



Disparities in Temporal and Geographic Patterns of Declining Heart Disease Mortality by Race and Sex in the United States, 1973-2010.

Adam S. Vaughan, *Emory University*

Harrison Quick, *Centers for Disease Control and Prevention*

Elizabeth B. Pathak, *University of South Florida*

[Michael Kramer](#), *Emory University*

Michele Casper, *Centers for Disease Control and Prevention*

Journal Title: Journal of the American Heart Association

Volume: Volume 4, Number 12

Publisher: American Heart Association: JAHA | 2015-12

Type of Work: Article | Final Publisher PDF

Publisher DOI: 10.1161/JAHA.115.002567

Permanent URL: <https://pid.emory.edu/ark:/25593/rmh3z>

Final published version: <http://dx.doi.org/10.1161/JAHA.115.002567>

Copyright information:

© 2015 The Authors. Published on behalf of the American Heart Association, Inc., by Wiley Blackwell.

This is an Open Access work distributed under the terms of the Creative Commons Attribution-NonCommercial 4.0 International License

(<http://creativecommons.org/licenses/by-nc/4.0/>).



Accessed August 24, 2022 4:50 AM EDT

Disparities in Temporal and Geographic Patterns of Declining Heart Disease Mortality by Race and Sex in the United States, 1973–2010

Adam S. Vaughan, MPH, MS; Harrison Quick, PhD; Elizabeth B. Pathak, PhD; Michael R. Kramer, PhD; Michele Casper, PhD

Background—Examining small-area differences in the strength of declining heart disease mortality by race and sex provides important context for current racial and geographic disparities and identifies localities that could benefit from targeted interventions. We identified and described temporal trends in declining county-level heart disease mortality by race, sex, and geography between 1973 and 2010.

Methods and Results—Using a Bayesian hierarchical model, we estimated age-adjusted mortality with diseases of the heart listed as the underlying cause for 3099 counties. County-level percentage declines were calculated by race and sex for 3 time periods (1973–1985, 1986–1997, 1998–2010). Strong declines were statistically faster or no different than the total national decline in that time period. We observed county-level race–sex disparities in heart disease mortality trends. Continual (from 1973 to 2010) strong declines occurred in 73.2%, 44.6%, 15.5%, and 17.3% of counties for white men, white women, black men, and black women, respectively. Delayed (1998–2010) strong declines occurred in 15.4%, 42.0%, 75.5%, and 76.6% of counties for white men, white women, black men, and black women, respectively. Counties with the weakest patterns of decline were concentrated in the South.

Conclusions—Since 1973, heart disease mortality has declined substantially for these race–sex groups. Patterns of decline differed by race and geography, reflecting potential disparities in national and local drivers of these declines. Better understanding of racial and geographic disparities in the diffusion of heart disease prevention and treatment may allow us to find clues to progress toward racial and geographic equity in heart disease mortality. (*J Am Heart Assoc.* 2015;4:e002567 doi: 10.1161/JAHA.115.002567)

Key Words: disparities • epidemiology • heart disease • mortality • trends

With >600 000 deaths per year, heart disease remains the leading cause of death in the United States,¹ despite large national declines in heart disease mortality over the past 60 years.^{2–5} Nationally, these declines have varied by both race and sex. White men have experienced large,

sustained declines in heart disease mortality, whereas white women have experienced smaller declines.^{6–8} Heart disease mortality among black men and black women has also declined but more slowly overall and with a period of minimal decline in the 1970s.^{7,8}

In addition to differential declines by race and sex, declines in heart disease mortality have been geographically disparate, with slower declines observed in rural areas and in the southern United States.^{6,9–14} After several decades of steady increases in heart disease death rates prior to 1960, the magnitude and timing of the onset of declines also varied geographically, with some local areas beginning overall declines in the 1960s and others much later.^{15,16}

Declining heart disease mortality results from substantial progress in heart disease prevention and treatment. Nevertheless, differences in the magnitude and timing of declines by race, sex, and geography could signal important differences in the spatiotemporal distribution of factors that promote heart disease prevention and treatment efforts.¹⁷ A significant body of past work has explored temporal trends

From the Department of Epidemiology, Rollins School of Public Health, Emory University, Atlanta, GA (A.S.V., M.R.K.); Division for Heart Disease and Stroke Prevention, Centers for Disease Control and Prevention, Atlanta, GA (A.S.V., H.Q., M.R.K., M.C.); Morsani College of Medicine, University of South Florida, Tampa, FL (E.B.P.).

An accompanying Data S1 is available at <http://jaha.ahajournals.org/content/4/12/e002567/suppl/DC1>

Correspondence to: Adam S. Vaughan, MPH, MS, Department of Epidemiology, Rollins School of Public Health, Emory University, 1518 Clifton Road NE, Atlanta, GA 30322. E-mail: asvaugh@emory.edu

Received August 17, 2015; accepted October 27, 2015.

© 2015 The Authors. Published on behalf of the American Heart Association, Inc., by Wiley Blackwell. This is an open access article under the terms of the Creative Commons Attribution-NonCommercial License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited and is not used for commercial purposes.

in heart disease mortality.^{5,6,10,11,15,16,18–22} These studies, however, were unable to assess potential spatiotemporal variations in declines by race and sex because they used cohort data, relied on national-level data, or were limited by analytic methods of the times. None have recently and systematically examined declining heart disease mortality using smaller geographic areas and newer, more powerful statistical methods, which are ideal, given small race- and sex-specific populations in some areas and the long duration of available data. By applying Bayesian statistical methods to county-level surveillance data, we sought to identify and describe temporal patterns in declining county-level heart disease mortality by race, sex, and geography between 1973 and 2010.

Methods

Heart Disease Mortality Data

Annual age-specific counts of heart disease deaths in each county in the continental United States from 1973 to 2010 for people aged ≥ 35 years were obtained from the National Vital Statistics System. This time period represents a continuous period in which all deaths, rather than a sample of deaths, were recorded. Heart disease deaths were defined based on underlying cause of death according to the following International Classification of Diseases (ICD) codes: ICD-8: 390 to 398, 402, 404, 410 to 429; ICD-9: 390 to 398, 402, 404 to 429; ICD-10: I00 to I09, I11, I13, I20 to I51. Comparability ratios between each ICD revision are approximately unity, indicating that temporal changes in the ICD codes introduced no bias into the study and that no adjustments for ICD coding changes were necessary.^{23,24} Annual population counts for persons age ≥ 35 were obtained from bridged-race population files.²⁵ To enhance rate stability due to small populations at risk, data for a common set of 3099 counties in the contiguous United States were aggregated into 2-year intervals, resulting in 19 biennial intervals. Death rates were age-standardized using the 2000 US standard population.

For each county and biennial interval, spatially smoothed, age-adjusted heart disease death rates were calculated for black men, black women, white men, white women, and the total of these 4 groups. Specifically, we used a recently developed Bayesian hierarchical model²⁶ that extends the model of Besag et al²⁷ to account for both spatial and temporal correlation and correlation between each of the race–sex groups (Data S1). This allows the model to borrow strength across space, time, and race–sex group to obtain more precise rate estimates. In addition, this model incorporates population size into variance estimates, giving more precise estimates to counties with high population sizes (and

thus more data). The output from this model includes posterior distributions for the expected death rate for each race–sex group in every county and for every biennial interval. From this posterior distribution, we obtained summary statistics, including the posterior median (the Bayesian analog of the point estimate) and the 95% Bayesian credible interval (the Bayesian analog of the classical 95% CI). For each county, data for a race–sex group were suppressed if the race- and sex-specific population of interest had < 100 persons at baseline.

Categorization of Temporal Trends

Using the Bayesian-derived county-level rates for the 4 race–sex groups, temporal trends in heart disease mortality were categorized as follows:

1. The study period was divided into 3 time periods. To allow differing temporal trends over the study period, the study period was divided into 3 time periods of equal width, representing the years 1973/1974–1985/1986, 1985/1986–1997/1998, and 1997/1998–2009/2010. For clarity, we refer to these time periods as 1973–1985, 1986–1997, and 1998–2010.
2. For each time period and each race–sex group:
 - a. The percentage decline (and the corresponding 95% Bayesian credible interval) was calculated. Declines within each time period were calculated by dividing the difference between the beginning and end rates by the beginning rate. We computed these declines at both the county and national levels for each of the 4 race–sex groups separately. National percentage declines were also computed for all 4 race–sex groups combined.
 - b. The percentage decline in each county was compared with the total national decline. Based on the 95% Bayesian credible interval, the percentage decline in each county was described as (1) a strong decline (ie, statistically faster or no different than the total national decline in that time period), (2) a weak decline (ie, statistically slower than the total national decline in that time period), or (3) imprecise (ie, the 95% Bayesian credible interval included both the total national decline in that time period and zero decline).
3. For each race–sex group in each county, a summary pattern of decline was assigned. Based on comparisons to the total national declines, counties with consistent declines across all time periods were categorized as either *continual strong declines* (strong declines for all time periods) or *continual weak declines* (weak declines for all time periods) (Table 1). Counties not experiencing consistent declines across the 3 time periods were categorized using the final time period (ie, 1998–2010). These patterns

Table 1. Patterns of Declining County-Level Heart Disease Mortality*, Continental United States, 1973–2010

Pattern of declines	Declines by Time Period [†]			Number of Counties [‡] (%)			
	1973–1985	1986–1997	1998–2010	White Men (n=3098)	White Women (n=3098)	Black Men (n=1614)	Black Women (n=1605)
Continual strong decline	↑	↑	↑	2260 (73.0)	1368 (44.2)	223 (13.8)	261 (16.3)
Delayed strong decline	↓	↑	↑	117 (24.5)	279 (21.7)	216 (19.9)	172 (14.9)
	↓	↓	↑	39 (8.2)	268 (20.8)	184 (16.9)	237 (20.5)
	↑	↓	↑	303 (63.5)	528 (41.0)	79 (7.3)	139 (12.0)
	↓	?	↑	0 (0)	4 (0.3)	46 (4.2)	30 (2.6)
	?	↓	↑	2 (0.4)	46 (3.6)	149 (13.7)	229 (19.8)
	?	?	↑	0 (0)	7 (0.5)	157 (14.5)	120 (10.4)
	↑	?	↑	10 (2.1)	45 (3.5)	42 (3.9)	75 (6.5)
	?	↑	↑	6 (1.3)	111 (8.6)	213 (19.6)	156 (13.5)
Total for delayed strong decline				477 (15.4)	1288 (41.6)	1086 (67.3)	1158 (72.1)
Recent weak decline	↑	↑	↓	199 (60.7)	76 (26.7)	14 (15.1)	10 (13.9)
	↑	↓	↓	105 (32.0)	156 (54.7)	8 (8.6)	7 (9.7)
	↓	↑	↓	24 (7.3)	37 (13.0)	30 (32.3)	19 (26.4)
	↓	?	↓	0 (0)	0 (0)	2 (2.2)	1 (1.4)
	?	↓	↓	0 (0)	12 (4.2)	18 (19.4)	25 (34.7)
	?	?	↓	0 (0)	0 (0)	7 (7.5)	4 (5.6)
	↑	?	↓	0 (0)	1 (0.4)	1 (1.1)	1 (1.4)
	?	↑	↓	0 (0)	3 (1.1)	13 (14)	5 (6.9)
Total for recent weak decline				328 (10.6)	285 (9.2)	93 (5.8)	72 (4.5)
Continual weak decline	↓	↓	↓	24 (0.8)	124 (4)	35 (2.2)	20 (1.2)
Imprecise decline	?	?	?	0 (0)	3 (9.1)	67 (37.9)	40 (42.6)
	↓	?	?	0 (0)	0 (0)	7 (4)	6 (6.4)
	?	↓	?	0 (0)	0 (0)	9 (5.1)	12 (12.8)
	↓	↓	?	0 (0)	0 (0)	5 (2.8)	0 (0)
	↓	↑	?	0 (0)	1 (3)	11 (6.2)	5 (5.3)
	↑	↓	?	0 (0)	1 (3)	2 (1.1)	2 (2.1)
	↑	↑	?	9 (100)	15 (45.5)	18 (10.2)	6 (6.4)
	↑	?	?	0 (0)	5 (15.2)	15 (8.5)	11 (11.7)
	?	↑	?	0 (0)	8 (24.2)	43 (24.3)	12 (12.8)
Total for imprecise decline				9 (0.3)	33 (1.1)	177 (11.0)	94 (5.9)

Percentages for pattern totals sum to 100 for each column. The individual declines by time period sum to 100 within each pattern of decline for each column.

*Continual strong or weak declines were statistically faster or slower, respectively, than the total decline for the entire study period; delayed strong or recent weak declines were statistically faster or slower, respectively, than the total decline in the last time period (1998–2010).

[†]↑ indicates that the percentage decline for the given time period was significantly faster (or no different) than the national total decline in that time period. ↓ indicates that the percentage decline for the given time period was significantly slower than the national total decline in that time period. ? indicates that the Bayesian credible interval for the given time period included both zero and the national total decline.

[‡]Due to race–gender population <100 at baseline, data were suppressed for the following numbers of counties: 1 for white men, 1 for white women, 1485 for black men, and 1494 for black women.

were designated as *delayed strong declines* (strong declines in the final time period) and *recent weak declines* (weak declines in the final time period). Counties with imprecise declines in the final time period were excluded because of insufficient data.

Concordance of Patterns of Decline Across Race–Sex Groups

The concordance correlation coefficient was calculated to explore similarity (ie, concordance) in county-level declines for

pairs of race–sex groups.^{28,29} Counties were included in this analysis only if sufficient data (ie, population >100 persons at baseline and a 95% Bayesian credible interval that did not include both the national decline and zero decline in the last time period) were available for both race–sex groups being compared. The concordance correlation coefficient for black men and white men, for example, was calculated using only counties with sufficient data for both black men and white men.

All analyses were completed in R (R Foundation for Statistical Computing). An R package to implement this model is currently under development, and code is available on request. Maps were created in ArcMap v10.1 (Esri).

Because this research used only publicly available county-level data, institutional review board approval was not required.

Results

National Declines in Heart Disease Mortality

Nationally, heart disease mortality decreased for all 4 race–sex groups across the study period (Figure 1). The magnitude of decline in heart disease mortality grew larger with each successive time period, increasing from 20.0% during the first time period (1973–1985) to 26.7% during the middle time period and ultimately to 35.4% in the most recent time period (1998–2010). The same trend was observed for each race–sex group (Table 2).

Racial differences in the magnitude of declining heart disease mortality changed over time (Table 2). During the earliest time period, national declines were much slower for

black men and black women (9.7% and 12.2%, respectively) than for white men and white women (22.6% and 18.3%, respectively). During the middle time period, racial differences in percentage decline converged, but declines remained slower for black persons than for white persons. By the most recent time period, national declines for the 4 race–sex groups were similar.

County-Level Declines: Temporal Patterns by Race and Sex

Following exclusion of counties for race–sex groups with populations <100 persons, the analysis included 3098 counties for white men and women, 1614 for black men, and 1605 for black women. Each race–sex group in almost all counties experienced declining heart disease mortality for all 3 time periods. Only a small fraction of counties experienced a statistically significant increase in heart disease mortality for any time period (2 [0.1%] for white men, 11 [0.4%] for white women, 37 [2.3%] for black men, 47 [2.9%] for black women).

For each race–sex group, a majority of counties were categorized as either *continual strong declines* or *delayed strong declines* (Figure 2, Tables 1 and 3); however, the distribution of these 2 categories varied by race–sex group. White men experienced *continual strong declines* in a majority of counties (73%), whereas a minority of counties experienced *continual strong declines* for white women (45%), black women (17%), and black men (16%). In these counties with *continual strong declines*, the magnitudes of decline were similar for all race–sex groups in all 3 time periods.

Conversely, for black men and black women, a larger proportion of counties were categorized as *delayed strong declines* (76% and 77%, respectively), compared with white men (15%) and white women (42%). In these counties, black men and black women initially experienced much smaller

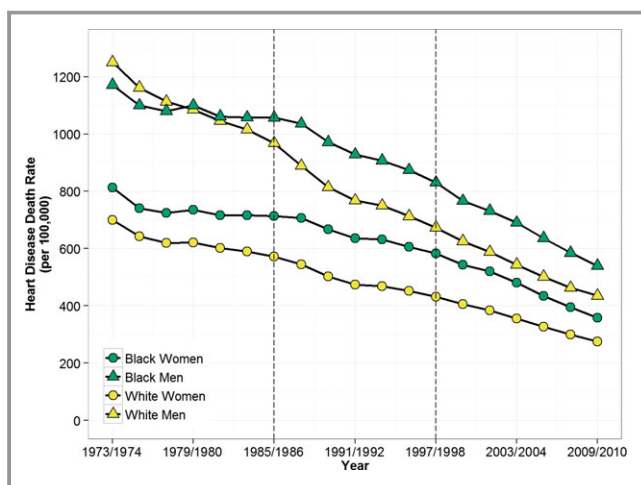


Figure 1. Age-standardized heart disease death rates for persons aged ≥35, by race–sex group, United States, 1973–2010. Vertical dashed lines represent the limits of the 3 time periods used in this analysis.

Table 2. Percentage Decline in Age-Standardized Heart Disease Mortality by Time Period and Race–Sex Group, Continental United States, 1973–2010

	Percentage Decline		
	1973–1985	1986–1997	1998–2010
Total*	20.0	26.7	35.4
White men	22.6	30.5	35.3
White women	18.3	24.6	36.2
Black men	9.7	21.5	35.0
Black women	12.2	18.3	38.4

*Total values represent the national percentage declines for these 4 race–sex groups combined.

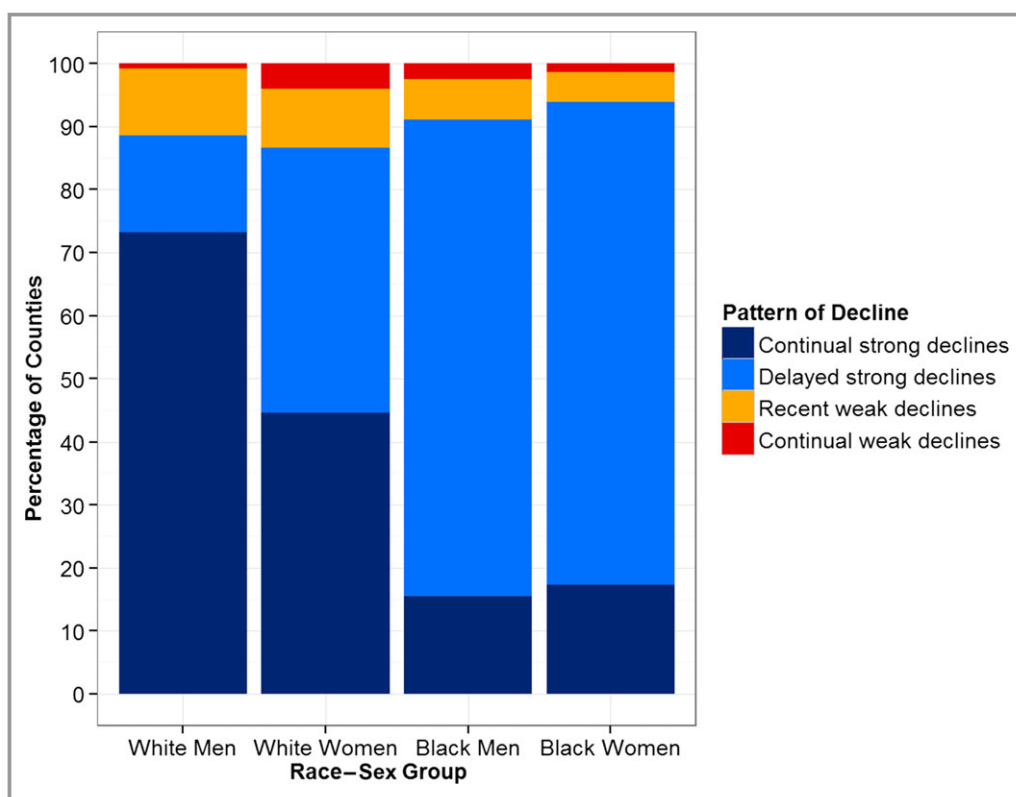


Figure 2. Patterns of declining county-level heart disease mortality by race-sex groups, continental United States, 1973–2010. Continual strong or weak declines were statistically faster or slower, respectively, than the total decline for the entire study period; delayed strong or recent weak declines were statistically faster or slower, respectively, than the total decline in the last time period (1998–2010). The number of counties included for each race-sex group were 3089 for white men, 3065 for white women, 1437 for black men, and 1511 for black women.

magnitudes of decline than white men and white women; however, by the most recent time period, the magnitudes of decline for black and white persons were similar.

Counties with *continual weak declines* constituted the smallest percentage of all counties for each race-sex group and were most prevalent for white women (4%) followed by black men (2%), black women (1%), and white men (<1%). In these counties, black men and women generally experienced increasing heart disease mortality in the initial time period (Table 3). In the final time period, magnitudes of decline for black persons remained less than those for white persons.

Counties experiencing *recent weak declines* were more common among white men (11%) and white women (9%) than for black men (7%) and black women (5%) (Figure 3). In these counties, however, the magnitudes of decline for black persons were less than those for white persons in each time period.

County-Level Declines: Temporal Patterns by Geography

Looking at broad geographic patterns, counties experiencing *continual strong declines* were concentrated in the Mid-

Atlantic region for black women and black men and were found nationwide (except in the South) for white men and white women. Although counties experiencing *delayed strong declines* were concentrated in the South for white men, these counties were more geographically dispersed for the other 3 race-sex groups. For each race-sex group, a band of counties stretching from eastern Texas through Alabama experienced *continual weak declines* (Figures 3A and 3B). Counties experiencing *recent weak declines* were further concentrated in a band reaching from Louisiana to Alabama.

Geographic patterns were most similar between black men and black women (concordance correlation coefficient of 79.4%) followed by white men and white women (64.5%). Concordance between racial groups was low for both women (40.9% between black women and white women) and men (33.6% between black men and white men).

Discussion

We observed disparities in temporal patterns of declining heart disease mortality by race, sex, and geography in the United States between 1973 and 2010. Although profound

Table 3. Mean Percentage Decline in County-Level Heart Disease Mortality* for Patterns of Declines by Time Period and Race–Sex Group, Continental United States, 1973–2010

Pattern/Race–Sex Group [†]	Number of Counties (%)	Mean Percentage Decline Among Counties (SD)		
		1973–1985	1986–1997	1998–2010
Continual strong declines				
White men	2260 (73.2)	22.7 (4.4)	29.3 (5.5)	34.5 (4.9)
White women	1368 (44.6)	20.3 (4.7)	26.2 (5.1)	34.8 (5.5)
Black men	223 (15.5)	20.6 (5.0)	28.0 (6.7)	37.5 (7.4)
Black women	261 (17.3)	21.7 (5.3)	25.4 (5.7)	39.7 (8.0)
Delayed strong declines				
White men	477 (15.4)	17.8 (6.5)	18.3 (7.5)	33.5 (4.8)
White women	1288 (42.0)	13.2 (7.5)	15.7 (8.6)	33.6 (5.7)
Black men	1086 (75.5)	6.1 (10.4)	14.7 (11.7)	36.4 (8.2)
Black women	1158 (76.6)	7.3 (10.8)	10.9 (11.6)	37.7 (8.3)
Recent weak declines				
White men	328 (10.6)	20.1 (4.9)	23.1 (7.8)	22.6 (4.2)
White women	285 (9.3)	15.8 (5.7)	15.4 (10.4)	20.3 (5.1)
Black men	93 (6.5)	7.6 (9.5)	17.4 (14.0)	14.6 (6.9)
Black women	72 (4.8)	9.9 (8.1)	12.2 (16.9)	15.6 (6.7)
Continual weak declines				
White men	24 (0.8)	11.7 (2.0)	14.2 (4.5)	21.6 (4.7)
White women	124 (4.0)	5.9 (5.1)	9.7 (6.0)	20.5 (4.8)
Black men	35 (2.4)	−5.3 (10.1) [‡]	3.3 (11.4)	15.9 (7.0)
Black women	20 (1.3)	−2.5 (8.7) [‡]	2.7 (11.7)	16.0 (6.6)

*Continual strong or weak declines were statistically faster or slower, respectively, than the total decline for the entire study period; delayed strong or recent weak declines were statistically faster or slower, respectively, than the total decline in the last time period (1998–2010).

[†]The number of counties included for each race–gender group were 3089 for white men, 3065 for white women, 1437 for black men, and 1511 for black women.

[‡]A negative percentage decline indicates increasing heart disease death rates.

declines occurred for each race–sex group, *continual strong declines* occurred most frequently for white men (73% of all counties), whereas *delayed strong declines* occurred most frequently for black women and black men (77% and 76%, respectively). The geographic distributions of these 2 patterns of decline varied by race–sex group. Counties experiencing *continual strong declines* were concentrated in the Mid-Atlantic region for black women and black men but were more diffuse for white women and white men (although much less prevalent in the South). Counties with *delayed strong declines* were focused in the South for white men but did not exhibit a strong geographic pattern for the other race–sex groups. Counties experiencing *continual weak* or *recent weak declines* were less prevalent and, for each race–sex group, exhibited a common geographic distribution concentrated in the South. Although the broad geographic patterns were similar across race–sex groups for the area of the country with data for all race–sex groups (ie, counties in the eastern United States), the more detailed patterns found by examining intracounty

concordance demonstrate greater agreement of patterns within each race than between races.

Previous studies have shown the equal contributions of primary prevention and medical treatment to national declines in heart disease mortality.² In our study, observed patterns of decline in heart disease mortality exhibited both racial and geographic disparities, suggesting differential diffusion of prevention and treatment efforts by race and geography and subsequently raising the question of whether the relative contributions of primary prevention and medical treatment also vary by race and geography.³⁰

Delayed, rather than fully absent, strong declines in heart disease mortality among black persons point to racial disparities in the timing of equitable delivery, initiation, and implementation of primary and secondary prevention of heart disease.³⁰ Given the pervasiveness of counties with *delayed strong declines* for black persons, nationwide factors that broadly and disproportionately affect black persons may contribute to racial disparities in the timing of access to

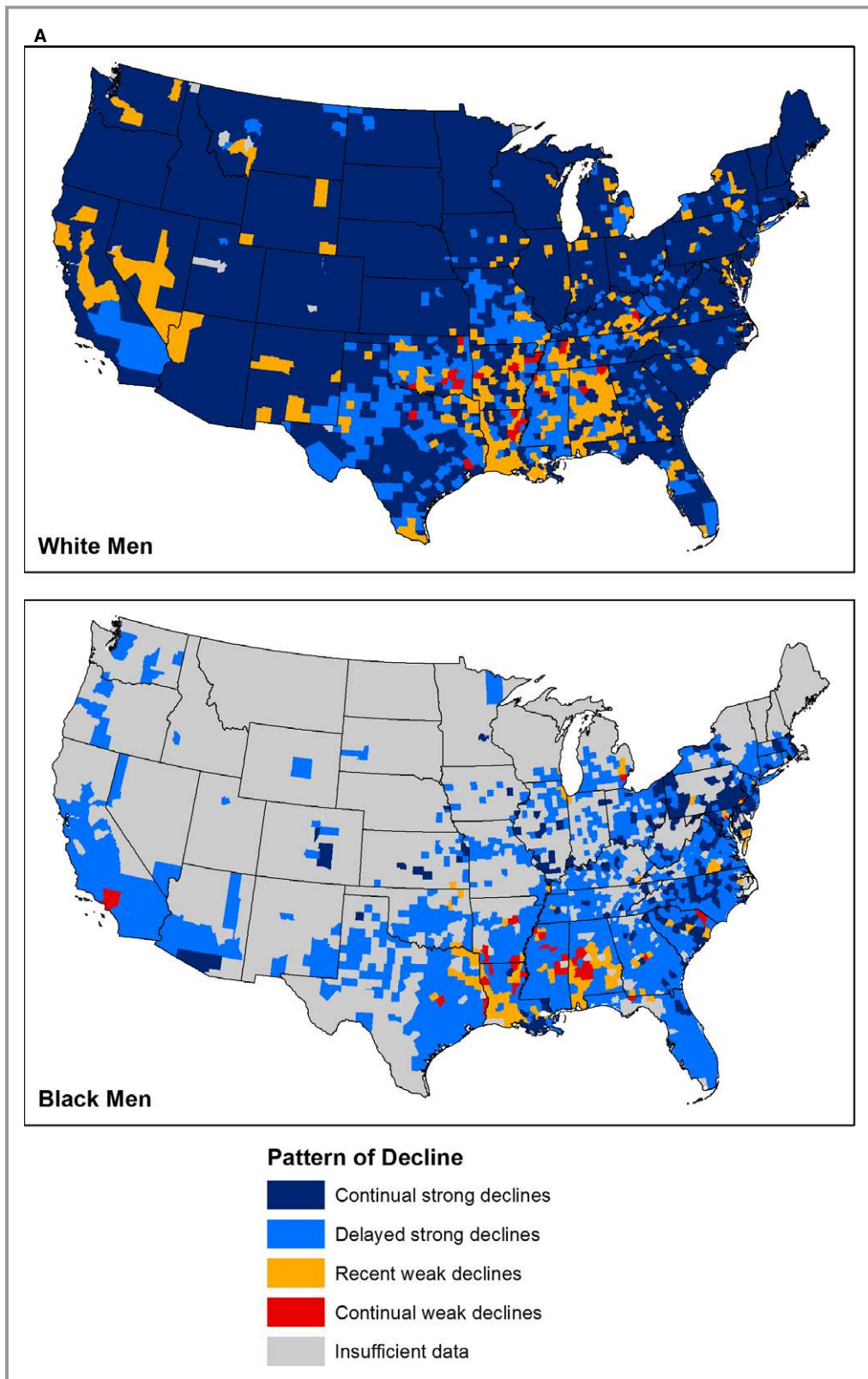


Figure 3. Patterns of declining county-level heart disease mortality for men (A) and for women (B), continental United States, 1973–2010. Continual strong or weak declines were statistically faster or slower, respectively, than the total decline for the entire study period; delayed strong or recent weak declines were statistically faster or slower, respectively, than the total decline in the last time period (1998–2010).

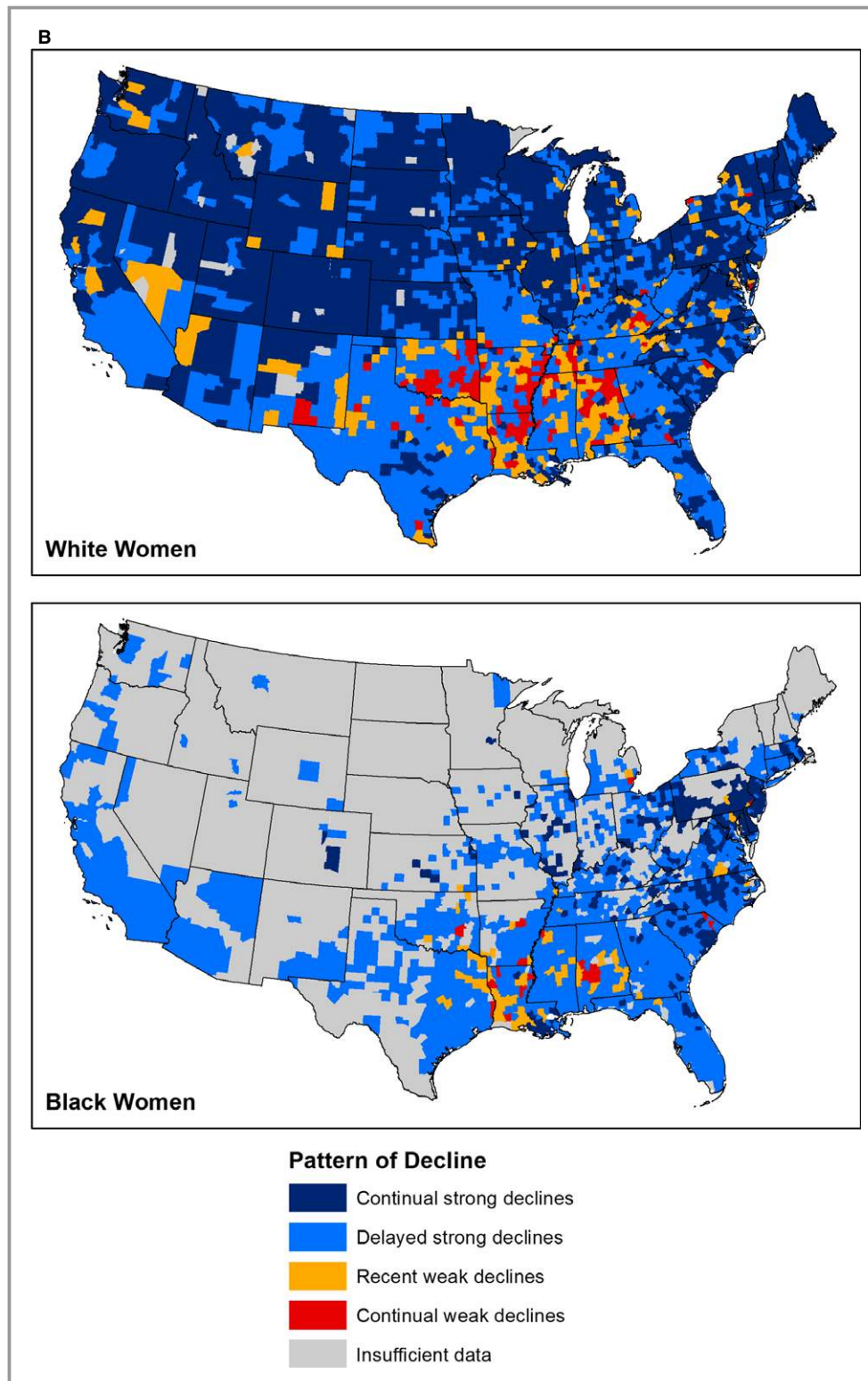


Figure 3. Continued.

heart disease prevention and treatment.³¹ Nevertheless, speculating on specific factors is difficult because the literature is focused on determinants of racial disparities in cardiovascular outcomes (eg, education, poverty, racial

residential segregation, risk factor awareness, disease control, access to care)^{17,31–37} rather than racial disparities in the temporal dissemination of prevention and treatment modalities.

In contrast to the results for white men, a majority of counties assessed for white women (55%) did not experience *continual strong declines*. This finding may result from historically lower heart disease mortality among white women compared with the other race–sex groups, subsequently resulting in less potential for strong declines (especially relative to national declines, as measured in this study).¹

In addition to racial disparities, we also observed 2 notable geographic disparities that occurred for both black and white persons: The concentration of counties in the South with weak declines and the Mid-Atlantic concentration of counties with *continual strong declines*. These 2 geographic concentrations indicate the importance of local factors in promoting (for those counties in the Mid-Atlantic region) or inhibiting (for those counties in the South) the diffusion of advances in heart disease prevention and treatment. The consistency across race–sex groups suggests similar drivers of these local geographic patterns for black and white persons.

Geographic disparities in heart disease mortality and other cardiovascular outcomes have been associated with factors related to heart disease treatment and prevention (eg, hospital quality, access to evidence-based health care) and measures of socioeconomic context (eg, rurality, poverty, occupational structure).^{9,10,38–46} Socioeconomic context provides a foundation for the potential success of prevention and treatment interventions.⁴⁷ Many southern counties are rural, impoverished, and medically underserved and experience other negative health outcomes.^{48,49} Although studies of access to health care began after the beginning of our study period, recent increases in cardiac services are clustered in metropolitan areas and thus may have increased rural–urban disparities in access to evidence-based care and resulting heart disease death rates.^{40,42} Finally, risk factors (eg, smoking, diet, and diabetes) may also have a strong time-varying geographic pattern. The South, with high prevalence of smoking, diabetes, and obesity, has lagged behind the rest of the United States in improving these measures.^{50–54}

Understanding both historic and recent patterns of decline is a first step in identifying national and local determinants of the dissemination of heart disease treatment and prevention. Future work investigating multilevel determinants of racial and geographic disparities in the temporal patterns of declining heart disease mortality (ie, social environment; medical care quality and access; and psychosocial, behavioral, and physiological risk factors) would benefit from race- and sex-specific, area-based, and context-sensitive measures of prevention and treatment over time. Although the availability of such local data are currently limited, the increased adoption of electronic health records in both outpatient and inpatient settings will hopefully provide richer local data in the future. Similarly,

implementation of the Affordable Care Act represents potential for a natural experiment. Greater accessibility of prevention activities and health insurance coverage in some jurisdictions may improve access to heart disease prevention and treatment, thereby reducing disparities in mortality. Greater understanding of the determinants of these declines will facilitate the development of racially and geographically focused interventions to reduce disparities in heart disease mortality.

Strengths and Limitations

This study's strengths stem from its application of complex analytic methods to national surveillance data. By using Bayesian statistical methods, we could include more counties with relatively small race- and sex-specific populations. These methods leverage the information of neighboring counties, nearby time periods, and other race–sex groups to obtain more precise estimates of the rates of heart disease deaths, especially in counties with small populations and few events. These powerful methods allow us to build on previous studies by using smaller geographic units and attaining greater precision in small-area rates.^{6,11,15,16,22,55} In addition, unlike some other studies of temporal trends in heart disease mortality that relied on cohort data, this analysis used national vital statistics data that includes all deaths.^{19,56,57} As such, concerns regarding selection bias and the generalizability of the results are minimized. Finally, several prior studies have explored trends in heart disease mortality assuming a linear change over the entire study period.^{6,11,13,18,19,22} We avoided this limitation by dividing our study period into 3 time periods, thereby enabling the assessment of nonlinear trends over the study period.

This study's limitations result from our use of national surveillance data and from summarizing complex data. Over the study duration, the classification of race and ethnicity changed nationally, restricting our study population to black and white persons and excluding other racial and ethnic groups.⁵⁸ In addition, national surveillance data relies on nonvalidated death certificate data. Although these data may sometimes overestimate the number of heart disease deaths, their use in aggregate is valid⁵⁹; however, the potential for geographic and racial variation in reporting heart disease as the underlying cause of death represents a potential source of bias in these data.⁵⁹ Our inclusion of deaths due to all diseases of the heart (rather than the subgroup for coronary heart disease or other specific diagnoses) reduces the potential for this misclassification.

By categorizing 4 race–sex groups in 3099 counties into spatiotemporal patterns of decline based upon 37 years of data, some nuance of the trends was inevitably lost. To reduce arbitrary decisions in defining these categories and to

facilitate their comparison by race–sex and county, we used the total trends at the national level as the standard. Moreover, despite the use of Bayesian methods, estimates for some counties remained imprecise in the final time period and thus could not be assigned a temporal pattern.

Conclusion

The racial and geographic disparities observed in the timing and magnitude of declining heart disease death rates highlight the need to better understand and ameliorate racial and geographic disparities in the diffusion of effective prevention and treatment of heart disease.¹ Reductions in racial and geographic disparities in heart disease mortality have been a focus of national organizations and initiatives.^{60,61} Nevertheless, to close existing and long-standing racial and geographic gaps in heart disease mortality, we must surpass the parallel declines for black and white persons observed at the end of the study period (which, despite improving relative to earlier time periods, will only maintain existing racial disparities in the magnitude of the rates) and accelerate declines in the South (Figure 1). Targeted improvements in areas and among populations that lag behind the nation could lead to progress toward racial and geographic equity of heart disease mortality in the United States.

Acknowledgments

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

Sources of Funding

This research was supported in part by appointments for Dr Kramer and Mr Vaughan to the Research Participation Program at the Centers for Disease Control and Prevention administered by the Oak Ridge Institute for Science and Education through an interagency agreement between the U.S. Department of Energy and CDC. Dr Kramer was also supported by the Eunice Kennedy Shriver National Institute of Child Health & Human Development of the National Institutes of Health under Award number K01HD074726.

Disclosures

None.

References

- Mozaffarian D, Benjamin E, Go A, Arnett D, Blaha M, Cushman M, de Ferranti S, Després J, Fullerton H, Howard V, Huffman M, Judd S, Kissela B, Lackland D, Lichtman J, Lisabeth L, Liu S, Mackey R, Matchar D, McGuire D, Mohler ER, Moy C, Muntner P, Mussolino M, Nasir K, Neumar R, Nichol G, Palaniappan L, Pandey D, Reeves M, Rodriguez C, Sorlie P, Stein J, Towfighi A, Turan T, Virani S, Willey J, Woo D, Yeh R, Turner M. Executive summary: heart disease and stroke statistics—2015 update: a report from the American Heart Association. *Circulation*. 2015;131:434–441.
- Ford ES, Ajani UA, Croft JB, Critchley JA, Labarthe DR, Kottke TE, Giles WH, Capewell S. Explaining the decrease in U.S. deaths from coronary disease, 1980–2000. *N Engl J Med*. 2007;356:2388–2398.
- Miniño A. Death in the United States, 2009. *NCHS Data Brief*. 2011;64:1–8.
- Centers for Disease Control and Prevention. Achievements in public health, 1900–1999: decline in deaths from heart disease and stroke—United States, 1900–1999. *MMWR Morb Mortal Wkly Rep*. 1999;48:649–656.
- Yang Q, Cogswell ME, Flanders WD, Hong Y, Zhang Z, Loustalot F, Gillespie C, Merritt R, Hu FB. Trends in cardiovascular health metrics and associations with all-cause and CVD mortality among US adults. *JAMA*. 2012;307:1273–1283.
- Gillum R, Mehari A, Curry B, Obisesan T. Racial and geographic variation in coronary heart disease mortality trends. *BMC Public Health*. 2012;12:410.
- Kramer MR, Valderrama A, Casper M. Decomposing black-white disparities in heart disease mortality in the U.S., 1973–2010: an age-period-cohort analysis. *Am J Epidemiol*. 2014;182:302–312.
- Sempos C, Cooper R, Kovar M, McMillen M. Divergence of the recent trends in coronary mortality for the four major race-sex groups in the United States. *Am J Public Health*. 1988;78:1422–1427.
- Barnett E, Strogatz D, Armstrong D, Wing S. Urbanisation and coronary heart disease mortality among African Americans in the US South. *J Epidemiol Community Health*. 1996;50:252–257.
- Barnett E, Halverson JA. Regional and urban rural disparities in premature coronary heart disease mortality trends among blacks and whites, 1985–1995. *Public Health Rep*. 2000;115:52–64.
- Barnett E, Halverson JA. Local increases in coronary heart disease mortality among blacks and whites in the United States, 1985–1995. *Am J Public Health*. 2001;91:1499–1506.
- Ingram D, Gillum R. Regional and urbanization differentials in coronary heart disease mortality in the United States, 1968–1985. *J Clin Epidemiol*. 1989;42:857–868.
- Kulshreshtha A, Goyal A, Dabhadkar K, Veledar E, Vaccarino V. Urban-rural differences in coronary heart disease mortality in the United States: 1999–2009. *Public Health Rep*. 2014;129:19–29.
- Vaughan AS, Kramer MR, Waller LA, Schieb LJ, Greer S, Casper M. Comparing methods of measuring geographic patterns in temporal trends: an application to county-level heart disease mortality in the United States, 1973 to 2010. *Ann Epidemiol*. 2015;25:329–335.
- Wing S, Hayes CG, Heiss G, John E, Knowles M, Riggan W, Tyroler HA. Geographic variation in the onset of decline of ischemic heart disease mortality in the United States. *Am J Public Health*. 1986;76:1404–1408.
- Wing S, Barnett E, Casper M, Tyroler HA. Geographic and socioeconomic variation in the onset of decline of coronary heart disease mortality in white women. *Am J Public Health*. 1992;82:204–209.
- Cooper R, Cutler J, Desvigne-Nickens P, Fortmann SP, Friedman L, Havlik R, Hogelin G, Marler J, McGovern P, Morosco G, Mosca L, Pearson T, Stamler J, Stryer D, Thom T. Trends and disparities in coronary heart disease, stroke, and other cardiovascular diseases in the United States: findings of the National Conference on Cardiovascular Disease Prevention. *Circulation*. 2000;102:3137–3147.
- Rosamond WD, Chambless LE, Folsom AR, Cooper LS, Conwill DE, Clegg L, Wang C-H, Heiss G. Trends in the incidence of myocardial infarction and in mortality due to coronary heart disease, 1987 to 1994. *N Engl J Med*. 1998;339:861–867.
- Rosamond WD, Chambless LE, Heiss G, Mosley TH, Coresh J, Whitsel E, Wagenknecht L, Ni H, Folsom AR. Twenty-two-year trends in incidence of myocardial infarction, coronary heart disease mortality, and case fatality in 4 US communities, 1987–2008. *Circulation*. 2012;125:1848–1857.
- Wellenius GA, Mittleman MA. Disparities in myocardial infarction case fatality rates among the elderly: the 20-year Medicare experience. *Am Heart J*. 2008;156:483–490.
- Yeh RW, Sidney S, Chandra M, Sorel M, Selby JV, Go AS. Population trends in the incidence and outcomes of acute myocardial infarction. *N Engl J Med*. 2010;362:2155–2165.
- Wing S, Casper ML, Davis WB, Hayes CG, Riggan WB, Tyroler HA. Trends in the geographic inequality of cardiovascular disease mortality in the United States, 1962–1982. *Soc Sci Med*. 1990;30:261–266.
- Anderson R, Miniño A, Hoyert D, Rosenberg H. Comparability of cause of death between ICD-9 and ICD-10: preliminary estimates. *Natl Vital Stat Rep*. 2001;19:1–32.

24. Klebba A, Scott J. Estimates of selected comparability ratios based on dual coding of 1976 death certificates by the Eighth and Ninth Revisions of the International Classification of Diseases. *Mon Vital Stat Rep.* 1980;28:1–19.
25. United States Department of Health and Human Services (US DHHS) Centers for Disease Control and Prevention (CDC) National Center for Health Statistics (NCHS). Bridged-race population estimates, United States July 1st resident population by state, county, age, sex, bridged-race, and Hispanic origin. 2013.
26. Quick H, Waller LA, Casper M. A nonseparable multivariate space-time model for analyzing county-level heart disease death rates for race and gender. *ArXiv Preprint.* 2015;arXiv:1507.02741.
27. Besag J, York J, Mollié A. Bayesian image restoration with two applications in spatial statistics. *Ann Inst Stat Math.* 1991;43:1–59.
28. Carrasco JL, Martinez JP, Jover L. Ccorm: Ccorm. R package version 1.1. 2012.
29. King T, Chinchilli V. A generalized concordance correlation coefficient for continuous and categorical data. *Stat Med.* 2001;20:2131–2147.
30. Phelan JC, Link BG. Controlling disease and creating disparities: a fundamental cause perspective. *J Gerontol B Psychol Sci Soc Sci.* 2005;60(Spec No 2):27–33.
31. Williams DR, Jackson PB. Social sources of racial disparities in health. *Health Aff.* 2005;24:325–334.
32. Hertz RP, Unger AN, Cornell JA, Saunders E. Racial disparities in hypertension prevalence, awareness, and management. *JAMA Intern Med.* 2005;165:2098–2104.
33. Rooks RN, Simonsick EM, Klesges LM, Newman AB, Ayonayon HN, Harris TB. Racial disparities in health care access and cardiovascular disease indicators in black and white older adults in the Health ABC study. *J Aging Health.* 2008;20:599–614.
34. Mensah G, Mokdad A, Ford E, Greenlund K, Croft J. State of disparities in cardiovascular health in the United States. *Circulation.* 2005;111:1233–1241.
35. McWilliams JM, Meara E, Zaslavsky AM, Ayanian JZ. Differences in control of cardiovascular disease and diabetes by race, ethnicity, and education: U.S. trends from 1999 to 2006 and effects of Medicare coverage. *Ann Intern Med.* 2009;150:505–515.
36. Jha AK, Fisher ES, Li Z, Orav EJ, Epstein AM. Racial trends in the use of major procedures among the elderly. *N Engl J Med.* 2005;353:683–691.
37. Christian A, Rosamond W, White A, Mosca L. Nine-year trends and racial and ethnic disparities in women's awareness of heart disease and stroke: an American Heart Association national study. *J Womens Health.* 2007;16:68–81.
38. Yamashita T, Kunkel S. The association between heart disease mortality and geographic access to hospitals: county level comparisons in Ohio, USA. *Soc Sci Med.* 2010;70:1211–1218.
39. Garg P, Landrum M, Normand S, Ayanian J, Hauptman P, Ryan T, McNeil B, Guadagnoli E. Understanding individual and small area variation in the underuse of coronary angiography following acute myocardial infarction. *Med Care.* 2002;40:614–626.
40. Busingye D, Pedigo A, Odoi A. Temporal changes in geographic disparities in access to emergency heart attack and stroke care: are we any better today? *Spat Spatiotemporal Epidemiol.* 2011;2:247–263.
41. Goldman LE, Dudley RA. United States rural hospital quality in the hospital compare database—accounting for hospital characteristics. *Health Policy.* 2008;87:112–127.
42. Horwitz JR, Nichols A, Nallamothu BK, Sasson C, Iwashyna TJ. Expansion of invasive cardiac services in the United States. *Circulation.* 2013;128:803–810.
43. Shuaib FM, Durant RW, Parmar G, Brown TM, Roth DL, Hovater M, Halanych JH, Shikany JM, Howard G, Safford MM. Awareness, treatment and control of hypertension, diabetes and hyperlipidemia and area-level mortality regions in the Reasons for Geographic and Racial Differences in Stroke (REGARDS) study. *J Health Care Poor Underserved.* 2012;23:903–921.
44. Durant RW, Parmar G, Shuaib F, Le A, Brown TM, Roth DL, Hovater M, Halanych JH, Shikany JM, Prineas RJ, Samdarshi TJ, Safford MM. Awareness and management of chronic disease, insurance status, and health professional shortage areas in the Reasons for Geographic and Racial Differences in Stroke (REGARDS): a cross-sectional study. *BMC Health Serv Res.* 2012;12:208.
45. Leeper B, Centeno M. Disparities in cardiac care for patients with complex cardiovascular care needs. *J Cardiovasc Nurs.* 2012;12:114–119.
46. Yan G, Cheung AK, Ma JZ, Yu AJ, Greene T, Oliver MN, Yu W, Norris KC. The associations between race and geographic area and quality-of-care indicators in patients approaching ESRD. *Clin J Am Soc Nephrol.* 2013;8:610–618.
47. Kreiger N. Theories for social epidemiology in the 21st century: an ecosocial perspective. *Int J Epidemiol.* 2001;30:668–677.
48. Holt J. The topography of poverty in the United States: a spatial analysis using county-level data from the Community Health Status Indicators project. *Prev Chronic Dis.* 2007;4:A111.
49. Hall H, Li J, McKenna M. HIV in predominantly rural areas of the United States. *J Rural Health.* 2005;21:245–253.
50. Davis S, Malarcher A, Thorne S, Maurice E, Trosclair A, Mowery P. State-specific prevalence and trends in adult cigarette smoking—United States, 1998–2007. *Morb Mortal Wkly Rep.* 2009;58:221–226.
51. Ezzati M, Martin H, Skjold S, Hoorn SV, Murray CJL. Trends in national and state-level obesity in the USA after correction for self-report bias: analysis of health surveys. *J R Soc Med.* 2006;99:250–257.
52. Dwyer-Lindgren L, Freedman G, Engell RE, Fleming TD, Lim SS, Murray CJ, Mokdad AH. Prevalence of physical activity and obesity in us counties, 2001–2011: a road map for action. *Popul Health Metr.* 2013;11:7.
53. Mokdad AH, Bowman BA, Ford ES, Vinicor F, Marks JS, Koplan JP. The continuing epidemics of obesity and diabetes in the United States. *JAMA.* 2001;286:1195–1200.
54. Mokdad AH, Ford ES, Bowman BA, Nelson DE, Engelgau MM, Vinicor F, Marks JS. Diabetes trends in the US: 1990–1998. *Diabetes Care.* 2000;23:1278–1283.
55. Davis WB, Hayes CG, Knowles M, Riggan WB, Van Bruggen J, Tyroler HA. Geographic variation in declining ischemic heart disease mortality in the United States, 1968–1978. *Am J Epidemiol.* 1985;122:657–672.
56. Parikh NI, Gona P, Larson MG, Fox CS, Benjamin EJ, Murabito JM, O'Donnell CJ, Vasan RS, Levy D. Long-term trends in myocardial infarction incidence and case fatality in the National Heart, Lung, and Blood Institute's Framingham Heart study. *Circulation.* 2009;119:1203–1210.
57. Newman JD, Shimbo D, Baggett C, Liu X, Crow R, Abraham JM, Loehr LR, Wruck LM, Folsom AR, Rosamond WD. Trends in myocardial infarction rates and case fatality by anatomical location in four United States communities, 1987 to 2008 (from the Atherosclerosis Risk in Communities Study). *Am J Cardiol.* 2013;112:1714–1719.
58. Mays VM, Ponce NA, Washington DL, Cochran SD. Classification of race and ethnicity: implications for public health. *Annu Rev Public Health.* 2003;24:83–110.
59. Coady SA, Sorlie PD, Cooper LS, Folsom AR, Rosamond WD, Conwill DE. Validation of death certificate diagnosis for coronary heart disease: the Atherosclerosis Risk in Communities (ARIC) Study. *J Clin Epidemiol.* 2001;54:40–50.
60. Institute of Medicine. *A Nationwide Framework for Surveillance of Cardiovascular and Chronic Lung Diseases.* Washington, DC: The National Academies Press; 2011.
61. Koh HK. A 2020 vision for healthy people. *N Engl J Med.* 2010;362:1653–1656.

Disparities in Temporal and Geographic Patterns of Declining Heart Disease Mortality by Race and Sex in the United States, 1973–2010

Adam S. Vaughan, Harrison Quick, Elizabeth B. Pathak, Michael R. Kramer and Michele Casper

J Am Heart Assoc. 2015;4:e002567; originally published December 15, 2015;
doi: 10.1161/JAHA.115.002567

The *Journal of the American Heart Association* is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Online ISSN: 2047-9980

The online version of this article, along with updated information and services, is located on the World Wide Web at:

<http://jaha.ahajournals.org/content/4/12/e002567>

Data Supplement (unedited) at:

<http://jaha.ahajournals.org/content/suppl/2015/12/15/JAHA.115.002567.DC1.html>