JP, Fullerton HJ, Howard VJ, Huffman MD, Isasi CR, Jiménez MC, Judd SE, Kissela BM, Lichtman JH, Lisabeth LD, Liu S, Mackey RH, Magid DJ, McGuire DK, Mohler ER, Moy CS, Muntner P, Mussolino ME, Nasir K, Neumar RW, Nichol G, Palaniappan L, Pandey DK, Reeves MJ, Rodriguez CJ, Rosamond W, Sorlie PD, Stein J, Towfighi A, Turan TN, Virani SS, Woo D, Yeh RW, Turner MB, American Heart Association Statistics Committee, Stroke Statistics Subcommittee. Heart disease and stroke statistics-2016 update: a report from the American Heart Association. *Circulation* 2016;133:e38–e360.
7. Roger VL, Weston SA, Redfield MM, Hellermann-Homan JP, Killian J, Yawn BP, Jacobsen SJ. Trends in heart failure incidence and survival in a community-based population. *JAMA* 2004;292:344–350.
8. Center for Disease Control and Prevention National Center for Health Statistics. CDC Wonder: multiple cause of death 1999−2018. Available at: https://wonder.cdc.gov/mcd.html. Accessed on May 5, 2023.
9. Pham R, Gorodeski EZ, Al-Kindi S. Social vulnerability and location of death in heart failure in the United States. *Curr Probl Cardiol* 2023;48:101689.
10. Office of Disease Prevention and Health Promotion, Healthy People 2030. National Vital Statistics System - Mortality (NVSS-M). Available at: https://health.gov/healthypeople/objectives-and-data/data-sources-and-methods/data-sources/national-vital-statistics-system-mortality-nvss-m. Accessed on June 13, 2023.
11. National Cancer Institute Division of Cancer Control and Population Sciences. Joinpoint regression program. Available at: https://surveillance.cancer.gov/joinpoint/. Accessed on June 10, 2023.
12. Kim HJ, Fay MP, Feuer EJ, Midthune DN. Permutation tests for joinpoint regression with applications to cancer rates. *Stat Med* 2000;19:335–351.
13. Kim HJ, Luo J, Chen HS, Green D, Buckman D, Byrne J, Feuer EJ. Improved confidence interval for average annual percent change in trend analysis. *Stat Med* 2017;36:3059–3074.
14. Kim HJ, Yu B, Feuer EJ. Selecting the number of change-points in segmented line regression. *Stat Sin* 2009;19:597–609.
15. Clegg LX, Hankey BF, Tiwari R, Feuer EJ, Edwards BK. Estimating average annual per cent change in trend analysis. *Stat Med* 2009;28:3670–3682.
16. Yu B, Barrett MJ, Kim H-J, Feuer EJ. Estimating joinpoints in continuous time scale for multiple change-point models. *Comp Stat Data Anal* 2007;51:2420–2427.
17. Loh JC, Creaser J, Rourke DA, Livingston N, Harrison TK, Vandenbogaart E, Moriguchi J, Hamilton MA, Tseng CH, Fonarow GC, Horwich TB. Temporal trends in treatment and outcomes for advanced heart failure with reduced ejection fraction from 1993−2010: findings from a university referral center. *Circ Heart Fail* 2013;6:411–419.
18. Sandhu AT, Heidenreich PA. The affordability of guideline-directed medical therapy: cost sharing is a critical barrier to therapy adoption. *Circulation* 2021;143:1073–1075.
19. Centers for Medicare and Medicaid Services. Medicare provider utilization and payment data: part D prescriber. Available at: https://www.hhs.gov/guidance/document/medicare-provider-utilization-and-payment-data-part-d-prescriber-0. Accessed on June 14, 2023.
20. Goldman DP, Joyce GF, Zheng Y. Prescription drug cost sharing: associations with medication and medical utilization and spending and health. *JAMA* 2007;298:61–69.
21. Choudhry NK, Bykov K, Shrank WH, Toscano M, Rawlins WS, Reisman L, Brennan TA, Franklin JM. Eliminating medication copayments reduces disparities in cardiovascular care. *Health Aff (Millwood)* 2014;33:863–870.
22. Hung CL, Chao TF, Su CH, Liao JN, Sung KT, Yeh HI, Chiang CE. Income level and outcomes in patients with heart failure with universal health coverage. *Heart* 2021;107:208–216.
23. Greenland P, Reicher-Reiss H, Goldbourt U, Behar S. In-hospital and 1-year mortality in 1,524 women after myocardial infarction. Comparison with 4,315 men. *Circulation* 1991;83:484–491.
24. Fisher LD, Kennedy JW, Davis KB, Maynard C, Fritz JK, Kaiser G, Myers WO. Association of sex, physical size, and operative mortality after coronary artery bypass in the Coronary Artery Surgery Study (CASS). *J Thorac Cardiovasc Surg* 1982;84:334–341.
25. Dries DL, Rosenberg YD, Waclawiw MA, Domanski MJ. Ejection fraction and risk of thromboembolic events in patients with systolic dysfunction and sinus rhythm: evidence for gender differences in the studies of left ventricular dysfunction trials. *J Am Coll Cardiol* 1997;29:1074–1080.
26. Curtis LH, Al-Khatib SM, Shea AM, Hammill BG, Hernandez AF, Schulman KA. Sex differences in the use of implantable cardioverter-defibrillators for primary and secondary prevention of sudden cardiac death. *JAMA* 2007;298:1517–1524.
27. Hess PL, Hernandez AF, Bhatt DL, Hellkamp AS, Yancy CW, Schwamm LH, Peterson ED, Schulte PJ, Fonarow GC, Al-Khatib SM. Sex and race/ethnicity differences in implantable cardioverter-defibrillator counseling and use among patients hospitalized with heart failure: findings from the get with the guidelines-heart failure program. *Circulation* 2016;134:517–526.
28. Al-Khatib SM, Hellkamp AS, Hernandez AF, Fonarow GC, Thomas KL, Al-Khalidi HR, Heidenreich PA, Hammill S, Yancy C, Peterson ED, Get With the Guidelines Steering Committee and Hospitals. Trends in use of implantable cardioverter-defibrillator therapy among patients hospitalized for heart failure: have the previously observed sex and racial disparities changed over time? *Circulation* 2012;125:1094–1101.
29. LaPointe NM, Al-Khatib SM, Piccini JP, Atwater BD, Honeycutt E, Thomas K, Shah BR, Zimmer LO, Sanders G, Peterson ED. Extent of and reasons for nonuse of implantable cardioverter defibrillator devices in clinical practice among eligible patients with left ventricular systolic dysfunction. *Circ Cardiovasc Qual Outcomes* 2011;4:146–151.
30. Cohn JN, Tognoni G, Valsartan Heart Failure Trial Investigators. IA randomized trial of the angiotensin-receptor blocker valsartan in chronic heart failure. *N Engl J Med* 2001;345:1667–1675. https://doi.org/10.1056/NEJMoa010713.
31. Pfeffer MA, Swedberg K, Granger CB, Held P, McMurray JJ, Michelson EL, Olofsson B, Ostergren J, Yusuf S, Pocock S, CHARM Investigators and Committees. Effects of candesartan on mortality and morbidity in patients with chronic heart failure: the CHARM-Overall programme. *Lancet* 2003;362:759–766.
32. Pitt B, Poole-Wilson PA, Segal R, Martinez FA, Dickstein K, Camm AJ, Konstam MA, Riegger G, Klinger GH, Neaton J, Sharma D, Thiyagarajan B. Effect of losartan compared with captopril on mortality in patients with symptomatic heart failure: randomised trial−the losartan Heart Failure Survival Study ELITE II. *Lancet* 2000;355:1582–1587.

33. Pitt B, Remme W, Zannad F, Neaton J, Martinez F, Roniker B, Bittman R, Hurley S, Kleiman J, Gatlin M, Eplerenone Post-Acute Myocardial Infarction Heart Failure Efficacy and Survival Study Investigators. Eplerenone, a selective aldosterone blocker, in patients with left ventricular dysfunction after myocardial infarction. *N Engl J Med* 2003;348:1309–1321.
34. Pitt B, Zannad F, Remme WJ, Cody R, Castaigne A, Perez A, Palensky J, Wittes J. The effect of spironolactone on morbidity and mortality in patients with severe heart failure. Randomized Aldactone evaluation study investigators. *N Engl J Med* 1999;341:709–717.
35. Simon T, Mary-Krause M, Funck-Brentano C, Jaillon P. Sex differences in the prognosis of congestive heart failure: results from the Cardiac Insufficiency bisoprolol Study (CIBIS II). *Circulation* 2001;103:375–380.
36. Ghali JK, Piña IL, Gottlieb SS, Deedwania PC, Wikstrand JC, MERIT-HF Study Group. Metoprolol CR/XL in female patients with heart failure: analysis of the experience in Metoprolol Extended-Release Randomized Intervention Trial in Heart Failure (MERIT-HF). *Circulation* 2002;105:1585–1591.
37. Packer M, Coats AJ, Fowler MB, Katus HA, Krum H, Mohacsi P, Rouleau JL, Tendera M, Castaigne A, Roecker EB, Schultz MK, DeMets DL, Carvedilol Prospective Randomized Cumulative Survival Study Group. Effect of carvedilol on survival in severe chronic heart failure. *N Engl J Med* 2001;344:1651–1658.
38. Taylor AL, Lindenfeld J, Ziesche S, Walsh MN, Mitchell JE, Adams K, Tam SW, Ofili E, Sabolinski ML, Worcel M, Cohn JN, A-HeFT Investigators. Outcomes by gender in the African-American Heart Failure Trial. *J Am Coll Cardiol* 2006;48:2263–2267.
39. Taylor AL, Ziesche S, Yancy C, Carson P, D'Agostino R Jr, Ferdinand K, Taylor M, Adams K, Sabolinski M, Worcel M, Cohn JN, African-American Heart Failure Trial Investigators. Combination of isosorbide dinitrate and hydralazine in blacks with heart failure. *N Engl J Med* 2004;351:2049–2057.
40. Jackson SL, Tong X, King RJ, Loustalot F, Hong Y, Ritchey MD. National burden of heart failure events in the United States, 2006 to 2014. *Circ Heart Fail* 2018;11:e004873.
41. Jain V, Minhas AMK, Khan SU, Greene SJ, Pandey A, Van Spall HGC, Fonarow GC, Mentz RJ, Butler J, Khan MS. Trends in HF hospitalizations among young adults in the United States from 2004 to 2018. *JACC Heart Fail* 2022;10:350–362.
42. Gupta A, Allen LA, Bhatt DL, Cox M, DeVore AD, Heidenreich PA, Hernandez AF, Peterson ED, Matsouaka RA, Yancy CW, Fonarow GC. Association of the hospital readmissions reduction program implementation with readmission and mortality outcomes in heart failure. *JAMA Cardiol* 2018;3:44–53.
43. Wolfe JD, Joynt Maddox KE. Heart failure and the Affordable Care Act: past, present, and future. *JACC Heart Fail* 2019;7:737–745.
44. Dunlay SM, Roger VL. Understanding the epidemic of heart failure: past, present, and future. *Curr Heart Fail Rep* 2014;11:404–415.
45. Fonarow GC, Albert NM, Curtis AB, Stough WG, Gheorghiade M, Heywood JT, McBride ML, Inge PJ, Mehra MR, O'Connor CM, Reynolds D, Walsh MN, Yancy CW. Improving evidence-based care for heart failure in outpatient cardiology practices: primary results of the Registry to Improve the Use of Evidence-Based Heart Failure Therapies in the Outpatient Setting (IMPROVE HF). *Circulation* 2010;122:585–596.
46. Roger VL. The heart failure epidemic. *Int J Environ Res Public Health* 2010;7:1807–1830.
47. Einstein AJ, Shaw LJ, Hirschfeld C, Williams MC, Villines TC, Better N, Vitola JV, Cerci R, Dorbala S, Raggi P, Choi AD, Lu B, Sinitsyn V, Sergienko V, Kudo T, Nørgaard BL, Maurovich-Horvat P, Campisi R, Milan E, Louw L, Allam AH, Bhatia M, Malkovskiy E, Goebel B, Cohen Y, Randazzo M, Narula J, Pascual TNB, Pynda Y, Dondi M, Paez D, The INCAPS COVID Investigators Group. International impact of COVID-19 on the diagnosis of heart disease. *J Am Coll Cardiol* 2021;77:173–185.
48. Leong DP, Eikelboom JW, Yusuf S. The indirect consequences of the response to the COVID-19 pandemic. *J Am Coll Cardiol* 2021;77:186–188.
49. Pessoa-Amorim G, Camm CF, Gajendragadkar P, De Maria GL, Arsac C, Laroche C, Zamorano JL, Weidinger F, Achenbach S, Maggioni AP, Gale CP, Poppas A, Casadei B. Admission of patients with STEMI since the outbreak of the COVID-19 pandemic: a survey by the European Society of Cardiology. *Eur Heart J Qual Care Clin Outcomes* 2020;6:210–216.
50. Lechner I, Reindl M, Tiller C, Holzknecht M, Troger F, Fink P, Mayr A, Klug G, Bauer A, Metzler B, Reinstadler SJ. Impact of COVID-19 pandemic restrictions on ST-elevation myocardial infarction: a cardiac magnetic resonance imaging study. *Eur Heart J* 2022;43:1141–1153.
51. Chew NWS, Ow ZGW, Teo VXY, Heng RRY, Ng CH, Lee CH, Low AF, Chan MY, Yeo TC, Tan HC, Loh PH. The global effect of the COVID-19 pandemic on STEMI care: a systematic review and meta-analysis. *Can J Cardiol* 2021;37:1450–1459.
52. Baldi E, Sechi GM, Mare C, Canevari F, Brancaglione A, Primi R, Klersy C, Palo A, Contri E, Ronchi V, Beretta G, Reali F, Parogni P, Facchin F, Bua D, Rizzi U, Bussi D, Ruggeri S, Oltrona Visconti L, Savastano S, Lombardia CARe Researchers. Out-of-hospital cardiac arrest during the Covid-19 outbreak in Italy. *N Engl J Med* 2020;383:496–498.
53. Huffman MD, Berry JD, Ning H, Dyer AR, Garside DB, Cai X, Daviglus ML, Lloyd-Jones DM. Lifetime risk for heart failure among white and black Americans: cardiovascular lifetime risk pooling project. *J Am Coll Cardiol* 2013;61:1510–1517.
54. Piña IL, Jimenez S, Lewis EF, Morris AA, Onwuanyi A, Tam E, Ventura HO. Race and ethnicity in heart failure: JACC focus Seminar 8/9. *J Am Coll Cardiol* 2021;78:2589–2598.
55. Whitaker KM, Jacobs DR Jr, Kershaw KN, Demmer RT, Booth JN 3rd, Carson AP, Lewis CE, Goff DC Jr, Lloyd-Jones DM, Gordon-Larsen P, Kiefe CI. Racial disparities in cardiovascular health behaviors: the coronary artery risk development in young adults study. *Am J Prev Med* 2018;55:63–71.
56. Virani SS, Alonso A, Benjamin EJ, Bittencourt MS, Callaway CW, Carson AP, Chamberlain AM, Chang AR, Cheng S, Delling FN, Djousse L, Elkind MSV, Ferguson JF, Fornage M, Khan SS, Kissela BM, Knutson KL, Kwan TW, Lackland DT, Lewis TT, Lichtman JH, Longenecker CT, Loop MS, Lutsey PL, Martin SS, Matsushita K, Moran AE, Mussolino ME, Perak AM, Rosamond WD, Roth GA, Sampson UKA, Satou GM, Schroeder EB, Shah SH, Shay CM, Spartano NL, Stokes A, Tirschwell DL, VanWagner LB, Tsao CW, American Heart Association Council on Epidemiology and Prevention Statistics Committee and Stroke Statistics Subcommittee. Heart disease and stroke Statistics-2020 update: a report from the American Heart Association. *Circulation* 2020;141:e139–e596.
57. Kamimura D, Cain LR, Mentz RJ, White WB, Blaha MJ, DeFilippis AP, Fox ER, Rodriguez CJ, Keith RJ, Benjamin EJ, Butler J, Bhatnagar A, Robertson RM, Winniford MD, Correa A, Hall ME. Cigarette smoking and incident heart failure: insights from the Jackson Heart study. *Circulation* 2018;137:2572–2582.
58. Centers for Disease Control and Prevention. Behavioral Risk Factor Surveillance System. Available at: http://www.cdc.gov/brfss. Accessed on July 10, 2023.
59. Ebong IA, Goff DC Jr, Rodriguez CJ, Chen H, Bertoni AG. Mechanisms of heart failure in obesity. *Obes Res Clin Pract* 2014;8:e540–e548.
60. Siddiqi TJ, Khan Minhas AM, Greene SJ, Van Spall HGC, Khan SS, Pandey A, Mentz RJ, Fonarow GC, Butler J, Khan MS. Trends in heart failure-related mortality among older adults in the United States from 1999−2019. *JACC Heart Fail* 2022;10:851–859.
61. Pierce JB, Shah NS, Petito LC, Pool L, Lloyd-Jones DM, Feinglass J, Khan SS. Trends in heart failure-related cardiovascular mortality in rural versus urban United States counties, 2011−2018: a cross-sectional study. *PLoS One* 2021;16:e0246813.
62. Vuong JT, Jacob SA, Alexander KM, Singh A, Liao R, Desai AS, Dorbala S. Mortality from heart failure and dementia in the United States: CDC WONDER 1999−2016. *J Card Fail* 2019;25:125–129.
63. Yu B, Akushevich I, Yashkin AP, Yashin AI, Lyerly HK, Kravchenko J. Epidemiology of geographic disparities in heart failure among US older adults: a Medicare-based analysis. *BMC Public Health* 2022;22:1280.
64. Ghani AR, Mughal MS, Kumar S, Aslam S, Alam M, Usman MH, Mikhalkova D. The contemporary trends and geographic variation in premature mortality due to heart failure from 1999 to 2018 in the United States. *Int J Cardiol Heart Vasc* 2021;34:100812.
65. Khan MZ, Khan MU, Munir MB. Trends and disparities in palliative care encounters in acute heart failure admissions; insight from national inpatient Sample. *Cardiovasc Revasc Med* 2021;23:52–56.

66. Ziaeian B, Kominski GF, Ong MK, Mays VM, Brook RH, Fonarow GC. National differences in trends for heart failure hospitalizations by sex and race/ethnicity. *Circ Cardiovasc Qual Outcomes* 2017;10:e003552.
67. Dickson SD, Thomas IC, Bhatia HS, Nishimura M, Mahmud E, Tu XM, Lin T, Adler E, Greenberg B, Alshawabkeh L. Methamphetamine-associated heart failure hospitalizations across the United States: geographic and social disparities. *J Am Heart Assoc* 2021;10:e018370.
68. Lawson CA, Zaccardi F, Squire I, Ling S, Davies MJ, Lam CSP, Mamas MA, Khunti K, Kadam UT. 20-year trends in cause-specific heart failure outcomes by sex, socioeconomic status, and place of diagnosis: a population-based study. *Lancet Public Health* 2019;4:e406–e420.
69. Jain V, Minhas AMK, Morris AA, Greene SJ, Pandey A, Khan SS, Fonarow GC, Mentz RJ, Butler J, Khan MS. Demographic and regional trends of heart failure-related mortality in young adults in the US, 1999−2019. *JAMA Cardiol* 2022;7:900–904.
70. Chuzi S, Molsberry R, Ogunseitan A, Warraich HJ, Wilcox JE, Grady KL, Yancy CW, Khan SS. Trends in place of death for cardiovascular mortality related to heart failure in the United States from 2003 to 2017. *Circ Heart Fail* 2020;13:e006587.
71. Win TT, Davis HT, Laskey WK. Mortality among patients hospitalized with heart failure and diabetes mellitus: results from the national inpatient sample 2000 to 2010. *Circ Heart Fail* 2016;9:e003023.
72. Minhas AMK, Ijaz SH, Jamal S, Dani SS, Khan MS, Greene SJ, Fudim M, Warraich HJ, Shapiro MD, Virani SS, Nasir K, Khan SU. Trends in characteristics and outcomes in primary heart failure hospitalizations among older population in the United States, 2004 to 2018. *Circ Heart Fail* 2022;15:e008943.
73. Salah HM, Minhas AMK, Khan MS, Khan SU, Ambrosy AP, Blumer V, Vaduganathan M, Greene SJ, Pandey A, Fudim M. Trends in hospitalizations for heart failure, acute myocardial infarction, and stroke in the United States from 2004 to 2018. *Am Heart J* 2022;243:103–109.
74. Khan MS, Sreenivasan J, Lateef N, Abougergi MS, Greene SJ, Ahmad T, Anker SD, Fonarow GC, Butler J. Trends in 30- and 90-day readmission rates for heart failure. *Circ Heart Fail* 2021;14:e008335.
75. Salah HM, Minhas AMK, Khan MS, Khan SU, Ambrosy AP, Blumer V, Vaduganathan M, Greene SJ, Pandey A, Fudim M. Trends and characteristics of hospitalizations for heart failure in the United States from 2004 to 2018. *ESC Heart Fail* 2022;9:947–952.
76. Clark KAA, Reinhardt SW, Chouairi F, Miller PE, Kay B, Fuery M, Guha A, Ahmad T, Desai NR. Trends in heart failure hospitalizations in the US from 2008 to 2018. *J Card Fail* 2022;28:171–180.
77. Shetty S, Malik AH, Ali A, Yang YC, Briasoulis A, Alvarez P. Characteristics, trends, outcomes, and costs of stimulant-related acute heart failure hospitalizations in the United States. *Int J Cardiol* 2021;331:158–163.
78. Khan SU, Khan MZ, Alkhouli M. Trends of clinical outcomes and health care resource use in heart failure in the United States. *J Am Heart Assoc* 2020;9:e016782.
79. Afzal A, van Zyl J, Nisar T, Kluger AY, Jamil AK, Felius J, Hall SA, Kale P. Trends in hospital admissions for systolic and diastolic heart failure in the United States between 2004 and 2017. *Am J Cardiol* 2022;171:99–104.
80. Miller PE, Patel S, Saha A, Guha A, Pawar S, Poojary P, Ratnani P, Chan L, Kamholz SL, Alviar CL, van Diepen S, Nasir K, Ahmad T, Nadkarni GN, Desai NR. National trends in incidence and outcomes of patients with heart failure requiring respiratory support. *Am J Cardiol* 2019;124:1712–1719.
81. Sidney S, Quesenberry CP Jr, Jaffe MG, Sorel M, Go AS, Rana JS. Heterogeneity in national U.S. mortality trends within heart disease subgroups, 2000−2015. *BMC Cardiovasc Disord* 2017;17:192.
82. Quelal K, Olagoke O, Shahi A, Torres A, Ezegwu O, Golzar Y. Trends and predictors of palliative care consultation among patients admitted for LVAD: a retrospective analysis from the nationwide inpatient sample database from 2006−2014. *Am J Hosp Palliat Care* 2022;39:353–360.
83. Clark AM, DesMeules M, Luo W, Duncan AS, Wielgosz A. Socioeconomic status and cardiovascular disease: risks and implications for care. *Nat Rev Cardiol* 2009;6:712–722.
84. Akintoye E, Briasoulis A, Egbe A, Dunlay SM, Kushwaha S, Levine D, Afonso L, Mozaffarian D, Weinberger J. National trends in admission and in-hospital mortality of patients with heart failure in the United States (2001−2014). *J Am Heart Assoc* 2017;6:e006955.
85. Chen J, Dharmarajan K, Wang Y, Krumholz HM. National trends in heart failure hospital stay rates, 2001 to 2009. *J Am Coll Cardiol* 2013;61:1078–1088.
86. Taylor DO, Stehlik J, Edwards LB, Aurora P, Christie JD, Dobbels F, Kirk R, Kucheryavaya AY, Rahmel AO, Hertz MI. Registry of the International Society for Heart and Lung Transplantation: twenty-sixth official adult heart transplant report-2009. *J Heart Lung Transplant* 2009;28:1007–1022.