GEOGRAPHIC VARIATION IN CARDIOVASCULAR DISEASE MORTALITY IN US BLACKS AND WHITES

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Cardiovascular disease mortality rates have dropped significantly over the past several decades, but a shift has occurred over time in the geographic patterns of both coronary heart disease (CHD) and stroke mortality. This article describes these patterns and discusses how they vary by sex, race, age, and over time.

Death certificate information for Health Service Areas (HSAs) in 1988-1992 was used to analyze the geographic patterns of CHD and stroke death rates by race, sex, and age. Changes in these patterns from 1979-1993 also were examined. In 1988-1992, considerable geographic variation in both CHD and stroke mortality was demonstrated for each sex and race group. Coronary heart disease rates were particularly high in the lower Mississippi valley and Oklahoma for all four groups, in the Ohio River valley and New York for whites, and to a lesser extent for blacks. Areas of high rates among whites in the Carolinas resemble stroke mortality patterns. There were greater differences by racial group than by gender, by the definition of heart disease. Over time, rates have declined for both CHD and stroke, but regional differences in the rates of change give the appearance of a southwesterly movement of high heart disease rate clusters and a breakup of the "Stroke Belt."

Further research is needed to elucidate the cause of regional variation in CHD and stroke mortality. Similar geographic patterns of high rates of CHD and stroke in the southeastern United States may reflect common risk factors. This knowledge can be used to help develop appropriate interventions to target these high-rate areas in the Mississippi and Ohio River valleys. (*J Natl Med Assoc.* 1999;91:545-556.)

Key words: coronary disease ◆ stroke ◆ geographic variations

Cardiovascular disease mortality rates have dropped significantly over the past several decades (Figure 1), but rates have not declined at the same pace everywhere, causing a shift over time in the geographic patterns of both coronary heart disease and stroke mortality. Mortality rates among white residents were highest in the northeast in 1970,[1] but are now high in states adjoining the Ohio and Mississippi Rivers, an area recently termed the "Coronary Valley." This article describes the current geographic patterns of heart disease and stroke mortality and discusses how these patterns vary by a number of factors including sex, race, age, and time.

Mapping has played an important role in public health investigations since John Snow mapped the location of cholera cases around the London water pumps in the mid-1800s.[2] More than 100 years later,

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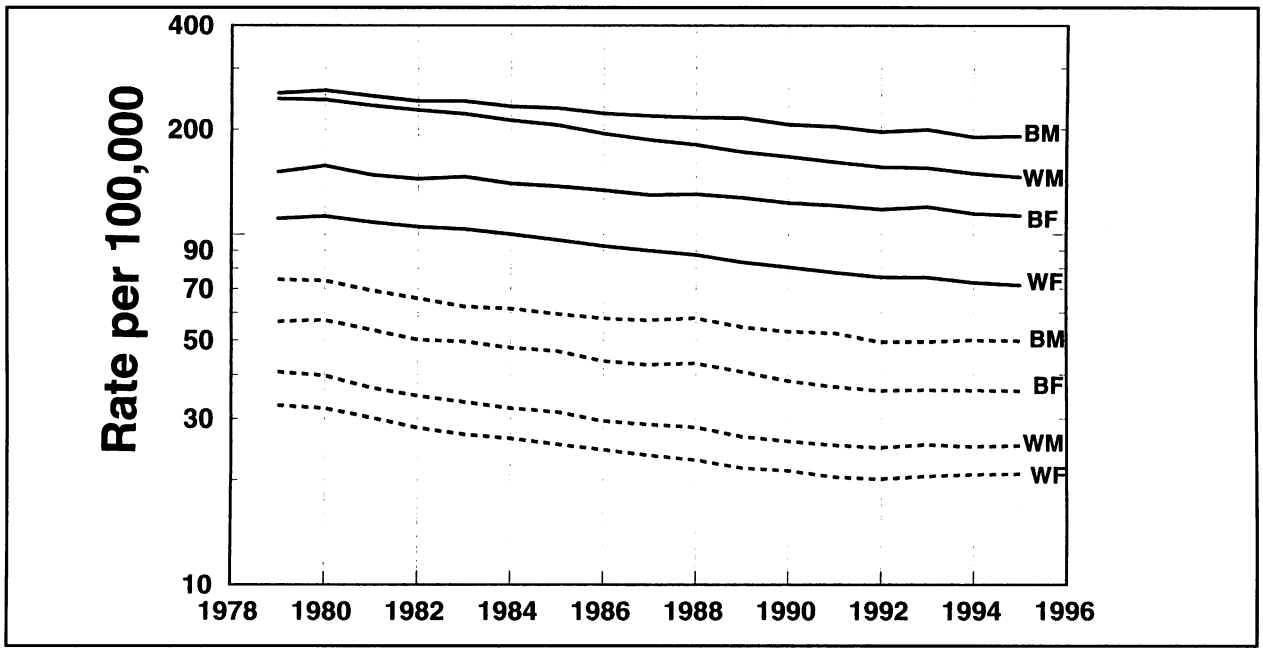

Figure 1. Age-adjusted death rates per 100,000 population for coronary heart disease and stroke, 1979-1995, by sex and race.

improvements in computer systems permitted mapping of small area levels across the United States.[3] Subsequent mortality atlases have led to a greater understanding of the regional differences of disease rates in this country by elucidating geographic patterns at both the regional and local level. Exploring the broad geographic patterns in the mortality data can generate etiologic hypotheses that can be further refined and tested in field studies. For example, the first cancer atlas showed a strong clustering of high oral cancer rates in the southeast among white women.[3] Initially thought to be due to occupational exposures, a case-control study identified dipping snuff as the primary risk factor in this population.[4] At a more local level, mortality maps may be used to identify specific locations where changes in health policy need to be made or prevention programs started. For example, in a situation similar to cardiovascular disease, cervical cancer death rates were found to be relatively high in West Virginia by the 1970s[5] despite sharply declining rates for more than 30 years in most regions. This led state officials to change their Medicaid policy to include pap smears.

For decades, coronary heart disease (CHD) death rates have been higher in the eastern United States than in the west, which contrasts somewhat with the "Stroke Belt" of the southeastern states.[6-13] An analysis of a national cohort study demonstrated higher coronary heart disease incidence in the southeastern United States compared with other regions.[12] This suggests that intervention to lower coronary risk factors should be targeted to areas with high mortality rates. The recent slowing of the long-term decline in mortality rates due to both coronary heart disease and stroke (Figure 1) signals the importance of continued detailed monitoring of mortality patterns and trends.[14] A number of descriptive analyses have previously described geographic patterns of coronary mortality.[6,7] However, recent innovations in computer mapping and statistical modeling techniques, and the availability of mortality data through 1992 for small geographic areas have allowed new analyses to describe geographic mortality patterns adequately by race, sex, and age, and to contrast current patterns with those described previously for earlier periods.[15] Examination of age-specific patterns may suggest cohort effects and presage patterns in decades to come.

MATERIALS AND METHODS

Death certificate information for each death in the United States collected by each state is compiled at the National Center for Health Statistics (NCHS). For each of 18 underlying causes of death, the num-

ber of deaths during 1988-1992 among residents of the 50 states and the District of Columbia were summarized by sex, race (black and white), age, and place of residence.[16] Age-specific rates were computed by dividing each of the counts by the similarly-stratified 1990 census counts that were multiplied by five to correspond to the five years of heart disease deaths. Directly age-adjusted rates were also computed for each combination of sex, race, and place of residence, using the 1940 total US population as the standard. The resulting rates were mapped in the *Atlas of United States Mortality*.[15] To examine changes in the geographic patterns over time, rates also were computed using these same methods for five three-year time periods, beginning with 1979-1981.

For the Atlas, the broadest definition of heart disease was used ("All heart disease," ICD categories 390-398, 402, 404-429), to be consistent with previously published statistics from NCHS.[16,17] In this article, patterns are compared using this definition with those of two more restrictive definitions: ICD categories 402, 410-414, and 429.2; and 410-414, which will be referred to as "coronary heart disease" and "ischemic heart disease," respectively.

Place of residence of the decedent, originally reported at the level of county or similar administrative unit, was assigned to one of 805 Health Service Areas (HSA).[18] These are defined as aggregations of counties that are relatively self-contained with respect to location of hospital care.[18] Each HSA was assigned to the state where it was located or, for 77 of the 805 HSAs that included counties in two states, to the state where the majority of its population lived. Regions were defined as Census Divisions, with the exception that the South Atlantic Division was subdivided to create 12 regions, plus Alaska and Hawaii (Figure 2).

Statistical Analysis

To examine the contribution of local and regional effects on the overall geographic patterns of heart disease mortality, the underlying data were analyzed using a mixed effects log-linear cubic spline model for the age-specific rates.[19] That is, logarithms of the age-specific rates were modeled as a function of age and these regression age effects for the HSAs within a region were assumed to vary randomly around the overall regional age effects. This analytic approach was developed for a project to map death rates for all leading causes of death in the United States.[15,20] The age-specific rates for heart disease and stroke deaths were found to be well explained by this model.

Predicted age-specific rates for each HSA and for each region were computed from this model using SAS PROC MIXED.[20,21] The predicted HSA rates were further smoothed by a nonparametric smoothing algorithm, weighted by the inverse of the rates' standard errors.[22] The purpose of this additional step was to bring the picture of broad geographic patterns into better focus by moderating extreme rates in HSAs with few deaths. The resulting smoothed age-specific maps can point to different contributions by age group to the summary age-adjusted rate patterns.

All maps were produced using ArcView software.[23] The maps were color-coded according to the percentiles of the rate distribution. The age-specific rate categories each represent approximately 20% of the 798 rates, excluding Alaska and Hawaii. The age-adjusted rate categories include, respectively, the lowest 10%, next 10%, 20%, 20%, 20%, 10%, and highest 10% of the 805 HSAs. For blacks, over 25% of HSAs had no deaths due to heart disease. These HSAs were all assigned to the lowest color category on the age-adjusted maps; consequently, the second to lowest category is unused for blacks. Areas on the age-adjusted rate maps that have unreliable rates (defined as having a coefficient of variation of at least 23%) are hatched. These rates have a large standard error because they are based on sparse data, typically fewer than 20 deaths, and therefore should be interpreted with caution. Further details of data collection and analytic methods are available in the *Atlas of United States Mortality*.[15]

RESULTS

Heart Disease

Defining Heart Disease. Figure 3 shows the age-adjusted rate maps for white males according to the three heart disease definitions. All three maps show the same general pattern: a band of high rates from New York to Louisiana, termed the "Coronary Valley," plus a small cluster centered in Oklahoma, and a band of high rates in the Carolinas and Georgia that resembles the Stroke Belt.[13] However, there are some individual HSAs that are categorized differently according to the definition used. For example, HSAs in Alabama and Nevada have high rates using the broadest definition, but are low using the more specific ones. This could just be chance or

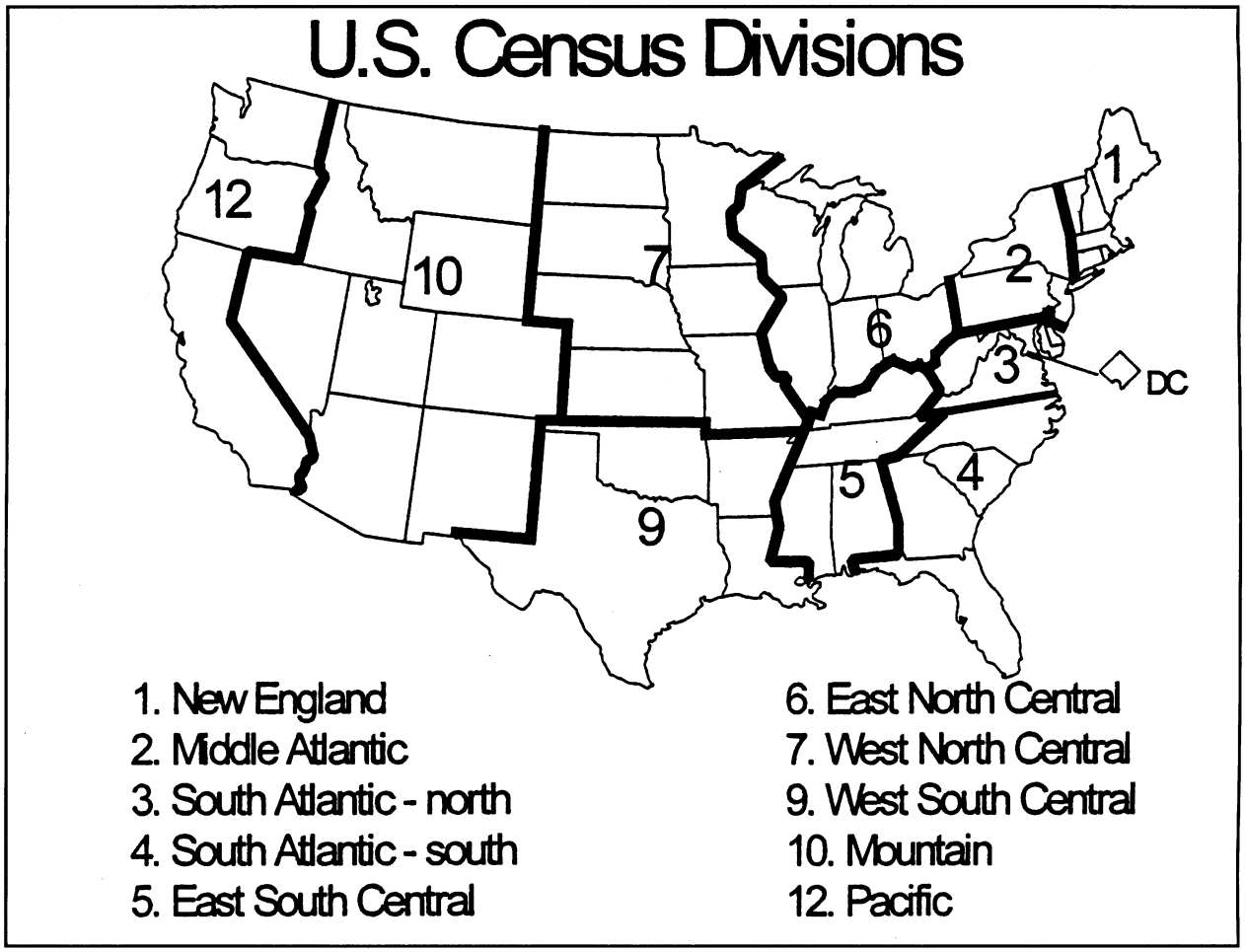

Figure 2. Definition of US Census regions.

it could indicate a difference in the underlying type of heart disease found in Alabama and Nevada, or a difference in the specificity of information provided on the death certificate. The latter explanation is supported by the higher proportion of heart disease deaths coded to less specific ICD categories in these two states (predominantly cardiac arrest [ICD 427.5] and heart failure [ICD 428] in Alabama) and a lower proportion coded to ischemic heart disease (Table 1).

Geographic Patterns. The map of age-adjusted coronary heart disease rates for white women shows more clearly three primary clusters of high rates: in the Coronary Valley states, in Oklahoma, and in the Carolinas and Georgia (Figure 4B). There is a cluster of particularly high rates along the shared borders of Kentucky, Ohio, West Virginia, and Virginia. This is apparent to some degree for men and women, blacks and whites. The East South Central region (MS, AL, TN, KY) is also consistently high: its regional rate ranks first or second of all the regions for all four sex/race groups and has a rate significantly higher than most of the other regions. Rates in southern California are somewhat elevated on all four maps.

The geographic patterns for black men and women are less clear because of greater variability of rates for the smaller populations, but the Coronary Valley states still tend to have higher than average mortality rates (Figures 4C-4D). Rates are only slightly elevated in the Carolinas, and there is no band of high rates as seen for whites. Only minor differences in patterns are seen between men and women for either racial group.

Maps of estimated age-specific rates (not shown) from the mixed effects model show a stronger clustering of relatively high rates in the Coronary Valley

Table 1. Percent of All Heart Disease Deaths Coded to Component ICD Codes for White and Black Males in Alabama, Nevada, and the Total United States, 1988-1992

Cause of Death	ICD Categories	White Males			Black Males		
		US	Alabama	Nevada	US	Alabama	Nevada
Acute rheumatic fever, chronic rheumatic heart disease	390-398	0.5	0.4	0.0	0.4	0.3	0.0
Hypertensive heart disease	402	1.9	1.5	8.5	7.0	7.1	22.7
Hypertensive heart and renal disease, secondary hypertension	404, 405	0.2	0.1	0.0	0.8	0.8	0.0
Ischemic heart disease	410-414	71.4	61.5	64.3	52.8	42.6	46.8
Diseases of pulmonary circulation, other forms of heart disease	415-429*	17.2	29.8	0.0	25.0	39.2	0.0
Cardiovascular disease, unspecified	429.2	8.8	6.7	27.2	14.0	10.1	30.6

*Excluding 429.2.

states for age 40 compared with age 70, even though the rates for the younger age group are much lower. For blacks, the high-rate cluster for age 40 rates does not extend into the Ohio Valley. Few other differences were noted among the sex/race groups.

Time Trends. Coronary heart disease mortality rates have dropped by nearly 40% among whites and 28% among blacks from 1979 to 1993, while stroke mortality has declined by 33%-37% during this time (Figure 1). However, the rate of decline varied by region, so that the geographic patterns of mortality changed. Clusters of high rate areas among white males in 1979-1981 were centered in West Virginia and eastern North Carolina (Figure 5). Over time, this cluster of relatively high rates moved in a southwesterly direction, so that by 1991-1993 high rates were seen along the Mississippi River. Similar shifts were seen for white women and for blacks.

Effect of Geographic Unit. The Health Service Area was chosen as the geographic unit for the NCHS Atlas so that sufficient numbers of deaths were available to produce stable mortality rate estimates. While this provides the best available data for judging state and substate geographic patterns of mortality, it may mask meaningful differences at a very localized level.

As an example of pattern differences in maps of HSAs compared to counties, Figure 6 shows coronary heart disease mortality rates among white males in eastern Kentucky. Health Service Areas 272 and 18 include Louisville, KY, and Lexington, KY, respectively. At the HSA level, these areas have average or slightly high mortality rates (Figure 6A). However, when mapped at the county level (Figure 6B), both of these HSAs contain counties in four or five of the five color categories, indicating a wide range of rates. It is interesting to note that rates in and near Louisville and Lexington are average or low, whereas rates in more rural counties farther from these cities, although still within the same HSA, have higher rates. However, because of greater numbers of deaths, the cities' rates dominate the aggregated HSA rates, hiding some very high county rates in eastern Kentucky.

Stroke

Similar to heart disease, stroke mortality rates have declined by approximately 35% for all four sex/race groups from 1979 to 1993, but differences in the pace of these declines have altered the geographic patterns. A number of publications have noted the recent breakup of the "Stroke Belt," a band of counties from North Carolina to Mississippi with high stroke mortality rates. The maps shown in Figure 7 are consistent with these prior reports–rates in Alabama are relatively lower and rates in Arkansas/Tennessee are relatively higher, giving the appearance of a break of the original high rate "belt." Although rates for blacks are about twice those for whites, this relative change in the geographic patterns over time is seen for all four groups.

The geographic patterns of stroke mortality have been presented in detail elsewhere.[13] Maps of stroke rates by ages 50, 70, and 90 for white and black women during 1988-1992 show relatively high rates in the Carolinas and Georgia for every age, with a cluster of high rates seen more and more west of the

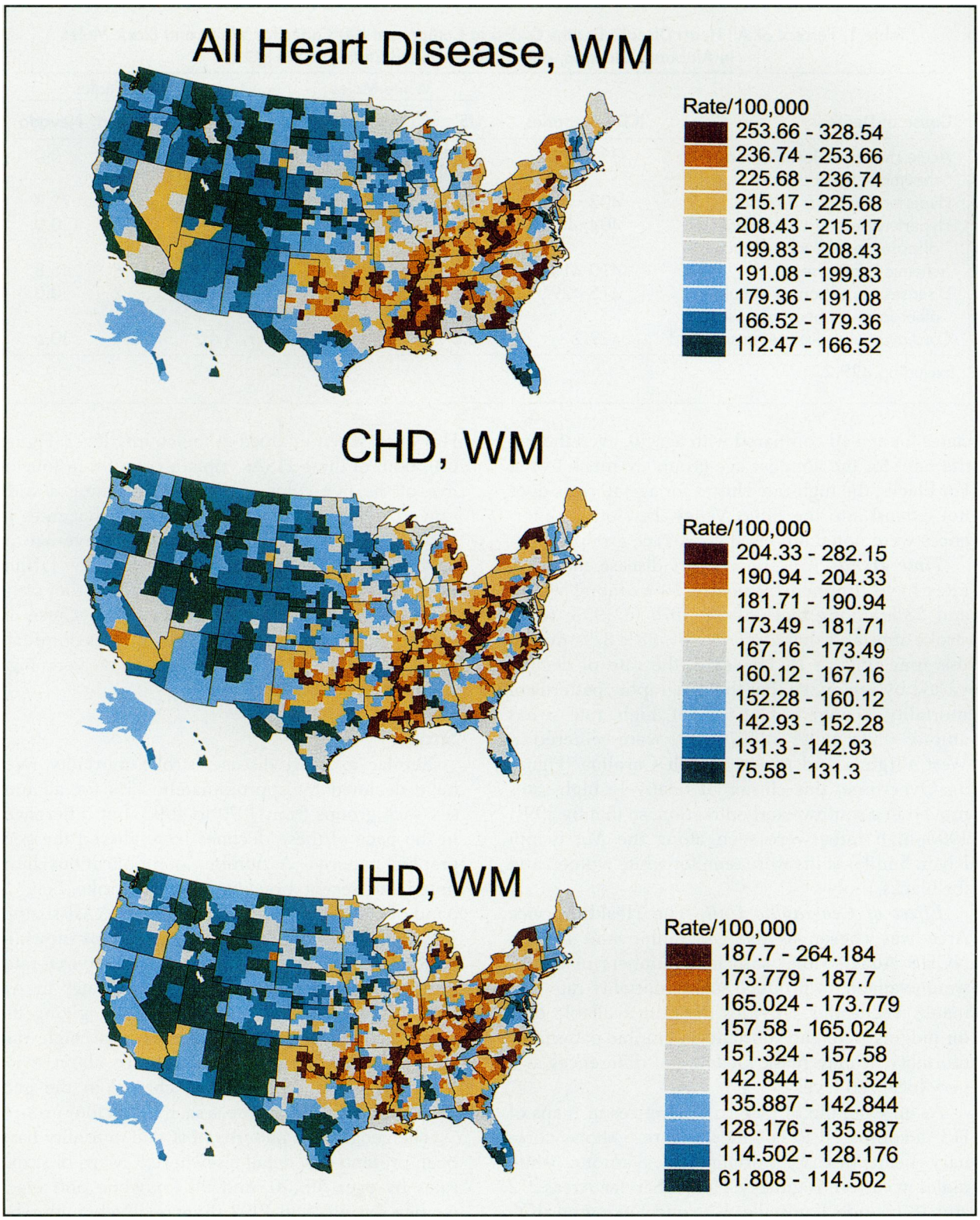

Figure 3. Age-adjusted death rates per 100,000 population for heart disease, according to three different definitions, among white men, 1988-1992.

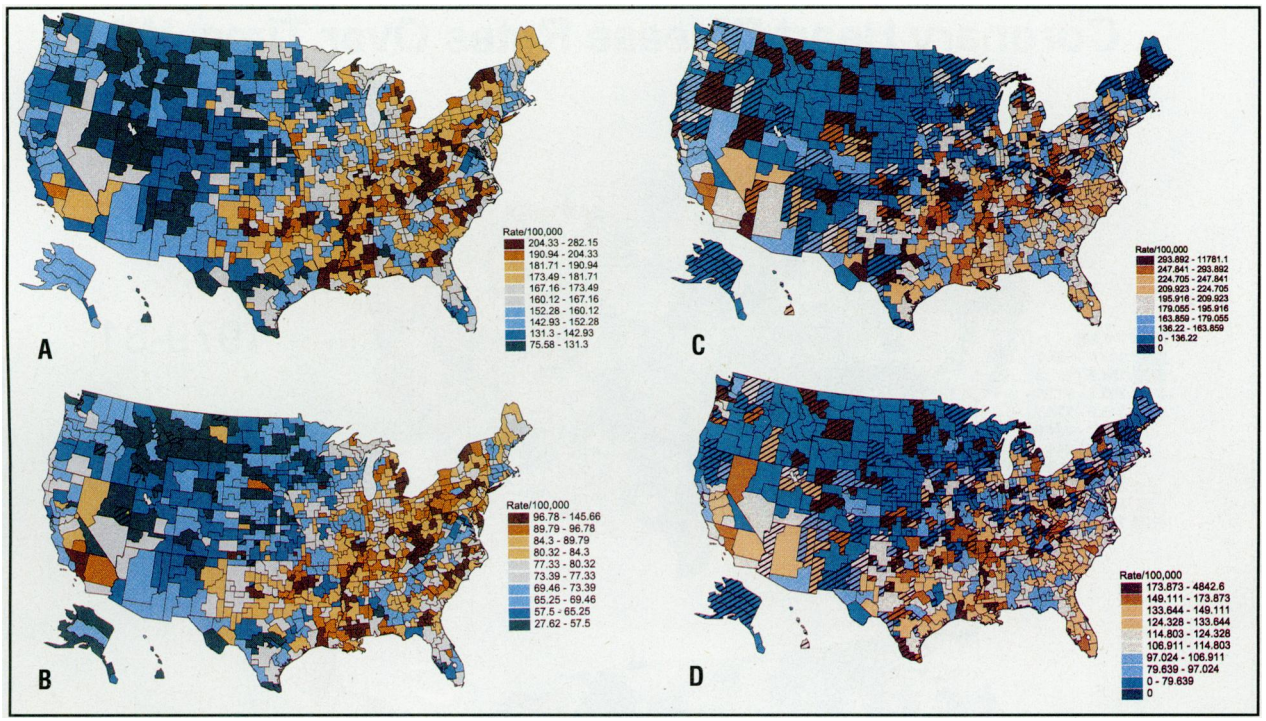

Figure 4. Age-adjusted death rates per 100,000 population for coronary heart disease by sex and race, 1988-1992 for (A) white males, (B) white females, (C) black males, and (D) black females. (Note: hatching denotes rates considered unreliable.)

original Stroke Belt for younger white women.[13] In addition, rates are high in southern California for black women and in all Pacific states for white women for all age groups.[13] The elevations on the west coast are not seen for men.

Comparisons of Geographic Patterns of Heart Disease and Stroke

Although mortality rates for heart disease are much higher than for stroke, the geographic patterns for these two causes of death are similar. In the Southeast, a band of relatively high coronary heart disease rates in the Carolinas and Georgia resembles the Stroke Belt pattern. Rates for both heart disease and stroke are also high in the states just east of the Mississippi River but high stroke mortality rates do not extend northward into the Ohio Valley as do coronary heart disease rates. This clustering of high rates along the Mississippi River is similar to that seen for lung cancer mortality rates,[15] suggesting an influence of cigarette smoking or related factors on the cardiovascular mortality patterns.

CONCLUSION

The Coronary Valley states have high coronary heart disease death rates, especially east of the Mississippi River, and there also is a band of high rates in the Carolinas and Georgia that resemble the remaining section of the Stroke Belt. Differences in the maps due to the definition of coronary heart disease were minor, and there were greater differences by racial group than by gender. There is a stronger clustering of relatively high rates in the Coronary Valley for younger than for older ages. Over time, rates have declined, but there are regional differences in the rates of change so that there is an appearance of a southwesterly movement of the high heart disease rate clusters within the Coronary Valley states. There were some detailed differences between maps for Health Service Areas versus counties, but it remains to be seen if these are important or informative.

Compared with previous reports, the current data show a shift in the geographic patterns for coronary mortality between 1950 and 1990. From 1949 to 1951, CHD death rates were highest in the middle Atlantic division followed by the Pacific.[6] During the following decade, rates increased for white men in all divisions except the Pacific, where a decline was noted. Among white women, rates declined in seven

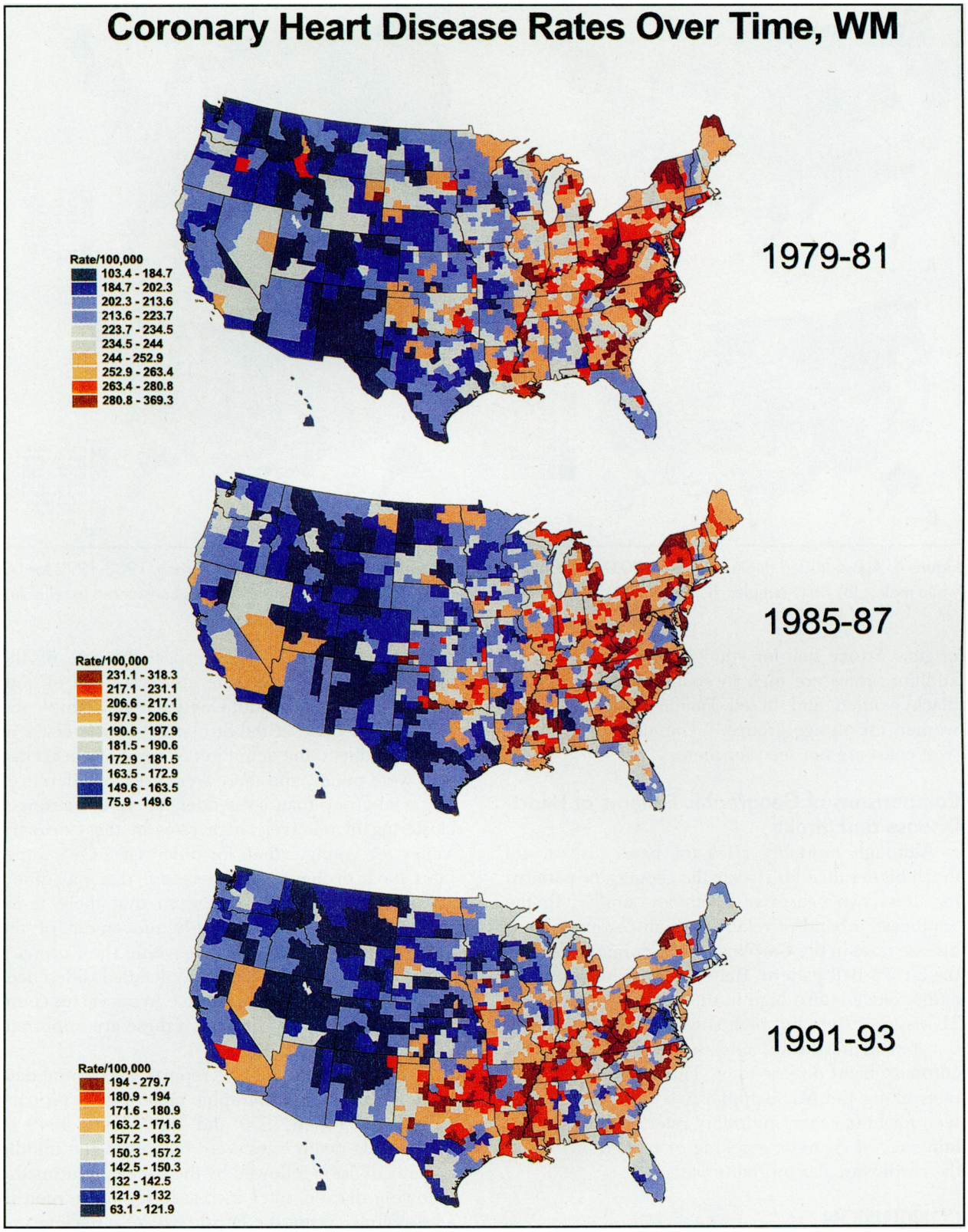

Figure 5. Age-adjusted death rates per 100,000 population for coronary heart disease among white males by time period.

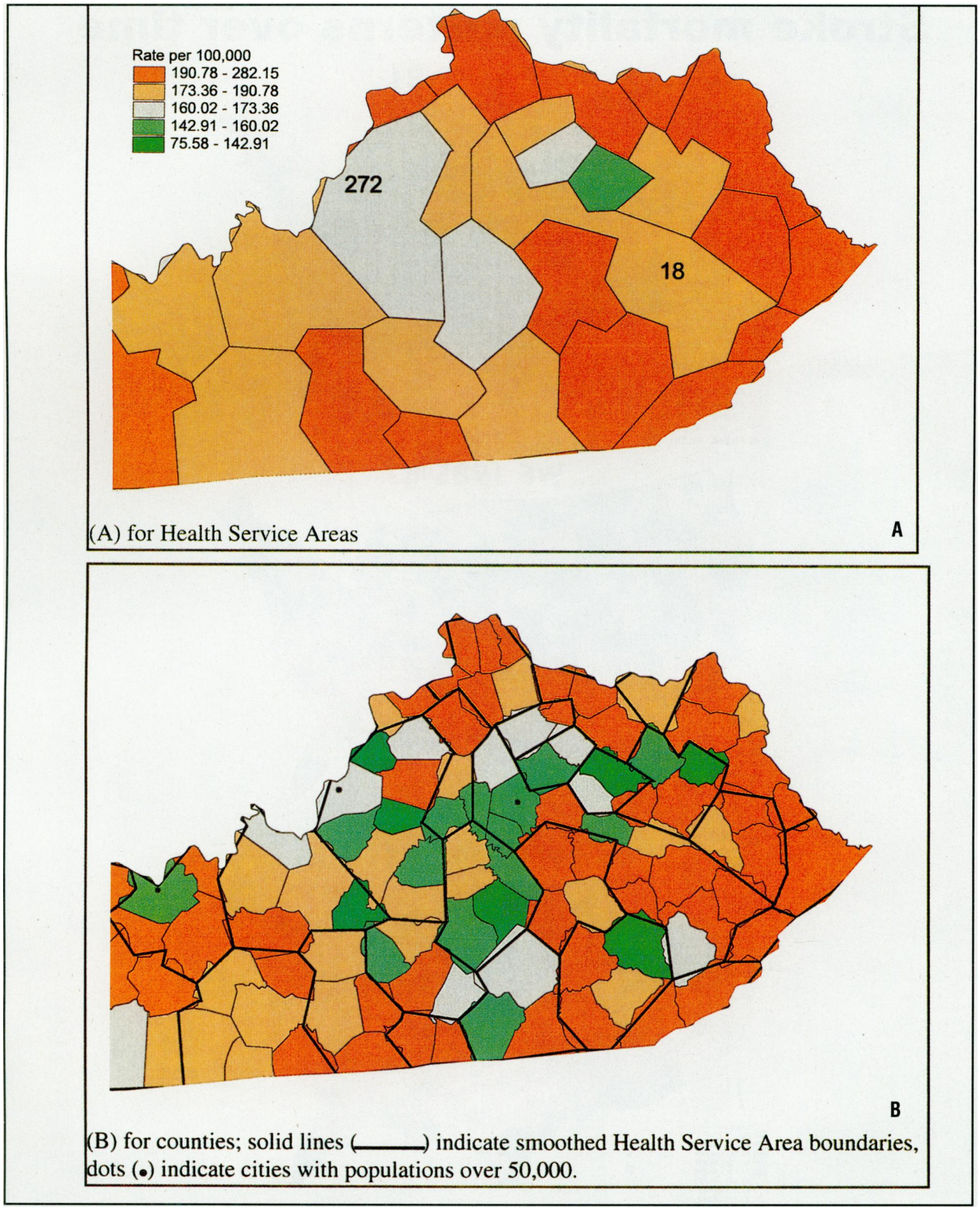

Figure 6. Age-adjusted death rates per 100,000 population for coronary heart disease among white males in eastern Kentucky, 1988-1992, by (A) Health Service Area and (B) county.

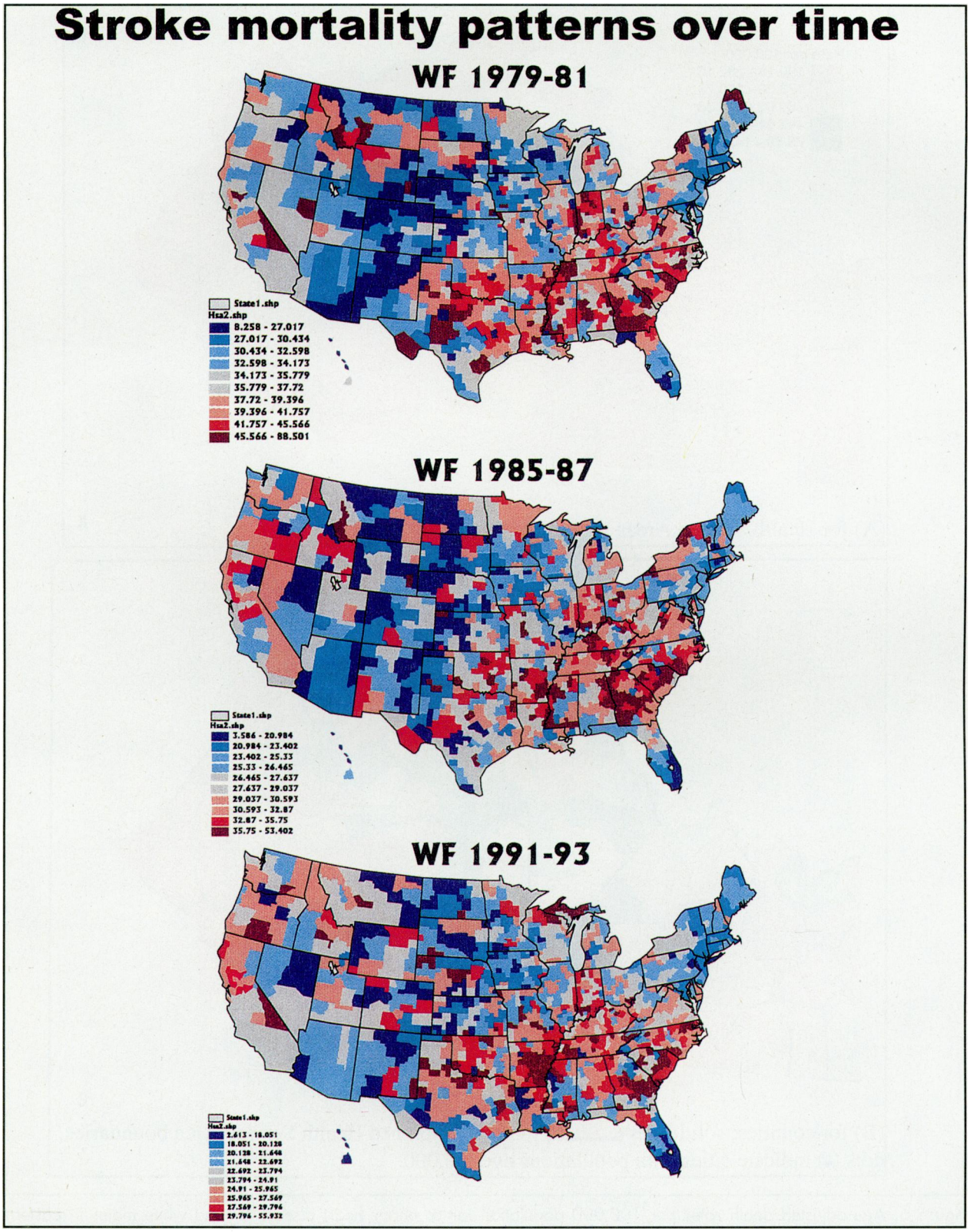

Figure 7. Age-adjusted death rates per 100,000 population for stroke among white females by time period.

of the nine divisions, but most rapidly in the Pacific. However, rates in Kentucky and West Virginia increased for both sexes. In 1959-1961, rates at ages 45-64 were highest in the mid-Atlantic states (New Jersey, New York, Pennsylvania) in each sex, race group except nonwhite females in whom rates were still higher in the east, north, central, and south Atlantic regions.[6] Rates were relatively low in the east south central and Pacific regions.

In whites in 1968-1971, this pattern persisted with a ridge of high-rate areas following the Appalachian Mountains from Tennessee to New York state, and high rates in eastern Indiana, southern Illinois and southern Louisiana, perhaps the beginning of the shift towards the Mississippi and Ohio valleys.[1] In nonwhites, high-rate areas stretched from Pennsylvania south through the Carolinas, and also included Louisiana, Chicago, and southern Illinois. Indeed, in much of the lower Mississippi and Ohio valleys and Appalachian region, the onset of the decline was delayed until after 1968.[24,25]

Comparing rates for whites in 1978 with 1968-1972, more rapid declines in death rates in some eastern states resulted in a shift of areas with the highest rates to a cluster centered in the Appalachian and northeastern regions.[26] In blacks, rates in Kentucky and Illinois remained high and rates in West Virginia increased (the only state to do so) resulting in a cluster in the Ohio River valley. Rates in Pennsylvania ranked high for whites but low for blacks. Unlike other regions, the south had the highest CHD death rates in nonmetropolitan areas and the rate of decline was less than in metropolitan areas so that the urbanization gap widened over time.[7,24,25]

By 1991-1993, the shift of high-rate areas westward to the Mississippi and Ohio valleys was more pronounced especially in whites (Figure 5). However, rates in the Appalachian and south Atlantic regions remained relatively high. White women and men also showed a shift of areas with the highest stroke mortality from coastal southeastern states to east south central and west south central states including the Mississippi River valley.[13] Pennsylvania continued to rank high among whites but low among blacks for coronary death; stroke rates tended to rank low or average for all groups. The similarity in westward shift in both coronary and stroke mortality is not surprising since coronary disease and stroke share several risk factors. The reasons for a more rapid fall in cardiovascular mortality rates in the southeast than in the Mississippi and Ohio valleys since 1970 is not clear, but might relate to programs designed to respond to the "Stroke Belt" as defined in the 1970s and 1980s.

A source of possible bias in any mortality study is misclassification because of inaccurate diagnoses coded on death certificates, as discussed at length elsewhere.[24,25,27] However, the overwhelming body of evidence is against geographic patterns of mortality being purely artefactual.[6-10,28-33] The Atherosclerosis Risk in Communities (ARIC) study found the same geographic pattern of lower CHD death rates in Minneapolis compared to Jackson or Forysth County whether validated events or unvalidated death certificates were used.[29]

Further research is needed to elucidate the cause of regional variation in cardiovascular disease mortality. Rapid declines in CHD mortality in the northeast have left Mississippi and Ohio valley states with relatively high mortality rates; this trend may continue. However, rates also remain high in the southeast, similar to patterns for stroke. Continued monitoring of CHD mortality, morbidity, and risk factors within and among regions is needed to explain these patterns and ongoing trends. Pending this further research, appropriate interventions should be developed to target areas of high coronary mortality as identified by the maps presented here.

Acknowledgments

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