Mortality and Geographic Distribution of Arteriosclerotic Heart Disease

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WE HAVE previously reported recent changes in mortality from cardiovascular-renal diseases (CVR) in California (*1*). Particular emphasis was given to the changes that had occurred during the past decade and to the observed differences in the pattern of mortality from these diseases between the sexes and among the races.

One of our important findings was that death rates from arteriosclerotic heart disease (ASHD), including coronary disease (ISC 420), had declined in California during the period from 1950 to 1960 (*1*). The importance of this finding was that the observed decline in the ASHD death rates in California did not correspond with the trend for the United States as a whole, where mortality increased during the past decade (*2, 3*).

The dissimilarity of mortality trends in California and the United States from 1950 to 1960 is illustrated in figure 1. The age-specific death rates for the middle-aged white population are shown for California and for all other contiguous States of the nation. For both sexes, the death rates in California were about 10 to 15 percent lower in 1960 than in 1950; whereas, for the remainder of the country, mortality from arteriosclerotic heart disease increased about 12 percent for males and 3 percent for females from 1950 to 1960.

The objectives of our present study were twofold:

1. To examine the changes in mortality from arteriosclerotic heart disease during the past decade for each of the conterminous States of the nation.
2. To determine the relationship of changes in mortality in California and such factors as urbanization, nativity, migration, and geographic distribution of deaths within the State.

Methods and Materials

Mortality data for each State except California were taken from annual publications (*4*) and special reports (*5*) of the National Office of Vital Statistics. The data for California were obtained from the facilities of the California State Department of Public Health. To stabilize the death rates, a 3-year mortality average centered around the census year was used. For simplicity, we referred to the 3-year average as the census-year rate; for example, 1959–61 rates are referred to as the 1960 rates. All rates are for 100,000 population.

Only death rates for white persons 35 to 64 years of age were included. Cardiovascular-renal deaths under the age of 35 are relatively few, and beyond the age of 65 the underlying cause of death becomes rather difficult to identify accurately (*6*). Restricting the age group to 35–64 is in keeping with the system used in many recent publications. The direct method of adjustment was used for the age-adjusted death rates, based on the 1960 U.S. white population.

To examine the possible influence of migration on the mortality pattern in California, the deaths during 1959–61 were allocated sepa-

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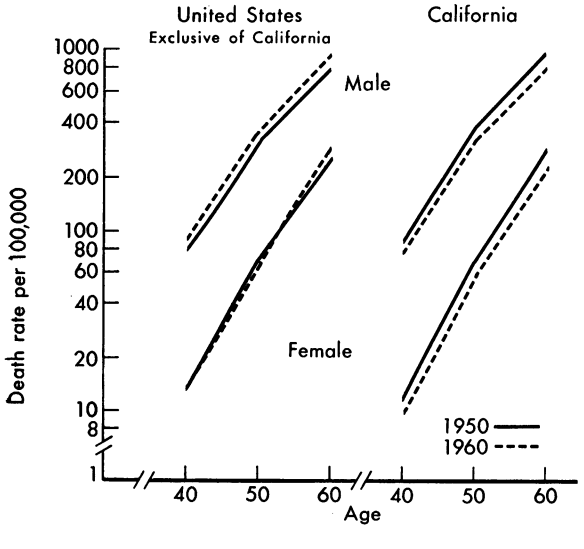
rately by nativity and a crude dichotomy relating death to length of residence in California. These are virtually the only data on migration for which related data exist on the death certificates and the 1960 census reports. It should be recognized that census records and death certificates are different sources of information. To our knowledge there are no available studies of the comparability of reporting migration from these two sources. Our use of "native born" refers to persons born in the United States or any of its territories or possessions. For calculating the death rates by length of residence in California, the population at risk was obtained from census reports, which listed the number of persons who were residents in California as of April 1, 1955. Comparison by length of residence in California thus refers to the mortality among recent migrants (those not living in California on April 1, 1955) and nonrecent migrants (those living in California before April 1, 1955).

For analyzing the geographic distribution of mortality in California, 39 of the 58 counties of the State were considered autonomous, and the remaining 19, which are composed of lightly populated rural counties, were grouped into 6 different areas. The basis for the grouping of the 19 counties was similarity of terrain and climate and geographic proximity (fig. 2).

Figure 1. Average annual age-specific ASHD death rates, including diseases of the coronary arteries (ISC 420), by sex of white population, for California and conterminous United States exclusive of California, 1949–51 and 1959–61



The contiguity ratio developed by Geary (7) was used to detect the statistical significance of the observed geographic distribution of mortality from arteriosclerotic heart disease. This technique provides a means for ascertaining whether geographic statistics are randomly distributed or form a pattern.

The logic of the contiguity ratio is that if the death rates are geographically distributed at random, the contiguity ratio will be close to unity, while if the rates for adjoining States (counties) are more alike than those for States (counties) not adjoining, the ratio will be less than unity. Thus the magnitude of the ratio shows a measure of the degree of geographic clustering.

The equation for the contiguity ratio, c, which is essentially the ratio of two estimates of variance, is given by

$$c=\frac{(n-1)\sum_{t\neq t'}' (z_t-z_{t'})^2}{2K_1\sum (z_t-z_t)^2} \qquad [1]$$

where

n=number of geographic States (counties)
z_t=the death rate of the t^{th} State
$K_1=\sum k_t$ and k_t refers to the number of States bordering on the t^{th} State
$\sum$=the sum for all the States
$\sum'$=the sum for contiguous States.

For computational purposes, equation 1 can be put into the equivalent form:

$$c=\frac{(n-1)\,2\left(\sum k_t z_t^2-2\sum_{t<t'}' z_t z_{t'}\right)}{2K_1\left[\sum z_t^2-\frac{(\sum z_t)^2}{n}\right]} \qquad [2]$$

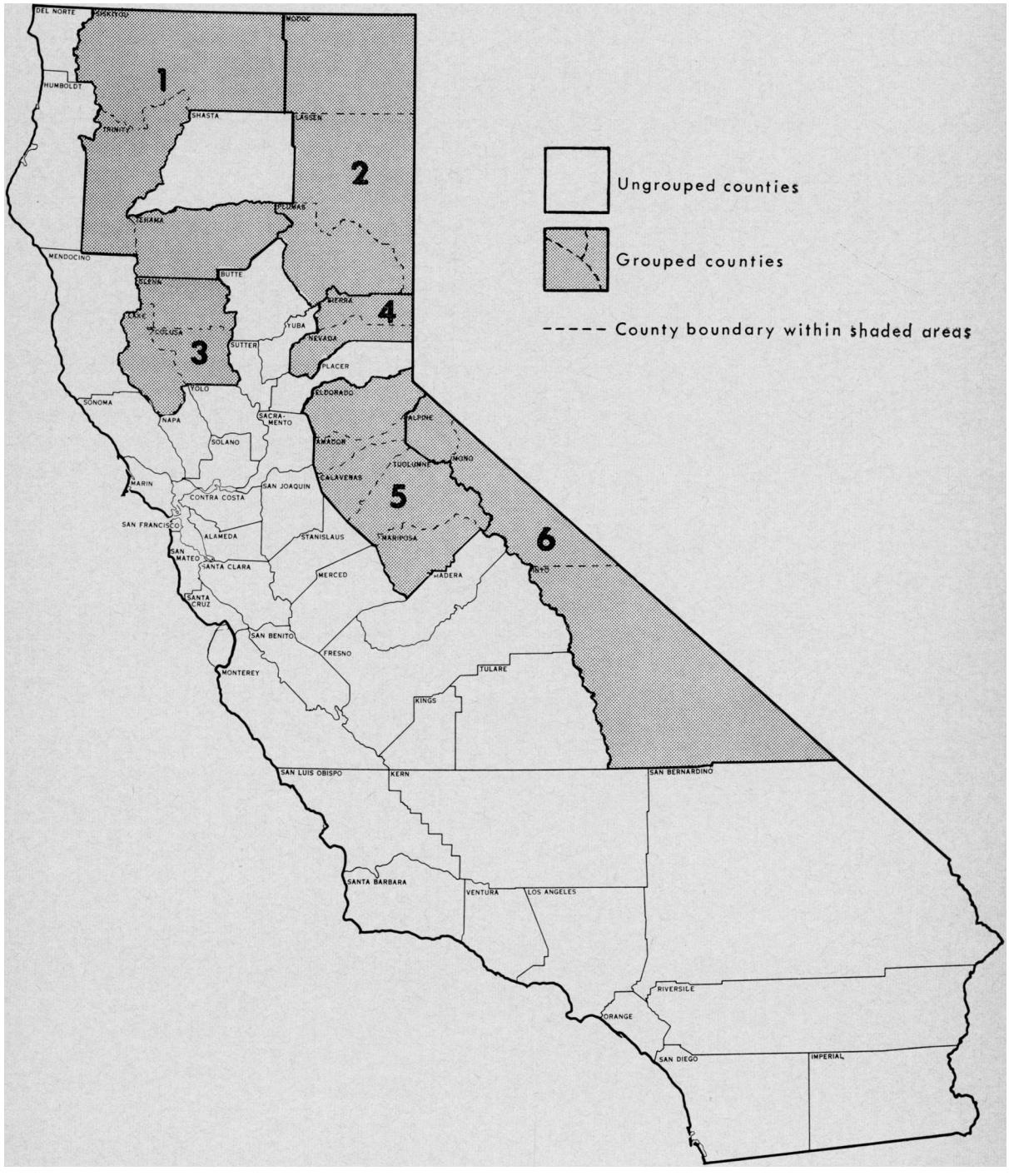
Geary (7) showed that the asymptotic variance of the contiguity ratio is given approximately by

$$\text{Var}\,(c)\simeq\frac{2}{n}\left[\frac{k_2}{k_1^2}+\frac{1}{k_1}-1\right] \qquad [3]$$

where $k_1=\sum k_t/n$ and $k_2=\sum k_t^2/n$.

If n is not too small, the usual normality assumption can be made to test the significance of the departure from unity in the calculated value of the contiguity ratio. That is, the criti-

Figure 2. Grouping of counties in California for analyzing geographic distribution of mortality in the State



cal ratio, $\frac{(c-1)}{\sqrt{\text{var }(c)}}$, can be tested for statistical significance by referring to tables of the normal distribution.

Findings

MORTALITY CHANGES IN THE UNITED STATES. To demonstrate geographic distribution of mortality from arteriosclerotic heart disease in the United States, the age-adjusted death rates for 1950 and 1960 were depicted by quartile in figures 3–6 for white males and females. Clustering in geographic distribution of ASHD mortality is appreciable for both males and females and for 1950 and 1960. It is interesting to note that in the Far West, especially California, there was a substantial decline in the quartile rank from 1950 to 1960. The contiguity ratio for each of the geographic distributions is shown in table 1. In each case the contiguity ratios for males and females, in both 1950 and 1960, differ significantly from unity ($P<0.01$). Analysis therefore confirms the visual impression of a pronounced geographic clustering of ASHD mortality in the United States, and the magnitude of the contiguity ratio suggests that clustering is more marked among females than males.

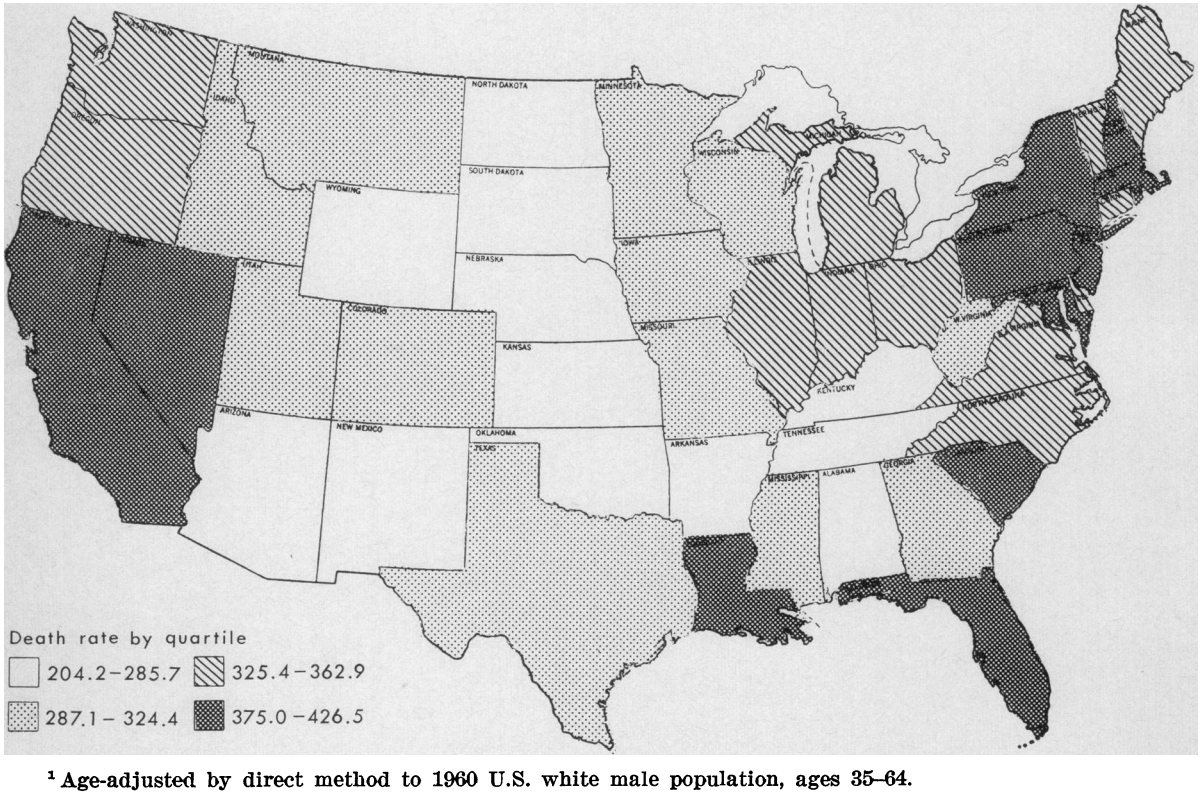
Table 1. Contiguity ratio for age-adjusted ASHD death rates (ISC 420), by sex, for conterminous U.S. white population, 1949–51 and 1959–61

Year and sex	Value of contiguity ratio c	Significance test $(1-c)/\sqrt{\text{var }(c)}$
1950:		
Male	0.51	[1] 4.1
Female	.40	[1] 5.0
1960:		
Male	.57	[1] 3.6
Female	.38	[1] 5.2

[1] $P<0.01$.

Although most of the States maintained about the same relative position in mortality in 1960

Figure 3. Average annual age-adjusted ASHD death rates, including diseases of the coronary arteries (ISC 420), per 100,000 population, for white males, by State, 1949–51 [1]



[1] Age-adjusted by direct method to 1960 U.S. white male population, ages 35–64.

that they had in 1950, death rates have changed noticeably in a few States during the past decade. This trend is illustrated in figures 7 and 8, which show the States arranged within their geographic division. The increase in the median age-adjusted death rates from 1950 to 1960 was approximately 12 percent for white males and 3 percent for white females.

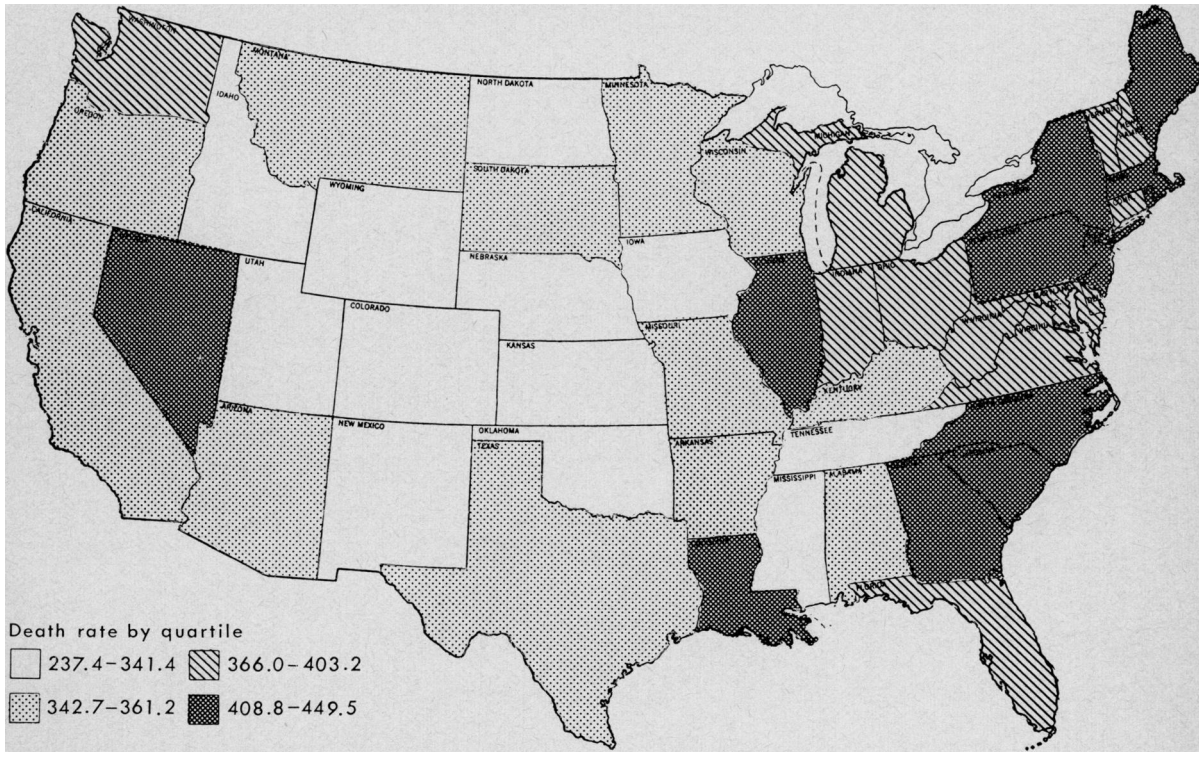
For white males, mortality from arteriosclerotic heart disease declined in only two States from 1950 to 1960 (fig. 7). Utah, near the 20th percentile in 1950, had the second lowest mortality in 1960; and California, which had the second highest mortality in 1950, declined to about the 45th percentile in 1960. The decline was 4 percent for Utah and 12 percent for California. Two other States, New York and Vermont, showed a very small increase during the decade. Figure 7 also reveals the interesting fact that among the Mountain States (Nevada, Montana, Idaho, Wyoming, Colorado, Utah, Arizona, and New Mexico) Nevada and New Mexico were at almost opposite ends of the mortality scale. New Mexico had the lowest mortality both in 1950 and 1960 while Nevada, which was in the 80th percentile in 1950, had the second highest mortality in 1960.

For white females, about one-third of the States had a decline in mortality during the 10-year period (fig. 8). The largest decreases were in Utah (20 percent), California (15 percent), and New York (12 percent). A comparison of figures 7 and 8 reveals that, in general, the relative positions of the States within the geographic division are similar for both males and females.

MORTALITY CHANGES IN CALIFORNIA. Since the recent change in mortality from arteriosclerotic heart disease is different in California as compared with most other States, we examined further the State's pattern of mortality.

1. Geographic distribution. The geographic distribution of the age-adjusted death rates from arteriosclerotic heart disease in the State of California is shown in figures 9 and 10 for white males and females. The age-adjusted

Figure 4. Average annual age-adjusted ASHD death rates, including diseases of the coronary arteries (ISC 420), per 100,000 population, for white males, by State, 1959–61 [1]



[1] Age-adjusted by direct method to 1960 U.S. white male population, ages 35–64.

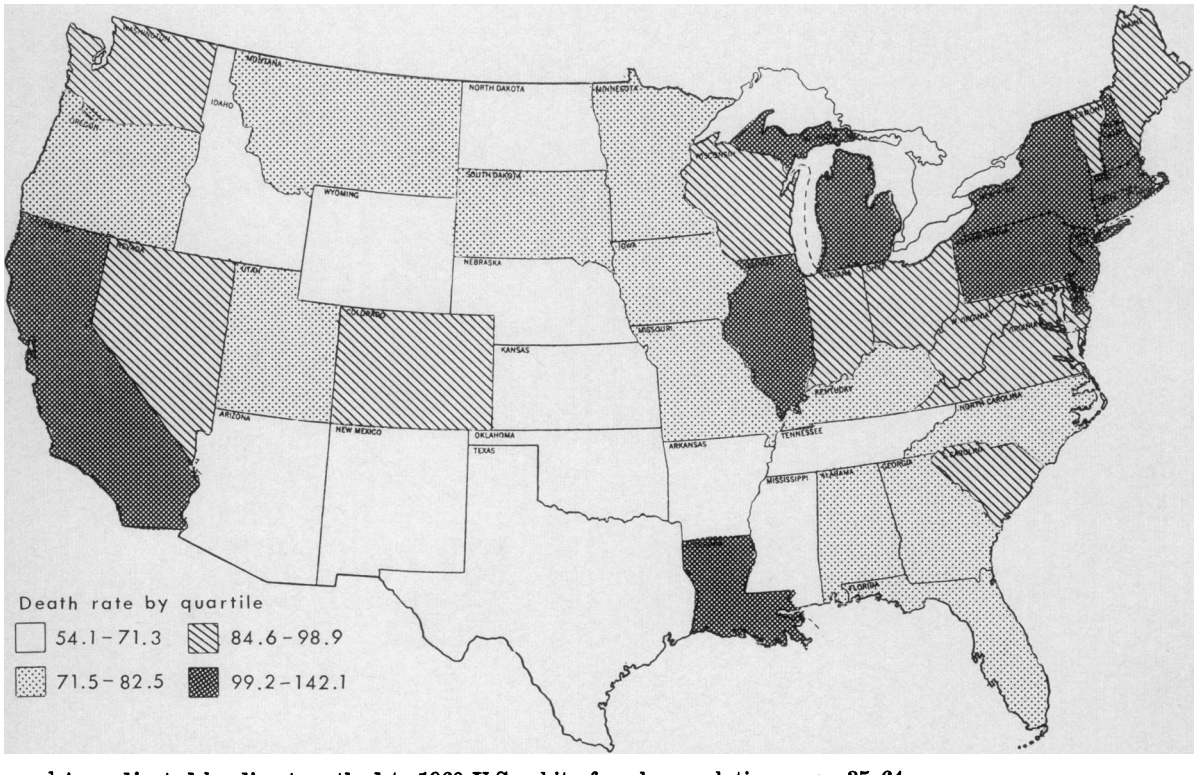
death rates per 100,000 population in the counties of California range from 236 to 436 for the males and from 29 to 141 for the females. Figures 9 and 10 do not indicate geographic clustering. Applying the contiguity ratio with its standard error to the county death rates gives values of 0.83 ± 0.12 for the males and 1.02 ± 0.12 for the females. In each case the contiguity ratio does not differ significantly from unity ($P > 0.05$). This analysis indicates that the geographic distribution of mortality from arteriosclerotic heart disease, by counties within the State of California, is compatible with random variation.

There are other methods which can be applied to mortality data to detect the presence or absence of geographic clustering. One such method is to examine the degree of association between rates for males and females. If geographic clustering were present, perhaps due to environmental factors peculiar to certain areas, one would expect some degree of similarity between the male and female death rates. For instance in the United States, the rank correlation between the State's male and female age-adjusted death rates for arteriosclerotic heart disease is 0.69 ($P < 0.01$). For the counties of California, however, the rank correlation between the male and female death rates is only 0.15 with a value not significantly different from zero ($P > 0.05$). To avoid the stringent assumptions underlying the use of the product moment coefficient of correlation, Kendall's rank correlation was used.

Another procedure which may shed some light on the possible presence of geographic clustering is to examine the difference between mortality in urban and in rural areas. For this purpose the counties in the State of California were grouped, according to their degree of urbanization, into four classes (*8*) : greater metropolitan, lesser metropolitan, adjacent, and rural.

For analytic purposes, a metropolitan area consists of a county or group of contiguous counties which are essentially metropolitan in character and economically and socially inte-

Figure 5. Average annual age-adjusted ASHD death rates, including diseases of the coronary arteries (ISC 420), per 100,000 population, for white females, by State, 1949–51 [1]



[1] Age-adjusted by direct method to 1960 U.S. white female population, ages 35–64.

grated with a central city or cities of 50,000 or more inhabitants. The counties that comprise the metropolitan areas with populations in excess of a million have been classified as greater metropolitan. The remaining counties in the smaller metropolitan areas have been called lesser metropolitan. All counties contiguous to the metropolitan counties have been classified as adjacent. The remainder have been designated as rural.

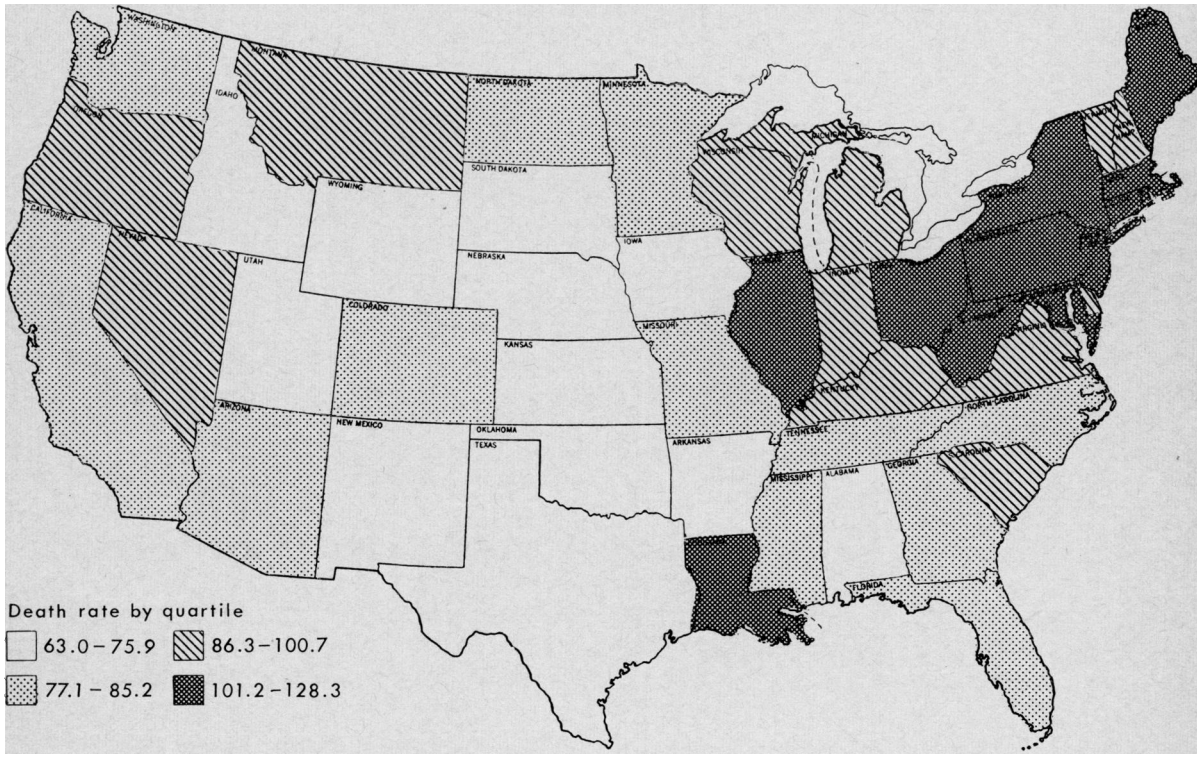
The mean and standard deviation of the male and female age-adjusted death rates for the four classes are shown in table 2. To ascertain if significant differences exist between the four urbanization classes, the Kruskal-Wallis rank sum test was applied (*9*). (The Kruskal-Wallis test is a nonparametric test for ranks and is analogous to a one-way analysis of variance.) The results are given in the lower half of the table. As can be seen from the value of the probability level associated with the observed chi-square, there is no statistically discernible difference in mortality from arteriosclerotic heart disease between the four urbanization classes in California.

Thus, based on these methods, we have determined that mortality from arteriosclerotic heart disease is randomly distributed within the State of California.

2. Nativity and length of residence. The 1960 age-specific death rates from arteriosclerotic heart disease, by nativity, are listed in table 3. In this analysis, those born in the United States were further grouped according to whether or not their place of birth was in California. Among those born in the United States and residing in the State of California, the death rates were at least 10 percent higher for those born outside of California as compared with those born in the State. For the foreign-born males, the age-specific death rates were about 7 to 14 percent lower than for the California born; for the females, there was no evidence of a systematic difference between the foreign born and the California born.

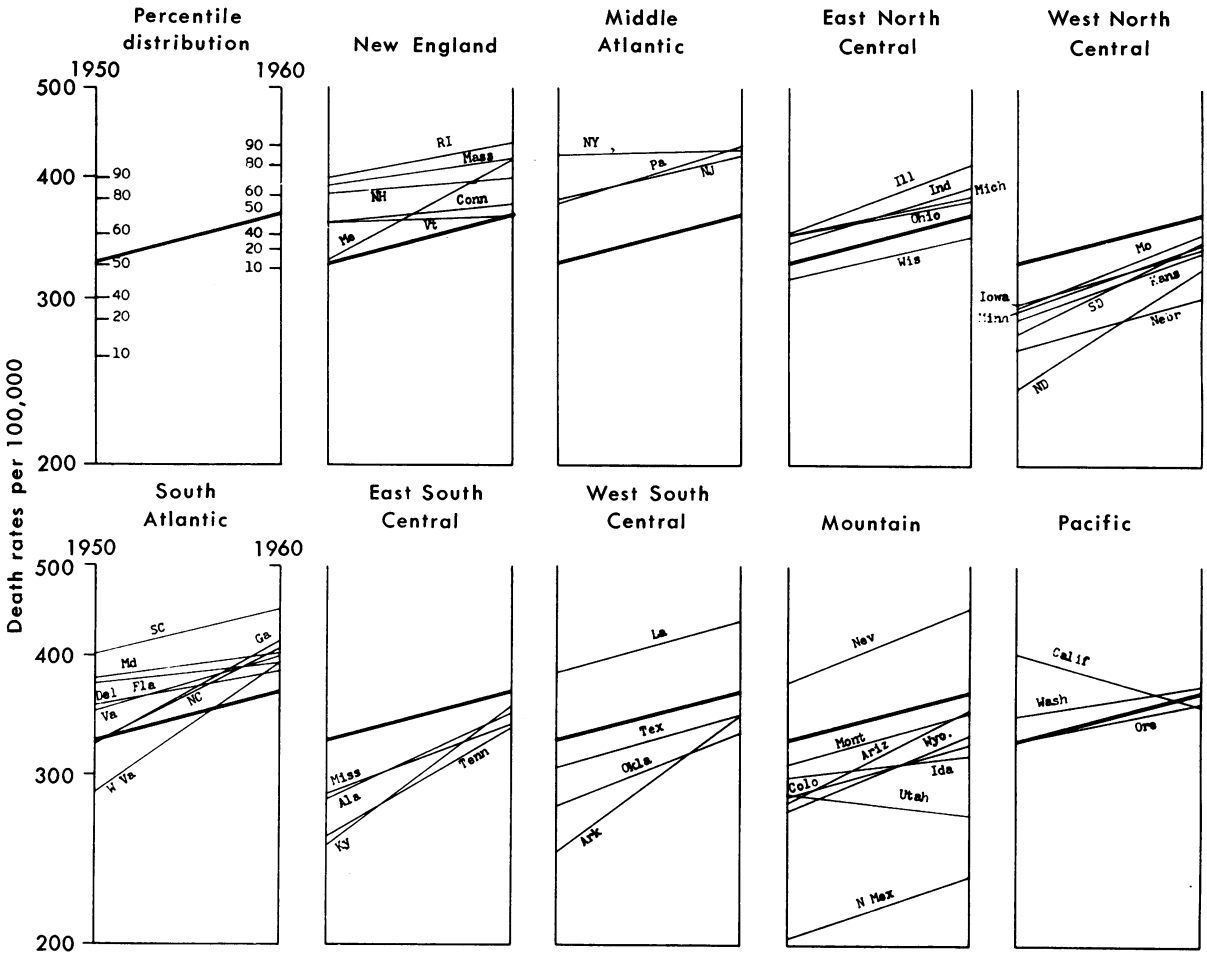
Table 4 presents a contrast between death

Figure 6. Average annual age-adjusted ASHD death rates, including diseases of the coronary arteries (ISC 420), per 100,000 population, for white females, by State, 1959–61 [1]



[1] Age-adjusted by direct method to 1960 U.S. white female population, ages 35–64.

Figure 7. Average annual age-adjusted ASHD death rates per 100,000 population, by State within geographic division and percentile distribution by States, white males, 1949–51 and 1959–61 [1]



[1] Age-adjusted by direct method to 1960 U.S. white male population, ages 35–64.

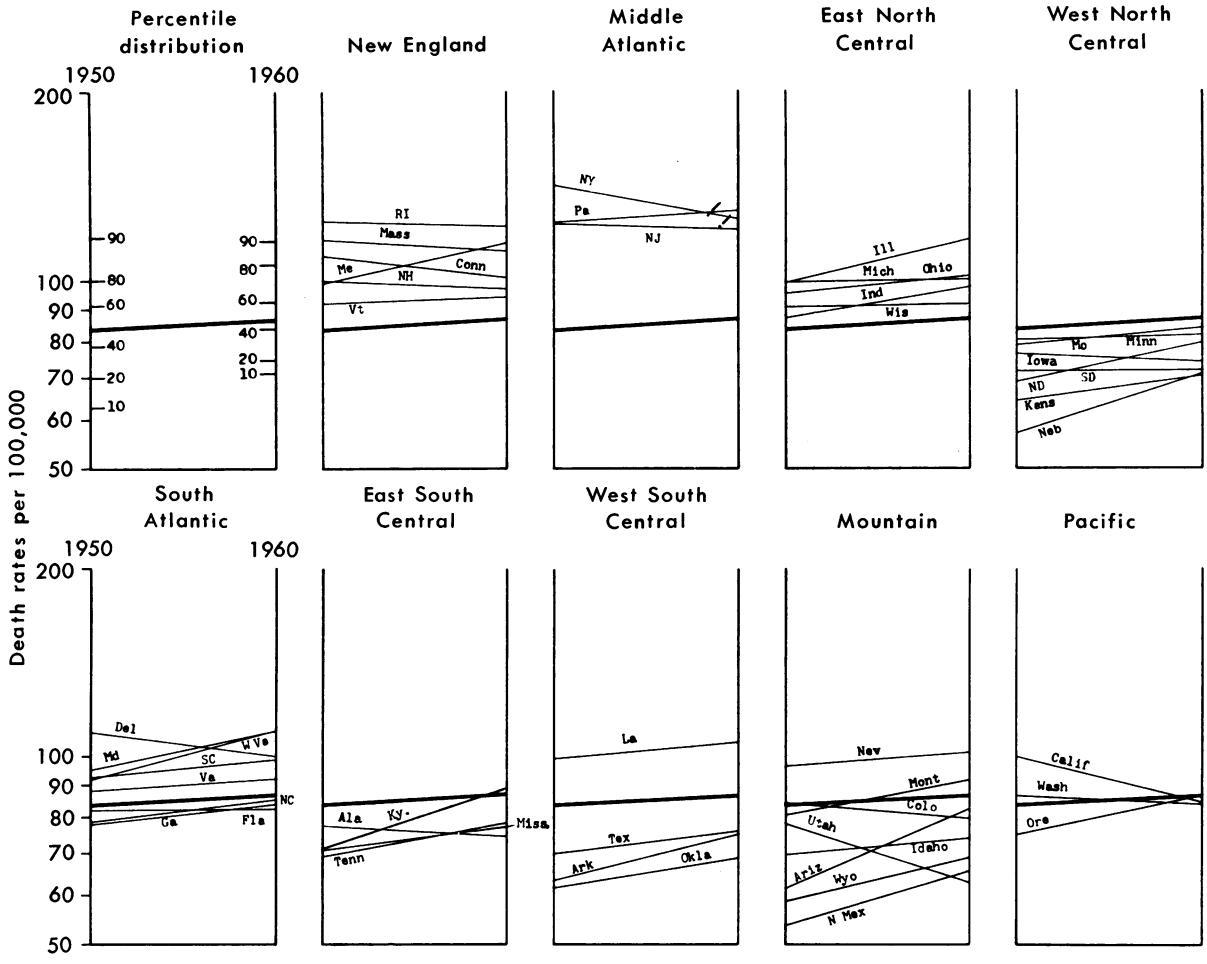
NOTE: The 1950 age-adjusted death rates are shown on the left axis and the 1960 rates on the right axis. The key in the upper left corner designates the relative ranking of the States in 1950 and 1960. The solid heavy line in each division refers to the 50th percentile or median.

rates among recent migrants and nonrecent migrants. The recent migrants have lower mortality rates than the nonrecent migrants; 29, 4, and 6 percent for the three age groups of females and about 17 percent lower for males. These findings suggest that perhaps one reason for the observed decline in mortality from arteriosclerotic heart disease in California could possibly be the recent migration of healthier middle-aged people into California. However, migration cannot be considered the only reason for the observed reduction in mortality. When the recent migrants to California are excluded, the decline in ASHD mortality from 1950 to 1960, as shown in last column of table 5, is still evident.

Discussion

When the mortality attributable to a particular disease, especially a chronic disease, changes within a short period of time, it is most difficult to identify accurately the factors responsible for that change. The rise and fall in mortality may be from such diverse factors as diagnostic interests or fashions, coding classifications, vagaries of chance, and so forth. To

Figure 8. Average annual age-adjusted ASHD death rates per 100,000 population, by State within geographic division and percentile distribution by States, white females, 1949–51 and 1959–61 [1]



[1] Age-adjusted by direct method to 1960 U.S. white female population, ages 35–64.

NOTE: The 1950 age-adjusted death rates are shown on the left axis and the 1960 rates on the right axis. The key in the upper left corner designates the relative ranking of the States in 1950 and 1960. The solid heavy line in each division refers to the 50th percentile or median.

ascertain if the observed changes are of possible epidemiologic significance, it is usually necessary to know not only the short-term changes but also the long-term or secular trends.

Unfortunately, for the specific components of cardiovascular diseases, it is virtually impossible to reconstruct secular trends. Over the years there have been such pronounced changes in the definition of diseases and in diagnostic skills and procedures that the trends for the specific components of cardiovascular diseases cannot be validly constructed or interpreted (*6*, *10*). Furthermore, changes in death certification and coding procedures complicate the construction of secular trends. For example, before arteriosclerotic heart disease was listed in the sixth revision of the International List of Causes of Deaths in 1948, most coronary deaths were listed under chronic myocarditis even though diseases of the coronary arteries had been introduced as diagnostic entities in 1930. In the decade between the sixth and seventh revisions significant changes also occurred in the procedures for coding the underlying cause of death for certain CVR diseases such as hypertension and stroke (*1*).

Figure 9. Age-adjusted ASHD death rates per 100,000 population, for white males, by county, California, 1959–61

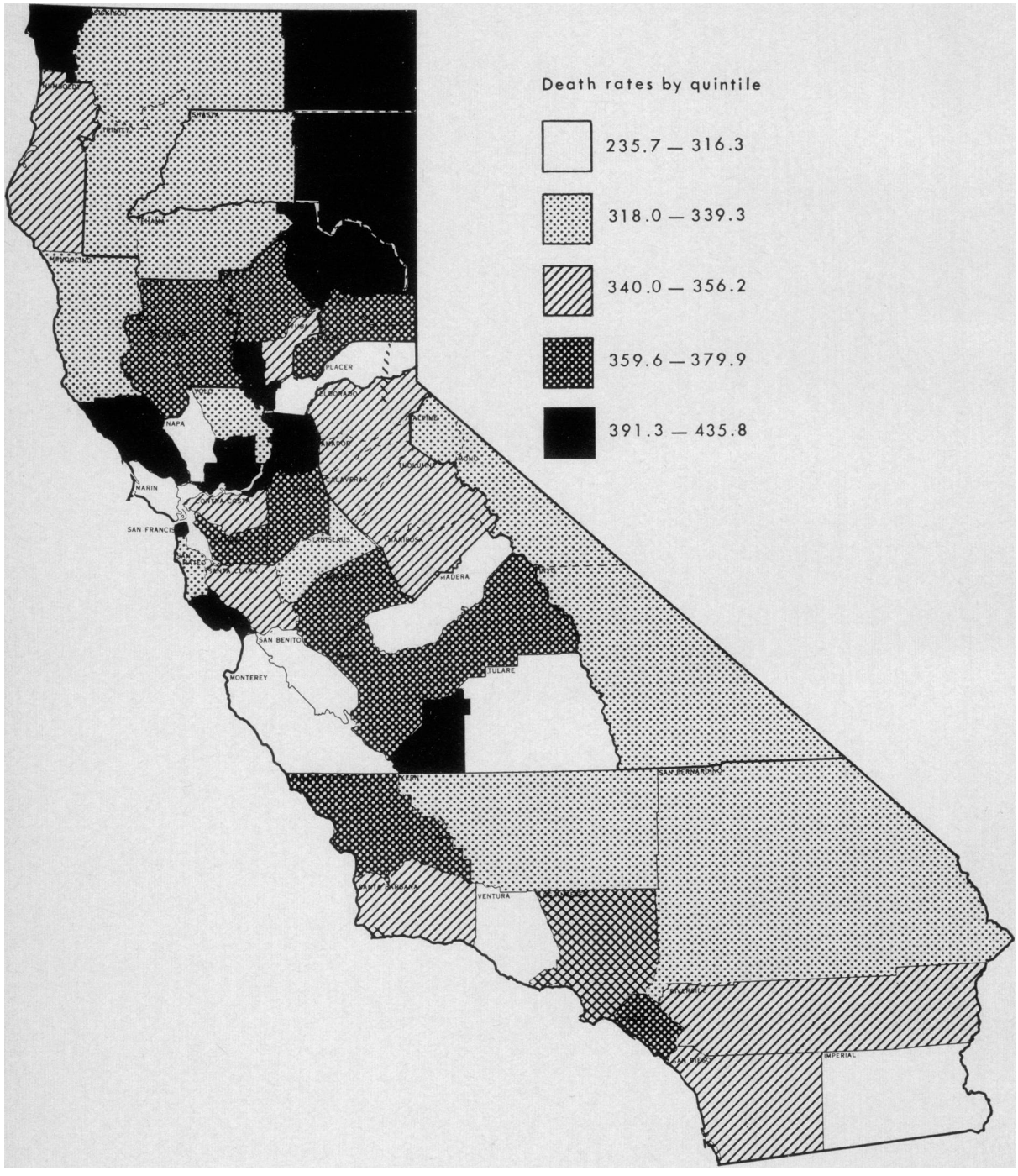
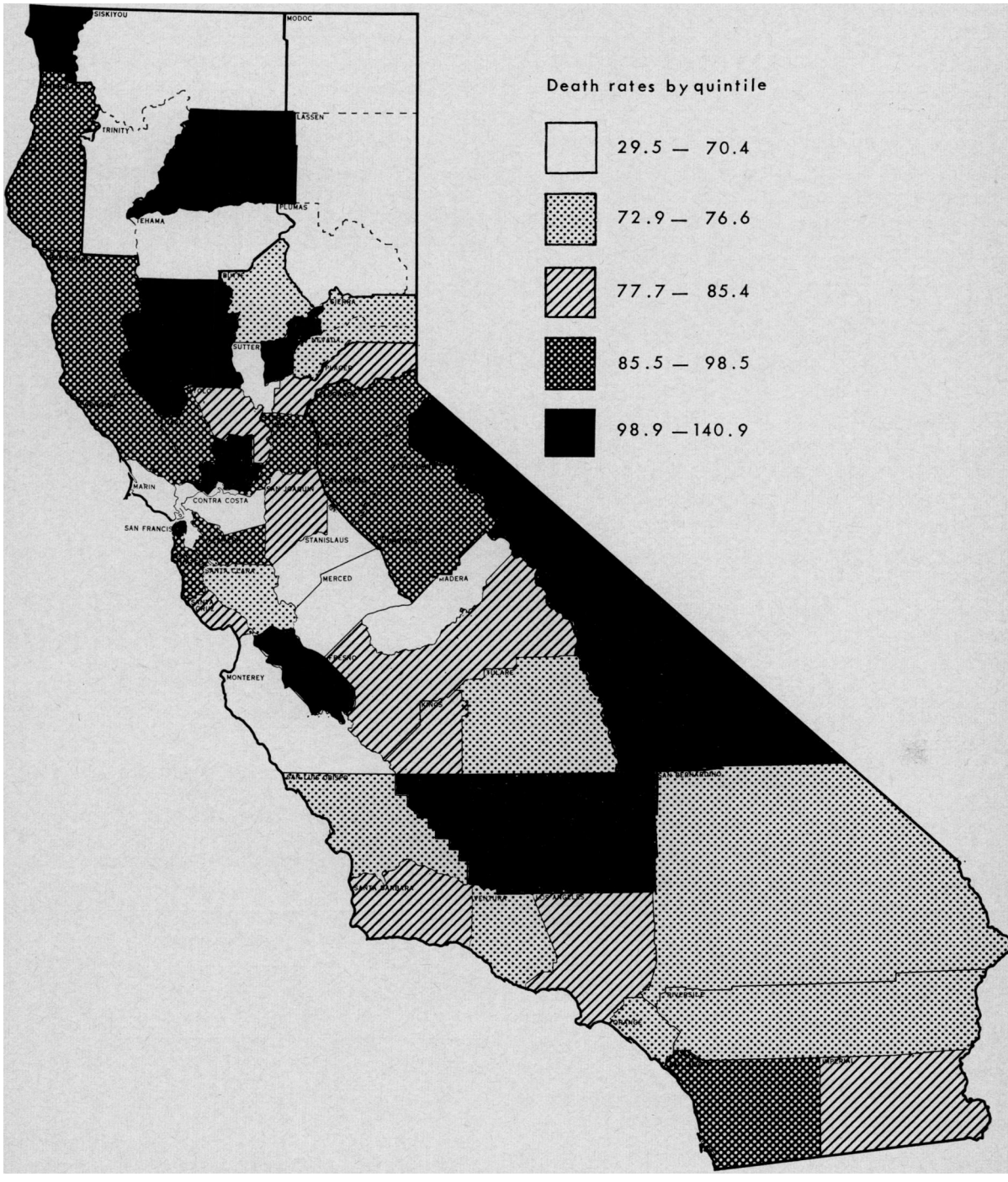


Figure 10. Age-adjusted ASHD death rates per 100,000 population, for white females, by county, California, 1959–61



Nevertheless, the findings in this report, especially those dealing with the recent changes in California and the geographic distribution within the State, raise some relevant questions concerning the epidemiology of coronary artery disease. Although these empirical observations in themselves will not establish causal explanations, they may help to delineate factors and provide guiding hypotheses for experimental research and preventive programs.

In only two States, California and to a much lesser degree Utah, has the mortality from arteriosclerotic heart disease among the middle-aged white male population declined during the past decade. In the other States the increase ranged from as little as 1 percent in New York and Vermont to as much as 40 percent in Kentucky. One problem encountered in comparing death rates in different time periods is that the population base is usually affected by migration, which is especially heavy in California. It is well known that since the opening of the western frontier, California's population has been growing at a prodigious rate. Since 1860 the population has increased roughly geometrically, with a doubling time of approximately 18 to 20 years. In 1950 there were 10.6 million people living in California; by 1960 the population had increased to 15.7 million.

The influence of recent migration on mortality was examined by contrasting the death rates of the recent migrants and that of the nonrecent migrants. Although this comparison by length of residence in California is admittedly crude, it reveals that the slightly lower death rates among the recent migrants in 1960 are not enough to explain the decline in mortality from arteriosclerotic heart disease in California between 1950 and 1960. Furthermore, the influence of migration on mortality in other States appears to be paradoxical. For example, Utah, the only other State in which mortality from arteriosclerotic heart disease declined during the past decade, had very little migration between 1950 and 1960 (*11*). On the other hand, States with heavy immigration, such as New Jersey, Arizona, Maryland, Ohio, and Florida, showed an appreciable increase in mortality from arteriosclerotic heart disease during the decade.

A positive association between the level of blood pressure and subsequent mortality from coronary heart disease has been well established in many epidemiologic studies (*12*, *13*). Furthermore, the mortality from hypertensive heart diseases has declined in each State by at least 38 percent. Thus if an elevated blood pressure is a risk factor contributing to mortality from coronary heart disease, then the marked reduc-

Table 2. Mean and standard deviation of average annual age-adjusted ASHD death rates per 100,000 population (ISC 420), by sex of white population and degree of urbanization for counties of California, 1959–61 [1]

Degree of urbanization in California [2]	Number of counties (areas)	Mean ± standard deviation of age-adjusted death rate	
		Male	Female
Greater metropolitan	9	365 ± 46	87 ± 16
Lesser metropolitan	8	359 ± 28	84 ± 10
Adjacent	16	337 ± 53	74 ± 19
Rural	12	349 ± 33	95 ± 25
Overall test of difference between urbanization classes:			
Chi-square value, χ^2_3		2. 33	4. 80
Probability level, $P(\chi^2_3)$		≃0. 52	≃0. 18

[1] Age-adjusted by direct method to 1960 U.S. white population, ages 35–64.
[2] See text for definition.

Table 3. Average annual age-specific ASHD death rates per 100,000 population (ISC 420), by sex and nativity of white population, California, 1959–61 [1]

Age group and sex	U.S. born		Foreign born
	California	Not California	
35–44:			
Male	65. 7	88. 0	58. 9
Female	9. 1	10. 4	5. 3
45–54:			
Male	294. 8	354. 6	254. 5
Female	49. 6	58. 8	51. 3
55–64:			
Male	809. 3	899. 2	755. 1
Female	217. 7	245. 5	261. 0

[1] Nativity was not coded on death certificates for 1959; death rates represent a 2-year average for 1960 and 1961.

Table 4. Average annual age-specific ASHD death rates per 100,000 population (ISC 420), by sex and length of residence of white population, California, 1959–61

Age group and sex	Nonrecent migrants [1]	Recent migrants [2]
35–44:		
Male	80. 5	66. 7
Female	10. 0	7. 1
45–54:		
Male	326. 4	270. 3
Female	54. 5	52. 5
55–64:		
Male	843. 9	699. 6
Female	234. 5	220. 4

[1] Living in California on April 1, 1955.
[2] Not living in California on April 1, 1955.

tion in mortality from hypertension should have influenced the mortality from arteriosclerotic heart disease. Yet with the exception of Utah and California, and especially the latter, the mortality from arteriosclerotic heart disease among the middle-aged white male population of the United States has not declined despite the large reduction in mortality from hypertension. It may be that a longer period of time is needed for the reduction in mortality from hypertension to show its effect on mortality from arteriosclerotic heart disease. Or it may be that the association between an elevated blood pressure and mortality from coronary heart disease is through other factors which differ in magnitude from State to State. There is need for well-designed epidemiologic studies to determine not only the effect of the current use of antihypertensive medications on mortality but also to scrutinize and document the relationship between mortality from hypertension and that of arteriosclerotic heart disease in various geographic areas.

The geographic clustering of 1950 mortality from arteriosclerotic heart disease in the United States has been previously reported (*14*). It has also been noted for 1956 mortality in the State of Ohio (*15*) and 1950 mortality in New York State (*16*), as well as in other countries such as England and Wales (*17*) and the Republic of Ireland (*18*). Yet in California there was no evidence to indicate that geographic distribution within the State was other than random. Why should California not reveal the strong urban-rural differential in mortality that has been reported in other places? Epidemiologic studies are needed to investigate the relationship of factors such as way of life, socioeconomic structures of the community, and mortality from arteriosclerotic heart disease.

Summary

In the United States during the past decade, an important reduction has occurred in mortality from most major cardiovascular-renal diseases. The one significant component of heart disease that has not declined is arteriosclerotic heart disease (ISC 420). Across the country, mortality from arteriosclerotic heart disease increased about 12 percent for males

Table 5. Percent change from 1950 to 1960 and average annual age-specific ASHD death rates per 100,000 population (ISC 420), by sex of white population, California

Age group and sex	Age-specific death rates		Percent change from 1950	Age-specific death rates for nonrecent migrants, 1960	Percent change from 1950 [1]
	1950	1960			
35–44:					
Male	84. 2	77. 8	−9	80. 5	−4
Female	11. 0	9. 6	−14	10. 0	−9
45–54:					
Male	374. 4	321. 8	−13	326. 4	−13
Female	62. 3	54. 6	−12	54. 5	−12
55–64:					
Male	944. 2	832. 8	−11	843. 9	−11
Female	280. 7	235. 7	−15	234. 5	−16

[1] Excluding recent migrants.

and about 3 percent for females during the period 1950 to 1960. Among the individual States, California and, to a lesser degree, Utah were exceptions to the increasing pattern of mortality from arteriosclerotic heart disease. Among white males, California showed a decline of 12 percent during the decade and Utah a decline of 4 percent. Migration, a possible explanation of the recent changes in mortality from arteriosclerotic heart disease in California, was found to exert minor influence on the State's mortality pattern.

In the United States there was pronounced evidence of geographic clustering, but within California there was no evidence to suggest that the geographic distribution of ASHD mortality was other than random.

NOTE: Tables on average annual age-specific death rates per 100,000 population for selected causes, white males and females, 1949–51 and 1959–61, and on percent change from 1950 to 1960 in the average annual age-adjusted death rates for selected causes for white population, by sex and State, are available from Dr. Borhani.

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