


ORIGINAL RESEARCH

Changing Spatiotemporal Trends in County-Level Heart Failure Death Rates in the United States, 1999 to 2018

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BACKGROUND: Amid recently rising heart failure (HF) death rates in the United States, we describe county-level trends in HF mortality from 1999 to 2018 by racial/ethnic group and sex for ages 35 to 64 years and 65 years and older.

METHODS AND RESULTS: Applying a hierarchical Bayesian model to National Vital Statistics data representing all US deaths, ages 35 years and older, we estimated annual age-standardized county-level HF death rates and percent change by age group, racial/ethnic group, and sex from 1999 through 2018. During 1999 to 2011, ~30% of counties experienced increasing HF death rates among adults ages 35 to 64 years. However, during 2011 to 2018, 86.9% (95% CI, 85.2–88.2) of counties experienced increasing mortality. Likewise, for ages 65 years and older, during 1999 to 2005 and 2005 to 2011, 27.8% (95% CI, 25.8–29.8) and 12.6% (95% CI, 11.2–13.9) of counties, respectively, experienced increasing mortality. However, during 2011 to 2018, most counties (67.4% [95% CI, 65.4–69.5]) experienced increasing mortality. These temporal patterns by age group held across racial/ethnic group and sex.

CONCLUSIONS: These results provide local context to previously documented recent national increases in HF death rates. Although county-level declines were most common before 2011, some counties and demographic groups experienced increasing HF death rates during this period of national declines. However, recent county-level increases were pervasive, occurring across counties, racial/ethnic group, and sex, particularly among ages 35 to 64 years. These spatiotemporal patterns highlight the need to identify and address underlying clinical risk factors and social determinants of health contributing to these increasing trends.

Key Words: geography ■ heart failure ■ mortality rate ■ race and ethnicity ■ trends

In the United States, heart failure (HF) death rates have recently begun to increase following a decade of declines.^{1–3} However, these national trends in HF mortality are not uniform and differ markedly by age, racial/ethnic group, and time period. Between 2000 and 2010, national HF death rates declined in older adults, but were unchanged in younger adults.^{1,2} Since 2011, concurrent with plateauing declines in heart disease death rates among adults ages 35 to 64 years,⁴ HF death rates increased across age groups and sex,

with the greatest relative increases observed among adults ages 35 to 64 years.¹

Likewise, since 2011, HF death rates have increased for all racial/ethnic groups except non-Hispanic American Indian/Alaska Native populations, with the strongest national increases among non-Hispanic Black populations.^{1–3} These increases align with longstanding racial and ethnic disparities in the underlying epidemiology of HF. HF death rates among Black populations are higher than those among White

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CLINICAL PERSPECTIVE

What Is New?

- Following many years of widespread declines in the United States, since 2011 county-level heart failure (HF) death rates have increased and become pervasive across racial/ethnic groups and sex, and particularly among ages 35 to 64 years.

What Are the Clinical Implications?

- Within the context of increasing prevalence of cardiovascular disease risk factors at younger ages, our results reinforce the urgency of primary prevention of HF by improving management of cardiovascular risk factors in young and middle-aged adults.
- The observed increases in HF mortality among those ages 65 years and older demonstrate the need for improved management and care of all adults with HF, especially given high HF death rates and increasing heart failure-related hospitalizations in older adults.

Nonstandard Abbreviations and Acronyms

CI	credible interval
HRRP	Hospital Readmissions Reduction Program
MCMC	Markov chain Monte Carlo
NCHS	National Center for Health Statistics
NVSS	National Vital Statistics System

populations, with the largest disparities occurring among younger adults.^{1–3} Younger Black populations also have higher HF prevalence and incidence than younger White populations, with the HF incidence of Hispanic populations being between that of Black and White populations.^{5–8}

HF event and death rates in the United States also differ markedly by geography.^{9–11} However, no studies have examined geographic variation in temporal trends of HF mortality. Better understanding of the intersection of HF mortality differences across time, place, and demographic group can refine our understanding of national trends and inform appropriate responses by the clinical and public health communities and policy-makers. Within this context of changing secular trends in national HF death rates and disparities in those trends across demographic groups, this article describes county-level trends in HF mortality from 1999 to 2018 by racial/ethnic group and sex for ages 35 to 64 years and 65 years and older.

METHODS

Heart Failure Mortality Data

We obtained annual HF death counts by county of residence, age group (ages 35–64 and 65 and older), racial/ethnic group, and sex from 1999 through 2018 from the National Vital Statistics System (NVSS) of the National Center for Health Statistics (NCHS). Racial/ethnic groups were defined using the standard five NCHS categories: American Indian/Alaska native, Asian/Pacific Islander, Black, Hispanic, and White. Hispanic ethnicity includes all races; all races exclude Hispanic ethnicity. Deaths from HF were defined as those for which any listed cause of death included “heart failure” (*International Classification of Diseases, Tenth Revision* [ICD-10]: I50) and the underlying cause of death was “diseases of the heart” (ICD-10: I00–I09, I11, I13, I20–I51). Nosologists consider HF to be a mediator between disease and death and not an underlying cause of death. Therefore, this definition permitted an examination of heart disease mortality related to HF while excluding deaths among individuals with HF from other causes (eg, cancer, accidents).¹²

The unit of analysis was the county. Given changes in county definitions during the study period (eg, the creation of new counties), a single set of 3136 counties was used for the entire study period. We used NCHS bridged-race estimates for annual county-level populations.

Estimating Death Rates

We estimated county-level HF death rates and 95% credible intervals (95% CIs) for ages 35 to 64 and 65 and older by racial/ethnic group and sex for the years 1999 through 2018 using a Bayesian multivariate space-time conditional autoregressive model. Details of this model have been published previously, and the model has been used extensively for heart disease and stroke mortality.^{4,13–17} Briefly, this model is based on the Besag-York-Mollié conditional autoregressive model for spatially referenced count data¹⁸ and incorporates correlation across space, time, and demographic group. By iteratively estimating parameters and borrowing strength from spatiotemporal and demographic neighbors, these models generate more precise, reliable rates, even in the presence of small case counts and small populations.^{13,19} We fit this model with a Markov chain Monte Carlo (MCMC) algorithm using user-developed code in the R programming language. HF death rates were estimated as the medians of the posterior distributions defined by the MCMC iterations. Death rates were age-standardized to the 2010 US population using 10-year age groups.

Estimating Trends in Death Rates

For each age group, we measured county-specific temporal trends by racial/ethnic group and by sex by

estimating percent change in HF death rates using log-linear regression. To account for potential nonlinearity in trends, we calculated total percent change across three 6-year intervals (1999–2005, 2005–2011, and 2011–2018). We then calculated the percentage of counties with increasing HF death rates for each interval and demographic group. All calculations used the posterior distributions of HF death rates and percent change (rather than the point estimates), thus accounting for uncertainty in the estimated percent change.

All analyses were completed in R v3.6.3. All code is available on request. Because all data are publicly available through NCHS, institutional review board approval was not required.

Inclusion Criteria

For a given demographic group within a given county to be included in this analysis, we required that the estimated rates were reliable (ie, the CI width must be less than the point estimate) and the group-specific population was >500 for at least 18 of 20 (90%) years in the study period. These inclusion criteria ensured that we reported only reliable rates in sufficiently large populations and that the same set of counties was used for the entire study period for each demographic group.

Given these criteria, included counties represented large percentages of populations and deaths for results by age group, racial/ethnic group, and sex (Tables 1 and 2, Table S1). The single exception was for American Indian/Alaska Native populations ages 65 and older, for whom only 49 counties representing 35.4% of the population and 37.4% of deaths met inclusion criteria (Table 1). Results for this group are presented in order to be complete, but should be interpreted with caution.

RESULTS

National HF Death Rates and Trends

National HF death rates (per 100 000) for ages 35 to 64 years were 14.8 (95% CI, 14.5–15.0) in 1999 and 15.4 (95% CI, 15.2–15.7) in 2018, and for ages 65 years and older were 531.6 (95% CI, 529.0–534.1) in 1999 and 425.7 (95% CI, 423.7–427.6) in 2018 (Table 3). Following declines during 1999 to 2011, national HF death rates increased during 2011 to 2018 by 34.9% (95% CI, 30.4–39.6) for ages 35 to 64 years and by 9.7% (95% CI, 6.4–13.1) for ages 65 years and older.

For both age groups, this pattern of decreasing rates followed by recent increases (Table 4, Table S1) was consistent across racial/ethnic groups and for female and male individuals, with the exception of American

Table 1. County-Level Age-Standardized Heart Failure Death Rates and Total Percent Change in Heart Failure Death Rates by Year and Age Group, United States, 1999 to 2018

	Ages 35–64 y	Ages 65 y and Older
Number of counties*	2906	2977
Percent of population included	99.3	99.9
Percent of deaths included	99.3	99.9
Median county-level rate (per 100 000) (IQR)		
1999	15.8 (11.7 to 21.3)	572.9 (496.2 to 662.4)
2005	13.9 (10.0 to 20.2)	531.1 (452.3 to 622.0)
2011	12.4 (8.8 to 17.8)	442.9 (381.8 to 513.0)
2018	16.6 (11.9 to 23.5)	476.3 (417.2 to 536.8)
Median county-level total percent change (%) (IQR)		
1999–2005	–14.1 (–24.8 to –1.1)	–9.3 (–16.2 to –1.5)
2005–2011	–12.9 (–23.1 to –1.6)	–16.8 (–23.1 to –9.9)
2011–2018	35.0 (19.1 to 52.1)	8.2 (–1.7 to 17.9)
Percent of counties with increases (95% CI)		
1999–2005	30.1 (27.0 to 33.1)	27.8 (25.8 to 29.8)
2005–2011	29.5 (25.9 to 32.9)	12.6 (11.2 to 13.9)
2011–2018	86.9 (85.2 to 88.2)	67.4 (65.4 to 69.5)

*Numbers of counties are based on inclusion criteria, which result in a common set of counties for each combination of age group and racial/ethnic group across all years. (See Methods for details.)

Indian/Alaska Native and Asian/Pacific Islander populations ages 65 years and older.

County-Level HF Death Rates and Trends by Age Group

For ages 35 to 64 years, the median county-level HF death rates decreased from 15.8 deaths per 100 000 in 1999 to 12.4 deaths per 100 000 in 2011 and increased to 16.6 deaths per 100 000 in 2018 (Table 1, Figure S1, Table S2). These median county-level rates corresponded to a median percent change of a 14.1% decrease during 1999 to 2005, a 12.8% decrease during 2005 to 2011, and a 35.0% increase during 2011 to 2018. Despite the median county-level percent change before 2011 representing an overall decrease, some counties within each interval experienced increasing HF death rates. During 1999 to 2005 and 2005 to 2011, roughly 30% of counties (30.1% [95% CI, 27.0–33.1] and 29.5% [95% CI, 25.9–32.9], respectively), experienced increasing death rates. During 1999 to 2005, increases were concentrated in the Mississippi Delta and Oklahoma; during 2005 to 2011, increases were concentrated in the South Central United States and Northern Plains. During 2011 to 2018, most counties (86.9% [95% CI, 85.2–88.2]) experienced increasing HF death rates.

Table 2. County-Level Age-Standardized Heart Failure Death Rates and Total Percent Change in Heart Failure Death Rates by Year, Age Group, and Racial/Ethnic Group, United States, 1999 to 2018

	American Indian/ Alaska Native	Asian/Pacific Islander	Black	Hispanic	White
Ages 35–64 y					
Number of counties*	325 [†]	454	1229	873	2698
Percent of population included	70.6	95.3	97.8	96.4	97.9
Percent of deaths included	77.2	95.8	98.0	96.7	97.8
Median county-level rate (per 100 000) (IQR)					
1999	15.9 (13.9 to 17.8)	6.1 (5.8 to 6.4)	33.3 (26.8 to 40.4)	10.0 (8.6 to 11.4)	14.8 (11.0 to 19.7)
2005	17.9 (15.6 to 20.5)	4.5 (4.2 to 4.8)	32.0 (24.6 to 43.0)	8.4 (7.1 to 10.1)	12.9 (9.4 to 18.3)
2011	14.8 (12.6 to 17.4)	3.5 (3.1 to 3.8)	26.7 (20.6 to 35.0)	6.8 (5.7 to 8.1)	11.7 (8.4 to 16.3)
2018	22.2 (17.4 to 26.6)	5.2 (4.7 to 5.9)	37.4 (29.5 to 45.1)	8.4 (6.8 to 10.2)	15.7 (11.2 to 21.5)
Median county-level total percent change (%) (IQR)					
1999–2005	15.1 (6.6 to 23.1)	–30.0 (–36.4 to –24.7)	–3.3 (–15.8 to 11.1)	–16.5 (–22.6 to –10.1)	–15.8 (–26.4 to –2.8)
2005–2011	–7.1 (–13.7 to –1.4)	–25.8 (–30.0 to –21.0)	–17.0 (–24.8 to –8.8)	–18.0 (–26.9 to –9.3)	–12.3 (–23.8 to 0.2)
2011–2018	52.1 (36.7 to 75.9)	43.6 (34.8 to 54.4)	40.7 (25.1 to 57.1)	26.5 (12.2 to 44.2)	33.9 (17.6 to 51.6)
Percent of counties with increases (95% CI)					
1999–2005	76.6 (60.3 to 83.1)	3.3 (0.4 to 8.4)	45.7 (40.4 to 50.8)	18.6 (12.8 to 25.1)	28.5 (24.6 to 32.4)
2005–2011	30.8 (20.3 to 47.1)	3.5 (1.5 to 10.6)	19.6 (15.2 to 26.0)	17.5 (11.2 to 28.4)	31.9 (28.5 to 36.0)
2011–2018	94.9 (91.7 to 97.5)	98.2 (90.1 to 99.6)	91.1 (88.9 to 93.5)	81.3 (76.6 to 86.3)	84.6 (82.8 to 86.3)
Ages 65 y and older					
Number of counties*	49 [†]	159	734	293	2920
Percent of population included	35.4	88.2	93.7	90.2	99.8
Percent of deaths included	37.4	90.6	92.8	91.8	99.8
Median county-level rate (per 100 000) (IQR)					
1999	387.9 (354.6 to 463.0)	238.4 (204.4 to 277.5)	480.7 (413.7 to 554.1)	354.3 (296.0 to 423.4)	582.1 (505.9 to 675.0)
2005	371.1 (275.4 to 484.6)	202.4 (173.6 to 239.8)	472.2 (387.1 to 561.6)	322.9 (259.9 to 388.2)	538.4 (460.4 to 630.3)
2011	359.0 (251.8 to 449.9)	166.5 (142.0 to 213.5)	372.5 (312.2 to 445.5)	249.9 (197.6 to 309.6)	451.6 (389.4 to 522.3)
2018	365.6 (258.9 to 415.0)	179.7 (151.8 to 215.9)	421.9 (364.0 to 484.8)	250.1 (206.5 to 320.3)	486.6 (429.6 to 550.6)
Median county-level total percent change (%) (IQR)					
1999–2005	0.3 (–8.8 to 15.4)	–14.8 (–20.3 to –8.3)	–6.2 (–14.5 to 5.4)	–12.8 (–20.9 to –3.9)	–9.5 (–16.4 to –1.3)
2005–2011	–6.8 (–12.0 to 4.1)	–14.1 (–20.9 to –7.9)	–20.6 (–28.0 to –13.0)	–20.8 (–28.5 to –14.3)	–16.4 (–22.8 to –9.4)
2011–2018	2.4 (–9.0 to 9.2)	5.1 (–4.0 to 13.9)	14.9 (3.1 to 26.6)	5.8 (–4.0 to 15.4)	8.8 (–1.0 to 18.7)
Percent of counties with increases (95% CI)					
1999–2005	55.1 (40.8 to 67.3)	16.0 (10.1 to 23.3)	39.2 (35.0 to 43.7)	23.9 (17.7 to 29.0)	28.0 (26.0 to 29.8)
2005–2011	38.8 (22.4 to 55.1)	15.7 (10.7 to 23.9)	10.1 (7.8 to 13.1)	8.5 (4.8 to 12.6)	13.5 (11.8 to 14.9)
2011–2018	53.1 (38.8 to 65.3)	59.1 (51.6 to 69.2)	75.4 (70.8 to 78.6)	62.5 (56.6 to 68.3)	68.4 (66.6 to 70.8)

*Numbers of counties are based on inclusion criteria which result in a common set of counties for each combination of age group and racial/ethnic group across all years. (See Methods for details.)

[†]As a result of inclusion criteria, very few counties were included for American Indian/Alaska Native populations, especially for ages 65 and older. These results should be interpreted with caution.

These increases occurred in counties across the country (Figure 1).

For ages 65 years and older, the median county-level HF death rates decreased from 573.0 deaths per 100 000 in 1999 to 442.9 deaths per 100 000 in 2011 and increased to 476.3 deaths per 100 000 in 2018 (Table 1, Figure S2, Table S3). These median

county-level rates corresponded to a median percent change of a 9.3% decrease during 1999 to 2005, a 16.8% decrease during 2005 to 2011, and an 8.2% increase during 2011 to 2018. Despite the median county-level percent change before 2011 representing an overall decrease, some counties within each interval experienced increasing HF death

Table 3. National Age-Standardized Heart Failure Death Rates and Total Percent Change in Heart Failure Death Rates by Year and Age Group, United States, 1999 to 2018

	Ages 35–64 y	Ages 65 and Older y
National rates (per 100 000) (95% CI)		
1999	14.8 (14.5 to 15.0)	531.6 (529 to 534.1)
2005	13.5 (13.2 to 13.7)	481.4 (479.1 to 483.7)
2011	11.5 (11.3 to 11.7)	394.1 (392.1 to 396.1)
2018	15.4 (15.2 to 15.7)	425.7 (423.7 to 427.6)
National total percent change (%) (95% CI)		
1999–2005	–11.8 (–16.4 to –7.1)	–10.9 (–13.3 to –8.4)
2005–2011	–14.9 (–18.5 to –11.1)	–18 (–21.8 to –13.9)
2011–2018	34.9 (30.4 to 39.6)	9.7 (6.4 to 13.1)

rates. During 1999 to 2005 and 2005 to 2011, 27.8% (95% CI, 25.8–29.8) and 12.6% (95% CI, 11.2–13.9), respectively, experienced increasing HF death rates. During 1999 to 2005, increases were concentrated in the Mississippi Delta and Southwest. By the most recent interval (2011–2018), most counties (67.4% [95% CI, 65.4–69.5]) experienced increasing HF death rates. Increasing HF death rates occurred in counties across the country. However, a band of counties with decreasing HF death rates was observed from Oklahoma through Georgia, and within New York (Figure 1).

County-Level HF Death Rates and Trends by Age Group and Racial/Ethnic Group

For ages 35 to 64 years, the median county-level HF death rates for all racial/ethnic groups mirrored national increases in HF death rates since 2011 (Table 2). For the duration of the study period, the distributions of county-level HF death rates for Black populations were almost completely distinct and higher than those for all other racial and ethnic groups (Table 2, Figure 2). Median county-level rates for ages 35 to 64 years ranged from ~5 per 100 000 for Asian/Pacific Islander populations to ~30 per 100 000 for Black populations. Across years and racial/ethnic groups, the highest HF death rates for ages 35 to 64 years were concentrated in New England; Wisconsin, Minnesota, and Iowa; and across the Rocky Mountains (Figure S1, Table S2).

Although Black populations had the highest county-level HF death rates throughout the study period, the percentages of counties experiencing increasing HF death rates varied by racial/ethnic group over time. Among ages 35 to 64 years in the first 2 intervals, their percentage of counties experiencing increasing HF death rates ranged from 3.3% for Asian/Pacific Islander populations to 76.6% for American Indian/Alaska Native populations, with increases concentrated in the South and West (Table 2, Figure S3). By the most recent interval (2011–2018), the prevalence of increasing HF death rates across racial/ethnic groups had converged, with

Table 4. National Age-Standardized Heart Failure Death Rates and Total Percent Change in Heart Failure Death Rates by Year, Age Group, and Racial/Ethnic Group, United States, 1999 to 2018

	American Indian/Alaska Native	Asian/Pacific Islander	Black	Hispanic	White
Ages 35–64 y					
National rates (per 100 000) (95% CI)					
1999	13.7 (10.8 to 17.1)	6.3 (5.4 to 7.2)	29.9 (28.8 to 31.1)	10.3 (9.5 to 11.1)	13.2 (12.9 to 13.4)
2005	15.9 (13.0 to 18.7)	5.2 (4.6 to 5.9)	30.1 (29.1 to 31.1)	8.9 (8.3 to 9.5)	11.5 (11.2 to 11.7)
2011	14.8 (12.3 to 17.3)	4.1 (3.6 to 4.6)	24.4 (23.5 to 25.2)	7.0 (6.6 to 7.5)	9.9 (9.7 to 10.1)
2018	22.4 (19.5 to 25.3)	6.1 (5.5 to 6.6)	33.0 (32.1 to 33.9)	8.9 (8.4 to 9.3)	12.9 (12.7 to 13.2)
National total percent change (%) (95% CI)					
1999–2005	18.4 (–1.6 to 42.3)	–24.4 (–40.1 to –4.5)	–0.6 (–5.1 to 4.1)	–14.1 (–20.5 to –7.3)	–16.0 (–20.9 to –10.8)
2005–2011	–7.4 (–19.3 to 6.4)	–19.8 (–42.9 to 12.6)	–17.9 (–21.6 to –14.1)	–21.4 (–27.7 to –14.6)	–15.0 (–19.6 to –10.2)
2011–2018	59.7 (20.4 to 111.9)	36.3 (4.9 to 77.0)	36.5 (28.5 to 45.0)	30.3 (22.2 to 38.9)	32.5 (28.4 to 36.9)
Ages 65 y and Older					
National rates (per 100 000) (95% CI)					
1999	415.1 (375.7 to 454.5)	273.9 (260.0 to 287.7)	463.2 (454.8 to 471.5)	352.6 (342.2 to 363.1)	542.7 (540.0 to 545.4)
2005	363.9 (330.2 to 397.5)	218.3 (208.4 to 228.2)	443.0 (435.0 to 450.9)	316.7 (308.2 to 325.1)	491.7 (489.2 to 494.2)
2011	343.5 (314.8 to 372.3)	182.3 (175.0 to 189.6)	345.4 (338.9 to 351.8)	248.8 (242.6 to 254.9)	405.7 (403.6 to 407.8)
2018	300.3 (279.0 to 321.5)	192.4 (186.6 to 198.2)	385.4 (379.5 to 391.4)	261.8 (256.7 to 266.9)	442.4 (440.3 to 444.5)
National total percent change (%) (95% CI)					
1999–2005	–4.1 (–19.9 to 14.7)	–17.1 (–26.2 to –6.9)	–7.0 (–11.3 to –2.5)	–12.2 (–17.5 to –6.5)	–10.9 (–13.3 to –8.3)
2005–2011	–4.0 (–12.6 to 5.6)	–16.8 (–21.0 to –12.4)	–21.3 (–25.6 to –16.8)	–22.3 (–25.5 to –19)	–17.4 (–21.4 to –13.1)
2011–2018	–7.4 (–16.5 to 2.6)	3.6 (–4.1 to 11.8)	13.2 (9.6 to 16.9)	7.2 (1.6 to 13.1)	10.8 (7.4 to 14.3)

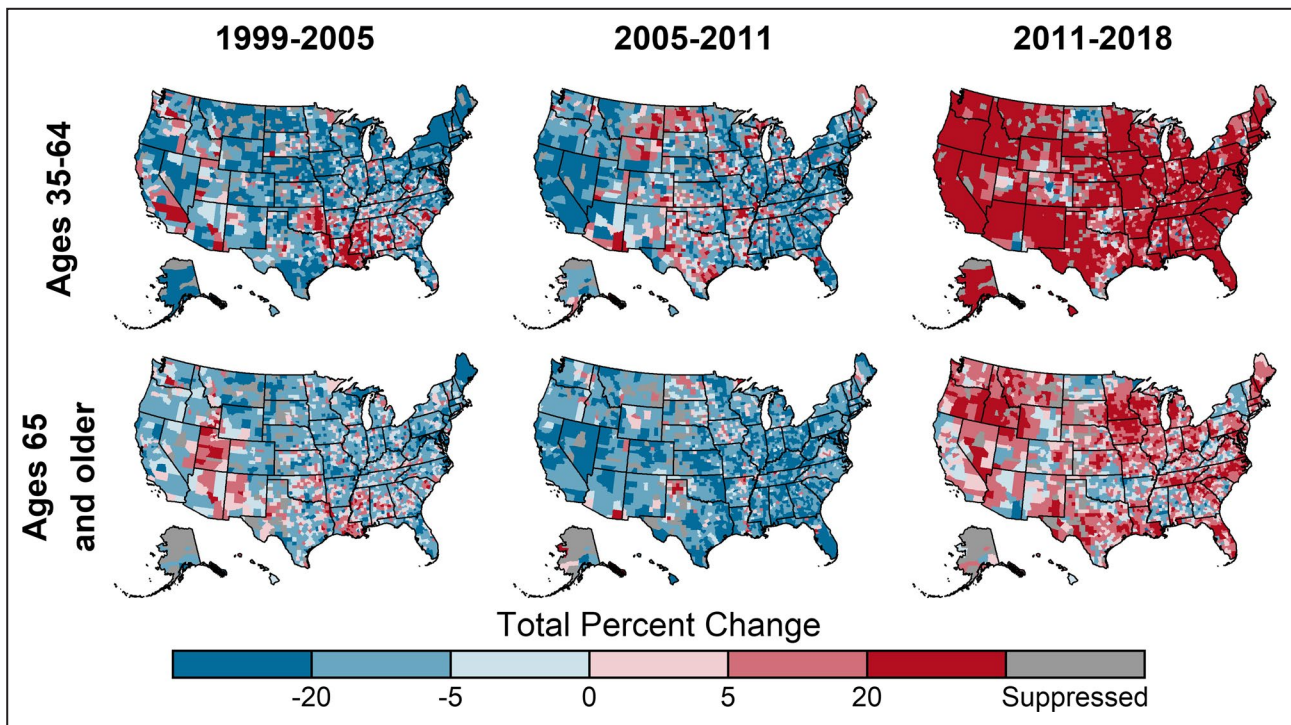


Figure 1. County-level HF death total percent change by time period and age group, United States, 1999 to 2018. Quartile ranges are shown in Table 1.

most counties and racial/ethnic groups experiencing increases (ranging from 81.3% for Hispanic populations to 98.2% for Asian/Pacific Islander populations) (Table 2, Figure 3).

For ages 65 years and older, the range of median county-level HF death rates among racial/ethnic groups varied from \approx 200 per 100 000 for Asian/Pacific Islander populations to over 500 per 100 000 for White populations (Table 2, Figure 2). The highest rates among ages 65 years and older were geographically diffuse, with concentrations in Florida and the Southwest (Figure S2, Table S3).

For ages 65 years and older, declining HF death rates were common across racial/ethnic groups in the two earliest intervals (Table 2, Figure 3), although some counties within each racial/ethnic group experienced increasing HF death rates during these intervals (ranging from 8.5% of counties for Hispanic populations to 55.1% for American Indian/Alaska Native populations). Increases prior to 2011 were concentrated in the West (Figure S4). A majority of counties for all racial/ethnic groups ages 65 years and older experienced increases in the last interval (2011–2018).

County-Level HF Death Rates and Trends by Age Group and Sex

For males and females in both age groups, geographic and temporal patterns in the median county-level rates

and trends mirrored those observed for the entire population by age group (Figures S5 and S6, Tables S1 and S4). For both males and females, less than one third of counties experienced increasing HF death rates before 2011. However, during 2011 to 2018 for ages 35 to 64 years, more than 80% of counties experienced increasing HF death rates (81.8% [95% CI, 79.8–83.5] and 87.5% [95% CI, 85.6–89.6] for females and males, respectively). For ages 65 years and older, fewer counties (but still a large majority) experienced increasing death rates (73.6% [95% CI, 71.1–75.8] and 60.7% [95% CI, 58.3–63.1] for females and males, respectively).

DISCUSSION

Our county-level analysis of HF death rates found a marked reversal of local HF death rate declines since 2011, with increases in HF death rates occurring in most counties across age, racial/ethnic group, and sex, whereas a minority of counties continued to decline. Prior to 2011, declines in heart failure death rates were geographically widespread across age, racial/ethnic groups, and sex. However, increasing rates in some counties before 2011 were masked by previous national studies and preceded recent national increases.^{1–3} Over time, these increases shifted from being more prevalent among Black populations and younger (ages 35–64 years) adults in the South and

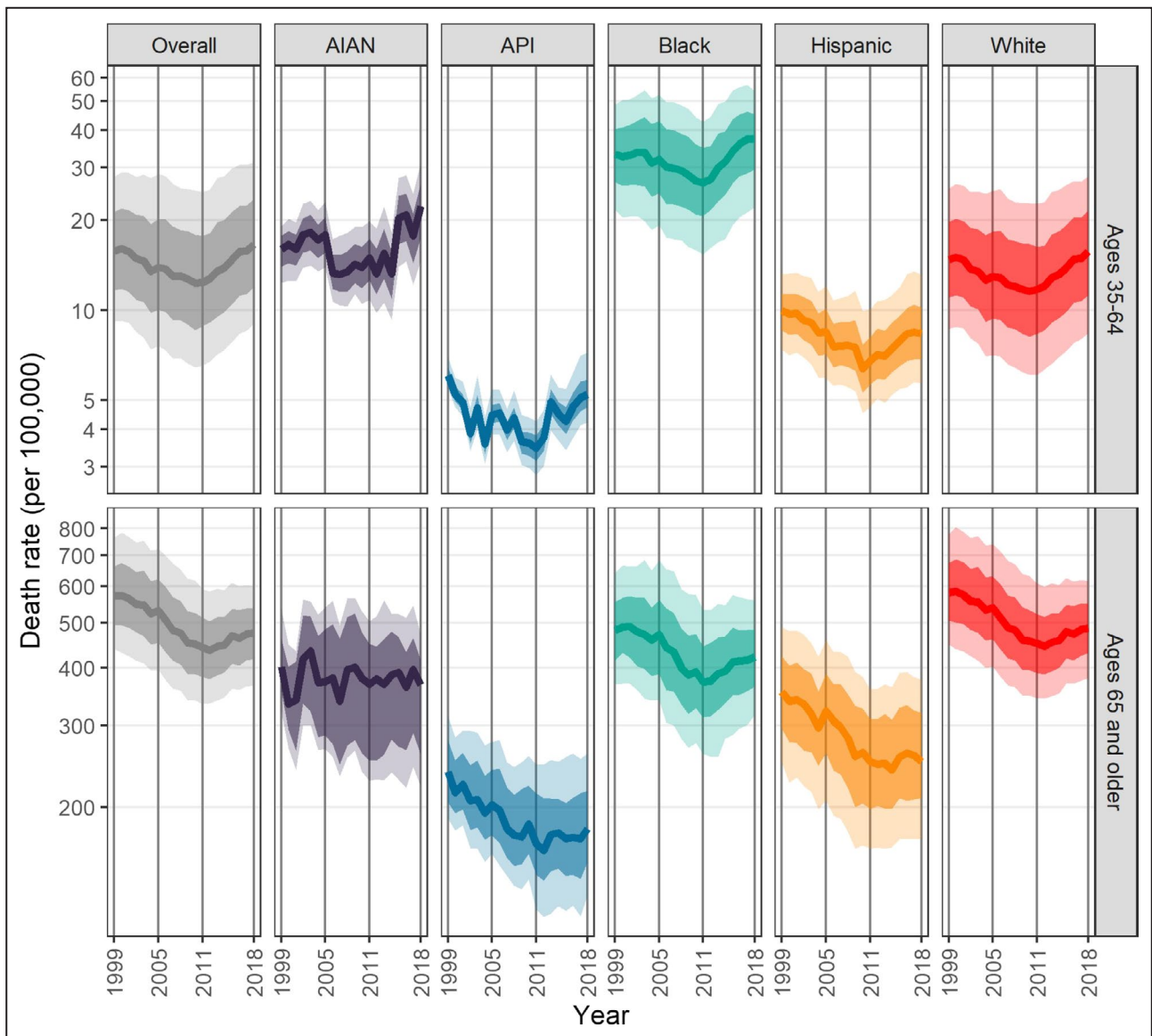


Figure 2. Distributions of county-level age-standardized heart failure (HF) death rates by year, age group, and racial/ethnic group*, United States, 1999 to 2018.

Colored lines are the median, dark band covers the 25th and 75th percentiles, and light band covers to 10th and 90th percentiles. The y-axis has been log-transformed to account for large differences in rates within each age group. *As a result of inclusion criteria, very few counties were included for American Indian/Alaska Native populations, especially for ages 65 years and older. These results should be interpreted with caution.

West to occurring commonly across counties, age groups, racial/ethnic groups, and sex.

The pervasive nature of recent increases in HF death rates suggests the involvement of factors that have acted across, but not necessarily independent of, age, racial/ethnic group, sex, and county. Because county-level increases in HF death rates have been more geographically widespread than those for all diseases of the heart,^{4,16} factors driving the reversal in HF mortality trends should be distributed broadly across the country and have specifically impacted trends in HF mortality.

One possible factor meeting these criteria is the Hospital Readmissions Reduction Program (HRRP).²⁰ This program, codified in 2010 and implemented in October 2012, aimed to reduce preventable hospitalizations for certain conditions, including HF. Multiple studies have found increased HF mortality among Medicare beneficiaries following implementation of HRRP.^{21–26} Given HRRP’s national scope, its impacts would be felt in counties across the country. However, because HRRP applies only to Medicare fee-for-service beneficiaries over age 65, it alone is unlikely to explain recent increases in the younger age group. In

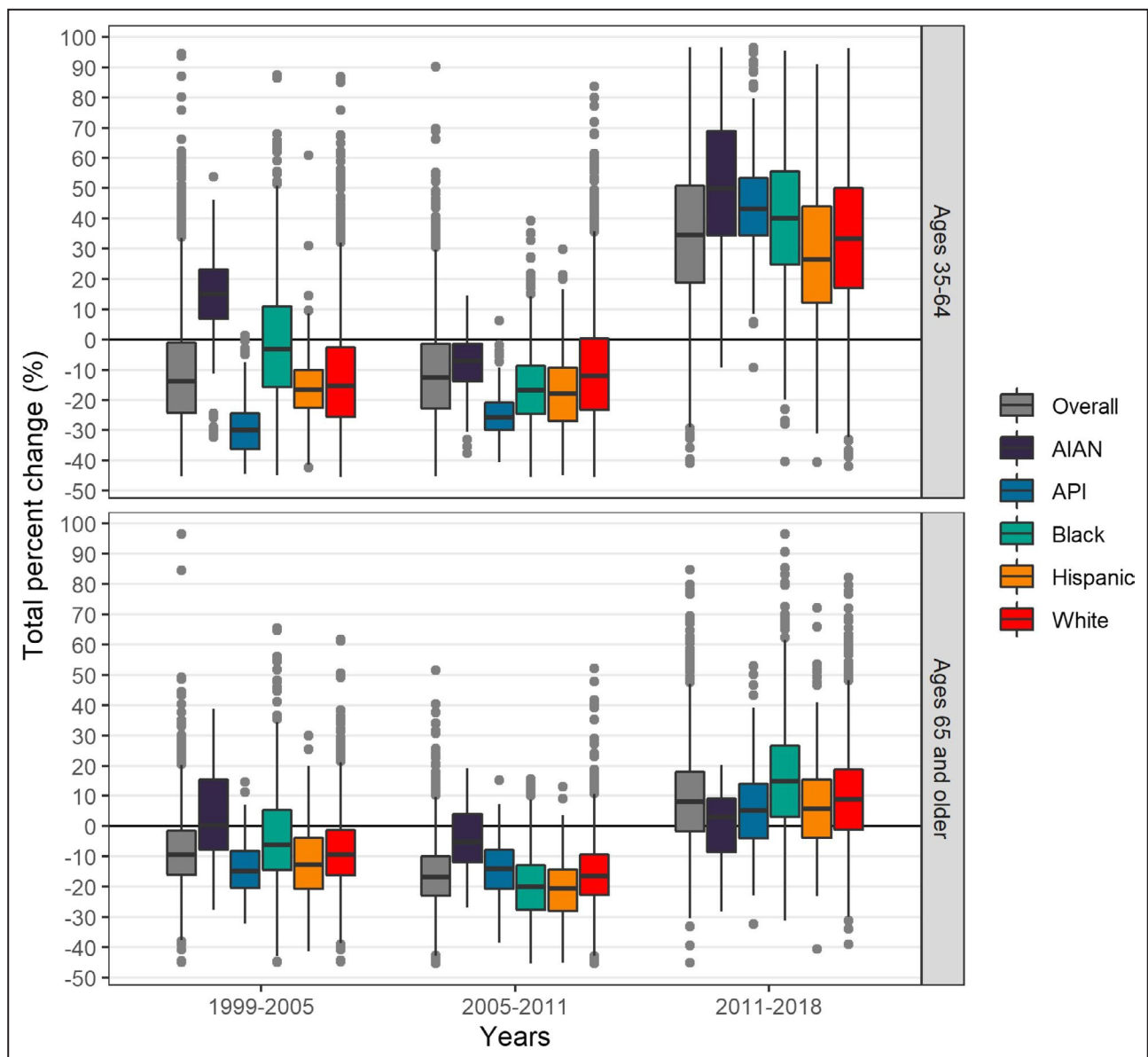


Figure 3. Distributions of percent change in county-level heart failure (HF) death rates by time period, age group, and racial/ethnic group*, United States, 1999 to 2018.

*As a result of inclusion criteria, very few counties were included for American Indian/Alaska Native populations, especially for ages 65 years and older. These results should be interpreted with caution.

addition, the timing of HRRP implementation precludes its role in increasing county-level HF death rates before 2010 in both age groups.

Therefore, although HRRP may have contributed to the recent increases, especially in adults age 65 and older, our county-level results suggest other potential drivers of increasing HF death rates, including clinical risk factors and social determinants of health. First, some counties experienced increasing HF death rates before 2011, especially Black populations of both age groups throughout the country and all racial/ethnic groups and both age groups in the South and West. Previous studies have found that

racial/ethnic and geographic disparities in HF epidemiology, including HF incidence and mortality, stem from differences in clinical risk factors for HF, including hypertension, obesity, and diabetes mellitus, especially among younger adults.^{5-8,27} In addition, our observed spatiotemporal pattern of HF mortality, with increases concentrated initially in the South and spreading across the country, mirrors spatiotemporal trends in obesity, hypertension, and diabetes mellitus.²⁸⁻³⁰

The development and subsequent control of these clinical risk factors for HF are rooted in macro-level factors related to their treatment and prevention (eg,

hospital quality, access to evidence-based health care) and social and economic context (eg, rurality, poverty, educational attainment, systemic racism).^{11,31–36} Likewise, HF outcomes, including medication adherence rates, hospital readmission rates, and mortality, have been associated with geographically varying social determinants of health, including education, wealth, family support, and employment status.^{11,37–40} The influence of these macro-level factors may also be reflected in the broader recent stagnation in cardiovascular disease mortality.^{31,41–43}

Recent temporal trends in HF death rates can also be viewed in the context of other changes in HF epidemiology. Since the 1950s, HF incidence has declined and survival has improved.⁴⁴ Furthermore, national hospitalization rates among patients hospitalized for HF declined from 1998 to 2008, although some states experienced increases.¹⁰ However, between 2006 and 2014, comorbid HF event rates, including emergency department visits and hospitalizations, increased,⁴⁵ potentially foreshadowing the observed widespread increases in HF-related mortality. Finally, these recent changes in HF death rates in the United States appear to differ from HF event and death rates in other nations. In the United Kingdom and Denmark, HF incidence and death rates have recently declined or remained stable.^{46–48}

Within the context of increasing prevalence of some traditional cardiovascular disease risk factors⁴⁹ and increases in HF incidence and hospitalizations among younger age groups,^{6,9,45,50} our results reinforce the urgency of primary prevention for HF in younger and middle-aged adults, especially given the atypical presentation of incident HF in younger adults.^{6,51} Incident HF in younger adults is less likely to be preceded by myocardial infarction^{6,7} and, subsequently, the underlying cause of HF-related deaths in younger adults is less likely to be coronary heart disease.³ A focus on primary prevention for younger adults could include addressing awareness and management of clinical risk factors (hypertension, obesity, and diabetes mellitus), especially given this group's poorer hypertension awareness, treatment, and control and rising mortality due to hypertensive diseases.⁵² Notably, the prevention of type 2 diabetes mellitus in early adulthood may markedly decrease the risk of subsequent death due to HF.⁵³ However, a strictly clinical approach may not be sufficient to reverse these current increases or to prevent future deaths. Our results reaffirm the importance of including social determinants of health in responses to these trends by the clinical and public health communities.^{54–56}

In addition to the prevention of HF and its risk factors in younger adults, the observed increases in HF mortality among those ages 65 years and older demonstrate the need for improved management and

care of all adults with HF, especially given the high HF death rates and increasing HF-related hospitalizations in older adults.⁵⁷ One key opportunity is promotion of cardiac rehabilitation, for which few HF patients receive referrals.^{58,59} In addition, medication adherence is critical to managing HF. Interventions that include pharmacists or nurses in medication reconciliation and the use of guideline-based treatment may be particularly beneficial given the complex recommended medication regimens for HF patients.^{60,61}

A key strength of this study is its application of a fully Bayesian spatiotemporal model to national surveillance data. By borrowing statistical strength across adjacent counties, groups, and years, this model estimated rates that were more precise than other statistical methods, even in counties with small numbers of deaths, thereby permitting the inclusion of more counties than would be possible with other methods.¹⁹ These county-level data allowed us to document deviations from national HF mortality trends. Finally, by using linear regression within the Bayesian results, our percent change estimates account for imprecision in underlying HF death rates.

The definition of the outcome represents a key limitation of this analysis. First, using heart disease as the underlying cause of death removes roughly one third of HF deaths,³ but ensures that those deaths are not due to non-heart disease causes that have recently increased (eg, drug deaths, accidents).^{43,62,63} Our sensitivity analysis of HF-related deaths including all underlying causes of death found higher rates but broadly similar patterns of trends (Table S5). In addition, HF as a cause of death may be overrepresented on death certificates in older adults, as observed for coronary heart disease.¹² However, a large increase in this misclassification over time would be required to have an impact on our findings. Therefore, although this misclassification may bias rates, it is unlikely to explain the observed trends.

In addition, classification of race and Hispanic origin is a limitation of this analysis. Misclassification of Hispanic origin and American Indian/Alaska Native race on death certificates is a known concern.⁶⁴ Misclassification of American Indian/Alaska Native deaths results in lower rates but similar trends compared to using data corrected for American Indian/Alaska Native race.⁶⁵ Furthermore, given small populations and numbers of HF deaths among American Indian/Alaska Native (especially for older adults) and differences in county-level death certificate misclassification of American Indian/Alaska Native race,⁶⁶ counties with higher rates and larger American Indian/Alaska Native populations were more likely to be included, potentially overestimating increases among these populations. Consequently, results for American Indian/Alaska Native populations, especially for ages 65 years and older, may not be representative of all counties

with that population. Finally, the government-defined categories of Asian/Pacific Islander and Hispanic are heterogeneous in terms of origin, culture, and cardiovascular disease risk. Therefore, our results may mask differences within Asian/Pacific Islander and Hispanic subgroups.^{67–69} Despite these limitations of racial and ethnic data from national vital statistics records, we present all nonsuppressed results for completeness.

CONCLUSIONS

Our study of temporal trends in county-level HF death rates from 1999 to 2018 revealed a detailed local picture that gives context to previously documented recent national increases.^{1,2} Although county-level declines in HF death rates were common before 2011, some counties and some demographic groups (notably Black populations in both age groups) experienced increasing HF death rates well before those observed nationally. Recent county-level increases were pervasive, particularly among ages 35 to 64 years, occurring independent of geography, racial/ethnic group, sex, and age group. The combination of earlier spatiotemporal variation in HF death rate trends followed by the recent broad similarities across counties and sociodemographic groups demonstrates the need to identify and address clinical risk factors, social determinants of health, and policy-related conditions contributing to these recent trends. By documenting these local trends in HF death rates, we hope to provide information that informs a more robust response by the clinical and public health communities and policymakers.

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Disclosures

None.

Supplementary Material

Tables S1–S5

Figures S1–S6

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SUPPLEMENTAL MATERIAL

Table S1. County-level age-standardized heart failure death rates and total percent change in heart failure death rates by year, age group, and sex, all diseases of the heart as the underlying causes of death, United States, 1999-2018.

	Ages 35-64		Ages 65 and older	
	Female	Male	Female	Male
Number of counties	2494	2647	2772	2637
Median county-level rates (per 100,000) (IQR)				
1999	11.1 (8.1, 15.3)	20.1 (14.7, 27.5)	524.5 (447.2, 611.9)	650.5 (567.4, 741.3)
2005	10.2 (6.9, 15.3)	18.2 (12.9, 26.6)	483.8 (408.3, 579.4)	593.0 (513.1, 686.6)
2011	8.9 (6.1, 13.3)	16.3 (11.5, 23.5)	395.6 (339.1, 466.5)	501.9 (435.8, 576.6)
2018	11.4 (7.9, 17.0)	22.3 (15.8, 32.3)	415.3 (360.9, 474.0)	553.1 (488.4, 619.9)
Median county-level total percent change (%) (IQR)				
1999-2005	-14.1 (-25.6, 0.1)	-11.4 (-21.9, 1.9)	-8.9 (-16.8, 0.0)	-9.8 (-16.3, -2.8)
2005-2011	-14.1 (-24.4, -3.5)	-11.8 (-21.7, -0.3)	-18.7 (-25.6, -10.9)	-14.9 (-21.5, -7.9)
2011-2018	30.6 (14.9, 49.5)	36.6 (21.5, 55.1)	5.0 (-4.9, 15.1)	11.2 (1.6, 20.5)
Percent of counties with increases (95% CI)				
1999-2005	32.0 (28.6, 35.8)	34.5 (31.6, 37.7)	25.9 (22.5, 28.3)	30.4 (28.4, 32.2)
2005-2011	28.5 (23.7, 31.9)	31.7 (29.3, 35.1)	14.6 (13.0, 16.6)	11.8 (10.6, 13.1)
2011-2018	81.8 (79.8, 83.5)	87.5 (85.6, 89.6)	73.6 (71.1, 75.8)	60.7 (58.3, 63.1)

Table S2 Quartile ranges of county-level HF death rates by year and race and Hispanic origin, ages 35-64, United States, 1999-2018.

	Quartile 1	Quartile 2	Quartile 3	Quartile 4
Overall				
1999	3.8, 11.7	11.8, 15.8	15.9, 21.3	21.4, 110.3
2005	3.2, 10.0	10.1, 13.9	14.0, 20.2	20.3, 165.1
2011	2.7, 8.8	8.9, 12.4	12.5, 17.8	17.9, 131.1
2018	3.8, 11.9	12.0, 16.6	16.7, 23.5	23.6, 142.3
American Indian/Alaska Native				
1999	7.7, 13.9	14.0, 15.9	16, 17.8	17.9, 26.6
2005	9.0, 15.6	15.7, 17.9	18, 20.5	20.6, 27.4
2011	7.8, 12.6	12.7, 14.8	14.9, 17.4	17.5, 26.9
2018	10.4, 17.4	17.5, 22.2	22.3, 26.6	26.7, 39.1
Asian/Pacific Islander				
1999	4.2, 5.8	5.9, 6.1	6.2, 6.4	6.5, 18.3
2005	2.7, 4.2	4.3, 4.5	4.6, 4.8	4.9, 22.4
2011	2.1, 3.1	3.2, 3.5	3.6, 3.8	3.9, 14.2
2018	3.4, 4.7	4.8, 5.2	5.3, 5.9	6.0, 14.7
Black				
1999	10.3, 26.8	26.9, 33.3	33.4, 40.4	40.5, 137.1
2005	8.5, 24.6	24.7, 32.0	32.1, 43.0	43.1, 182.3
2011	6.0, 20.6	20.7, 26.7	26.8, 35.0	35.1, 114.0
2018	10.3, 29.5	29.6, 37.4	37.5, 45.1	45.2, 169.5
Hispanic				
1999	2.7, 8.6	8.7, 10	10.1, 11.4	11.5, 22.2
2005	3.5, 7.1	7.2, 8.4	8.5, 10.1	10.2, 20.0
2011	2.4, 5.7	5.8, 6.8	6.9, 8.1	8.2, 21.2
2018	3.3, 6.8	6.9, 8.4	8.5, 10.2	10.3, 25.7
White				
1999	3.3, 11.0	11.1, 14.8	14.9, 19.7	19.8, 90.6
2005	2.7, 9.4	9.5, 12.9	13.0, 18.3	18.4, 113.1
2011	1.8, 8.4	8.5, 11.7	11.8, 16.3	16.4, 134.9
2018	2.8, 11.2	11.3, 15.7	15.8, 21.5	21.6, 138.0

Quartile ranges correspond to the categories shown in Figure S1.

Table S3. Quartile ranges of county-level HF death rates by year and race and Hispanic origin, ages 65 and older, United States, 1999-2018.

	Quartile 1	Quartile 2	Quartile 3	Quartile 4
Overall				
1999	257.9, 496.2	496.3, 572.9	573.0, 662.4	662.5, 1528.4
2005	201.1, 452.3	452.4, 531.1	531.2, 622.0	622.1, 1500.7
2011	122.1, 381.8	381.9, 442.9	443.0, 513.0	513.1, 1556.9
2018	140.9, 417.2	417.3, 476.3	476.4, 536.8	536.9, 1126.8
American Indian/Alaska Native				
1999	203.3, 354.6	354.7, 387.9	388.0, 463.0	463.1, 624.6
2005	142.2, 275.4	275.5, 371.1	371.2, 484.6	484.7, 581.3
2011	126.6, 251.8	251.9, 359.0	359.1, 449.9	450.0, 579.0
2018	111.1, 258.9	259.0, 365.6	365.7, 415.0	415.1, 571.3
Asian/Pacific Islander				
1999	158.8, 204.4	204.5, 238.4	238.5, 277.5	277.6, 464.2
2005	138.5, 173.6	173.7, 202.4	202.5, 239.8	239.9, 379.7
2011	100.1, 142	142.1, 166.5	166.6, 213.5	213.6, 347.3
2018	102.1, 151.8	151.9, 179.7	179.8, 215.9	216, 343.1
Black				
1999	251.8, 413.7	413.8, 480.7	480.8, 554.1	554.2, 1229.4
2005	202.6, 387.1	387.2, 472.2	472.3, 561.6	561.7, 1443.4
2011	117.4, 312.2	312.3, 372.5	372.6, 445.5	445.6, 1096.9
2018	154.2, 364.0	364.1, 421.9	422, 484.8	484.9, 1014.7
Hispanic				
1999	153.1, 296.0	296.1, 354.3	354.4, 423.4	423.5, 757.7
2005	140.0, 259.9	260.0, 322.9	323, 388.2	388.3, 755.0
2011	103.3, 197.6	197.7, 249.9	250, 309.6	309.7, 645.2
2018	109.6, 206.5	206.6, 250.1	250.2, 320.3	320.4, 785.5
White				
1999	256.9, 505.9	506.0, 582.1	582.2, 675.0	675.1, 1533.3
2005	198.8, 460.4	460.5, 538.4	538.5, 630.3	630.4, 1617.4
2011	121.1, 389.4	389.5, 451.6	451.7, 522.3	522.4, 1579.5
2018	139.7, 429.6	429.7, 486.6	486.7, 550.6	550.7, 1158.5

Quartile ranges correspond to the categories shown in Figure S2.

Table S4. Quartile ranges of county-level HF death rates by year, age group, and sex, United States, 1999-2018.

	Quartile 1	Quartile 2	Quartile 3	Quartile 4
Female, Ages 35-64				
1999	2.3, 8.1	8.2, 11.1	11.2, 15.3	15.4, 85.3
2005	1.7, 6.9	7.0, 10.2	10.3, 15.3	15.4, 140.0
2011	1.6, 6.1	6.2, 8.9	9.0, 13.3	13.4, 92.0
2018	2.4, 7.9	8.0, 11.4	11.5, 17.0	17.1, 98.7
Male, Ages 35-64				
1999	4.2, 14.7	14.8, 20.1	20.2, 27.5	27.6, 162.8
2005	3.1, 12.9	13, 18.2	18.3, 26.6	26.7, 244.5
2011	2.9, 11.5	11.6, 16.3	16.4, 23.5	23.6, 186.3
2018	5.1, 15.8	15.9, 22.3	22.4, 32.3	32.4, 197.9
Female, Ages 65 and older				
1999	224.3, 447.2	447.3, 524.5	524.6, 611.9	612.0, 1460.3
2005	173.2, 408.3	408.4, 483.8	483.9, 579.4	579.5, 1397.8
2011	94.5, 339.1	339.2, 395.6	395.7, 466.5	466.6, 1437.5
2018	110.7, 360.9	361.0, 415.3	415.4, 474.0	474.1, 986.0
Male, Ages 65 and older				
1999	278.9, 567.4	567.5, 650.5	650.6, 741.3	741.4, 1545.6
2005	239.0, 513.1	513.2, 593.0	593.1, 686.6	686.7, 1505.9
2011	149.2, 435.8	435.9, 501.9	502.0, 576.6	576.7, 1684.1
2018	173.4, 488.4	488.5, 553.1	553.2, 619.9	620.0, 1273.8

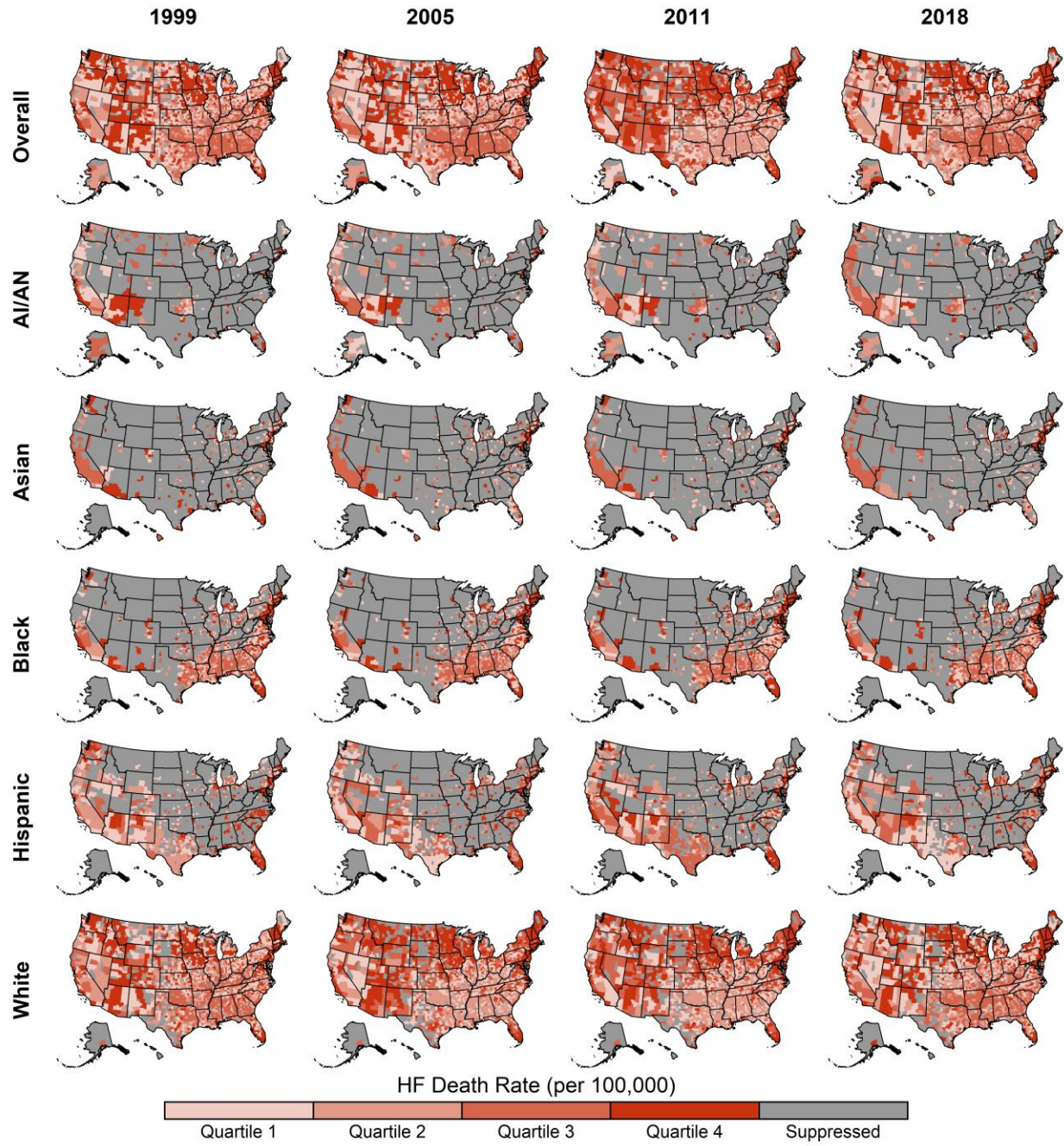
Quartile ranges correspond to the categories shown in Figure S5.

Table S5. County-level age-standardized heart failure death rates and total percent change in heart failure death rates by year, age group, and race and Hispanic origin, all underlying causes of death, United States, 1999-2018

	Overall	American Indian/Alaska Native	Asian/Pacific Islander	Black	Hispanic	White
Ages 35-64						
Number of counties	3028	312	458	1256	876	2932
Median county-level rates (per 100,000) (IQR)						
1999	26.9 (19.9, 35.6)	29.9 (24.7, 35.3)	9.5 (8.9, 10.2)	54.4 (44.2, 66.1)	17.1 (14.1, 20.6)	25.1 (18.7, 33.0)
2005	24.8 (17.6, 35.6)	33.5 (26.1, 40.5)	6.6 (6.0, 7.4)	54.4 (41.9, 70.8)	14.7 (11.8, 18.7)	23.0 (16.6, 32.1)
2011	23.1 (16.4, 33.1)	29.5 (22.5, 36.1)	5.7 (4.9, 6.5)	47.1 (35.7, 60.1)	12.6 (10.1, 16.2)	21.9 (15.5, 30.6)
2018	29.8 (21.7, 42.1)	46.1 (32.9, 60.2)	8.8 (7.6, 10.3)	65.7 (51.8, 82.1)	16.9 (13.3, 21.7)	30.5 (22.3, 42.3)
Median county-level total percent change (%) (IQR)						
1999-2005	-8.2 (-18.5, 4.7)	12.2 (-0.8, 21.8)	-31.3 (-38.0, -24.2)	-0.4 (-13.8, 14.2)	-16.9 (-24.0, -9.0)	-8.7 (-19.6, 4.1)
2005-2011	-7.4 (-18.1, 3.6)	-5.2 (-13.1, 2.8)	-14.7 (-20.8, -7.8)	-12.7 (-20.8, -3.4)	-15.9 (-25.4, -5.8)	-6.9 (-18.1, 5.6)
2011-2018	42.3 (24.3, 61)	63.2 (41, 85.8)	48.6 (39.1, 58.5)	43.6 (28.1, 58.8)	40.6 (23.4, 55.2)	42.0 (22.6, 61.5)
Percent of counties with increases (95% CI)						
1999-2005	37.4 (34.9, 39.9)	65.7 (59.0, 73.4)	4.6 (2.4, 10.5)	49.0 (45.1, 52.2)	20.0 (15.2, 27.1)	36.5 (33.5, 39.7)
2005-2011	36.5 (34.1, 39.5)	38.8 (29.2, 51.9)	19.2 (12.7, 31.0)	27.0 (23.2, 32.6)	22.8 (17.5, 29.2)	38.6 (36.3, 41.8)
2011-2018	91.2 (89.3, 92.6)	96.2 (92.3, 98.4)	98 (95.6, 99.6)	93.9 (91.9, 95.4)	90.1 (86.4, 92.5)	89.3 (87.1, 91.1)
Ages 65 and Older						
Number of counties	2977	49	159	734	295	2921
Median county-level rates (per 100,000) (IQR)						
1999	886.9 (761.7, 1034.4)	588.6 (502.3, 744.2)	355.6 (312.1, 425.4)	770.5 (669.2, 902.2)	559.1 (439.1, 679.8)	898.3 (772.6, 1052.5)
2005	845.8 (713.3, 994.6)	668.4 (483.1, 909.2)	316.6 (268.9, 376.5)	770.9 (637.5, 911.9)	523.9 (391.5, 647.2)	853.7 (721.9, 1005.6)
2011	733.0 (624.7, 857.7)	588.5 (427.9, 876.6)	266.9 (233.2, 343.5)	642.7 (537.4, 777.7)	426.5 (328.4, 527.8)	743.5 (635.2, 868.3)
2018	787.6 (681.3, 898.5)	643.1 (502.2, 791.9)	281.4 (247.3, 366.1)	717.7 (613.9, 841)	442 (347.5, 557.2)	812.1 (704.6, 921.6)

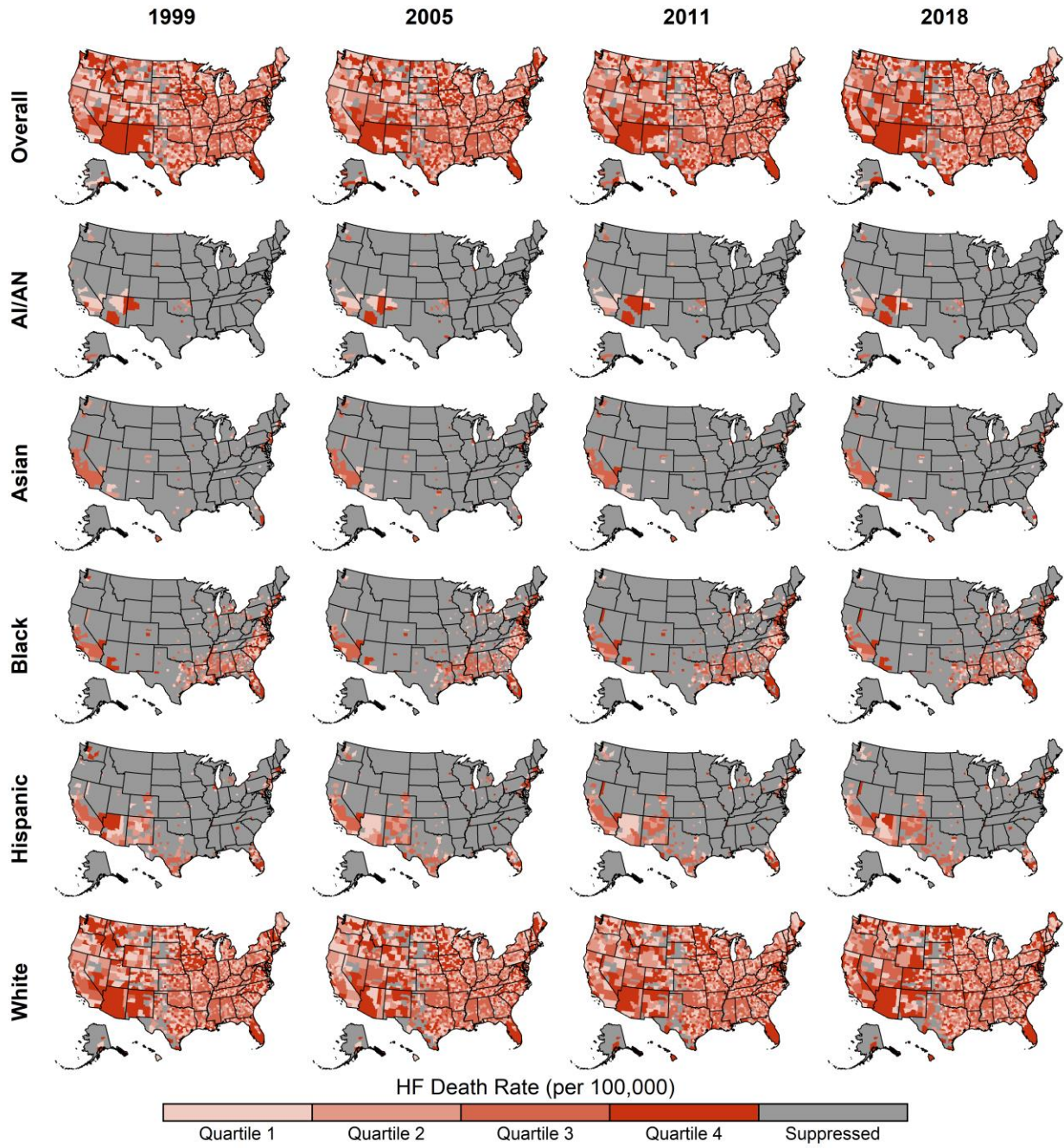
	Overall	American Indian/Alaska Native	Asian/Pacific Islander	Black	Hispanic	White
Median county-level total percent change (%) (IQR)						
1999-2005	-6.1 (-13.9, 2.4)	17.7 (1.0, 29.5)	-11.4 (-16.2, -5.1)	-2.7 (-12.0, 6.3)	-10.0 (-20.4, -2.4)	-6.2 (-13.9, 2.3)
2005-2011	-12.8 (-20.0, -5.4)	-6.0 (-15.7, 2.1)	-11.8 (-20.9, -3.8)	-14.9 (-22.3, -6.7)	-18.0 (-26.5, -11.3)	-12.4 (-19.8, -5.1)
2011-2018	9.2 (-1.6, 21.0)	2.2 (-6.8, 11.6)	6.1 (-3.0, 18.2)	12.8 (0.5, 26.5)	6.8 (-1.7, 20.0)	9.9 (-0.6, 21.8)
Percent of counties with increases (95% CI)						
1999-2005	34.8 (32.5, 36.4)	72.4 (61.2, 83.7)	22.6 (14.5, 29.6)	43.2 (38.4, 47.1)	28.1 (22.4, 33.9)	34.7 (32.6, 36.5)
2005-2011	19.0 (17.2, 20.4)	36.7 (22.4, 51.0)	23.3 (17.0, 30.8)	17.4 (14.7, 21.4)	11.9 (8.1, 15.6)	19.9 (18.1, 21.4)
2011-2018	69.3 (68.0, 70.9)	55.1 (42.9, 69.4)	64.8 (57.2, 72.3)	72.8 (69.6, 76.6)	66.1 (60.3, 71.9)	70.6 (69.1, 72.1)

Figure S1. County-level HF death rates by year and race and Hispanic origin, ages 35-64, United States, 1999-2018.



Quartile ranges are specific to each map (i.e., to each year and group) and are shown in Table S2.

Figure S2. County-level HF death rates by year and race and Hispanic origin, ages 65 and older, United States, 1999-2018.



Quartile ranges are specific to each map (i.e., to each year and group) and are shown in Table S2.

Figure S3. Total percent change in county-level HF death rates by year and race and Hispanic origin, ages 35-64, United States, 1999-2018.

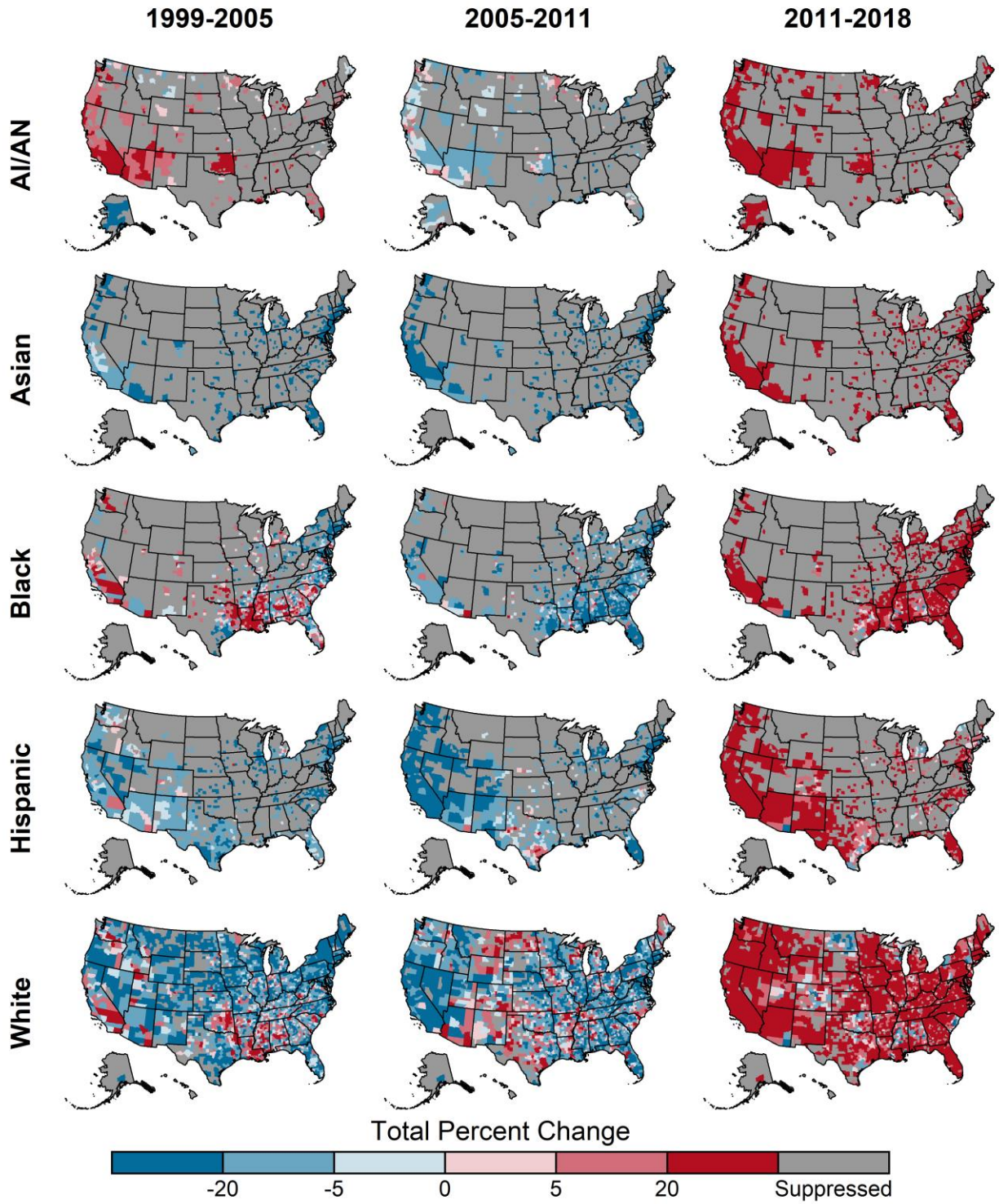


Figure S4. Total percent change in county-level HF death rates by year and race and Hispanic origin, ages 65 and older, United States, 1999-2018.

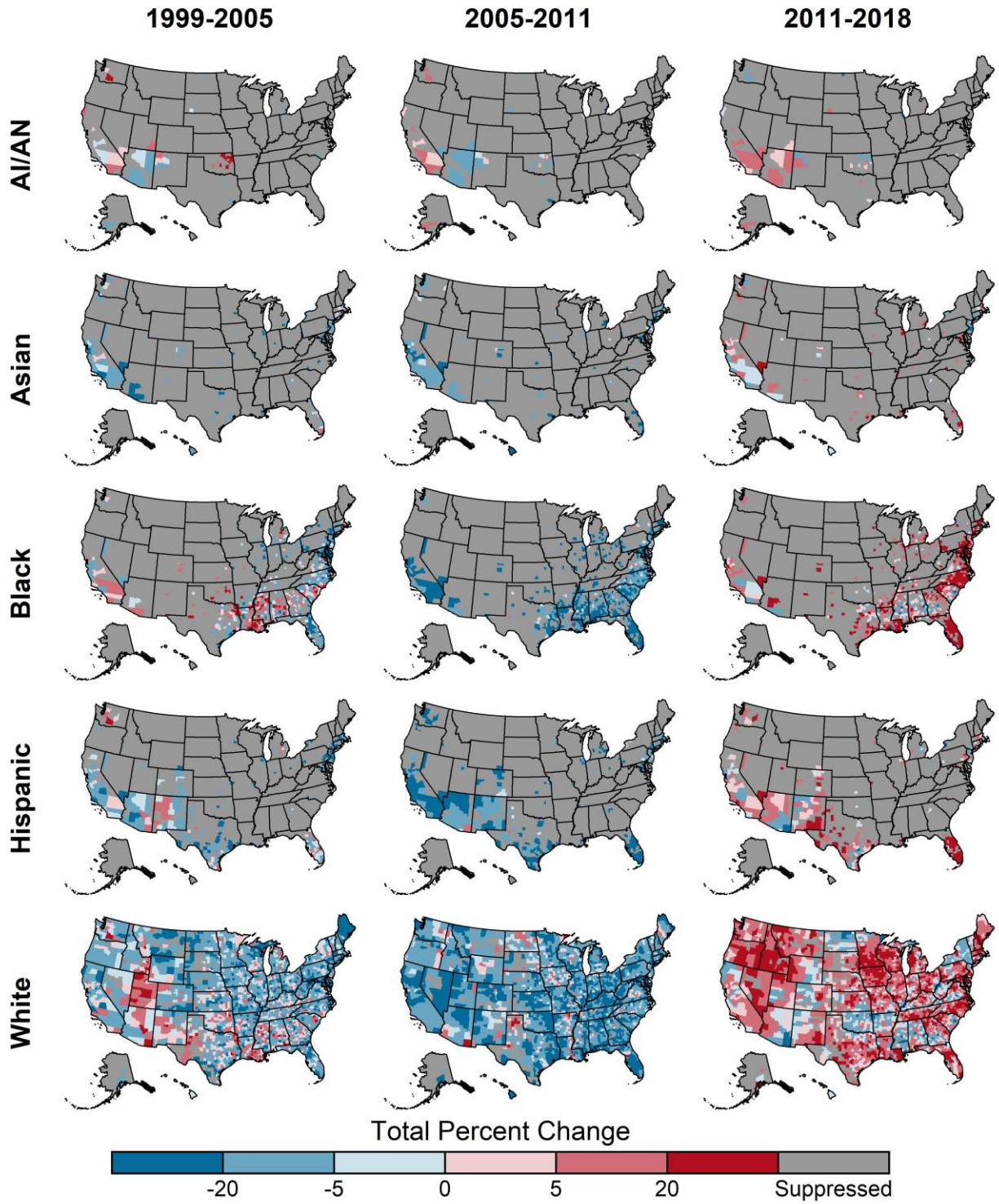
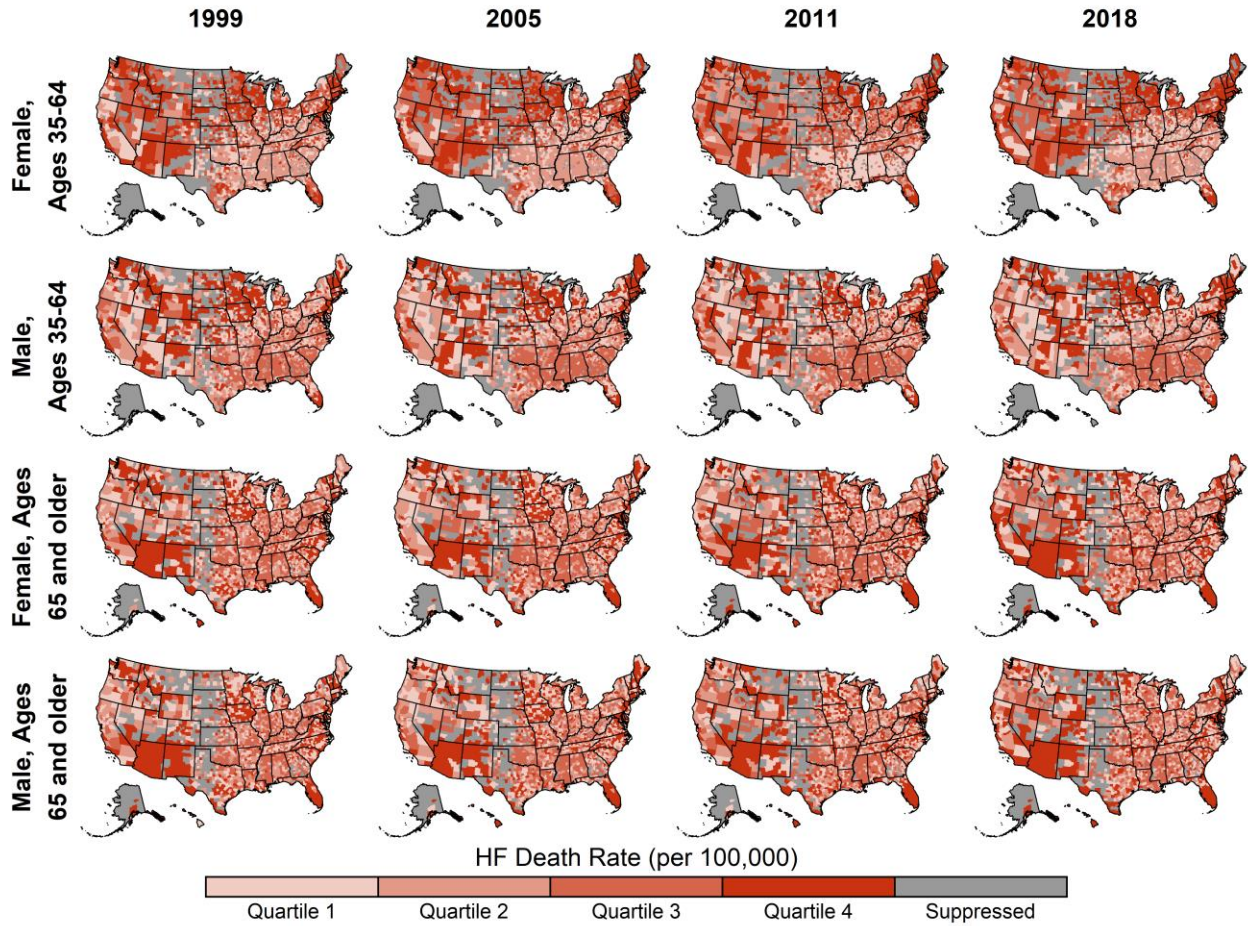


Figure S5. County-level HF death rates by year, age group, and sex, United States, 1999-2018.



Quartile ranges are specific to each map (i.e., to each year and group) and are shown in Table S4.

Figure S6. Total percent change in county-level HF death rates by year, age group, and sex, United States, 1999-2018.

