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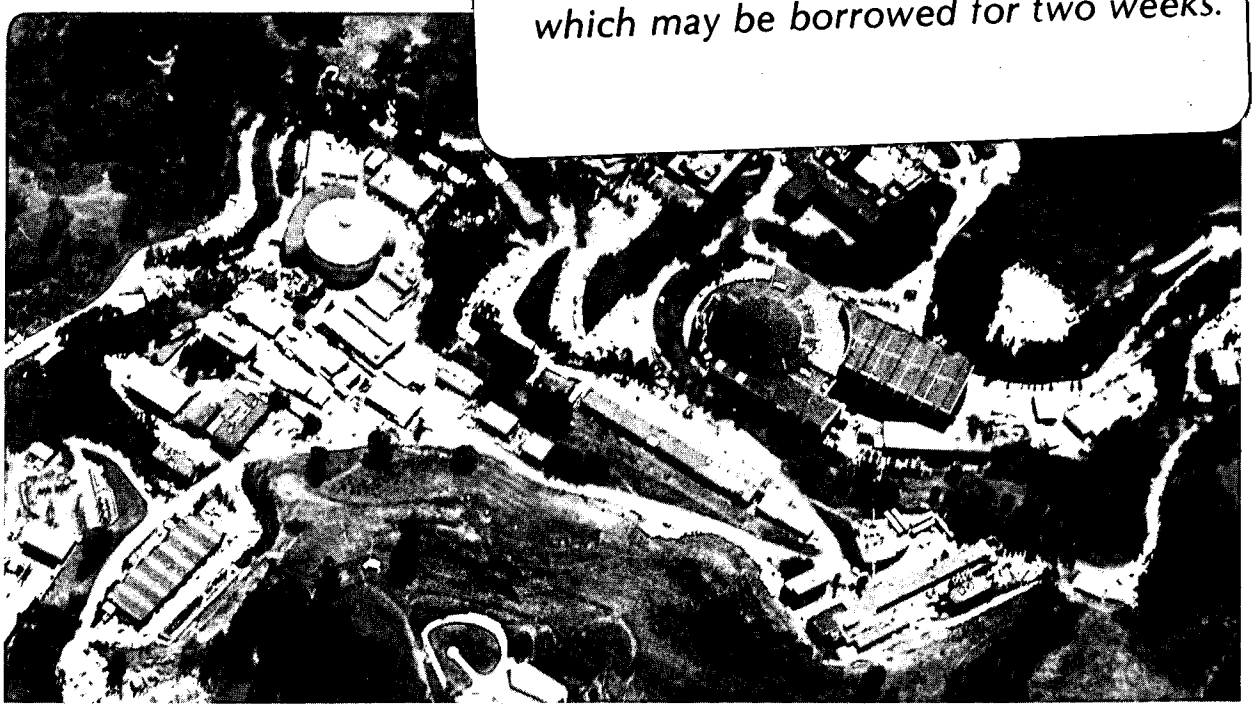

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The Onset of Decline in Ischemic Heart Disease Mortality in the United States

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Abstract

Temporal and spatial patterns of the onset of the decline in ischemic heart disease for each of the 48 contiguous U.S. states and the District of Columbia are examined for the years 1955-1978 for age-sex-race-specific mortality. Mortality rates are derived from National Center for Health Statistics mortality data and a polynomial interpolation is used to estimate intercensal population counts employing 1950, 1960, 1970, and 1980 U.S. Census data. A quadratic regression equation is used to estimate the date of highest rate, which marks the beginning of the decline for each of the U.S. states. The temporal distribution of the onset of the decline among men occurred primarily between 1960 and 1965. Among women the onset of decline was more variable. Furthermore, strong and regular spatial patterns were seen among the groups examined and these impressions are supported by statistical analysis. California, Maryland and the District of Columbia were early decliners in most groups studied, whereas states in the southeast were consistently among the last to experience the onset of decline. These patterns suggest the existence of an underlying phenomenon accounting for the spread or diffusion of the onset of decline in ischemic heart disease mortality.

diffusion, ischemic heart disease, mortality trends

Ischemic heart disease has been the leading cause of death in the United States since the 1930s. Over the last 25 years, the mortality rate for ischemic heart disease declined for all adult age groups, for both sexes, for whites and nonwhites, and the decline has occurred in all states of the U.S., as well as in several other countries (1-5). Age-adjusted rates indicate that this decline apparently began in the mid-sixties (2).

Little doubt exists that the decline is real, not a statistical or reporting artifact. Changes in ICDA death codes result in breaks in continuity only at the time of ICDA code changes. The Seventh Revision (1958-1967) resulted in fewer deaths being reported as ischemic heart disease (ICDA 420 - arteriosclerotic heart disease, including coronary heart disease) than the Sixth Revision (1948-1957), the ratio between the revisions being 0.99 (3). The Eighth Revision (1968-1978) resulted in more deaths being reported as ischemic heart disease (ICDA 410-413) than in the Seventh Revision. Specifically, the ratio of the eighth to the seventh revisions is 1.15, the increase resulting mainly from the transfer of hypertensive heart disease (Seventh Revision-ICDA 440-443) and other myocardial degeneration with arteriosclerosis (Seventh Revision-ICDA 422.1) to chronic ischemic heart disease (Eighth Revision-ICDA 412). These discontinuities in death coding are not sufficient to be a major component in the general ischemic heart disease mortality decline, particularly since rates continued to decline throughout the period of the Eighth Revision when no such breaks occurred.

Changes in diagnostic preference could produce artifactual declines in cause-specific mortality. However, there is no evidence of any substantial reassignment of cardiovascular deaths to noncardiovascular disease categories (6), and no evidence of shifts occurring within the cardiovascular subcategories of sufficient magnitude to account for a significant proportion of the decline (6,7). Furthermore, there has also been a concomitant decline in all-cause mortality as would be expected with a major reduction in the leading cause of death (6).

Many explanations for the observed fall in ischemic heart disease mortality rates

have been put forward although none have been widely accepted as explaining a substantial proportion of the decline. Reductions in known risk factors (e.g., cigarette smoking, blood pressure, and serum cholesterol) as well as improvements in treatment, such as intensive care units and emergency care, are the main factors but they are thought to account for only a small portion of the decline (1,6).

Although much thought has been given to explanations for the decline, the basic questions of where, when, and why the decline began has not been fully explored. Early declines were reported in California by Hecht and Borhani (8), in New York by Winkelstein (9), and nationally by Walker (10). The geographic distribution of the decline has been explored by Feinleib et al. (11), Kimm et al. (12), and Davis et al. (13). The geographic focus of these studies has been primarily the amount of decline, that is, per cent change in age-adjusted mortality. Kimm et al. (12) examined the onset of decline in the age-adjusted mortality rate for seven selected states. Recently Wing et al. (14) examined decline onset using age-adjusted mortality rates for white males for the 1968-1978 period.

This paper describes the temporal and spatial pattern of the onset of the decline in ischemic heart disease mortality in the United States between 1955-1978 for age-sex-race specific data by state for the white population. The 48 contiguous states and the District of Columbia provide sufficiently detailed information on the spatial distribution of the onset, yet are populous enough in most cases to produce stable age-specific rates, particularly for the younger age categories. The time span studied, 1955-1978, ensures that the decline onset occurred somewhere near the midpoint of the study period for most states (2).

MATERIALS AND METHODS

Population Data

The population data used to calculate mortality rates were the counts from the April 1 censuses for 1950, 1960, 1970, and 1980. It was necessary to interpolate the April

1 estimates to July 1 of each of the years 1955 through 1978. A third degree polynomial, using all four census years, produces a smooth curve which was utilized to interpolate intercensal population values. It should also be noted that this polynomial reproduces the exact population figures for 1950, 1960, 1970, and 1980, so that no error occurs in census years. This process produces smooth curves that accurately estimate te intercensal population counts. The midyear (July 1) polynomial estimates for 1955-1978 are the population estimates used to calculate mortality rates.

Mortality Data

Ischemic heart disease, which is essentially synonymous with coronary heart disease, has been defined by Stallones (15) as:

> ...the clinical manifestation of atherosclerosis, the obstruction of the flow of blood through the arterial network, when the vessels that are obstructed are the coronary arteries, which nourish the muscle of the heart.

The appropriate ICDA code for coronary heart disease for the Sixth and Seventh Revision Revisions was 420 (arteriosclerotic heart disease, including coronary heart disease); for the Eighth Revision the ICDA codes were 410-413, including both acute and chronic ischemic heart disease.

The mortality data used for 1968-1978 were tabulated by the Mortality Surveillance Project of the Johns Hopkins University (16) from the original mortality records collected by the National Center for Health Statistics. The cause of death category extracted from this data file is ischemic heart disease (ICDA code 410-413), producing a total of 3,225,603 cases for 1968-1978. Of these 2,253,783 were male and 971,820 were female. The mortality data from NCS for 1972 are based on a 50 per cent sample.

The mortality data (ICDA 420) for 1955-1967 were obtained from published mortality figures (Vital Statistics of the United States, 17). For 1962-1963 the state of New Jersey did not record deaths by race. Therefore it was necessary to prorate the death

count for these two years for New Jersey based on age-sex-specific race ratios for adjacent years. For 1955-1967 the total number of deaths due to coronary heart disease (ages 35-74) amounted to 3,500,906. Of these, 2,491,554 were male and 1,009,352 were female. This brings the total number of ischemic heart disease deaths for 1955-1978 for ages 35-74 to 6,726,509; 4,745,337 male and 1,981,172 female.

Year of Maximum Rate

Mortality rates per 100,000 population were calculated in the standard fashion for ten-year age groups, 35-44, 45-54, 55-64, 65-74, and are available elsewhere (18). Ischemic heart disease rates generally show an upward trend followed by a clear downward trend with some fluctuation from year to year. For this reason the date of first decline was estimated by fitting a quadratic expression to the mortality rates. It should be noted that if for a particular age-sex group in a given state the relationship was in fact linear, the quadratic component of the equation would become approximately zero, and the resulting equation would be linear. Wing et al (14) have also employed a quadratic model and found that it was a better fit than a two-segment linear model. The first and second derivatives of this quadratic expression provide an estimate of the time at which the maximum value (peak ischemic heart disease rate) occurred.

An additional problem in ascertaining the year of first decline is that the time period covered (1955-1978) included three revisions of the ICDA codes: the Sixth (1955-1957), the Seventh (1958-1967), and the Eighth (1968-1978). These changes were taken into account when estimating the year of maximum rate. One way to adjust for the three changes in coding is to use comparability ratios developed by the National Center for Health Statistics (3). However, these comparability ratios can be used only for the total population because the sample employed for the duplicate coding was not stratified by race, sex, or age. To make age-specific adjustments for the discontinuity caused by the coding revisions, two indicator variables, Δ_1 and Δ_2 were used in a quadratic

regression equation to account for changes over time in heart disease rubrics. The quadratic equation is expressed as:

$$y_i = a + bx_i + cx_i^2 + \delta_1\Delta_{1i} + \delta_2\Delta_{2i}$$

where y_i = mortality rate

x_i = ith year

a = constant

b = linear coefficient

c = quadratic coefficient

Δ_1, Δ_2 = binary indicator variables to account for three ICDA changes.

δ_1, δ_2 = indicator coefficients

Using this expression and age-sex-state-specific mortality data produces sex-age-state estimates of the year of maximum mortality, here called MAXYRs. The time of the onset of the decline is defined as the time when the maximum rate occurred. Variance estimates from the regression calculations and a Taylor's series expansion (19) were used to calculate the standard errors of the MAXYRs.

Temporal-Spatial Analysis

Maps of the MAXYR distribution were constructed for five-year and one-year intervals. The five-year interval maps of the MAXYRs divided into five categories (1955 and earlier, 1956-1960, 1961-1965, 1966-1970, and after 1970) are employed to describe the general pattern of the onset of decline. For the periods with the greatest number of newly declining states (i.e., states reaching their maximum), maps with one-year intervals were constructed to present a more refined view of the temporal and spatial patterns of the decline. Spearman's rank correlations (all correlations used in this paper are Spearman rank correlations) are used to assess the similarity in the order of decline onset among states for age-and sex-specific groupings. Rankings are based on the MAXYR date for each state for each of the age-sex groups. If, for two groups, the first state to

decline is the same in each of the groups and the second state is the same in each of the groups, and so on until the 49th state, then the correlation is perfect. In other words, the order in which the states declined for these two groups is identical.

A new statistical method was developed to quantify the visual impressions of the maps. The underlying principal used to design the method is that if a diffusion-like process is at work, then a newly declining state is likely to be contiguous to a previously declining state. On the other hand, if no diffusion process is at work the likelihood of two states being contiguous is simply a function of random variation. A general discussion of spatial diffusion can be found in Hagerstrand (20). To develop a statistical measure, states are placed in ascending order of decline onset by date of onset of decline. Next, states are assigned a 1 if they are contiguous to a previously declining state. This number is then weighted by the number of remaining undeclined states. If a state is not contiguous to a previously declining state then it is assigned a 0. The first state to decline is assigned a 0 since it cannot be contiguous to a previously declining state. The second state is assigned a 1 x 47 = 47 if it is contiguous to the first state or a 0 if it is not and so on for each of the 49 states. The last state to decline (49th) will necessarily be contiguous to a previously declining state and will therefore be assigned a 1. However, it will be weighted by a 0 since no undeclined states remain. These counts of weighted contiguities are summed to produce a total number for each of the sex-age groups that reflects the intensity of any 'diffusion' process.

The states are then ranked in descending order of onset of decline and the same procedure performed. This produces a statistical measure that will reflect the occurrence of contiguous states which occurr at the end of the period of decline. Analyses of both ascending and descending rank orders capture both observed aspects of the temporal-spatial patterns, early and late onset clusters. The ascending analysis is sensitive to clusters of early declining states; analysis of descending order increases sensitivity to clusters of late declining states.

The value of the weighted number of contiguities, both ascending and descending, are then totaled for each sex-age combination. The likelihood of occurrence of the weighted contiguities (significance probabilities) are estimated from a probability distribution produced by Monte Carlo simulation techniques. A distribution based on 5000 simulated sets of data, when the contiguities occur strictly by chance, provides the null distribution and, therefore, the significance probabilities for a statistical evaluation.

States can be defined as contiguous in a number of ways. For this study states are considered contiguous if they share a boundary, either a line or point (such as Utah, Colarado, New Mexico, Arizona). Additionally, two separate criteria were used to classify a state as contiguous to a previously declining state: the first requires a state to be touching one other previously declining state to be recorded as contiguous to it, and the second stricter criterion requires that a state be touching two previously declining states to be recorded as contiguous to them.

RESULTS

Temporal Patterns

Table 1 presents the years of maximum rates (MAXYRs) and their standard errors for males. Calculation of MAXYRs using the race-adjusted censuses for 1970 and 1980 made little difference. As can be seen, most states began declining in the early-to mid-sixties. The period 1960-1965 showed the largest increase in the number of newly declining states. Figure 1 is a plot of the cumulative distribution of decline onset by year. These curves are rather similar among the four age groups of men. Rates for men aged 65-74, however, began to decline somewhat later than rates for the other groups. As of 1955 men aged 45-54 had seven states already declining whereas the other groups had one or two. The standard errors of the MAXYRs vary considerably among these groups.

MAXYRs preceding the study period (1955-1978) were extrapolated and have limited utility as dates of onset. However, they were used in determining the rank orders of

the MAXYRs of their respective states. For males this occurred only a small number of times (11 out 196 possible times, or 5.6 per cent) and the lack of reliability of declines is reflected in the associated large standard errors. It is interesting to note that California, Maryland, and the District of Columbia have estimated MAXYRs prior to 1955 in 2 age groups each, indicating that perhaps they did, in fact, begin to decline prior to 1955. In the case of the District of Columbia an early MAXYR (1861.53) was extrapolated for men aged 35-44 and is certainly the result of small numbers and random variation in this category. In addition, for the state of Nevada a year of minimum rate (as indicated by a positive second derivative) was estimated for males aged 45-54 and was excluded from further analysis.

Table 2 presents the MAXYRs and standard errors for females. As with males, the onset dates estimated are primarily in the early-to mid-sixties. However, there are several notable differences in the temporal patterns. First, it can be seen that younger women (35-44) and older women (55-74) had distinct patterns of onset (see Figure 2, which presents the cumulative distribution of decline onset by year for females). For younger women the decline began later and the onset was never as steep as that for the older women. However, it must be emphasized that in the case of women, particularly young women, the derived curve is not highly reliable due to small numbers of deaths in this age group.

Second, the standard errors of the MAXYRs were greater for women than men. Like their male counterparts, The explanation for this is twofold: first, the number of ischemic heart disease deaths were much smaller among women (especially those under 55) than men; and second, women, especially those 55-64, showed more variablilty in the MAXYR measure. Pre-1955 decline onset dates occurred among women with approximately the same frequency as among men in three of the four age groups: 35-44, 45-54, and 65-74 (7 out of 147 times, or 4.8 per cent in the three groups). Among women aged 55-64 13 states (26.5 per cent) declined prior to 1955. One post-1978 date occurs in

females aged 55-64 (Wyoming) and among women aged 45-54 six minimum rates were estimated (the District of Columbia, Maryland, Mississippi, Nevada, Virginia, and Wyoming) and were excluded from further analysis. As with men the states with extreme estimated dates or minimum dates had associated higher standard errors.

Spatial Patterns

Although maps were constructed for each age-sex group, only the maps for males aged 55-64 are presented. Differences between these and the maps for the other groups are noted. The remainder of the maps can be found elsewhere (18) or are available from the authors.

Map A (Figure 3) shows that the decline onset first occurred in California and Maryland. Inspection of Map B (onset 1956-1960) indicates that the decline has spread to Pennsylvania, New York, New Jersey, Connecticut, Massachusetts, New Hampshire, and Rhode Island in the east and Washington, Idaho, and Wyoming in the west, and a new center of decline has arisen in Florida. In Map C (onset 1961-1965) all but six states have begun to decline: West Virginia, Tenessee, Kentucky, Oklahoma, New Mexico, and Utah. By 1970 (Map D) all states have begun to decline.

The spatial patterns exhibited in the other age and sex groups (not shown) are similar; the west and east have clusters of early declining states, whereas the southeast has a pronounced tendency to lag behind. This tendency to decline later in the southeast is less striking among both males and females aged 35-44. Furthermore, the spatial patterns are in general less pronounced in this age-sex group. The only exception to this general pattern is for females aged 55-64, where thirteen states had declined as of 1955. In addition to clusters in the west and the northeast, this group exhibited a strong cluster of early declining states in the north central region of the U.S. The southeast once again tended to decline later.

Figure 4 presents the results for the period 1960 - 1965 in one-year intervals for white males aged 55-64, to give a closer look at this period during which many states

began to decline. Map A of Figure 4 indicates a spread in the northeast to include the District of Columbia. In the west the decline appears to have spread to Montana and South Dakota. Map B shows that the northeast remains the same and in the west, the decline had begun to occur in Oregon, Nevada, and Colorado. Newly declining states have arisen in the midwest: Indiana, Wisconsin, and Missouri. From map C of Figure 4 it is evident that the decline is now spreading throughout the midwest, but there is a notable lack of declining states in the southeast: only Florida, Louisiana, and Texas had begun to decline as of 1963. By 1964 there are ten states that have not declined (Map D); four of these are in the southeast: North Carolina, Tennessee, Kentucky, and West Virginia.

The one-year interval maps for men aged 55-64 are representative of the patterns for the other groups (not shown). However, there are a few exceptions. For males aged 65-74 the onset of decline spread more slowly and hence more states had still not experienced a decline in ischemic heart disease mortality rates as of 1964. Among females the patterns were essentially the same except that the period of steepest onset tended to vary.

Temporal-Spatial Patterns

Statistical analysis (with significance defined as having less than 0.05 probability of occurring by chance) indicates that the order in which the onset occurred (ranks of MAXYRs) was similar in males and females of the same age groups. Spearman's correlation coefficient was significant ($p < 0.05$) among all four comparisons and ranged from 0.38 for males and females aged 45-54 to 0.66 for males and females aged 35-44, as can be seen in Table 3. Table 4 indicates that among males ranks were not significantly different across all four age groups, with correlation coefficients ranging from 0.409 to 0.598. This indicates that the order of decline onset was approximately the same in the four age groups of men. Among females the results were not as strong. Two of the age

comparisons had nonsignificant results. The remaining four were significant and correlation coefficients ranged between 0.308 and 0.369.

Results of the statistical test of 'diffusion' are given in Tables 5 and 6. Table 5 employs the first definition of contiguous. Results for the ascending order analysis, which is sensitive to early clusters, indicate that among both males and females aged 55-64 decline onset spread in a fashion consistent with a diffusion-like process, with p-values of 0.021 and less than 0.001, respectively. The ascending contiguity count for females aged 35-44 approached significance ($p = 0.079$). Note that these significance probabilities, as well as all others, are found from a Monte Carlo simulated null distribution of 5000 trials.

The descending analysis, which is sensitive to clusters of late declining states, also resulted in significant findings for both males and females aged 55-64, with p-values of 0.005 and 0.010, respectively. In this descending analysis for males p-values are lower in all groups but one, with males aged 65-74 having nearly significant results ($p = 0.079$). Females aged 45-54 also exhibit nearly significant results ($p = 0.079$). It should also be noted that females aged 35-44 and 55-64 exhibit lower contiguity counts in the descending analysis than in the ascending analysis, indicating that the decline was more clustered in the initial phases and late declining states were more diffuse.

The sum of counts (ascending plus descending), when compared to the simulated probability distribution of contiguities, indicates that evidence exists of 'diffusion' occurring among both males and females aged 55-64. Males aged 65-74 have nearly significant results.

Table 6 presents the results employing the more stringent definition of contiguous, that is, a state must be contiguous to two previously declining states in order to be counted as contiguous. This definition requires greater evidence that the apparent spatial distribution on the maps is nonrandom. The ascending analysis results in significant findings again for both males and females aged 55-64 ($p = 0.010$ and 0.001,

respectively), and nearly significant results for males aged 65-74 ($p = 0.062$). The p-values are lower in employing this definition than they were using the former definition, except in the case of 35-44 year old females.

Results of the descending analysis for the second definition (Count 2, Table 6) demonstrate that for both males and females aged 55-64 and males aged 65-74 the spatial pattern over time was nonrandom. Additionally, for males aged 45-54 the contiguity count was nearly significant, with a p-value of 0.062. As with the first criterion contiguity counts were higher in the descending analysis than in the ascending analysis, with the exception of females aged 35-44, 45-54, and 65-74.

The sum of contiguity counts in Table 6 indicates that among males and females aged 55-64 and males aged 65-74 there appears as before to be strong evidence of a diffusion-like temporal-spatial pattern even using a more stringent criteria of contiguous. Both males and females aged 45-54 (p-values of 0.087 and 0.057, respectively) and females aged 65-74 ($p = 0.057$) have nearly significant results. Only the 35-44 year old age groups, both male and female, have low contiguity count sums (nonsignificant).

DISCUSSION

This paper describes four useful findings concerning the temporal and spatial patterns of the onset of decline in age-sex-race-specific ischemic heart disease mortality rates between 1955 and 1978 in the United States. First, considerable temporal and spatial variation in the onset of decline was observed among the groups studied. For males, the dates of onset of decline occurred in a narrow time band, primarily 1960-1965. For females, however, the time period of most rapid rate of decline onset was not as similar across the age cohorts as among men. Some states were consistently early decliners (Maryland, District of Columbia) in female ischemic heart disease mortality and others consistently lagged (Kentucky, Tennessee, West Virginia). Second, the results indicate a temporal-spatial clustering of decline onset. Across age groups some states were consistently early decliners (California, Maryland, the District of Columbia) and some

consistently late (Kentucky, Tennessee, West Virginia) for both males and females. Third, correlation coefficients show that the order in which the decline began was similar across gender and age. Across gender, the correlation coefficients by age ranged from 0.38 to 0.66 (all p-values < 0.005). Across age-groups, among men, the correlation coefficients ranged from 0.409 to 0.598 (all p-values < 0.003); among women, the correlation coefficients across age were weaker, ranging from 0.101 to 0.369 (p-values < 0.02 for all but two groups). Fourth, analyses of the temporal-spatial patterns of ischemic heart disease mortality decline onset revealed a series of patterns consistent with a diffusion-like process, that is, the onset of decline in ishemic heart disease mortality appears to have spread across the nation from several initial foci of decline.

In a study of this type there are limitations regarding both the data and the analysis. The data for the younger age groups, particularly women, and in states with small populations such as Utah are often difficult to interpret in light of the increased random variation. The polynomial estimation of population counts employed here reduces comparability to other studies of the same phenomenon which in most cases use a linear interpolation over a more restricted time period. Nevertheless our results are similar to other studies which found both the decline in age-adjusted ischemic heart disease mortality to have begun in approximately 1963 (2) and later decline onset dates in several southern states (12). Where the basic assumptions underlying the quadratic regression used to arrive at the MAXYR are not met (i.e., where the rates for a given age-sex-state combination are not unimodal and concave), as may be the case for several groups of women, bias will result and such data was eliminated from analysis. There is evidence that cohorts of women born between 1886 to 1910 may have had declining ischemic heart disease mortality rates since 1945 or earlier (21). Klebba (2) noted an increase of 14.4 per cent between 1950-1957 and a decrease of 1.3 per cent between 1958-1967 for age-adjusted rates for white females. Either declining or stable rates over the time period studied would result in the extrapolation of early MAXYRs (outside the

data range) as happened with women aged 55-64 for thirteen states. The statistical technique used to measure the spread or diffusion of the decline accounts for the order of declining states both for early and late decliners. However, it is not highly sensitive to other aspects of the diffusion process: the amount of time occurring between successive ranks, distance between the populations of two given states (contiguity is used as a proxy for distance), or, for that matter, direction. The analysis, however, is consistent with what is visually apparent on the maps and it provides a statistical evaluation of date of onset of decline providing insight into the dynamics of rising and falling U.S. ischemic heart disease mortality rates.

Declining ischemic heart disease mortality has generally been described as a universal and uniform phenomenon occurring throughout the United States. Gordon and Thom (22) examined age-adjusted CHD mortality from 1968-1972 and noted that:

> ...in every specific group there has been a decrease in CHD mortality and that the percent decrease varied relatively little from one group to another. This is in flat contradiction to all previous experience, where trends by race and sex differed radically.

Cooper at al. (23) also examined age-adjusted CHD mortality, in this case from 1968-1975 and reached the same conclusion as Gordon and Thom. According to Cooper et al.:

> It is apparent over the years 1968-1975 a uniform and unprecendented departure from previous trends occurred. From 1968 to 1975 the age-adjusted CHD mortality rate for the total US population declined 19.3% while the crude rate dropped 10.6%. The magnitude of the downturn eliminated the individual differences in the trends for the major sex-color groups aged 35-74, and all four shared a continued, statistically significant improvement in death rates: 19% for white males, 24% for white females, 29% for nonwhite males, and 35% for nonwhite females. The fall in mortality was well distributed among the 10 yr

age groups.

Because of the work of Borhani (8) it is generally acknowleged that there may have been some geographic variation in decline onset (16). Nonetheless, it has been assumed that there was essentially no variation in onset by age and sex (16). Stallones (16), for instance, in commenting on the requirements a proposed causative factor would have to meet, states that it (the suspected causative agent) would have to occur at approximately the same time for males and females because the decline began at the same time for males and females. This study shows that, when inspected closely, the onset appears to vary by sex, and to a lesser degree by age.

Kimm et al. (12) also examined the onset of decline in ischemic heart disease mortality rates in four southern states (North Carolina, South Carolina, Georgia, and Virginia) and three non-southern states (California, Utah, and New York) from 1950-1976, using age-adjusted rates. They determined that these southern states did not begin to decline until 1968 and that California (males and females) began declining in the early 1950s, as did females in Utah and New York. Our results indicate that the south indeed lagged behind the rest of the nation in decline onset but our onset dates were earlier than those of Kimm et al. (see Table 1 and 2).

Wing et al. (14) examined the onset of decline by State Economic Areas for white males for the years 1968-1978 using age-adjusted data. For 65.5 per cent of the State Econmomic Areas, accounting for 79.8 per cent of the population, 1968, the first year of the time period examined, was the year of the highest estimated rate and therefore the beginning of the decline. This points to the need to examine pre-1968 mortality data in determining the onset of decline in IHD mortality. Results presented here with respect to later dates of onset in the southern portion of the nation are in accord with those of Wing et al.

Variation in the spatial pattern of the decline in terms of average rate and per cent change has been examined by Davis et al. (13). Using age-adjusted mortality data for all cause, ischemic heart disease, acute myocadial infarction, chronic ischemic heart disease for 1968-1978 the authors constructed maps of percent change and average rate by State Economic Areas. Using rank correlations, they found greater association in average rates for males and females than for per cent change in rates. They interpret this difference as meaning that similar factors may account for the occurrence of ischemic heart disease in males and females, whereas, dissimilar factors may account for the decline. Results presented here, based on age-specific rates, indicate that the rank order of ischemic heart disease decline onset was similar for males and females of the same age group.

The study of chronic disease generally involves determining which factors (social, economic, environmental, or other) account for disease presence or absence in the population. Information derived from the temporal-spatial pattern of decline onset in ischemic heart disease mortality is necessary for the study the factors associated with declining mortality rates. For example, the variation in onset of decline demonstrates that either different factors account for the decline or, more likely, the spread of health-related changes underlying the decline may have diffused somewhat differently in the different groups. In the case of an infectious disease such as cholera it was an actual microbe transported by people from one area to another; in the case of declining ischemic heart disease mortality rates what is presumed to spread are health-related changes. That is, cessation of cigarette smoking, changes in diet producing lower serum cholesterol, changes in hypertension control, improvements in medical treatment, and, indeed, unrecognized factors move in a systematic way across the United States. As stated by Kimm et al. (12) variation in decline onset implies that:

> ...the declines in mortality may not be due to revolutionary changes, either in lifestyle or in medical care, that occurred at one time, but are rather due to a series of changes that took place at various times in different regions.

Whether the factors reponsible for the decline in ischemic heart disease mortality were in fact major changes or series of smaller changes still remains to be determined.

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TABLE 1

MAXYRs and standard errors, United States, 1955-1978, white males, by age group

	35-44		45-54		55-64		65-74	
State	MAXYR	SE	MAXYR	SE	MAXYR	SE	MAXYR	SE
Alabama	1963.58	2.06	1963.76	0.79	1964.56	0.87	1966.39	0.68
Arizona	1967.52	3.31	1965.91	1.51	1964.09	1.24	1965.90	1.41
Arkansas	1964.62	1.98	1965.45	1.11	1964.78	0.86	1966.83	0.76
California	1962.10	0.84	1941.86	8.21	1952.82	2.59	1961.54	2.02
Colorado	1962.68	3.49	1962.03	1.93	1962.31	1.56	1964.89	1.52
Connecticut	1964.32	1.53	1960.47	2.47	1958.99	2.92	1963.66	1.09
Delaware	1959.24	5.82	1965.40	2.29	1961.44	3.23	1965.40	1.45
District of Columbia	1861.53	627.60	1954.39	9.01	1961.36	2.69	1962.22	3.63
Florida	1961.54	2.64	1950.15	14.44	1959.82	1.75	1965.50	1.18
Georgia	1961.89	1.90	1963.21	0.97	1964.81	0.43	1965.96	1.10
Idaho	1959.59	4.89	1964.35	1.72	1959.67	3.56	1964.67	1.88
Illinois	1964.45	1.03	1963.46	0.73	1963.39	0.82	1964.95	1.16
Indiana	1964.56	1.80	1958.17	3.44	1962.24	1.52	1966.34	1.13
Iowa	1973.43	9.63	1965.96	1.07	1964.18	0.77	1967.21	0.59
Kansas	1961.75	2.90	1962.11	2.16	1964.54	0.83	1965.48	1.08
Kentucky	1966.38	1.67	1967.99	0.94	1966.04	0.78	1968.09	0.71
Louisiana	1964.46	1.44	1961.83	1.30	1963.87	0.69	1963.95	1.41
Maine	1965.74	1.92	1967.12	2.58	1965.42	1.12	1966.13	1.17
Maryland	1959.79	3.38	1931.08	22.65	1954.39	3.73	1962.35	1.47
Massachusetts	1963.16	1.43	1957.20	4.39	1959.47	2.44	1964.02	1.41
Michigan	1959.21	3.01	1958.89	2.92	1964.74	0.63	1965.85	1.30
Minnesota	1963.97	1.29	1956.33	4.25	1963.49	1.07	1965.73	1.09
Mississippi	1964.17	3.59	1964.82	0.97	1964.90	0.79	1965.02	1.26
Missouri	1967.00	0.84	1963.53	2.69	1962.56	1.19	1965.79	1.26
Montana	1956.50	9.52	1949.71	15.05	1961.01	3.01	1958.09	4.22
Nebraska	1964.98	1.83	1964.73	1.37	1965.20	1.14	1965.83	1.12
Nevada	1964.55	2.18	*	*	1962.12	2.50	1963.93	3.81
New Hampshire	1967.23	1.81	1958.16	5.42	1960.33	4.05	1966.69	0.81
New JerseY	1962.31	1.19	1962.60	1.54	1960.53	1.02	1965.05	1.11
New Mexico	1965.15	2.16	1964.14	0.88	1967.21	0.94	1968.09	1.05
New York	1962.60	0.98	1954.81	4.26	1960.94	1.00	1962.98	1.98
North Carolina	1964.03	2.03	1964.39	1.17	1965.68	0.77	1967.88	1.08
North Dakota	1965.04	1.60	1961.85	5.99	1965.73	1.12	1966.38	1.51
Ohio	1963.47	1.11	1962.30	1.63	1963.76	0.67	1967.04	0.79
Oklahoma	1966.65	0.95	1968.65	1.48	1966.66	0.61	1968.12	0.86
Oregon	1962.23	5.09	1961.62	1.77	1962.96	1.71	1964.17	1.19
Pennsylvania	1962.23	1.07	1959.73	1.42	1960.26	1.14	1964.94	0.93
Rhode Island	1966.20	2.19	1951.02	27.17	1959.25	3.17	1966.43	1.11
South Carolina	1964.31	1.35	1961.22	1.66	1964.91	0.71	1963.42	1.67
South Dakota	1939.72	42.31	1969.13	3.02	1961.38	2.56	1964.17	2.22
Tennessee	1965.92	1.29	1966.69	0.52	1966.63	0.63	1968.31	0.74
Texas	1960.71	2.04	1960.43	1.68	1962.15	0.88	1964.62	1.02
Utah	1966.88	3.38	1963.27	3.29	1967.20	3.35	1945.22	75.35
Vermont	1969.55	7.16	1961.36	9.06	1964.35	1.42	1966.85	1.03
Virginia	1963.60	2.13	1963.49	1.02	1964.36	0.84	1967.36	0.80
Washington	1964.39	1.31	1959.93	2.31	1958.89	1.66	1964.02	1.05
West Virginia	1969.31	2.98	1964.85	2.58	1967.29	1.41	1968.23	1.01
Wisconsin	1961.69	2.27	1962.52	1.17	1962.08	0.98	1964.55	1.04
Wyoming	1965.81	2.88	1966.26	3.68	1957.19	16.62	1963.53	3.31

* The date of minimum rate rather than maximum rate was estimated.

TABLE 2

MAXYRs and standard errors, United States, 1955-1978, white females, by age group

	35-44		45-54		55-64		65-74	
State	MAXYR	SE	MAXYR	SE	MAXYR	SE	MAXYR	SE
Alabama	1962.91	2.92	1966.11	1.35	1961.89	2.70	1964.85	0.65
Arizona	1967.19	4.23	1965.79	4.49	1964.96	2.85	1964.33	1.67
Arkansas	1970.96	23.80	1968.23	1.62	1965.34	1.83	1964.74	0.69
California	1963.85	1.36	1959.28	3.26	1953.54	2.97	1958.61	1.29
Colorado	1966.10	2.14	1965.41	1.92	1962.10	2.32	1957.82	3.37
Connecticut	1967.26	1.09	1960.44	5.53	1892.68	131.10	1960.04	1.18
Delaware	1953.28	11.89	1959.87	6.66	1945.64	39.01	1959.45	3.35
District of Columbia	1964.41	5.70	*	*	1952.90	15.15	1951.52	7.59
Florida	1963.27	3.98	1951.52	16.33	1960.86	2.93	1961.38	1.68
Georgia	1960.37	2.15	1967.38	1.82	1965.45	0.93	1964.64	0.86
Idaho	1961.79	23.68	1965.88	3.33	1961.09	4.68	1964.97	1.81
Illinois	1967.03	0.96	1965.81	0.99	1958.13	2.45	1963.01	0.64
Indiana	1966.57	2.44	1958.57	5.71	1959.02	3.30	1963.70	0.67
Iowa	1969.19	2.33	1965.06	1.96	1965.22	1.52	1964.01	1.36
Kansas	1968.93	2.07	1964.74	7.21	1964.05	3.18	1960.72	2.90
Kentucky	1969.67	3.87	1964.22	4.52	1964.44	1.30	1963.78	1.72
Louisiana	1965.24	1.86	1970.50	21.53	1961.31	2.59	1962.09	1.85
Maine	1967.00	2.59	1894.83	463.92	1964.64	1.50	1964.00	1.31
Maryland	1954.53	19.57	*	*	1937.35	14.71	1960.14	1.40
Massachusetts	1962.25	3.89	1960.27	5.66	1919.60	44.38	1959.86	1.83
Michigan	1966.72	2.03	1966.35	1.67	1957.21	3.49	1963.81	0.98
Minnesota	1964.59	3.56	1957.88	10.37	1947.10	16.69	1961.53	1.30
Mississippi	1965.32	9.10	*	*	1963.11	1.86	1957.16	4.94
Missouri	1966.35	2.51	1959.94	25.23	1963.80	1.41	1963.10	1.11
Montana	1956.79	19.90	1961.95	2.13	1957.06	10.39	1963.17	1.77
Nebraska	1966.90	4.41	1967.80	1.82	1964.47	1.78	1961.86	2.29
Nevada	1962.90	2.28	*	*	1968.77	2.77	1956.78	13.63
New Hampshire	1973.55	3.48	1965.62	3.28	1959.73	4.08	1963.01	1.10
New Jersey	1962.22	1.67	1963.04	1.40	1940.91	10.54	1961.82	0.82
New Mexico	1967.92	3.11	1966.28	2.10	1960.20	4.01	1963.67	1.68
New York	1962.32	2.50	1961.32	1.41	1944.63	7.25	1956.35	1.96
North Carolina	1964.12	2.12	1966.17	1.35	1965.95	1.18	1963.28	0.96
North Dakota	1973.21	9.85	1965.07	3.73	1956.75	8.61	1950.58	17.40
Ohio	1965.69	1.54	1963.38	2.50	1958.76	3.04	1964.29	0.48
Oklahoma	1966.48	1.27	1967.60	1.82	1966.88	2.25	1966.26	1.00
Oregon	1965.50	5.86	1967.52	2.80	1964.02	2.48	1962.93	1.31
Pennsylvania	1963.35	1.57	1959.65	2.24	1949.84	3.36	1962.33	0.52
Rhode Island	1966.62	2.93	1958.63	8.59	1918.75	171.58	1961.24	1.60
South Carolina	1967.52	1.72	1964.89	2.14	1961.20	2.40	1962.90	1.08
South Dakota	1965.01	4.66	1968.05	2.36	1957.30	23.61	1960.52	2.46
Tennessee	1972.86	4.32	1966.12	1.75	1965.75	1.25	1965.16	0.81
Texas	1959.92	5.33	1963.33	3.19	1960.31	2.07	1960.48	1.87
Utah	1972.80	3.86	1968.78	5.26	1910.45	218.33	1964.97	1.94
Vermont	1956.83	28.29	1967.10	1.95	1956.74	6.60	1964.63	1.32
Virginia	1967.87	1.93	*	*	1964.97	1.52	1962.93	1.02
Washington	1969.41	3.06	1966.88	2.96	1962.82	1.06	1963.55	0.84
West Virginia	1972.17	20.79	1970.49	1.77	1965.47	3.18	1964.62	1.08
Wisconsin	1965.46	3.04	1965.66	2.15	1954.80	5.00	1961.79	1.23
Wyoming	1976.98	18.63	*	*	2047.39	1334.22	1956.98	7.54

* The date of minimum rate rather than maximum rate was estimated.

TABLE 3

Spearman rank-order correlation coefficients for MAXYRs with gender, United States, 1955-1978, whites, by age

Age	Coefficient	p
35-44	0.66	<0.001
45-54	0.38	0.004
55-64	0.48	<0.001
65-74	0.56	<0.001

TABLE 4

Spearman rank-order correlation coefficients for MAXYRs with age, United States, 1955-1978, by sex*

	35-44	45-54	55-64	65-74
		Males		
35-44	1.0	0.409 (0.002)	0.437 (0.001)	0.508 (<0.001)
45-54		1.0	0.539 (<0.001)	0.433 (0.001)
55-64			1.0	0.598 (<0.001)
65-75				1.0
		Females		
35-44	1.0	0.101 (0.245)	0.369 (0.005)	0.220 (0.064)
45-54		1.0	0.363 (0.005)	0.308 (0.016)
55-64			1.0	0.365 (0.005)
65-74				1.0

* p-values in parentheses

TABLE 5

Contiguity counts for adjacencies to at least one previously declining state, United States, 1955-1978, by age and sex

Age	Count 1*	p	Count 2†	p	Sum	p
			Males			
35-44	238	0.453	280	0.130	518	0.169
45-54	207	0.750	287	0.130	494	0.316
55-64	336	0.021	365	0.005	701	<0.001
65-74	258	0.323	301	0.079	559	0.077
			Females			
35-44	304	0.079	231	0.453	535	0.116
45-54	217	0.597	303	0.079	520	0.169
55-64	450	<0.001	350	0.010	800	<0.001
65-74	260	0.323	269	0.215	529	0.169

* ascending order
† descending order

TABLE 6

Contiguity counts for adjacencies to at least two previously declining states, United States, 1955-1978, by sex and age

Age	Count 1*	p	Count 2†	p	Sum	p
			Males			
35-44	108	0.409	128	0.277	236	0.259
45-54	112	0.409	168	0.062	280	0.087
55-64	199	0.010	213	0.005	412	<0.001
65-74	162	0.062	177	0.032	339	0.008
			Females			
35-44	92	0.565	133	0.174	225	0.259
45-54	147	0.107	135	0.174	282	0.057
55-64	239	0.001	254	<0.001	493	<0.001
65-74	148	0.107	140	0.174	288	0.057

* ascending order
† descending order

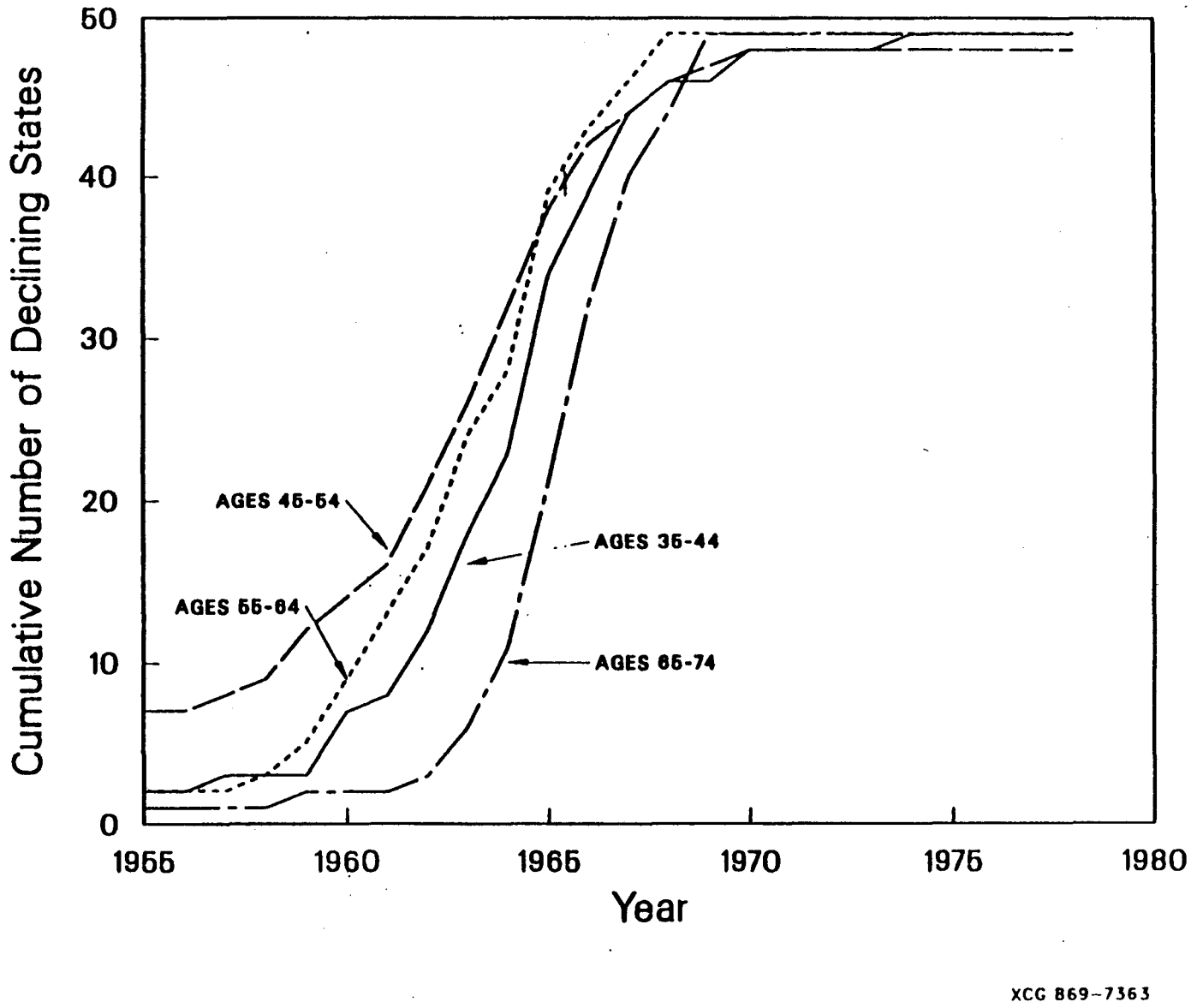
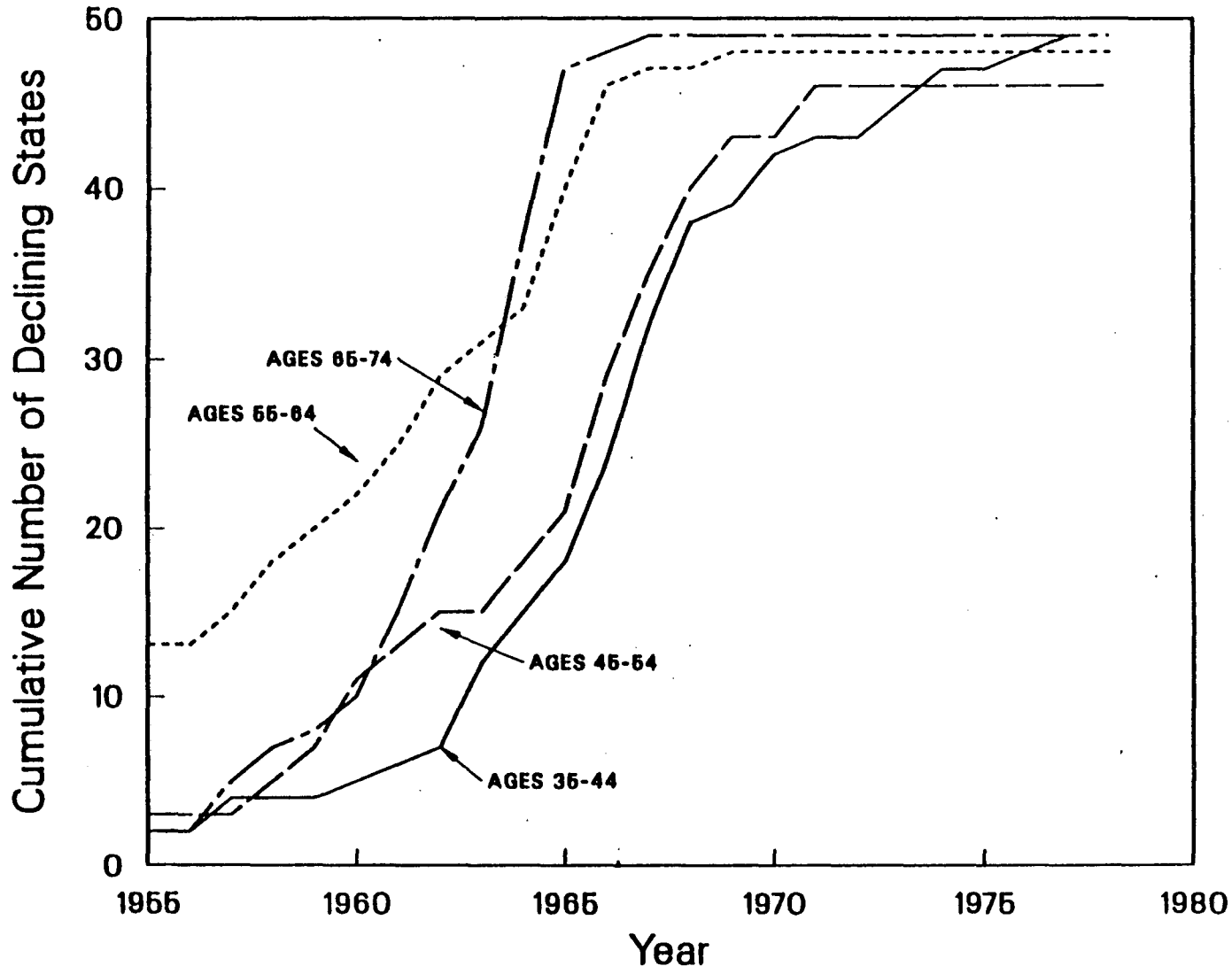
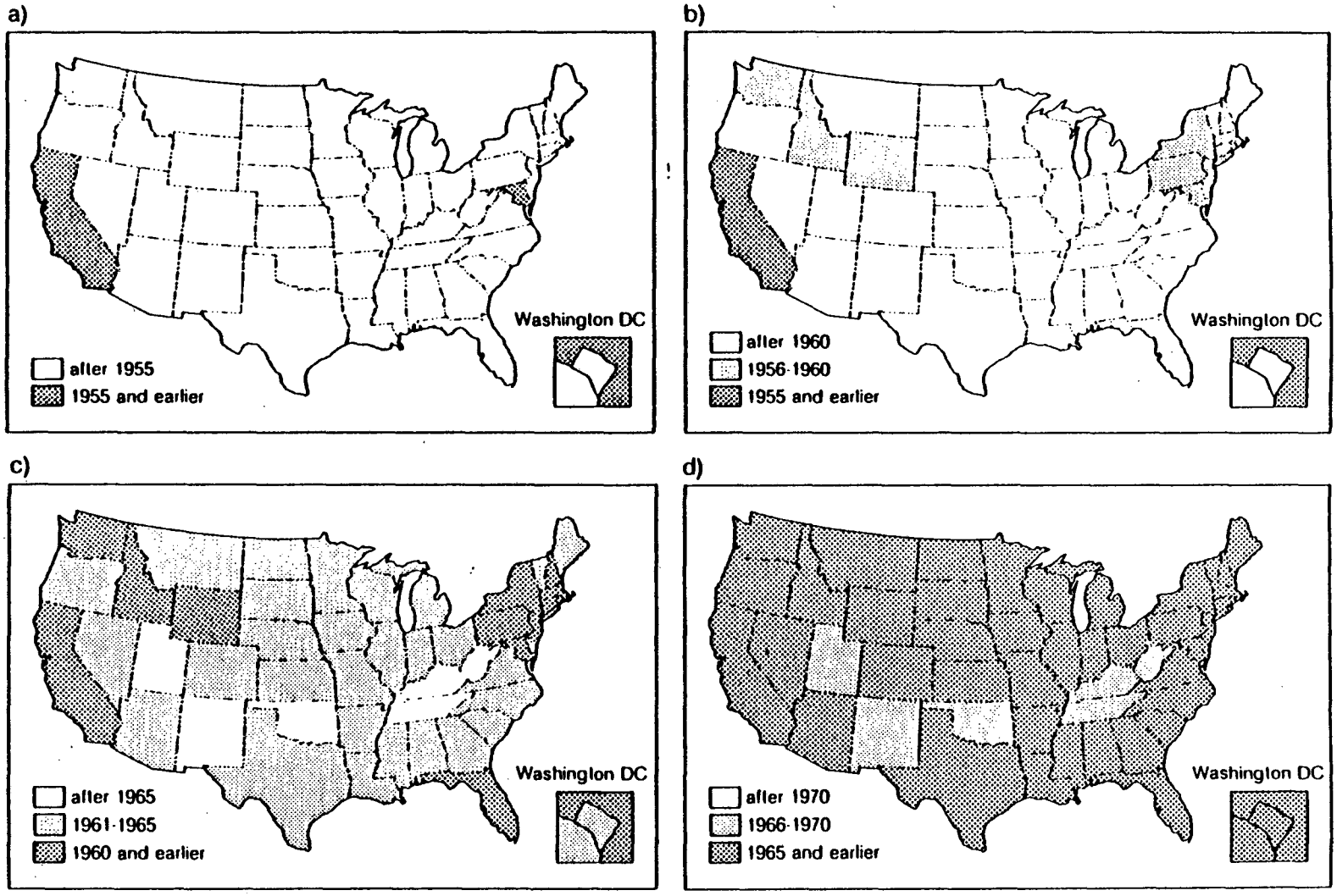


FIGURE 1. Cumulative number of states experiencing a decline in ischemic heart disease mortality, United States, 1955-1978, white males, by age.



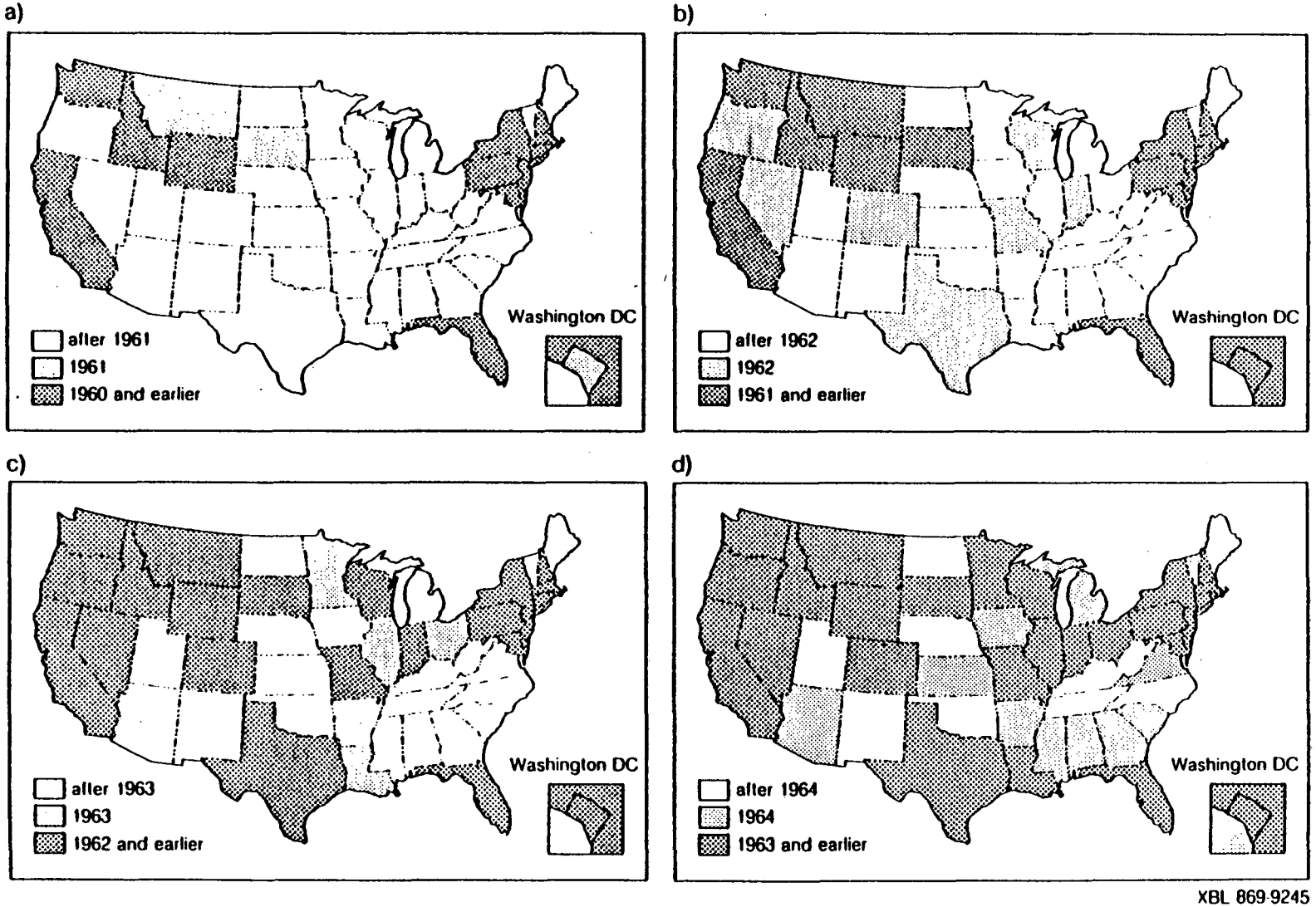
XCG 869-7364

FIGURE 2. Cumulative number of states experiencing a decline in ischemic heart disease mortality, United States, 1955-1978, white females, by age.



XBL 869-9244

FIGURE 3. Onset of ischemic heart disease mortality rate decline, white males, aged 55-64 years, United States, by state, 1955-1978, in five-year intervals.



XBL 869-9245

FIGURE 4. Onset of ischemic heart disease mortality rate decline, white males, aged 55-64 years, United States, by state, 1955-1978, in one-year intervals.

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