ANALYTICAL STUDIES

Series 3
Number 16

Cohort Mortality and Survivorship:

United States Death-Registration States, 1900-1968

An analysis of mortality rates by age, color, and sex of selected generations of 5-year birth cohorts born 1896-1900 through 1926-1930. Compares cohort and period life table survivorship (l_x) by single years of age, color, and sex for selected 5-year cohorts born 1899-1903 through 1928-1932. Based on death and population data for the death-registration States of the United States each year from 1900 to 1968.

DHEW Publication No. (HSM) 73-1400

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service

Health Services and Mental Health Administration
National Center for Health Statistics
Rockville, Md. November 1972

Vital and Health Statistics-Series 3-No. 16

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 - Price 70¢

NATIONAL CENTER FOR HEALTH STATISTICS

OFFICE OF HEALTH STATISTICS ANALYSIS

Vital and Health Statistics-Series 3-No. 16

DHEW Publication No. (HSM) 73-1400

Library of Congress Catalog Card Number 71-179928

CONTENTS

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COHORT MORTALITY AND SURVIVORSHIP:
UNITED STATES DEATH-REGISTRATION STATES, 1900-1968

Iwao M. Moriyama, Ph.D., and Susan O. Gustavus, Ph.D.[a]

INTRODUCTION

The official death statistics are derived from the mortality experience of a population for a particular time period, usually a calendar year. They represent a slice or a cross section of the mortality surface taken across the time axis, and are known as period mortality data. Another way of looking at death statistics is *along* the diagonal of the age and time axes rather than *across* the time axis. These longitudinal sections of the mortality surface show the mortality experience of cohorts of individuals from birth through the successive ages over their lifetimes (see appendix I). These cohort or generation mortality data are representations of what actually happens in life; nevertheless, data are seldom expressed in this way because a relatively long series of age-specific mortality statistics is needed to do so.

Following the same group of people over the lifetime of the cohort presents quite a different mortality and survival picture from that provided by the official annual mortality statistics. This is because of changes, usually improvements, in mortality rates during the life of the cohort.

[a]Iwao M. Moriyama, Director, Office of Health Statistics Analysis, National Center for Health Statistics, is presently on leave, serving as Chief, Statistics Department, Atomic Bomb Casualty Commission, Hiroshima, Japan. Susan O. Gustavus is Assistant Professor, Department of Sociology, The University of Utah, Salt Lake City.

This study presents the mortality and survivorship experience of four cohorts born a decade apart and subjected to the force of mortality in the United States during the period 1900 to 1968. These data are unique in that death rates and survivorship rates are derived for each calendar year.

The effects of the 1918 influenza pandemic may be seen in the experience of two of the four cohorts. The effects of other influenza epidemics of lesser proportions are also apparent in the generation curves.

The effects of World War II and of the Korean War are evident in cohort mortality curves of white males. Males of Negro and other races did not experience nearly the same increase in mortality during World War II, nor did the rate peak up to the same extent as the rate for white males in the Korean War.

Because of the decline in mortality over the years, the differences in cohort and period survivorship indicate that past period life tables have not represented the real-life mortality experience of a birth cohort. However, because the rate of decline in the mortality rates is slowing down, future period life tables should become better predictors of mortality in a cohort than were past period life tables.

Earlier Studies

The analysis of mortality patterns by the use of generation data is not new. While past efforts in examining mortality data by the cohort method have been limited by lack of suitable data, Kermack, McKendrick, and McKinlay[1] studied mortality data for cohorts at 10-year intervals from 1755 to 1925 in Great Britain and Sweden. No projections were attempted; consequently, data for most of the cohorts were incomplete. Their study showed that mortality patterns were fairly constant in each cohort, that is, that the most important factor in later mortality was the experience of the cohort before age 15 years, with each cohort having fairly similar mortality rates after that age. While later findings do not agree with this conclusion, this study was significant in that it was concerned with the mortality experience of cohorts of individuals instead of the total population at a fixed point in time.

Case[2] presented a review of cohort analysis and a detailed explanation of the logic of the technique including examples with data for England and Wales from 1851 to 1951. He compared the cohort and period approaches to mortality and commented on the "generation effect" and how it could be examined with cohort mortality data. The generation effect is based on the hypothesis that early mortality experience affects, or even determines, later mortality. This may occur in a variety of ways. For example, Pearson[3] and others felt that an effect of reducing infant mortality rates would be to raise mortality rates at later ages because such a lowering at the early ages would keep the "weak" alive and prevent natural selection from operating. However, this has not been borne out by later experience—or perhaps, the rapidity with which the death rate has declined may have obscured the effects, if any, of postponing deaths of presumably impaired lives. Case advanced the notion that the existing concepts of the laws of mortality were inadequate and could lead to improper inferences on the nature-nurture complex of problems because environment and therapeutic measures constantly change. He favored the use of the cohort analysis as a narrative or historical technique, and proposed "a synthesis of knowledge derived from social history, medical history, and cohort analysis to be made to interpret the narrative."

By far, the most frequent use of the cohort approach has been to examine mortality from specific diseases. Of these, Frost's[4] study of tuberculosis is a classic. He demonstrated that the actual pattern of mortality was not what was expected from previous findings on age-specific death rates for tuberculosis at one point in time. The latter approach showed that the greatest risk of death from tuberculosis was in the older ages, whereas the cohort data made it clear that the groups experiencing the highest risks at later ages had already passed through periods of even higher risks at the younger ages. Picken[5] confirmed Frost's results after applying Frost's methods to data for England and Wales for the same time period. However, Spicer[6] found from his analysis that the generation hypothesis gave a good description of mortality from respiratory tuberculosis until about 1930. After this period, the hypothesis no longer agreed satisfactorily with the facts.

The cohort method has been applied in studies of cancer mortality by Korteweg,[7] Stocks,[8,9] Haenszel and Shimkin,[10] Cutler and Loveland,[11] and others. These studies showed that successive cohorts experienced increased mortality for some sites and decreased mortality for other sites. In the Cutler and Loveland study, the cohort mortality rates for lung cancer were projected to estimate incidence rates. Deaths from other diseases have also been examined using the cohort approach.[12] In general, studies of cohort mortality data relating to specific diseases are much more meaningful than those encompassing all causes of death. The data for all causes of death are composites of the exposure to various diseases, and the cohort patterns of different diseases are averaged out. However, they are useful summaries of the total mortality experience of the cohorts as they are exposed to the actual force of mortality at various stages of life.

While life tables have often been used to determine death and survivorship rates, or years of life remaining at each age, they have generally been constructed for one point in time. Here again, lack of data has required analyses to rest on the assumption that the age-specific mortality rates for a particular year will prevail through the entire lifetime of the population presented in the life table. Dublin and Spiegelman[13] showed the weakness of such an assumption by demonstrating from life tables for the period 1871 to 1931 that there was a much greater "saving of life" during this period than would have been anticipated if the 1871 death rates applied in later years.

More recently, Spiegelman[14] used available vital statistics to create data on cohorts at 10-year intervals from 1900 to 1960. This study and others had several limitations. First, none of them was able to observe a cohort at shorter intervals than 5-year periods, and most used 10-year periods. Second, lacking data to complete their cohorts at young or old ages, incomplete cohorts had to be dealt with, or projections made on the basis of a number of assumptions. Alternatively, the analysis had to be limited to one period in each cohort's life, say, after age 45.

Data and Methodology

It is the purpose of this report to present mortality rates for four cohorts whose central years of birth are 1901, 1910, 1920, and 1930. The survivorship of these cohorts is also examined using both cohort and period mortality data in order to see how much difference exists in these two approaches, and the possible implications of this discrepancy.

The data in this report were produced from estimates of the population in 5-year age groups from birth to age 84 years in the period 1900 to 1968, inclusive. The number of deaths by age, sex, and color was obtained from the official vital statistics to which the war deaths were added from data made available by the Department of Defense. In this respect, the material is different from the conventional U.S. mortality statistics which include only deaths registered in the United States.

Data on both population and deaths refer to the expanding death-registration States for the years prior to 1933 and to the United States for subsequent years.[b]

Population and death data by single years of age were interpolated from the 5-year age groups by applying Beers' formula (see appendix II).

To prepare cohort or generation data, the statistics by age were combined in two ways. First, to produce *cohort mortality* tables, the data by single years of age for single-year birth cohorts were combined into 5-year birth cohorts to show mortality rates for 5-year age groups of cohorts for each calendar year. For example, the death rate for the cohort born 1896-1900 was computed for the year 1910 at which time the cohort was 10-14 years old, or age 12.5 on the average (refer to the column of x's in table A). A death rate at ages 11-15 was then computed for the same cohort in 1911 when the cohort was a year older, or 13.5 years old on the average (refer to the column of y's in table A). In this way, the cohort was followed through each calendar year until 1968.

Second, to produce *cohort survivorship* in detailed tables 1-8, the data were combined another way into 5-year birth cohorts to show mortality rates by single years of age for a succession of years of death. Thus, the death rate for a specified age represents the mortality experience of five birth cohorts at that age over a period of 5 calendar years. For example, the mortality rate for age 10 for the 1899-1903 birth cohort is based on population and deaths in the year 1909 for the 1899 component of the 5-year cohort, population and deaths in the year 1910 for the 1900 component, etc. (refer to the diagonal of o's in table A). The sum of the deaths in the five cohorts was divided by the sum of the five cohort populations to obtain a mortality rate for a single year of age. The life table death rate, q_x, was calculated from these mortality rates for each single year of age. Beginning with a population of 100,000 (radix), the q_x values were applied to the surviving life table populations to obtain the number dying at each age. The number surviving to each successive age was obtained by subtraction.

To produce the *period survivorship* in detailed tables 1-8, deaths and populations by single years of age were averaged over a period of 5 years. Death rates for the 5-year period were then computed from the average numbers of deaths and population. For example, the period survivorship table for 1910 is based on the average death rate by age for the period 1908 to 1912. An exception is the 1901 period

[b] For information on the death-registration States see the technical appendix of *Vital Statistics of the United States,* Vol. II–Mortality, Part A.

Table A. Example of data used in calculating cohort mortality rates for single years of time and cohort survivorship for single years of age

Year of birth	Year of death				
	1909	1910	1911	1912	1913
1896----------------------------------		*x*	*y*		
1897----------------------------------		*x*	*y*		
1898----------------------------------		*x*	*y*		
1899----------------------------------	*o*	*x*	*y*		
1900----------------------------------		*xo*	*y*		
1901----------------------------------			*o*		
1902----------------------------------				*o*	
1903----------------------------------					*o*

x Basis of the mortality rate of the cohort born 1896-1900 for the year 1910 (ages 10-14) at average age 12.5.
y Basis of the mortality rate of the cohort born 1896-1900 for the year 1911 (ages 11-15) at average age 13.5.
o Basis for the mortality rate from which survivorship from age 10 to age 11 was calculated for the cohort born 1899-1903.

survivorship table, which is based on averages for the 4 years 1900-1903. Survivorship in these tables was then computed in the same manner as in the cohort tables. (See appendix III.)

Because the original data on which the interpolation procedure was performed contained population estimates and deaths only for the period 1900 to 1968, the time periods which could be selected for examination were limited. Thus, the earliest 5-year birth cohort chosen for the study of survivorship was the cohort of 1899-1903. Since death rates for the years after 1968 were not included in this study, cohort mortality and survivorship tables are incomplete after this date. Consequently, the birth cohort of 1899-1903 can be followed only until it reaches age 70, the birth cohort of 1908-1912 until it reaches age 61, the birth cohort of 1918-1922 until it reaches 51 years, and the birth cohort of 1928-1932 only until it reaches age 41.

In spite of this time limitation, these data are unique in that they allow birth cohorts to be followed each year in time. Past uses of cohort techniques have been largely limited to looking at mortality experience of cohorts at 5- or 10-year intervals. By the use of the interpolation procedure, however, it is now possible to see changes in mortality in each calendar year. Such single-year data show variations in mortality that are not apparent from the 5-year estimates.

It would have been possible to examine 1-year birth cohorts, say the 1900 birth cohort, instead of grouping the data into 5-year birth cohorts. The specificity provided by a cohort of births occurring in a single year is a desirable feature. However, 5-year birth cohorts were used to smooth out irregularities that may have arisen in the data as a result of the interpolation procedure.

Qualifications of Data

In this study the populations referred to as cohorts are not cohorts in the true sense of the word. Technically, one would start with a cohort of births and observe the deaths each year until the cohort becomes extinct. In this study the cohort is, loosely speaking, the population at specified ages at a particular time period. The mortality data were derived from death statistics for the death-registration States, which was an expanding group that did not include all the States in the United States until 1933. Thus, the mortality data do not specifically relate to the original cohort as it aged over the years. However, the observed death rates may be taken as approximations of the true mortality rates of the cohort as it passed through the various ages.

To reduce variability in the rates and to minimize the effect of heaping in the terminal digits of 0 and 5 in the statements of age, the data were grouped into cohorts born over a 5-year period. However, these groupings produced damping effects inherent in the averaging process.

In order to derive survivorship tables, it was necessary to have death rates at specified ages. These were obtained by averaging the death rates for each specific age experienced by the cohort. For a 5-year cohort this meant the averaging of death rates over 5 calendar years. Although this is an acceptable procedure for computing survivorship data, it produces an undesirable effect in the analysis of cohort mortality. Because the death rates at any age are averaged over 5 calendar years, it is not possible to see the correspondence between an event and the exact time at which it occurred. For example, when the death rates over time are averaged, the effect of the influenza pandemic of 1918 appears at a peak in 1920 for the birth cohort of 1899-1903. In order to avoid this kind of distortion along the time axis, cohort mortality rates were computed on a basis different from that used for deriving the survivorship tables, as described above (page 3). This difference needs to be kept in mind in the interpretation of the cohort mortality and survival data.

Another problem is that it is not now possible to produce cohort mortality data for a complete generation. Because the mortality series for the United States is relatively short, the curves will be truncated until sufficient data are available so that a cohort may be followed to extinction.

These qualifications are not unique to this series of data. All cohort material based on data for the death-registration States has the same limitations. All cohort data that are combined in 5- or 10-year age groups are also subject to distortions arising from averaging age-specific rates for the span of the age group.

COHORT MORTALITY

The characteristic pattern of both cohort and period mortality rates is the high death rate at the two extremes of the age scale. The mortality risk is extremely high at birth, declines to a minimum in childhood (age about 10-12 years), and rises again. The highest level is reached in the older ages, but this is not always apparent from the data which do not carry the cohort to the end of its lifetime.

A number of unusual peaks in mortality may be observed in the cohort data, especially for white males (see figure 1). The effects of the 1918 influenza pandemic may be seen in the experience of two cohorts. The highest peak occurred in the 1896-1900 cohort in 1918 when the average age of the group was 20 years. A smaller peak in mortality occurred for the 1906-1910 cohort at the average age of 10; this cohort was not hit nearly as hard by the influenza epidemic as the older cohort. The effects of other respiratory disease epidemics of lesser proportions such as those that occurred in 1929, 1936, and 1937 are also apparent in the cohort curves at the following ages:

Cohort	Year of epidemic	
	1929	1936 and 1937
1896-1900----------	31	38 and 39
1906-1910----------	21	28 and 29
1916-1920----------		18 and 19

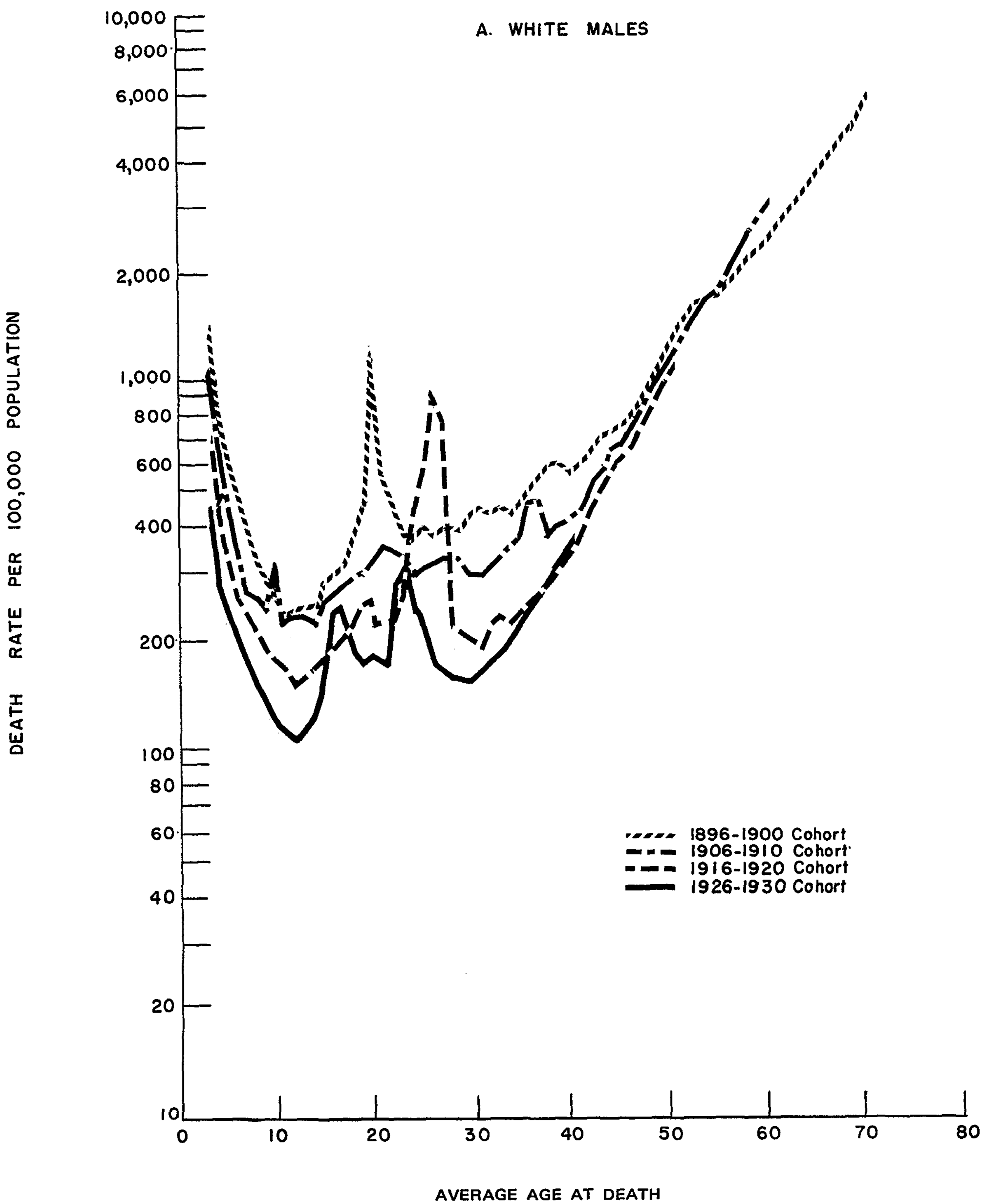
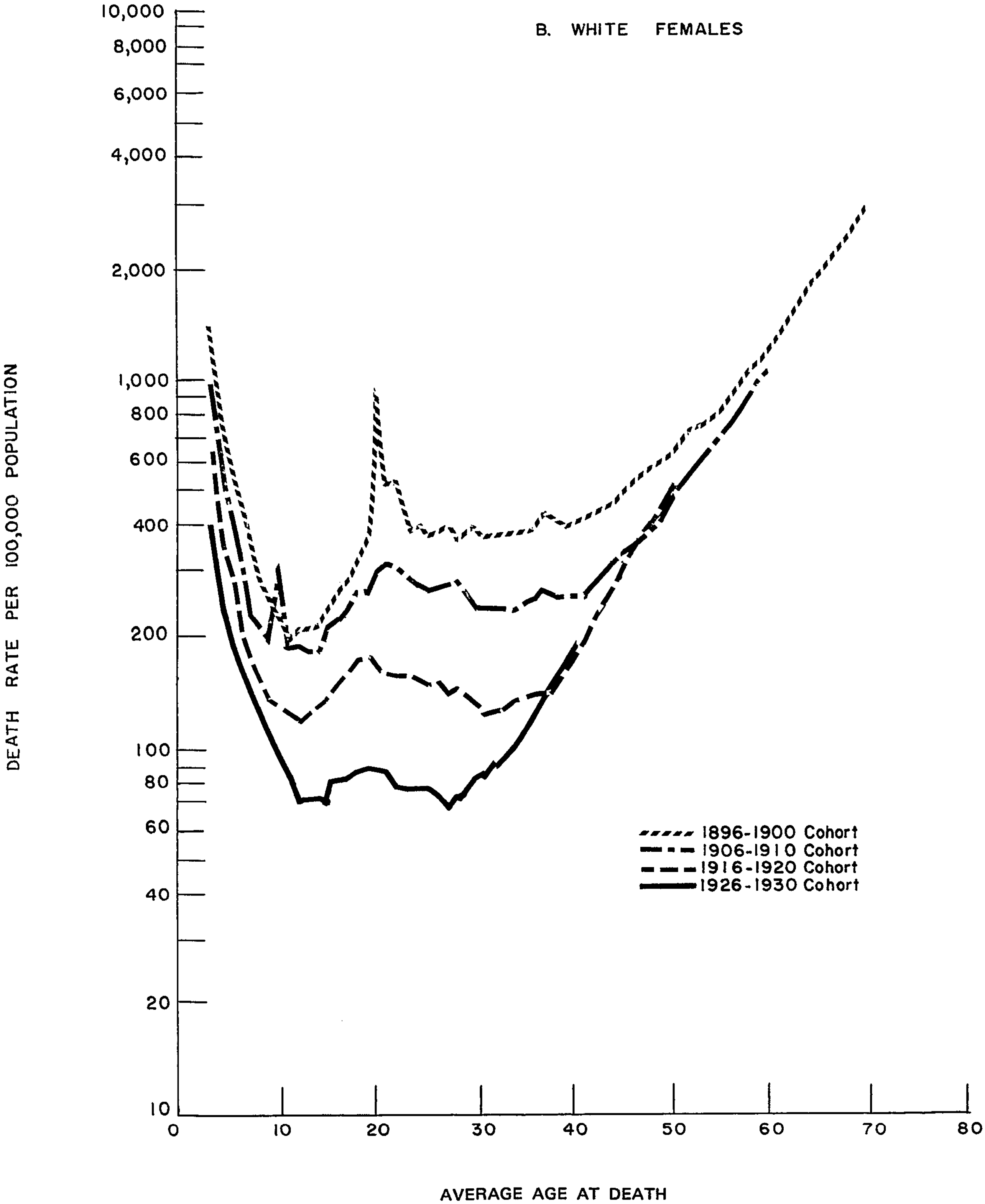


Figure 1. Mortality rates for cohorts born 1896-1900, 1906-1910, 1916-1920, and 1926-1930, by sex, color, and age: death-registration States, 1900-1968.



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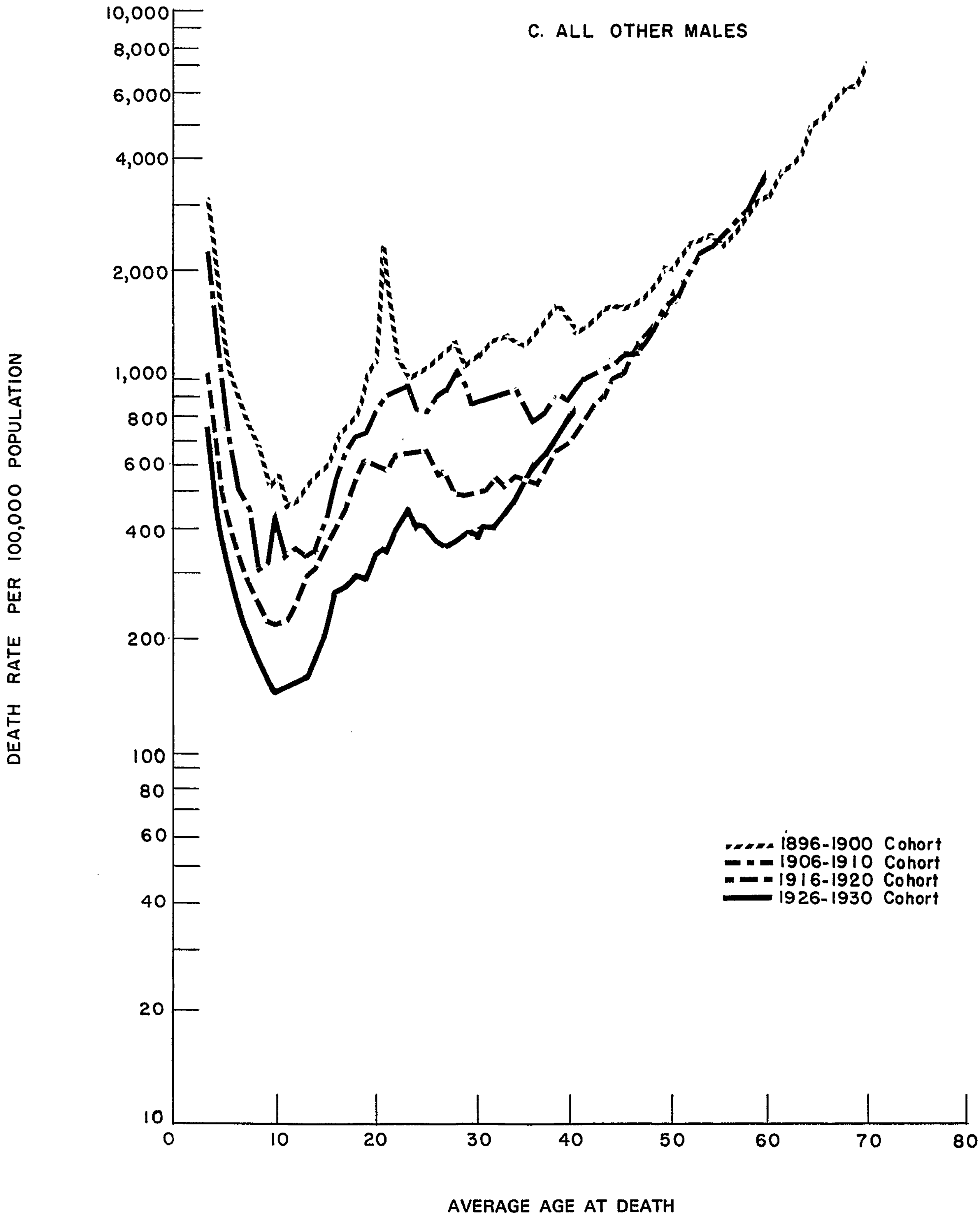

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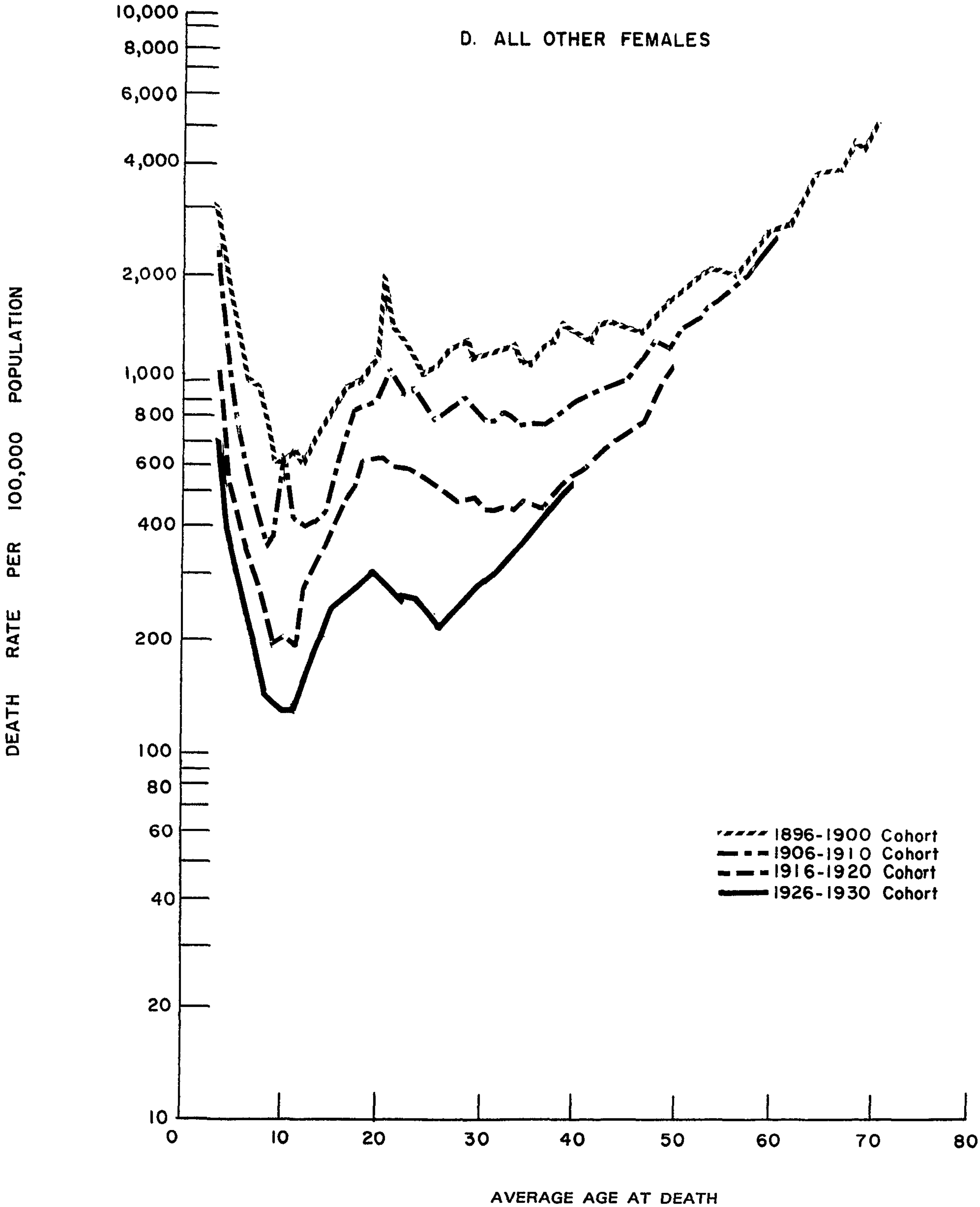

Figure 1. Mortality rates for cohorts born 1896-1900, 1906-1910, 1916-1920, and 1926-1930, by sex, color, and age: death-registration States, 1900-1968–Con.

The effect of World War II may be seen in the rates for cohorts of white males born after 1900. The greatest impact was on the cohort born between 1916 and 1920. This group was 24-28 years of age in 1944 when the peak of mortality was experienced in World War II. Lesser peaks appear in the curves for other cohorts. The death rate for the 1926-1930 cohort rose to a maximum in 1945 when the members were 15-19 years of age. If this peak resulted from World War II, only the older members of this cohort were presumably involved. This cohort was further exposed to war risks in 1951 during the Korean conflict. It would also appear from these data that even the 1906-1910 cohort was affected by World War II. A small upswing in mortality can be seen in the rates for the cohort when the individuals in the group were 34-39 years of age in 1944 and 1945.

The mortality rates for cohorts of males of Negro and other races show a little different picture from that of white males, in addition to their generally higher levels. The effects of the influenza pandemic of 1918 are evident in the 1896-1900 cohort and to a lesser degree in the 1906-1910 cohort. Also, there are a number of minor peaks representing the effects of influenza epidemics over the years. The consequences of World War II mortality are not as apparent in the rates for Negro and other races compared with the peak in mortality for white males. The effect of the Korean conflict is seen in the mortality experience of the 1926-1930 cohort of males of Negro and other races, but here again the rate did not peak up to quite the same extent as the rate for white males.

The mortality experience of females is similar to that of males except for the absence of war casualties and the lower level of mortality particularly at the older ages. Prominent are the peaks at ages 20 and 10 years for the 1896-1900 and 1906-1910 cohorts, respectively, resulting from the influenza pandemic of 1918. Lesser peaks from other influenza epidemics are also evident.

There is a greater similarity in the configuration of the cohort death rates between the sexes than between color groups. For Negroes and other races the range of the death rates is much greater and the base of the curve is much narrower than for whites. The death rates for races other than white exhibit greater variability because of the smaller frequencies of deaths. Also, the respiratory disease epidemics produced much greater upswings in the death rates for this group.

The improved mortality experience of the various cohorts is evidenced by the nest of curves for each color-sex group where most death rates for each succeeding cohort are lower than the rates for the previous cohort. At the older ages, there appears to be a convergence of death rates with those of the previous cohort. The point of convergence seems to be occurring earlier and earlier with each succeeding cohort. This suggests that the upturns in the death rates for the succeeding cohorts are occurring at younger ages. The narrowing of the base of the generation mortality curves appears significant. More is said about this phenomenon in the Discussion section below.

In addition to beginning at younger ages, the upturning death rates appear to be following a steeper rate of increase into the older ages for succeeding cohorts. As a consequence, there are points of crossover where the death rates of some cohorts begin to exceed those of the preceding cohort. Crossover points for the 1926-1930 cohort occur near age 35 for males of both color groups and near age 40 for white females. For females of other races, crossover has not yet occurred but appears imminent from the trend line for the 1926-1930 cohort (see figure 1D). All cohorts of males of other races shown in figure 1C demonstrate the crossover phenomenon. However, in comparison with the preceding cohort, only the 1926-1930 cohort of males of other races has demonstrated substantially higher mortality persisting over a number of years. Their comparatively high death rates between ages 35 and 40 during the 1960's are consistent with the rising death rates in these ages in recent years.[15]

The minimum level of mortality was reached in the childhood ages (between 6 and 16 years) in the various cohorts. There does not seem to be any great change in the age of occurrence of minimum mortality over the years. Also, no pattern of differentials by sex is discernible. However, there is a difference in age of minimum mortality for the two color groups. In general, the lowest point of the death rate among whites is at an age several years higher than that for Negro and other races. This age spread by color in the cohort mortality curves results from the low mortality among whites in the later years of childhood.

COHORT SURVIVORSHIP

The survivorship data for the various selected birth cohorts are given in detailed tables 1-8. As stated previously, these data were computed on a slightly different basis than the cohort mortality data already discussed. For the purpose of generation survivorship computations, the mortality rates over a period of 5 calendar years were averaged to obtain stability in the computed death rates. The same end was achieved in a different manner in computing cohort mortality rates, that is, the rates were averaged over the ages represented in the cohort for any particular year. In this way, the effect of events in a specific year is not obscured by the averaging process. Although the two sets of data are not precisely comparable, they are more suitable for the two purposes of this analysis than if they were computed in the same way.

In the cohort survivorship data the following abbreviations are made for the convenience of discussion:

Birth cohort of:	Cohort of births occurring in:
1901	1899-1903
1910	1908-1912
1920	1918-1922
1930	1928-1932

Survivorship of Birth Cohorts

The survivorship of birth cohorts of different color and sex groups is presented in figure 2. The most favorable survivorship pattern is that of white females, and the least favorable is that of males other than white. Of the white females in the 1901 birth cohort, more than 55 percent survived to age 70 years. Of males of other races born in the same period, less than 20 percent lived to age 70 years.

The effect of improvement in mortality over the years is evident in the survivorship curves for the different birth cohorts. It would appear that the reductions in mortality for the white population have been relatively uniform in time, whereas the decrease in mortality (or increase in survivorship) for the population other than white was particularly large between the 1901 and 1910 cohorts. It is possible that some of this change is only apparent and resulted from the large increase in the Negro population due to the growth of the death-registration area.

Cohort and Period Survivorship

The generation tables represent more or less what happens in real life as compared with the usual period life tables. Because of the decrease in mortality with attendant increase in life expectancy over time, the number surviving to each successive age is generally higher in the generation or cohort table than in the period life table. This is illustrated by figure 3 which shows the survivorship of the cohort of white males born 1899-1903 in comparison with the survivors as computed from the age-specific mortality rates for the period 1900 to 1903.

The relative differences between the numbers of survivors to successive selected ages in the period and cohort tables are shown in table B. It may be seen from these data that the percentage differences in the numbers of survivors between the generation and period mortality tables increase with age. Also, the differences in survivorship based on these two types of tables vary with time and with the population group involved.

As table B reveals, the largest discrepancies between cohort and period survivorship occur in the 1920 comparisons. This is because of the peculiarity in the mortality data for that period. The 5-year average centered on 1920 includes data for 1918 and 1919, the years of the influenza pandemic which took the largest death toll in the history of U.S. vital statistics. This was followed by a year of unduly low mortality so that basing the period data only on the mortality experience for 1920 would still give an atypical comparison. However, this would not have been nearly as misleading as the inclusion of data for the epidemic years. Therefore, it would be well not to attach much significance to the differences in survivorship in the 1920 generation and period tables.

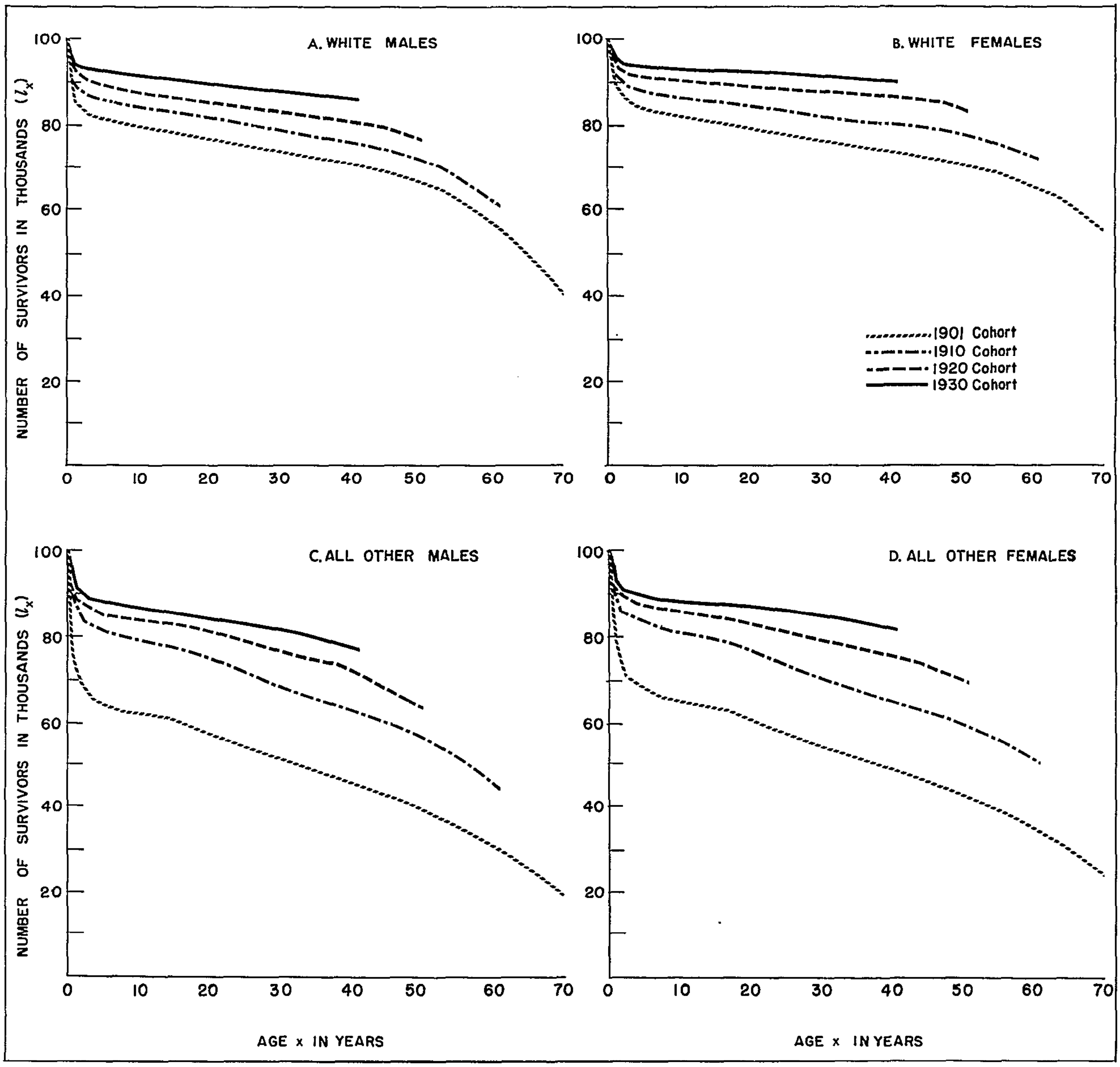

Figure 2. Survivorship (l_x) of birth cohorts of 1901, 1910, 1920, and 1930, by sex, color, and age: death-registration States, 1900-1968.

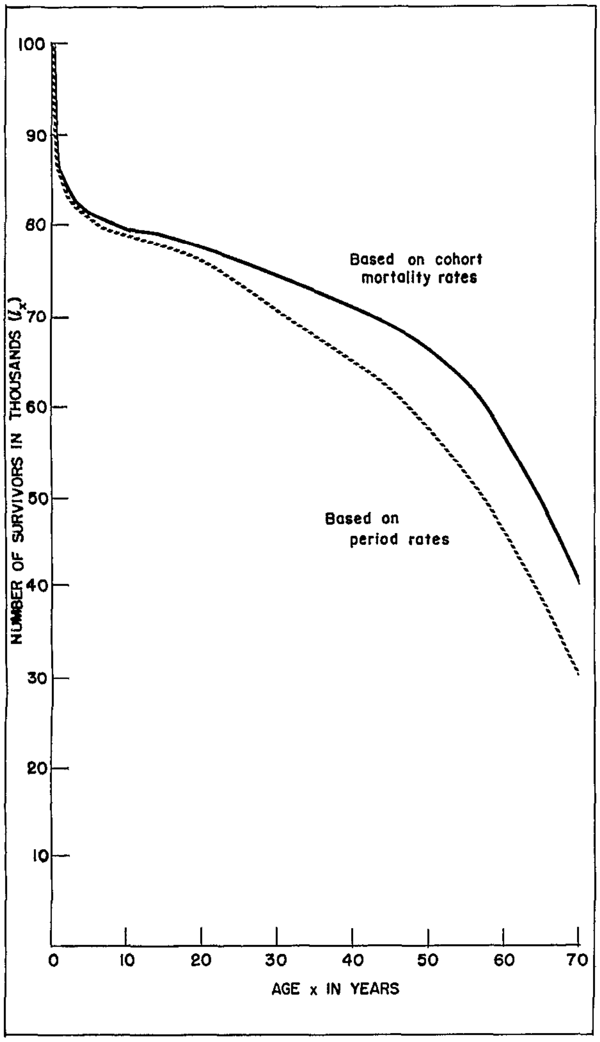

Figure 3. Survivorship(l_x)of white males in birth cohort of 1901 as compared with corresponding period survivorship, by single years of age: death-registration States, 1900-1968.

White males.—As may be seen from figure 4A (as well as in table B), the difference between generation and period survivorship of white males is less than 5 percent for the age groups under 30 years. From that point, the difference increases rather sharply. Although the 1930 period table came the closest to the actual mortality experience of white males, the variations in the different periods under comparison were relatively small.

The cohort and period survivorship difference at age 20 in the 1901 table was small because of the influenza epidemic. The birth cohort of 1901 would have been age 20 in 1919-1923. Thus, the number surviving to this age in the cohort table was smaller than would have been expected had there not been an influenza epidemic.

A similar change in the cohort and period survivorship difference is seen in the 1910 comparison for white males. At age 15 and earlier, this cohort experienced higher mortality rates than would have been expected without the outbreak of influenza. Thus, the number surviving to age 15 was closer to the period mortality survivors of 1910 than might have been expected.

A significant dip can be observed at age 25 years in the difference between the cohort and period survivorship of the 1920 table. This resulted from the rise in mortality of white males aged 15-25 years during World War II.

White females.—As in the comparison for white males, the differences in generation and period survivorship for white females are relatively small for the age group under 30 years (see figure 4B). These differences increase rapidly in the older ages. At age 70 years, the difference is near 60 percent, the highest relative difference between generation and period survivorship of any color-sex group.

By age 35 years, the 1930 period table was the best predictor of the actual number of white female survivors from the cohort, but it was only slightly better than the table for 1910. As was true for white males, the variations in difference between periods were relatively small if the 1920 period comparison is excluded.

The events that affected the birth cohorts of white females, making survivorship differences less than expected, were the same that affected the survivorship of white males in the 1901 and 1910 cohorts. A decrease in survivorship differences is apparent at age 20 for the 1901 birth cohort, and before age 15 for the 1910 birth cohort.

Males of other races.—There appears to be an increase in the survivorship differences between the generation and period data for males of other races at age 15 for the 1901 birth cohort and at age 20 for the 1910 birth cohort (figure 4C). The reason for these changes is not clear.

Table B. Percent difference[1] between cohort and period survivorship (l_x), by sex, color, and age: 1901, 1910, 1920, and 1930

Age in years	1901				1910			
	Male		Female		Male		Female	
	White	All other	White	All other	White	All other	White	All other
5	0.4	-0.1	0.4	0.2	0.3	1.6	0.3	1.5
10	0.7	0.3	0.8	0.8	0.4	2.3	0.4	2.1
15	1.0	1.4	1.1	2.3	0.5	3.2	0.6	3.5
20	1.1	1.7	1.3	2.6	1.0	4.7	1.1	5.4
25	2.3	2.4	2.4	2.4	2.1	5.9	2.1	6.8
30	4.1	3.0	4.2	2.4	3.6	7.4	3.6	8.4
31	4.6	3.2	4.6	2.6	4.0	7.8	4.0	8.9
32	5.0	3.4	5.0	2.8	4.4	8.3	4.4	9.4
33	5.5	3.6	5.5	3.2	4.8	8.8	4.8	10.0
34	5.9	3.8	6.0	3.6	5.2	9.3	5.2	10.6
35	6.4	4.0	6.5	3.9	5.6	10.1	5.7	11.3
40	9.1	4.8	9.2	5.1	8.3	14.7	8.3	15.5
45	12.3	6.7	12.5	8.2	11.5	19.8	11.2	21.2
50	15.6	10.0	16.4	12.4	14.8	25.3	14.8	28.4
55	18.8	13.9	21.9	17.3	17.8	31.5	19.4	37.8
60	22.9	22.0	29.9	26.2	21.2	37.4	26.2	51.2
65	27.2	28.4	41.5	36.0	---	---	---	---
70	32.7	30.9	58.9	45.9	---	---	---	---

[1]Percent difference is the difference between cohort l_x and period l_x as a percent of the period l_x; based on data in tables 1-8.

Table B. Percent difference[1] between cohort and period survivorship (l_x), by sex, color, and age: 1901, 1910, 1920, and 1930—Con.

Age in years	1920				1930			
	Male		Female		Male		Female	
	White	All other	White	All other	White	All other	White	All other
5	0.7	1.1	0.8	1.1	0.2	0.2	0.2	0.2
10	1.2	1.6	1.3	1.8	0.5	0.6	0.4	0.6
15	1.7	2.3	1.8	2.9	0.8	1.1	0.7	1.2
20	2.8	4.5	2.9	5.3	1.2	2.8	1.4	3.6
25	3.3	8.4	5.2	9.6	1.7	5.8	2.6	7.5
30	5.3	12.7	8.2	14.6	2.8	9.8	4.0	12.0
31	5.9	13.7	8.9	15.8	3.1	10.7	4.3	12.9
32	6.6	14.7	9.5	16.9	3.4	11.6	4.6	13.8
33	7.3	15.8	10.2	18.2	3.6	12.5	4.9	14.8
34	7.9	16.9	10.9	19.5	3.9	13.5	5.2	15.8
35	8.6	18.1	11.5	20.8	4.2	14.4	5.5	16.8
40	11.8	23.8	14.7	27.5	5.8	19.3	7.3	22.6
45	14.5	28.5	17.8	34.4	---	---	---	---
50	17.0	32.0	21.3	42.9	---	---	---	---
55	---	---	---	---	---	---	---	---
60	---	---	---	---	---	---	---	---
65	---	---	---	---	---	---	---	---
70	---	---	---	---	---	---	---	---

[1]Percent difference is the difference between cohort l_x and period l_x as a percent of the period l_x; based on data in tables 1-8.

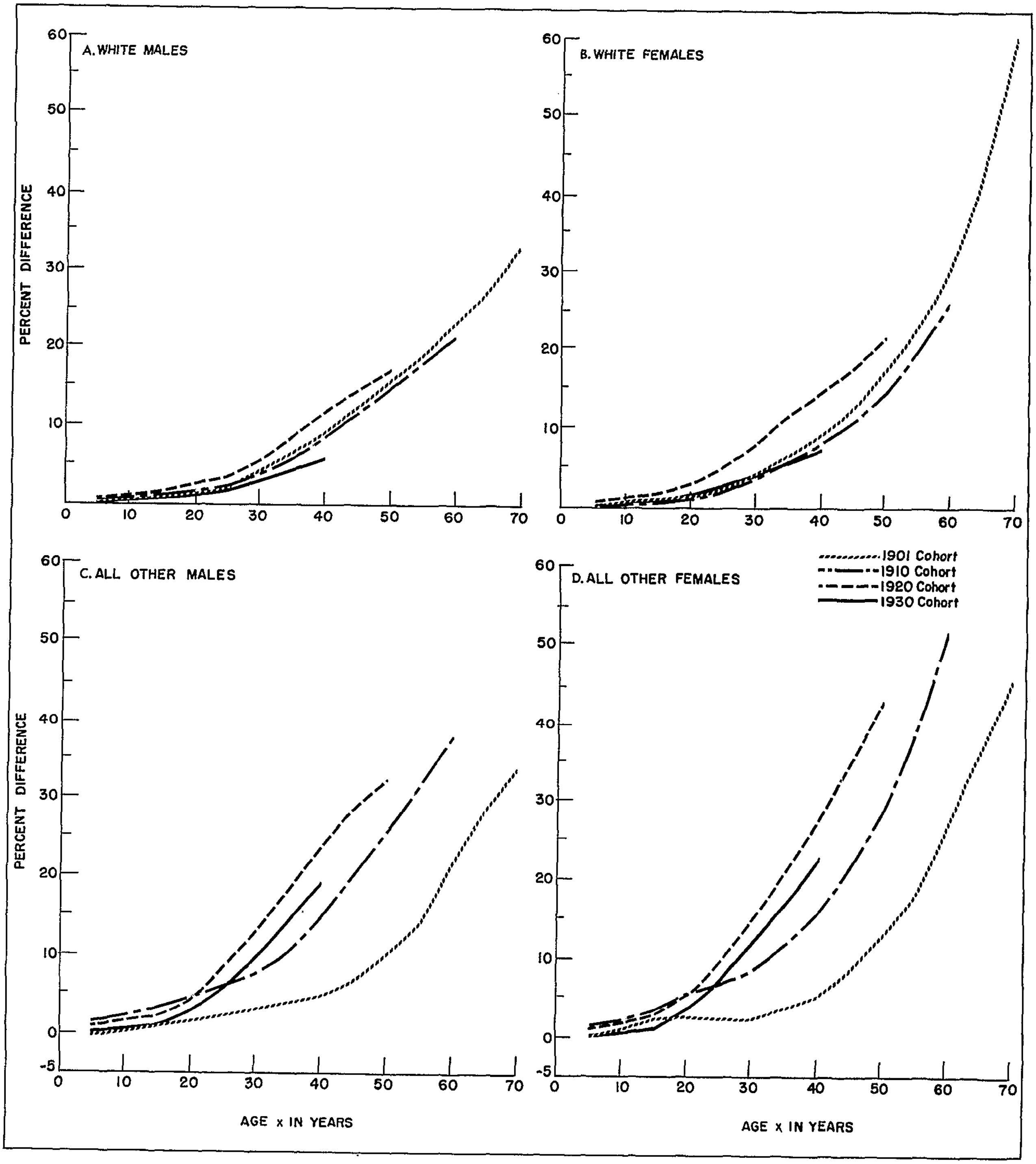

Figure 4. Percent difference between cohort and period survivorship (l_x) of birth cohorts of 1901, 1910, 1920, and 1930, by sex, color, and age: death-registration States, 1900-1968.

As compared with the pattern for white males, the spread in the experience of various birth cohorts of males of other races is large. Also, it would appear that the period table that came closest to the actual mortality experience of a birth cohort was that for 1901 for males of other races. The 1930 period table turned out to be a poor third.

Because mortality rates have decreased over time, it was expected that the cohort tables would always show greater numbers of survivors at each age than would the period tables. The one exception to this, indicated by the negative difference in table B, is the difference in the male survivors of other races to age 5 in the 1901 tables. This difference from the expected pattern is a result of higher death rates in the 1901 cohort table than in the 1901 period table until age 3. The death rates affecting males of other races aged 0-3 years in the years 1902, 1903, and 1904 were higher than the corresponding death rates in 1901. While the difference is not great, it is a deviation from the general pattern.

Females of other races.—The general pattern of survivorship differences between the generation and period tables for females of other races resembles that for males of the corresponding color group. However, the differences in survivorship are uniformly greater for females of this group. Also, as may be seen in figure 4D, there is an unusual plateau in the survivorship differences between ages 15 and 30 years for the 1901 birth cohort. This plateau covers the years 1914-1933, but the reasons for the relatively high cohort death rates are not known.

DISCUSSION

The annual mortality statistics have been valuable in following the course of mortality over the years, but such period mortality data do not represent the real-life situation in which a population cohort goes through life being subjected to changing forces of mortality. By generating mortality data on an annual basis for various birth cohorts, it is also possible to see the effects of specific events, such as respiratory disease epidemics and wars, on mortality of specific population groups. Thus, a new dimension (longitudinal) is added to mortality statistics.

The big disadvantage of generation or cohort mortality statistics is that a large body of statistics is needed. The mortality series for the United States is now sufficiently long so that it would be worth while examining the longitudinal experience of various cohorts. As was done in Sweden, it would be desirable to tabulate annually mortality statistics by single years of age. These statistics could then be grafted to this report's data which were derived by an interpolation procedure from mortality statistics by 5-year age groups.

Cohort data by causes of death should provide more insight into mortality from various diseases and their determinants. Because statistics on all causes of death are a weighted average of death rates for the different component diseases, it would be expected that the data in this report would show only the grossest changes in mortality. This turned out to be the case. The influenza epidemic of 1918 and some of the lesser epidemics of other years, as well as the effects of World War II and the Korean War on the male population, appear to be reflected by the cohort data.

Of special interest is the pattern of cohort mortality data which consisted of a nest of U-shaped curves. In these curves, the base of the U's of the cohort mortality curves for whites is much broader than that for all other races. Also, with the improvement in mortality experience for the succeeding cohorts, there is a continuous narrowing of the base. This same phenomenon may be seen in the cohort mortality curves for Sweden presented by Bolander.[16] This seems contrary to expectations. With decreasing mortality, one would expect a broadening of the base. In fact, if all people were constructed like Longfellow's one-hoss shay, the shape of the curve would approach the mirror image of an L which would depict a zero mortality from birth until the appointed age when the death rate would be 100 percent.

The narrowing of the base of the generation mortality curves with improvement in mortality suggests that over the years the decline in mortality has taken place primarily at the younger ages. If this tendency should continue, the point will be reached before too long where large changes in generation mortality will become severely limited.

The examination of differences in cohort and period survivorship for four time periods by color and sex has shown that, generally speaking, past period life tables have not represented the actual mortality experience of a birth cohort. This is largely true because mortality rates have decreased over time so that each birth cohort is exposed to more favorable mortality rates throughout its lifetime than those prevailing at the time of its birth. Thus, to the extent that mortality rates improved, the period survivorship tables gave values that were too low. However, mortality at the older ages is no longer declining very much in the successive cohorts. In the last few years, the mortality rates after age 35 of later born cohorts have risen above those of earlier born cohorts, demonstrating a crossover effect. Also, the age range in which substantial improvements in mortality are possible is narrowing. At the moment, this age range is from birth to about age 30 years. Unless major breakthroughs are achieved, further declines in mortality will be small compared with past improvements. From this it follows that future period life tables should become better predictors of the mortality experience of a cohort than past period life tables have been. This should be more true of whites than of races other than white and more true for females than for males.

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LIST OF DETAILED TABLES

Table 1. Cohort survivorship (l_x) from birth to age 70 of white males and females born 1899-1903 compared with corresponding period survivorship: death-registration States, 1900-1968

Age x in years	White males		White females	
	Cohort l_x	Period l_x	Cohort l_x	Period l_x
0	100,000	100,000	100,000	100,000
1	86,686	86,686	88,939	88,939
2	83,716	83,661	86,164	86,124
3	82,503	82,356	84,995	84,858
4	81,765	81,533	84,268	84,055
5	81,242	80,941	83,755	83,450
6	80,822	80,460	83,354	82,972
7	80,489	80,063	83,035	82,581
8	80,216	79,734	82,773	82,260
9	79,994	79,458	82,560	81,993
10	79,808	79,221	82,383	81,765
11	79,640	79,009	82,225	81,561
12	79,480	78,808	82,075	81,367
13	79,321	78,606	81,929	81,170
14	79,152	78,390	81,775	80,957
15	78,964	78,151	81,603	80,718
16	78,704	77,880	81,366	80,446
17	78,396	77,572	81,092	80,136
18	78,038	77,228	80,777	79,790
19	77,654	76,851	80,432	79,415
20	77,259	76,446	80,062	79,015
21	76,955	76,012	79,745	78,592
22	76,661	75,550	79,433	78,145
23	76,373	75,066	79,129	77,677
24	76,083	74,567	78,823	77,192
25	75,795	74,058	78,520	76,691
26	75,508	73,541	78,221	76,175
27	75,216	73,016	77,923	75,645
28	74,924	72,483	77,632	75,103
29	74,633	71,941	77,350	74,553
30	74,343	71,388	77,072	73,997
31	74,056	70,824	76,801	73,435
32	73,769	70,250	76,537	72,868
33	73,476	69,665	76,264	72,296
34	73,174	69,068	76,008	71,718
35	72,856	68,458	75,737	71,136
36	72,527	67,835	75,465	70,550
37	72,192	67,200	75,191	69,960
38	71,854	66,552	74,920	69,364
39	71,515	65,890	74,658	68,759
40	71,169	65,214	74,399	68,143
41	70,807	64,523	74,136	67,514
42	70,427	63,816	73,867	66,871
43	70,026	63,093	73,590	66,215
44	69,606	62,355	73,305	65,549
45	69,164	61,601	73,007	64,875
46	68,699	60,829	72,699	64,193
47	68,204	60,037	72,378	63,499
48	67,673	59,221	72,042	62,785
49	67,098	58,380	71,689	62,040

NOTE: l_x refers to the number of survivors, of 100,000 born alive, at the beginning of age x.

Table 1. Cohort survivorship (l_x) from birth to age 70 of white males and females born 1899-1903 compared with corresponding period survivorship: death-registration States, 1900-1968—Con.

Age x in years	White males		White females	
	Cohort l_x	Period l_x	Cohort l_x	Period l_x
50	66,478	57,512	71,318	61,256
51	65,812	56,618	70,926	60,432
52	65,097	55,696	70,510	59,564
53	64,327	54,742	70,070	58,656
54	63,505	53,747	69,610	57,706
55	62,629	52,702	69,126	56,713
56	61,699	51,600	68,620	55,674
57	60,707	50,438	68,084	54,583
58	59,645	49,216	67,512	53,438
59	58,514	47,940	66,902	52,237
60	57,306	46,618	66,246	50,982
61	56,016	45,255	65,536	49,675
62	54,647	43,849	64,772	48,317
63	53,199	42,395	63,956	46,906
64	51,658	40,887	63,077	45,438
65	50,029	39,317	62,144	43,909
66	48,316	37,684	61,117	42,317
67	46,530	35,994	60,007	40,663
68	44,677	34,253	58,809	38,946
69	42,757	32,471	57,518	37,166
70	40,723	30,684	56,114	35,325

NOTE: l_x refers to the number of survivors, of 100,000 born alive, at the beginning of age x.

Table 2. Cohort survivorship (l_x) from birth to age 61 of white males and females born 1908-1912 compared with corresponding period survivorship: death-registration States, 1900-1968

Age x in years	White males		White females	
	Cohort l_x	Period l_x	Cohort l_x	Period l_x
0	100,000	100,000	100,000	100,000
1	89,712	89,712	91,510	91,510
2	87,452	87,390	89,410	89,349
3	86,512	86,372	88,527	88,403
4	85,959	85,733	88,009	87,792
5	85,555	85,267	87,634	87,348
6	85,211	84,880	87,323	86,988
7	84,897	84,562	87,038	86,690
8	84,632	84,298	86,802	86,441
9	84,398	84,075	86,596	86,230
10	84,188	83,880	86,410	86,045
11	83,997	83,700	86,240	85,875
12	83,829	83,525	86,100	85,710
13	83,665	83,344	85,964	85,540
14	83,499	83,149	85,825	85,358
15	83,322	82,933	85,674	85,157
16	83,129	82,690	85,506	84,932
17	82,916	82,416	85,320	84,680
18	82,684	82,111	85,116	84,401
19	82,440	81,776	84,900	84,097
20	82,189	81,414	84,676	83,770
21	81,933	81,024	84,443	83,419
22	81,677	80,607	84,207	83,045
23	81,421	80,171	83,974	82,652
24	81,168	79,724	83,744	82,245
25	80,917	79,273	83,516	81,829
26	80,666	78,819	83,290	81,404
27	80,422	78,361	83,069	80,969
28	80,185	77,897	82,857	80,526
29	79,954	77,422	82,655	80,074
30	79,727	76,934	82,471	79,615
31	79,494	76,431	82,290	79,149
32	79,250	75,914	82,110	78,675
33	78,976	75,380	81,930	78,192
34	78,681	74,827	81,749	77,697
35	78,390	74,255	81,566	77,189
36	78,103	73,662	81,379	76,667
37	77,821	73,049	81,192	76,132
38	77,548	72,417	81,005	75,586
39	77,278	71,769	80,819	75,032
40	76,992	71,107	80,630	74,472
41	76,688	70,429	80,434	73,906
42	76,361	69,734	80,228	73,331
43	76,011	69,019	80,011	72,745
44	75,636	68,281	79,783	72,142
45	75,265	67,516	79,543	71,519
46	74,829	66,722	79,289	70,873
47	74,361	65,915	79,019	70,203
48	73,850	65,061	78,730	69,506
49	73,285	64,178	78,417	68,778

NOTE: l_x refers to the number of survivors, of 100,000 born alive, at the beginning of age x.

Table 2. Cohort survivorship (l_x) from birth to age 61 of white males and females born 1908-1912 compared with corresponding period survivorship: death-registration States, 1900-1968—Con.

Age x in years	White males		White females	
	Cohort l_x	Period l_x	Cohort l_x	Period l_x
50	72,661	63,266	78,077	68,016
51	71,971	62,325	77,708	67,217
52	71,216	61,353	77,309	66,380
53	70,401	60,346	76,879	65,502
54	69,524	59,296	76,418	64,579
55	68,571	58,192	75,924	63,604
56	67,539	57,024	75,389	62,568
57	66,438	55,786	74,812	61,462
58	65,243	54,474	74,216	60,282
59	63,968	53,095	73,554	59,032
60	62,605	51,660	72,846	57,719
61	61,130	50,176	72,075	56,349

NOTE: l_x refers to the number of survivors, of 100,000 born alive, at the beginning of age x.

Table 3. Cohort survivorship (l_x) from birth to age 51 of white males and females born 1918-1922 compared with corresponding period survivorship: death-registration States, 1900-1968

Age x in years	White males		White females	
	Cohort l_x	Period l_x	Cohort l_x	Period l_x
0	100,000	100,000	100,000	100,000
1	92,322	92,322	93,898	93,898
2	90,823	90,576	92,533	92,288
3	90,149	89,750	91,926	91,514
4	89,737	89,196	91,549	90,979
5	89,431	88,769	91,269	90,573
6	89,174	88,406	91,038	90,233
7	88,953	88,092	90,849	89,951
8	88,760	87,819	90,692	89,713
9	88,593	87,580	90,561	89,507
10	88,445	87,366	90,448	89,321
11	88,311	87,168	90,346	89,145
12	88,185	86,975	90,250	88,970
13	88,055	86,776	90,153	88,787
14	87,920	86,559	90,051	88,589
15	87,773	86,312	89,941	88,369
16	87,610	86,028	89,821	88,120
17	87,434	85,702	89,692	87,836
18	87,250	85,336	89,558	87,514
19	87,064	84,934	89,422	87,153
20	86,877	84,502	89,288	86,753
21	86,663	84,038	89,158	86,313
22	86,370	83,540	89,027	85,835
23	85,862	83,013	88,895	85,326
24	85,192	82,466	88,765	84,795
25	84,591	81,905	88,639	84,250
26	84,100	81,335	88,520	83,694
27	83,720	80,757	88,406	83,128
28	83,477	80,170	88,301	82,556
29	83,321	79,573	88,198	81,980
30	83,163	78,963	88,097	81,401
31	83,001	78,341	87,998	80,821
32	82,837	77,708	87,897	80,241
33	82,671	77,070	87,795	79,663
34	82,504	76,433	87,690	79,089
35	82,334	75,802	87,582	78,523
36	82,156	75,179	87,468	77,962
37	81,966	74,562	87,347	77,407
38	81,761	73,948	87,217	76,856
39	81,537	73,334	87,077	76,308
40	81,291	72,716	86,925	75,760
41	81,022	72,092	86,760	75,212
42	80,727	71,460	86,579	74,661
43	80,400	70,816	86,376	74,102
44	80,040	70,155	86,159	73,528
45	79,566	69,473	85,919	72,932
46	79,127	68,767	85,655	72,312
47	78,643	68,035	85,365	71,665
48	78,109	67,278	85,049	70,989
49	77,519	66,497	84,707	70,284
50	76,872	65,692	84,337	69,550
51	76,157	64,862	83,933	68,784

NOTE: l_x refers to the number of survivors, of 100,000 born alive, at the beginning of age x.

Table 4. Cohort survivorship (l_x) from birth to age 41 of white males and females born 1928-1932 compared with corresponding period survivorship: death-registration States, 1900-1968

Age x in years	White males		White females	
	Cohort l_x	Period l_x	Cohort l_x	Period l_x
0	100,000	100,000	100,000	100,000
1	93,886	93,886	95,145	95,145
2	92,967	92,900	94,324	94,257
3	92,531	92,404	93,937	93,815
4	92,244	92,068	93,680	93,511
5	92,026	91,803	93,483	93,278
6	91,828	91,564	93,311	93,064
7	91,662	91,358	93,173	92,888
8	91,525	91,178	93,063	92,742
9	91,410	91,018	92,975	92,617
10	91,312	90,872	92,902	92,506
11	91,228	90,735	92,839	92,402
12	91,144	90,599	92,780	92,298
13	91,047	90,458	92,720	92,189
14	90,931	90,305	92,658	92,070
15	90,812	90,135	92,593	91,937
16	90,694	89,943	92,524	91,786
17	90,562	89,728	92,453	91,615
18	90,409	89,492	92,381	91,423
19	90,255	89,240	92,308	91,211
20	90,081	88,976	92,237	90,981
21	89,883	88,699	92,167	90,731
22	89,655	88,408	92,100	90,461
23	89,417	88,107	92,034	90,176
24	89,200	87,799	91,969	89,883
25	89,018	87,488	91,904	89,586
26	88,859	87,174	91,840	89,287
27	88,719	86,857	91,776	88,985
28	88,586	86,535	91,710	88,680
29	88,454	86,207	91,640	88,369
30	88,320	85,872	91,566	88,051
31	88,182	85,529	91,488	87,727
32	88,038	85,176	91,406	87,396
33	87,886	84,810	91,317	87,056
34	87,723	84,426	91,220	86,705
35	87,546	84,020	91,116	86,341
36	87,354	83,593	91,001	85,963
37	87,143	83,143	90,877	85,571
38	86,912	82,669	90,743	85,165
39	86,658	82,171	90,596	84,745
40	86,380	81,648	90,433	84,310
41	86,074	81,098	90,253	83,859

NOTE: l_x refers to the number of survivors, of 100,000 born alive, at the beginning of age x.

Table 5. Cohort survivorship (l_x) from birth to age 70 of males and females, other than white, born 1899-1903 compared with corresponding period survivorship: death-registration States, 1900-1968

Age x in years	All other males		All other females	
	Cohort l_x	Period l_x	Cohort l_x	Period l_x
0	100,000	100,000	100,000	100,000
1	75,511	75,511	78,985	78,985
2	69,158	69,186	73,079	73,131
3	66,696	66,815	70,581	70,482
4	65,406	65,552	69,255	69,126
5	64,593	64,682	68,269	68,113
6	63,916	63,976	67,556	67,367
7	63,403	63,423	66,992	66,751
8	63,006	62,975	66,539	66,228
9	62,687	62,599	66,168	65,764
10	62,420	62,253	65,846	65,320
11	62,197	61,919	65,556	64,882
12	61,975	61,559	65,278	64,420
13	61,734	61,170	64,970	63,917
14	61,472	60,742	64,630	63,367
15	61,158	60,280	64,222	62,775
16	60,693	59,761	63,661	62,132
17	60,141	59,193	63,012	61,446
18	59,533	58,576	62,316	60,737
19	58,889	57,928	61,599	60,033
20	58,241	57,263	60,892	59,351
21	57,659	56,581	60,238	58,688
22	57,042	55,895	59,570	58,040
23	56,404	55,201	58,891	57,404
24	55,748	54,507	58,207	56,775
25	55,095	53,811	57,525	56,150
26	54,433	53,120	56,839	55,527
27	53,761	52,431	56,153	54,907
28	53,111	51,744	55,498	54,290
29	52,492	51,064	54,883	53,669
30	51,890	50,388	54,297	53,038
31	51,300	49,721	53,737	52,388
32	50,718	49,059	53,196	51,726
33	50,154	48,402	52,677	51,048
34	49,580	47,749	52,167	50,374
35	48,974	47,097	51,634	49,714
36	48,339	46,446	51,066	49,073
37	47,695	45,794	50,483	48,439
38	47,070	45,138	49,906	47,802
39	46,477	44,476	49,353	47,148
40	45,893	43,800	48,809	46,449
41	45,301	43,106	48,241	45,701
42	44,690	42,395	47,632	44,905
43	44,065	41,666	47,007	44,064
44	43,447	40,912	46,396	43,206
45	42,831	40,144	45,807	42,351
46	42,209	39,347	45,226	41,494
47	41,569	38,528	44,627	40,641
48	40,914	37,678	44,016	39,782
49	40,237	36,808	43,392	38,908

NOTE: l_x refers to the number of survivors, of 100,000 born alive, at the beginning of age x.

Table 5. Cohort survivorship (l_x) from birth to age 70 of males and females, other than white, born 1899-1903 compared with corresponding period survivorship: death-registration States, 1900-1968—Con.

Age x in years	All other males		All other females	
	Cohort l_x	Period l_x	Cohort l_x	Period l_x
50	39,519	35,916	42,743	38,022
51	38,755	35,008	42,053	37,120
52	37,950	34,087	41,321	36,209
53	37,130	33,147	40,576	35,287
54	36,322	32,181	39,850	34,338
55	35,508	31,173	39,124	33,358
56	34,681	30,111	38,386	32,348
57	33,821	28,990	37,618	31,282
58	32,940	27,820	36,833	30,175
59	32,046	26,650	36,048	29,049
60	31,115	25,497	35,228	27,910
61	30,114	24,363	34,335	26,786
62	29,051	23,254	33,366	25,667
63	27,962	22,169	32,368	24,554
64	26,838	21,080	31,367	23,439
65	25,664	19,980	30,349	22,320
66	24,396	18,879	29,260	21,196
67	23,057	17,768	28,078	20,072
68	21,683	16,665	26,842	18,942
69	20,331	15,567	25,613	17,822
70	18,948	14,478	24,377	16,706

NOTE: l_x refers to the number of survivors, of 100,000 born alive, at the beginning of age x.

Table 6. Cohort survivorship (l_x) from birth to age 61 of males and females, other than white, born 1908-1912 compared with corresponding period survivorship: death-registration States, 1900-1968

Age x in years	All other males		All other females	
	Cohort l_x	Period l_x	Cohort l_x	Period l_x
0	100,000	100,000	100,000	100,000
1	88,429	88,429	90,114	90,114
2	83,895	83,433	85,925	85,494
3	82,184	81,403	84,268	83,489
4	81,278	80,227	83,349	82,379
5	80,725	79,448	82,766	81,554
6	80,216	78,777	82,285	80,935
7	79,756	78,254	81,804	80,400
8	79,406	77,820	81,416	79,932
9	79,130	77,453	81,096	79,514
10	78,891	77,123	80,821	79,127
11	78,670	76,804	80,574	78,747
12	78,463	76,474	80,354	78,348
13	78,237	76,112	80,118	77,901
14	77,976	75,700	79,835	77,382
15	77,667	75,226	79,477	76,771
16	77,297	74,682	79,027	76,060
17	76,863	74,059	78,492	75,257
18	76,377	73,372	77,889	74,395
19	75,840	72,642	77,247	73,525
20	75,255	71,889	76,588	72,678
21	74,622	71,117	75,919	71,858
22	73,961	70,329	75,264	71,056
23	73,292	69,533	74,623	70,271
24	72,634	68,734	73,999	69,498
25	71,977	67,936	73,387	68,733
26	71,303	67,140	72,776	67,977
27	70,616	66,346	72,164	67,232
28	69,944	65,553	71,566	66,491
29	69,299	64,758	70,996	65,748
30	68,689	63,958	70,460	64,996
31	68,096	63,154	69,944	64,230
32	67,501	62,343	69,425	63,448
33	66,911	61,519	68,897	62,649
34	66,336	60,673	68,381	61,838
35	65,846	59,804	67,890	60,975
36	65,333	58,911	67,420	60,152
37	64,830	57,997	66,963	59,323
38	64,320	57,067	66,506	56,483
39	63,804	56,125	66,042	57,624
40	63,269	55,174	65,560	56,740
41	62,703	54,212	65,052	55,823
42	62,109	53,238	64,521	54,870
43	61,491	52,251	63,977	53,885
44	60,859	51,254	63,436	52,879
45	60,213	50,250	62,889	51,863
46	59,540	49,241	62,322	50,841
47	58,828	48,225	61,728	49,810
48	58,069	47,193	61,105	48,762
49	57,271	46,129	60,456	47,686

NOTE: l_x refers to the number of survivors, of 100,000 born alive, at the beginning of age x.

Table 6. Cohort survivorship (l_x) from birth to age 61 of males and females, other than white, born 1908-1912 compared with corresponding period survivorship: death-registration States, 1900-1968—Con.

Age x in years	All other males		All other females	
	Cohort l_x	Period l_x	Cohort l_x	Period l_x
50	56,433	45,027	59,784	46,573
51	55,533	43,880	59,076	45,423
52	54,549	42,697	58,319	44,241
53	53,505	41,485	57,511	43,030
54	52,427	40,255	56,693	41,794
55	51,301	39,011	55,861	40,532
56	50,110	37,748	55,007	39,239
57	48,837	36,459	54,118	37,905
58	47,492	35,144	53,170	36,543
59	46,094	33,823	52,174	35,172
60	44,666	32,507	51,132	33,815
61	43,137	31,211	50,020	32,483

NOTE: l_x refers to the number of survivors, of 100,000 born alive, at the beginning of age x.

Table 7. Cohort survivorship (l_x) from birth to age 51 of males and females, other than white, born 1918-1922 compared with corresponding period survivorship: death-registration States, 1900-1968

Age x in years	All other males		All other females	
	Cohort l_x	Period l_x	Cohort l_x	Period l_x
0	100,000	100,000	100,000	100,000
1	89,935	89,935	91,650	91,650
2	87,240	86,848	89,227	88,844
3	86,217	85,586	88,272	87,651
4	85,670	84,875	87,710	86,901
5	85,279	84,375	87,328	86,365
6	84,925	83,883	86,960	85,869
7	84,648	83,503	86,676	85,474
8	84,422	83,201	86,459	85,151
9	84,236	82,954	86,290	84,874
10	84,072	82,723	86,150	84,618
11	83,912	82,491	86,018	84,360
12	83,739	82,238	85,872	84,075
13	83,545	81,945	85,690	83,741
14	83,322	81,596	85,472	83,337
15	83,066	81,176	85,208	82,844
16	82,768	80,672	84,887	82,250
17	82,425	80,076	84,507	81,551
18	82,044	79,384	84,082	80,758
19	81,635	78,601	83,628	79,893
20	81,210	77,736	83,174	78,976
21	80,762	76,785	82,727	78,012
22	80,264	75,756	82,283	77,004
23	79,740	74,687	81,841	75,974
24	79,210	73,627	81,413	74,947
25	78,718	72,610	81,014	73,938
26	78,276	71,651	80,644	72,957
27	77,877	70,741	80,300	72,002
28	77,499	69,862	79,972	71,066
29	77,133	68,986	79,651	70,136
30	76,760	68,092	79,335	69,201
31	76,377	67,173	79,024	68,258
32	75,987	66,235	78,715	67,310
33	75,597	65,281	78,404	66,355
34	75,219	64,325	78,096	65,368
35	74,839	63,376	77,783	64,405
36	74,455	62,435	77,460	63,440
37	74,065	61,500	77,120	62,473
38	73,648	60,572	76,760	61,508
39	73,196	59,651	76,380	60,546
40	72,705	58,735	75,981	59,589
41	72,171	57,824	75,556	58,637
42	71,586	56,915	75,096	57,687
43	70,951	56,002	74,610	56,731
44	70,274	55,077	74,103	55,757
45	69,544	54,134	73,573	54,757
46	68,759	53,178	73,021	53,727
47	67,901	52,207	72,433	52,664
48	66,980	51,222	71,804	51,569
49	65,999	50,222	71,136	50,444
50	64,962	49,206	70,441	49,293
51	63,842	48,170	69,702	48,115

NOTE: l_x refers to the number of survivors, of 100,000 born alive, at the beginning of age x.

Table 8. Cohort survivorship (l_x) from birth to age 41 of males and females, other than white, born 1928-1932 compared with corresponding period survivorship: death-registration States, 1900-1968

Age x in years	All other males		All other females	
	Cohort l_x	Period l_x	Cohort l_x	Period l_x
0	100,000	100,000	100,000	100,000
1	90,888	90,888	92,552	92,552
2	89,024	88,950	90,923	90,859
3	88,261	88,133	90,239	90,115
4	87,827	87,666	89,836	89,674
5	87,534	87,323	89,557	89,334
6	87,280	86,988	89,311	89,009
7	87,087	86,732	89,127	88,760
8	86,933	86,529	88,990	88,568
9	86,803	86,357	88,882	88,414
10	86,687	86,197	88,791	88,279
11	86,573	86,033	88,708	88,143
12	86,456	85,849	88,620	87,985
13	86,325	85,633	88,514	87,782
14	86,175	85,375	88,384	87,514
15	86,005	85,067	88,232	87,167
16	85,814	84,703	88,059	86,732
17	85,613	84,277	87,872	86,209
18	85,394	83,786	87,674	85,610
19	85,154	83,228	87,466	84,955
20	84,882	82,604	87,256	84,258
21	84,582	81,909	87,052	83,522
22	84,254	81,148	86,857	82,749
23	83,916	80,339	86,672	81,949
24	83,585	79,507	86,491	81,136
25	83,272	78,671	86,315	80,320
26	82,964	77,837	86,137	79,505
27	82,664	77,003	85,956	78,692
28	82,365	76,165	85,768	77,879
29	82,060	75,317	85,569	77,063
30	81,746	74,453	85,358	76,241
31	81,425	73,573	85,135	75,413
32	81,092	72,678	84,900	74,578
33	80,739	71,763	84,651	73,729
34	80,355	70,821	84,381	72,859
35	79,928	69,850	84,085	71,962
36	79,456	68,650	83,765	71,038
37	78,909	67,822	83,4[illegible]2	70,089
38	78,347	66,771	83,[illegible]	69,117
39	77,741	65,700	82,6[illegible]	68,121
40	77,082	64,610	82,242	67,099
41	76,354	63,500	81,783	66,047

NOTE: l_x refers to the number of survivors, of 100,000 born alive, at the beginning of age x.

APPENDIX I

RELATIONSHIP BETWEEN COHORT AND PERIOD MORTALITY

There are various ways in which age-specific mortality rates may be viewed. Following Spiegelman's[17] presentations, the schematic diagram shown below depicts mortality rates observed over a period of years in three ways—period mortality or mortality rates for a calendar year, time trend of mortality by age, and the generation mortality or mortality for a cohort of individuals born in a particular calendar year.

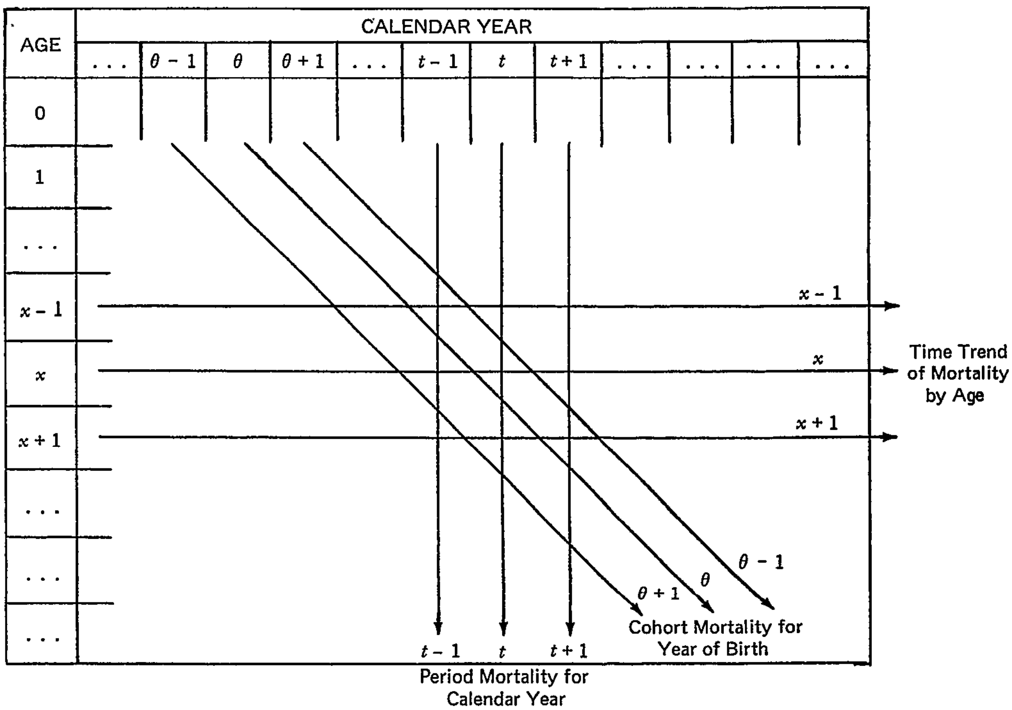
If $q_{x,t}$ denotes the mortality rate at age x in calendar year t, then:

(1) The vertical lines represent the case where t is constant and x alone varies. In this case the mortality rates by age are for a calendar year. These are the period mortality rates.

NOTE: The list of references follows the text.

(2) The horizontal lines represent the case where x is constant and t alone varies. In this case the observed time trend for age x is shown over a series of calendar years.

(3) The diagonal lines represent the case where both x and t jointly advance by the same unit interval of time, such that $t - x = \theta$ is a constant which defines the year of birth. In this case, the mortality rates are those for a generation traced from birth. Strictly speaking, deaths at age x as of the last birthday during the calendar year t will occur among births in calendar year $\theta - 1$ as well as in calendar year θ. Likewise, there will be deaths at age x in calendar year $t+1$ among births in year θ. To simplify the description, it is assumed that deaths are concentrated at the mid-age and at the middle of the calendar year.



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APPENDIX II

PRODUCTION OF THE SINGLE-YEAR DATA

The original data for the survivorship tables presented in this report were of two types: estimates of the population in 5-year age groups from age 0-4 to age 80-84 from 1900 through 1968, and age-specific deaths for the death-registration States during that same time period. In order to obtain deaths and population by single years of age, an interpolation procedure was used.

Interpolation as a generating procedure allows division of grouped data into smaller units. For example, interpolation is often used to produce single-year estimates of population or of deaths by smoothing a 5-year estimate into five single-year estimates. This is done by applying a set of constant multipliers to the 5-year data.

The interpolation formulas used to produce the data in this report are those derived by Beers.[18] These formulas were chosen in preference to osculatory formulas since they are based on fifth differences and are more suitable for smoothing deaths and population, which may have unusual distributions.

Because such a procedure can produce some irregularities, the interpolated data were then recombined into 5-year age groups or birth cohorts in order to minimize any irregularities so produced. Interpolating the data in this way allows examination of the yearly mortality rates of a birth cohort, instead of a view of the cohort only at 5-year intervals.

NOTE: The list of references follows the text.

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APPENDIX III

CONSTRUCTION OF THE COHORT AND PERIOD SURVIVORSHIP TABLES

(DETAILED TABLES 1-8)

Published Tables

For the years 1901, 1910, 1920, and 1930, published period life tables were available. However, various problems of comparability arose which led to the construction of period life tables from the same set of interpolated data as that used for the cohort tables.

First, the age-specific mortality rates used in the published period life tables covered 3-year periods. The cohort tables used age-specific mortality rates covering 5-year periods. Second, the published period life tables covered only the death-registration States in the 3 years surrounding these dates. The 1910 period life table available in published sources was computed for the death-registration States of 1900. Thus, by using the same set of interpolated data for both sets of tables, the cohort and period tables in this report at least begin using the same death-registration States. However, it was not possible to eliminate the problem of new States coming into the death-registration area during the time covered by the cohort tables. For races other than white there is some reason to believe that this may have produced irregularities. As new States were added with different types and numbers of people of other races (for example, with predominately rural or urban populations), the mortality rates may show fluctuation that would not be expected on the basis of age alone.

Finally, the published period tables were available only for Negroes, while the cohort tables were available only for all races other than white. The error that might have been introduced by assuming these were the same, while probably not large, nevertheless was a factor in the decision to construct both period and cohort tables from the same set of data. This is not to say that the period tables constructed from the interpolated data are any more correct than the published period tables for these dates. Such a procedure only makes the period tables more comparable to the cohort tables.

Method of Estimating Death Rates at Age 0-1

Death rates of infants aged 0-1 year in the population are generally computed by dividing the number of deaths of children of that age by the number of births in that year. The number of births are used in this calculation instead of the number of children aged 0-1 enumerated in the population since there is generally an undercount of infants in census data.

However, in constructing survivorship tables for the years included in this report, special problems arose in making an estimate of the births occurring in these years. The death-registration area and the birth-registration area were not the same prior to 1933. Consequently, even though some scant data were available to estimate births during these years, these data did not cover the same States as the death data available from the interpolated set.

The method of estimating births for these years was adapted from Glover.[19] In this procedure, population and death estimates for older ages were used to construct estimates of births at an earlier time. For example, births in 1910 should be equal to the sum of the population aged 3-4 in 1913, added to the deaths of children aged 2-3 in 1912, deaths of children aged 1-2 in 1911, and deaths of children aged 0-1 in 1910. In symbols this procedure appears as follows:

$$B^{1910} = P^{1913}_{3-4} + D^{1912}_{2-3} + D^{1911}_{1-2} + D^{1910}_{0-1}$$

where B = births, P = population, and D = deaths.

Each of these estimates of population and deaths was adjusted by separation factors so as to include only those persons who were part of the birth cohort being estimated. This procedure was necessary since children aged 0-1 in 1910, for example, may not have been born in 1910. A child born in September of 1909 would still be age 0-1 in 1910. Likewise, children born in September of 1910 would still be age 0-1 in 1911.

NOTE: The list of references follows the text.

Separation factors were used to attempt to separate out those who were actually part of the cohort being estimated by considering infant mortality rates during the years in question. In order to calculate such separation factors, deaths by month of age were necessary. Monthly mortality data show what proportion of the infant deaths during a given year were of children actually born in that year versus what proportion of those deaths were of children born in the previous year.

The table shows the separation factors used for each year by color, sex, and age. The 1900 and 1910 estimates for whites were available from published sources. The 1930 white and other than white estimates were also available. The 1920 estimates for whites and people of other races were calculated to be congruent with the other sets. For the years 1900 and 1910 estimates for races other than white were similarly calculated.

One additional adjustment to these birth estimates was necessary in order to construct estimates of deaths of infants aged 0-1. This adjustment was made in order to allow for a changing death-registration area during the time periods in question. In the above estimate of births in 1910, for example, Kentucky and Missouri were admitted to the death-registration area in 1911, and Virginia was admitted in 1913. Consequently, the estimate of deaths for those 0-1 year of age in 1910 did not include those children in Kentucky and Missouri who died at that age and were part of the 1911 birth cohort. The population estimate of those aged 3-4 in 1913 included the children in Virginia at that age, but none of the death estimates in 1912, 1911, or 1910 included the children dying in this State before reaching age 3.

To compensate for this underestimation, data were obtained from the annual *Vital Statistics* volumes on mortality by color, sex, and single years of age under 5 in those States which entered the registration area during one of the birth estimation periods. In the above estimate, for example, the deaths of those children aged 2-3, 1-2, and 0-1 in Virginia in 1913—the first year for which such data were available for Virginia—were added to the birth estimate. These figures are only an approximation since they are not actually for the year in question. They do constitute, however, a needed, and perhaps not grossly inaccurate, adjustment.

Separation factors used in estimates, by color, sex, and age: percent dying from cohort born in previous year

Year and age	White		All other	
	Male	Female	Male	Female
1900 and 1910:				
0	.28	.29	.31	.32
1	.41	.41	.41	.41
2	.47	.47	.47	.47
3	.48	.48	.48	.48
4	.48	.48	.48	.48
1920:				
0	.23	.24	.26	.27
1	.41	.41	.41	.41
2	.47	.47	.47	.47
3	.48	.48	.48	.48
4	.48	.48	.48	.48
1930:				
0	.19	.20	.21	.22
1	.41	.41	.41	.41
2	.47	.47	.47	.47
3	.48	.48	.48	.48
4	.48	.48	.48	.48

SOURCES: 1900 and 1910 estimates for whites from M. Spiegelman, Introduction to Demography, Chicago, The Society of Actuaries, 1955, p. 75. 1930 estimates from U.S. Life Tables and Actuarial Tables 1939-41 (1947), p. 118. 1920 estimates for whites and all others and 1900 and 1910 estimates for all others calculated to be congruent with other sets.

Deaths at Other Ages and Survivors

As noted above, the number of deaths in each year were combined in different ways to produce the cohort and period death rates for survivorship tables. In order to produce the cohort tables, the data were combined by 5-year birth cohorts (as shown earlier in table A) to produce mortality rates by single years of age for a succession of birth dates. For a given succession of birth dates (cohort), the particular single year of age determines the calendar years of data to be combined in computing the cohort's average age-specific death rate. The 1908-1912 cohort, for example, was 50 years old in 1958-1962, so the deaths at age 50 in this latter period of years were combined in computing their average death rate at age 50. Their death rate at age 51 was based on deaths occurring in 1959-1963, at age 52 in 1960-1964, and at other ages in like fashion. To produce the period tables, the average single-year age-specific mortality rates were computed from the same 5-year period of data, irrespective of age, with the central year the same as the central year of birth of the cohorts being examined. For example, the period rates for 1908-1912, like the 1908-1912 cohort rates, have a central year of 1910. But unlike the 1908-1912 cohort death rate at age 50, the corresponding period rate is based on death and population at age 50 in 1908-1912. The period rate at age 51 and all other ages is based on 1908-1912 data. The period rates are thus based on the average age-specific death rate prevailing at one 5-year period in time.

The death rates, m_x, produced by the combination procedures were converted into life table death rates, q_x. This procedure was necessary since the death rate m_x was calculated for those alive at the midpoint of the age interval. For life table purposes, the q_x death rate shows the death rate for those alive at the beginning of the age interval. This conversion was accomplished by use of the approximation formula:

$$q_x = \frac{m_x}{1 + 1/2\ m_x}$$

After the death rates were computed, the number dying at each year of age was obtained by multiplying the number alive at the beginning of that age interval (l_x) by these death rates (q_x). The result is the number dying during that year of age (d_x). Beginning with 100,000 alive at age 0, the number surviving to each successive age was then computed by subtraction (l_x).

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☆ U. S. GOVERNMENT PRINTING OFFICE : 1972 515-208/31

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