The Changing Pattern of American Mortality Decline, 1940-77, and Its Implications for the Future

Eileen M. Crimmins

The Changing Pattern of American Mortality Decline, 1940–77, and Its Implications for the Future

Eileen M. Crimmins

Although this century has seen periods of rapid decline in American mortality, in the past two decades the view has come to be accepted that American mortality is likely to change only slowly over the coming years. Recently, however, there have been striking developments on the mortality scene that raise doubts about this view. The purpose of this article is to examine the course of American mortality change from 1940 to 1977 and assess its implications for the near term future. Particular emphasis is placed on analyzing trends in different age groups by principal causes. The 37 years from 1940 to 1977 are divided into three distinct periods, which are characterized by different trends in cause-specific and thus age-specific mortality rates. In addition age-by-cause-specific mortality trends in the third period are projected to the year 2000 to provide an estimate of the expectation of life and the distribution of deaths by cause for that date assuming recent trends continue.

Three periods of mortality decline

The American mortality decline since 1940 falls into three clearly demarcated periods. This is illustrated by the trend in the age-adjusted death rate shown in Figure 1. Examination of yearly rates shows that from 1940 to the mid-1950s mortality declined at a pace unprecedented in American history. Then there was a period of leveling off, so pronounced that it led analysts at the National Center for Health Statistics to caution that "the death rate for the United States has reached the point where further decreases as experienced in the past cannot be anticipated" (National Center for Health Statistics, 1964). While this statement seemed reasonable when it was made in 1964, it was very shortly undercut by subsequent events. Beginning in 1968 a new decline in mortality set in at rates close to those of the 1940s and early 1950s.

FIGURE 1   United States: crude and age-adjusted death rates, 1940–77
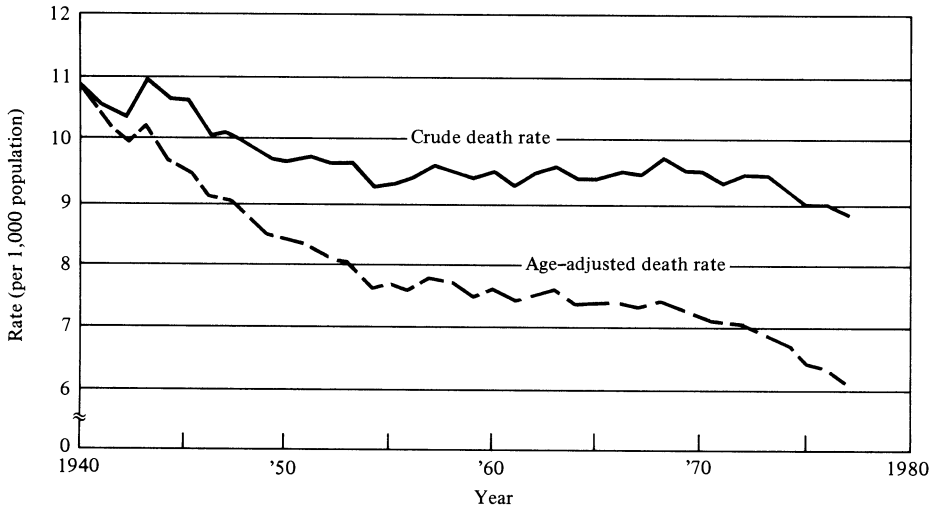
For the present analysis, the period from 1940 to 1977 has been divided into three segments: 1940 to 1954, 1954 to 1968, and 1968 to 1977. The average yearly declines in the age-adjusted death rates for each of the three periods were 2.0 percent, 0.4 percent, and 1.6 percent, respectively.

Age

Yearly rates of decline for individual age groups in each of the three periods are presented in Figure 2. Comparing these three curves indicates that in general when substantial declines are taking place, all age groups share in the decline; and correspondingly, when the decline is slight, all age groups suffer from reduced declines. The familiar historical pattern of greater improvement at the younger ages than at the older ages is also shown in each of the three periods. Some marked exceptions are apparent, however. In the most recent period, the rate of decline above age 84 exceeds that of all other age groups except infants. This rate of decline among the oldest age group in the most recent period is 75 percent higher than in the 1940 to 1954 period. While the high rate of recent mortality decline among the oldest age group is one distinguishing feature of the recent mortality decline, the low rate of decline among those 15 to 34 is another. Young adults have not experienced the same rapid mortality declines as those both older and younger in the most recent period; and between 1954 and 1968, mortality rates among those 15 to 44 actually increased, while slight decreases occurred from ages 45 to 85 and larger decreases among those less than 15.

FIGURE 2   United States: percent decline per year in age-specific
mortality rates for the total population, 1940–54, 1954–68, 1968–77
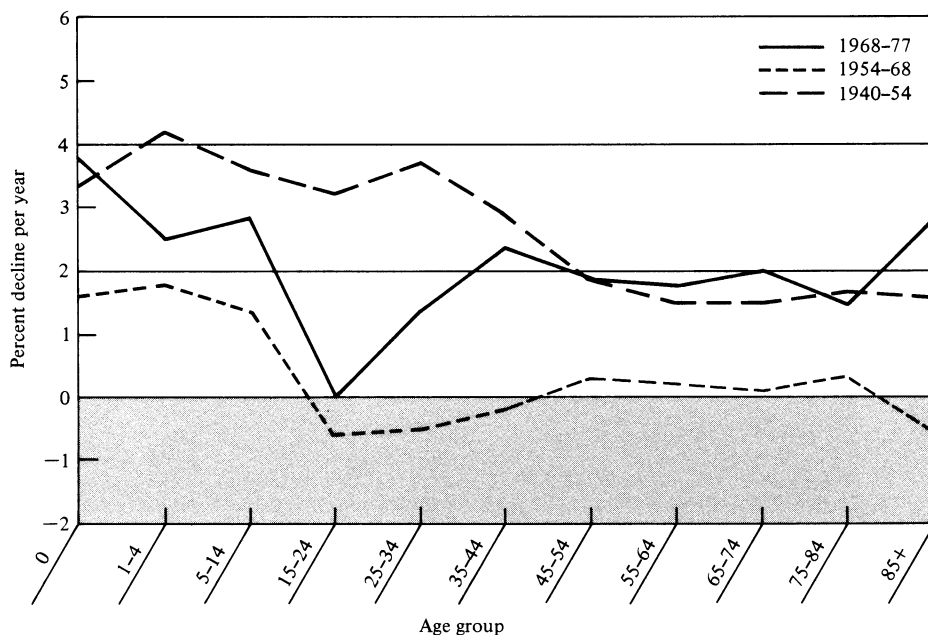
SOURCE: 1940, 1954: *Vital Statistics Rates in the United States, 1940–60,* PHS Pub. No. 1677, 1968. 1968, 1977:
Monthly Vital Statistics Department, *Final Mortality Statistics, 1977,* NCHS, 1979.

Race and sex

While this paper will not deal in detail with mortality change by race or sex,
before proceeding, I would like to establish that the three periods of mortality
decline generally characterize the trends in mortality for blacks and whites,
males and females. Figure 3 indicates that both racial groups experienced rapid
rates of decline—with similar patterns by age—from 1940 to 1954. Between
1954 and 1968 both races experienced the slowdown in mortality decline at
all ages. During this period significant decline occurred only at the youngest
ages, and there were some increases in mortality at ages above 15 for both
racial groups. In the recent phase, rapid mortality decline has characterized
both racial groups. The lack of improvement in the young adult ages, however,
has been limited to the white population. Nonwhite young adult mortality
continued to decline in the 1968–77 period. The recent large mortality declines
in the oldest age groups have occurred in both racial groups.

Both sexes experienced a period of reduced improvement in mortality
between two periods of more rapid decline (Figure 4, pp. 234–235). The
slowdown in mortality decline between 1954 and 1968, however, was greater

FIGURE 3   United States: percent decline per year in age-specific mortality rates by race, 1940–54, 1954–68, 1968–77
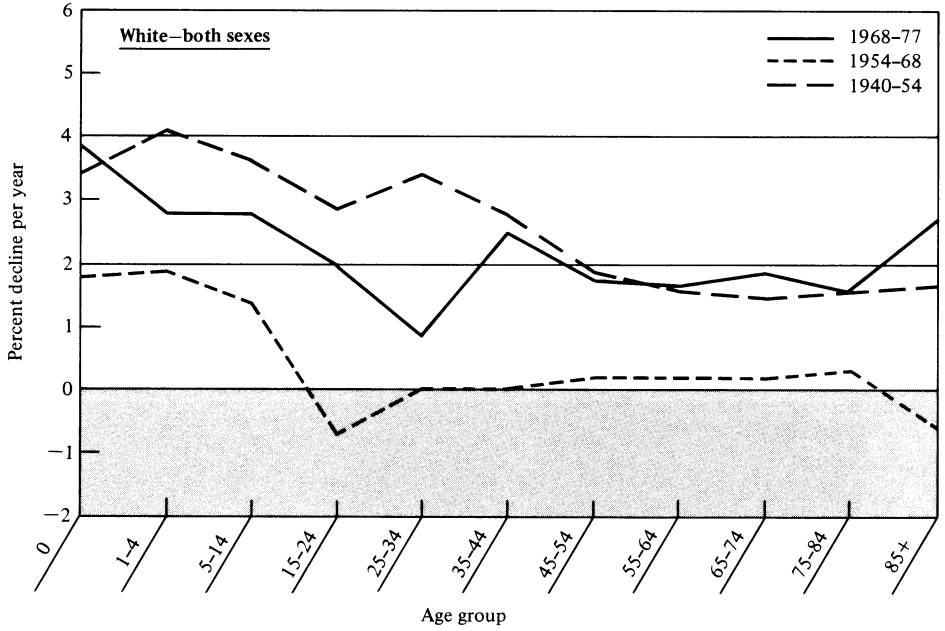
for males than for females. Mortality rates at most ages above 15 increased during these years among both black and white men. At the same time mortality increased only among nonwhite women over 65 and white women over 85. The recent lack of improvement in mortality rates among young white adults is characteristic of both males and females.

Cause of death

We now turn to an examination of the change in mortality rates by cause of death for these three periods. Because the classification scheme for causes of death changes periodically, it is difficult to follow the trend in death rates from some diseases over a sustained period. From 1940 to 1977 deaths were classified according to four different revisions of the *International Statistical Classification of Diseases, Injuries and Causes of Death* as follows:
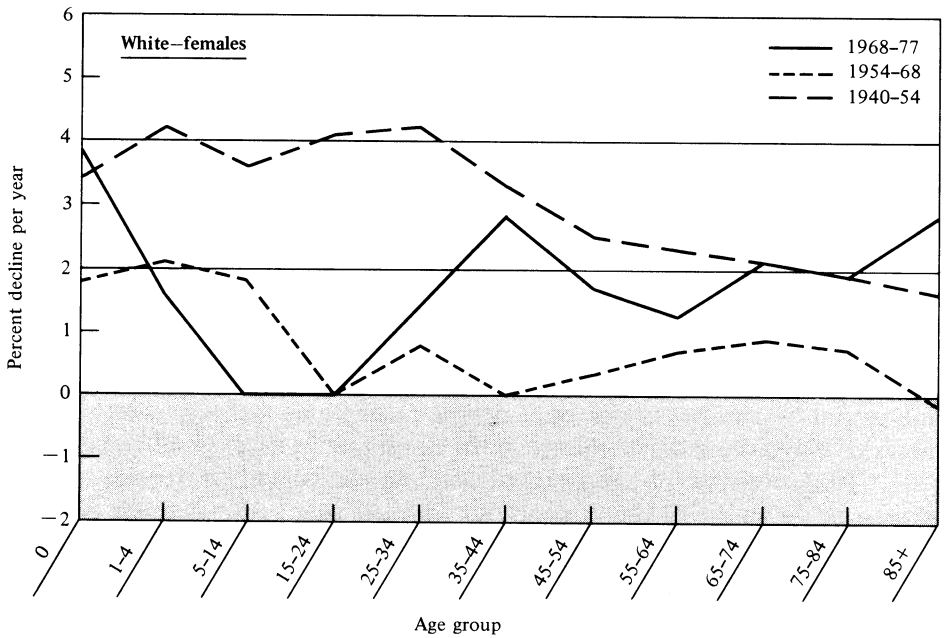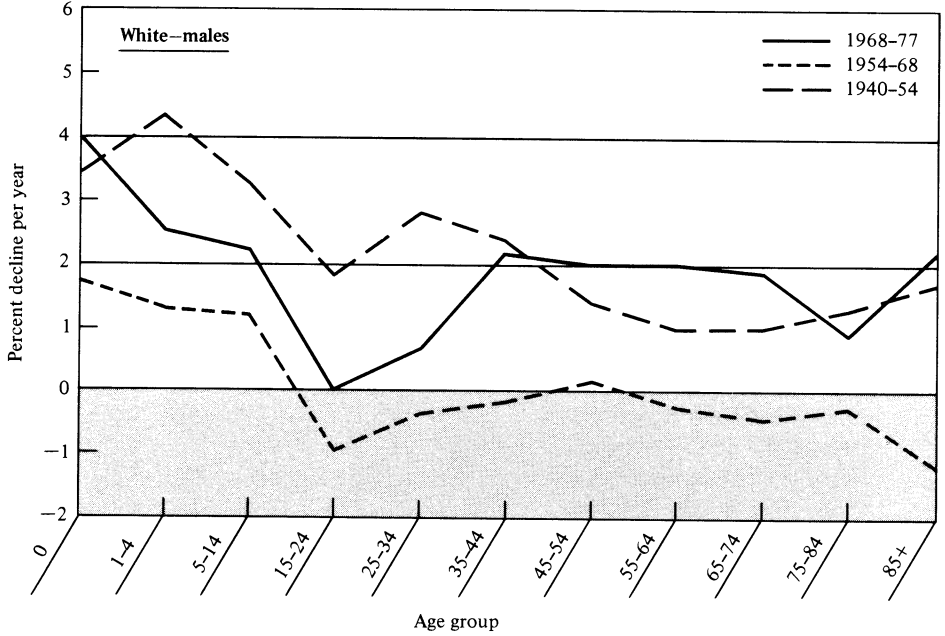
> 1940–1948 Fifth Revision
> 1949–1957 Sixth Revision
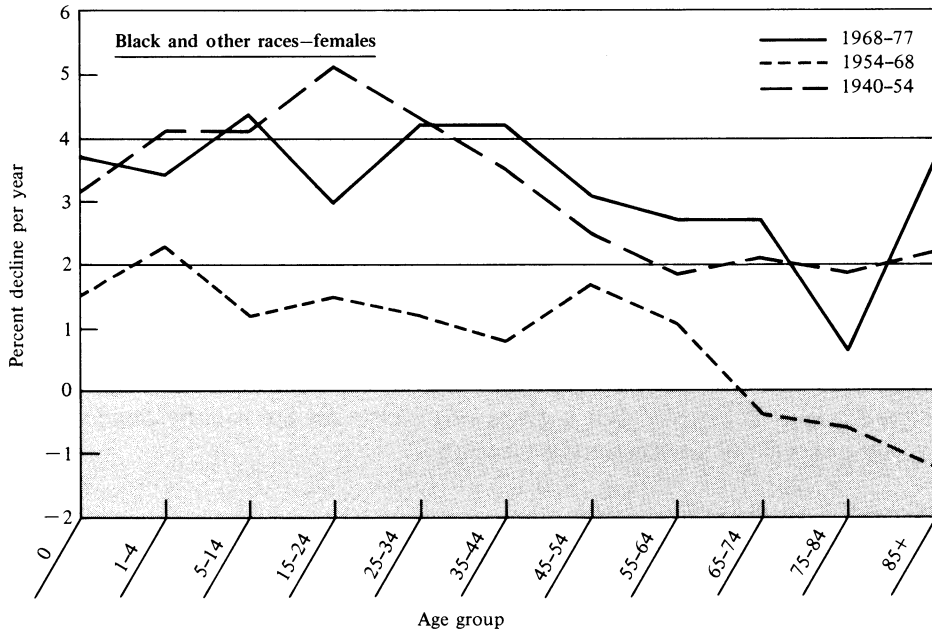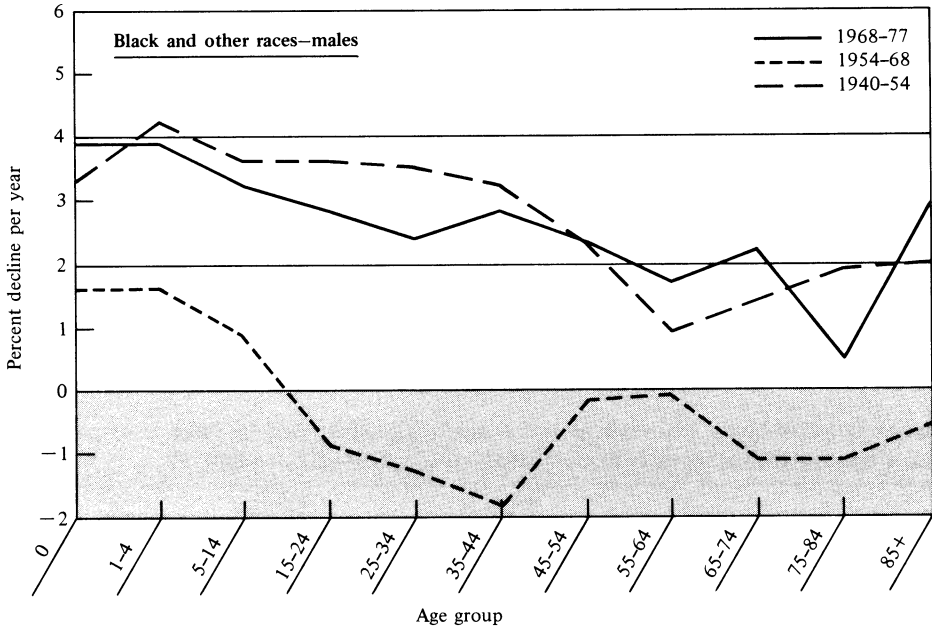> 1958–1967 Seventh Revision
> 1968–1977 Eighth Revision

This required that age-race-sex-specific comparability ratios be applied to cause-specific death rates for some dates in order to examine changes in death rates from consistently defined causes over time. Thus, the 1940 and 1967 rates were made comparable to the Sixth revision to analyze trends for the periods 1940–54 and 1954–67. Age-race-sex specific comparability ratios are not available for the Seventh to the Eighth revision, but since the 1968–77 period is covered by the Eighth revision, comparability of causes within the period is not a problem, although there is some discontinuity with the prior periods that is not serious for our purpose.

   In preliminary analysis, death rates from the 15 leading causes of death in 1968 to 1977, plus a category consisting of other infectious and parasitic diseases, and a residual category were examined for each of the three sub-periods.[1] For this study, however, all deaths are grouped into the following five categories: cancer (malignant neoplasms), cardiovascular diseases (diseases of heart, cerebrovascular diseases, and arteriosclerosis), violence (accidents, homicide, and suicide), diseases of infancy (diseases of infancy and congenital malformations), and all other causes.[2] After studying trends in more detailed causes, these categories were selected because they combine diseases influenced by similar factors; and, they are categories that are major components of either the level or change in the death rate in some or all age groups.

   The percent of the age-adjusted death rate accounted for by each of these causes is shown in Table 1, panel A. At each date cardiovascular diseases account for the greatest proportion of deaths. Over the 37 years, cancer increases in importance as a cause of death, and the category "Other" decreases in importance. The percent of intraperiod change in the age-adjusted mortality rate due to each of these categories is shown in panel B of Table 1. Interest centers on the first and third periods, because mortality change was relatively small in the second period. In each of these periods the mortality decline is

FIGURE 4   United States: percent decline per year in age-specific mortality rates by race and sex, 1940–54, 1954–68, 1968–77

Age group

Age group

Black and other races—males

Percent decline per year

Age group

1968-77
1954-68
1940-54

Black and other races—females

Percent decline per year

Age group

1968-77
1954-68
1940-54

TABLE 1   A. United States: total age-adjusted death rate and percent distribution by disease category: 1940, 1954, 1967, 1968, 1977

	Sixth revision			Eighth revision	
	1940	1954	1967	1968	1977
Total death rate					
(age-adjusted)	1076.1	770.5	728.7	746.7	612.3
Disease category					
Cancer	10.7	16.5	17.6	17.4	21.7
Cardiovascular diseases	38.2	49.9	47.9	47.0	43.3
Diseases of infancy	4.7	4.8	4.0	3.7	2.9
Violence	8.4	8.9	10.0	10.0	10.8
Other	37.9	20.0	20.6	21.9	21.3
All categories	100.0	100.0	100.0	100.0	100.0

B. United States: change in total age-adjusted death rate and percent change by disease category: 1940–54, 1954–67, 1968–77

	1940–54	1954–67	1968–77
Change in total death rate	305.6	41.8	134.4
Disease category			
Cancer	−3.7	−2.4	−2.1
Cardiovascular diseases	8.7	84.0	64.2
Diseases of infancy	4.5	19.1	7.2
Violence	7.4	−10.5	6.0
Other	83.1	9.8	24.7
All categories	100.0	100.0	100.0

concentrated in one category. Over four-fifths (83 percent) of the mortality decline in the first period was due to declines in "Other" diseases, which were heavily weighted by infectious diseases at this time, while almost two-thirds (64 percent) of the third period decline was due to cardiovascular diseases.

Cause by age: have declines in cause-specific mortality rates been the same across all age groups?

Trends in age-specific mortality rates for each of these causes are shown in Figure 5 (pp. 238–239). For a given cause changes are usually quite similar by age, except for deaths due to violence.

"Other" causes (Figure 5A)

During the first period, mortality from "Other" causes declined rapidly in all age groups. At this time, this residual category was substantially dominated by infectious and parasitic diseases and influenza and pneumonia. After 1954 every age group experienced lowered rates of decline in these diseases, and

for those over 55 there was no decline at all in mortality from these diseases in the middle period.

Cardiovascular diseases (Figure 5B)

The period-to-period trend in death rates from heart disease is similar for those age groups in which heart disease is an important component of mortality (those 25 and over). In general for these age groups there was an accelerating decline over the three periods, with much more rapid decline in the third period. At the other ages (i.e., under 25), where death from heart disease is not a very important component of the total death rate, the rapid decline in heart disease in the first period is due to decline in infectious diseases such as rheumatic fever, which resulted in reduced deaths from heart conditions.

Cancer (Figure 5C)

There is a steady upward trend in the cancer death rate at ages 45 and above, where cancer is an important cause of death. The rate of increase is low but fairly consistent across age groups for the three periods. Between ages 25 and 44 the trends are not as consistent. There are periods of decrease as well as increase. Recent declines are due in large part to decreased death rates from breast and cervical cancer for women and from digestive system cancers for both sexes.

Cancer is a relatively unimportant cause of death for those less than 25, but there have been dramatic declines in the relatively low cancer death rates among young people due to marked improvements in the cure and remission rates for childhood tumors and leukemia. For children less than five, declines began in the second period, for those 5 to 24, in the third period.
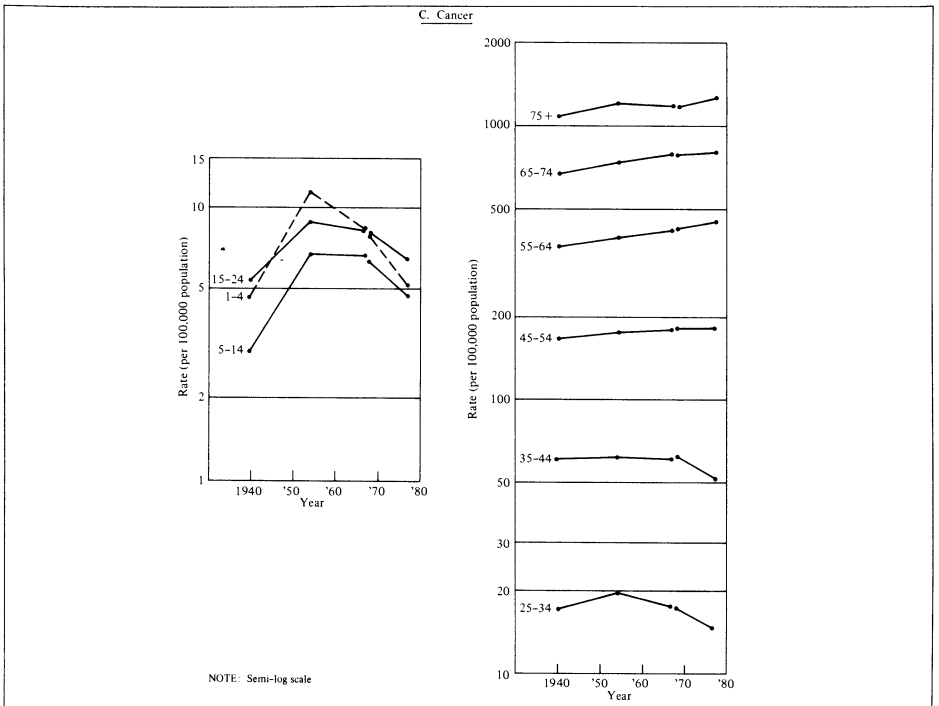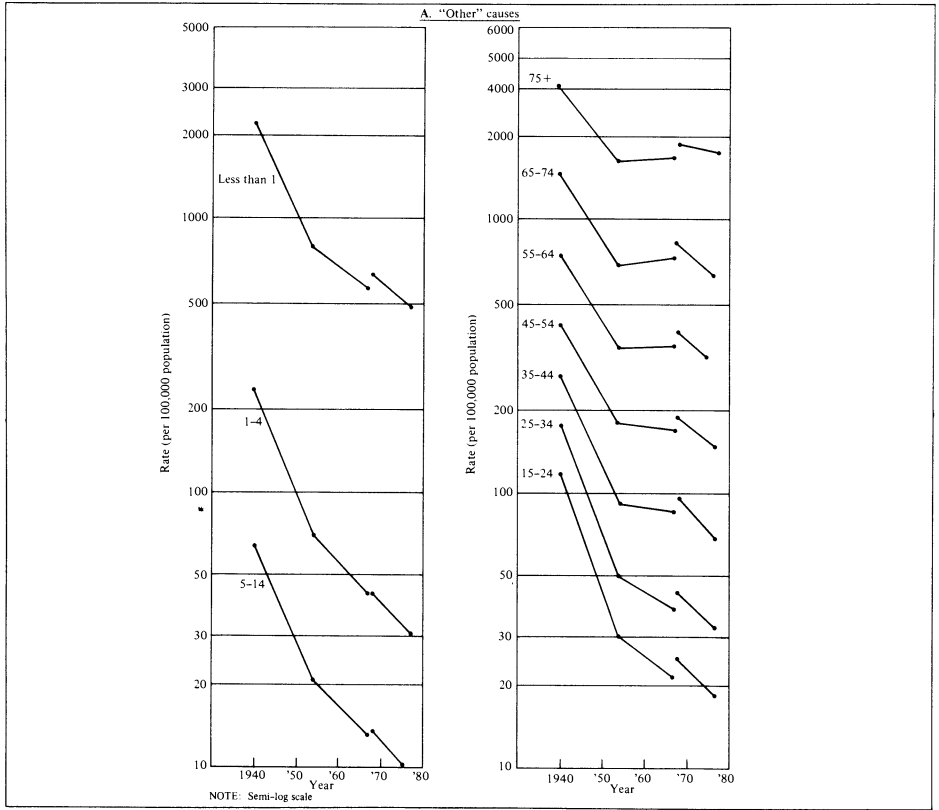
Violence (Figure 5D)

Violence is an imporant cause of death among children and young adults (those from 1 to 35). Death rates from violence fell markedly in the first period except among those 15 to 24. In the second period all of these age groups experienced marked interruptions in the fall with sharp increases in death from violence occurring among young adults 15 to 34. The pattern in the last period is also mixed. There are declines for those 1 to 14 and 25 to 34, but an increase occurs in the violence rate for 15–24 year olds.

Among the age groups where violence is a less important cause of death (those over 35), the trend in this cause is also mixed. Those 35 to 64 experienced trends similar to those of the 25–34 year olds described above. For people over 65 there were continuous declines in deaths from violence throughout the three periods.

The general similarity among ages in the trends in cause-specific rates for ages where the causes are important lends confidence to the conclusion that the trends by cause in all of the age groups reflect the influence of a common set of determinants. Thus, the decline in the category "Other" diseases ex-

FIGURE 5   Death rates for major causes of death by age, 1940—77 (per 100,000)

A. "Other" causes

NOTE: Semi-log scale

C. Cancer

NOTE: Semi-log scale

B. Cardiovascular diseases

Rate (per 100,000 population)

Year
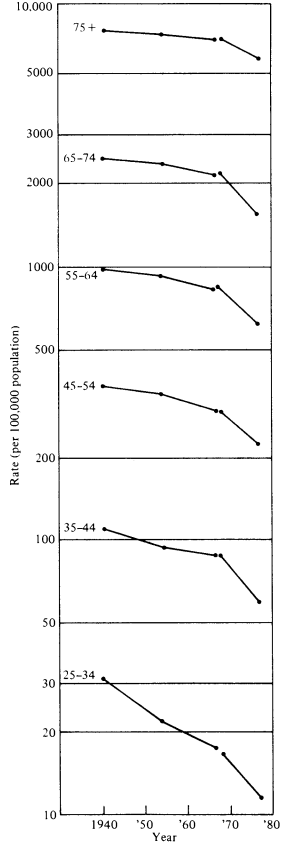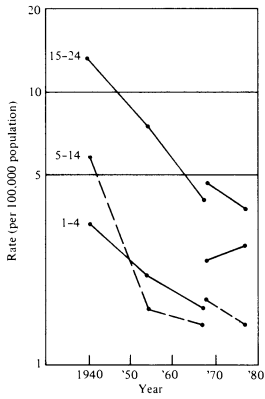
NOTE: Semi-log scale

D. Violence

Rate (per 100,000 population)

Year

NOTE: Semi-log scale

perienced by all age groups in the first period chiefly reflects the introduction and diffusion of antibiotics and sulfa drugs, and the recent decline in death rates from cardiovascular diseases above age 25 probably reflects the influence of a set of medical advances and changes in life-style to be discussed further below.

Age by cause: what has been the role of these cause-specific categories in shaping the trends for each age group?

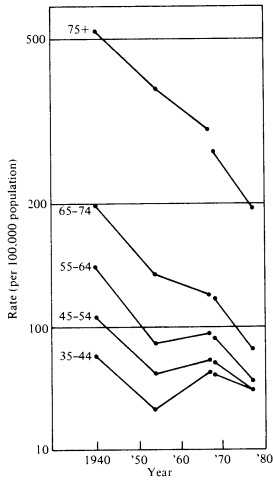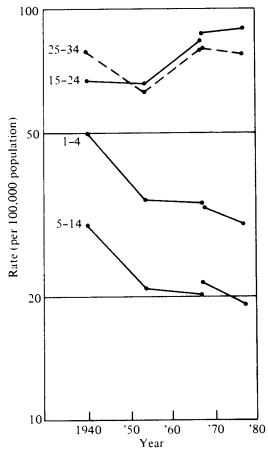The different causes analyzed here exert different weights from one age group to another in shaping the trend in the overall mortality rates. Figure 6 is designed to bring out the dominant causes in the trend for each age group.

Age groups 14 and under

The decline in the total rate for these age groups is largely a reflection of a decline in mortality due to "Other" causes. A marked slowing in the rate of decline occurs after 1954, presumably because the diffusion of the antibiotics has been largely accomplished by that date. However, for infants the retardation in decline is less marked, because their death rate also reflects the sizable and fairly steady decline over the three periods in causes largely or wholly peculiar to this age group.

Age groups 35 and over

For these age groups the total rate shows sharp declines in periods one and three, with little or no decline in period two. The decline in the first period is a reflection of the sharp decline in mortality due to "Other" causes, the force of which is largely spent by 1954. For these older age groups, the role of this category is, by and large, quite similar to that for younger age groups. In period three, cardiovascular diseases take over the role played by "Other" causes in period one and produce a renewed sharp downtrend.

Age groups 15 to 34

In these age groups there is a marked leveling off in the total rate after a sharp decline in the first period. One sees again the "Other" cause component playing the same role as for the previous age groups—contributing to a marked decline in the first period and a much slower decline thereafter. For this age group, the distinctive factor is the uptrend after 1954 in deaths due to violence, which offsets the negative impact of "Other" causes.

To sum up:

1 The role of "Other" causes has been remarkably similar among age groups from one period to the next—dominating the decline in the age-specific rates in period one, and thereafter, when it becomes a

less important cause, contributing at best only moderately to further declines.

2 In period three, a new trend—a sharp decline in mortality due to cardiovascular diseases—has caused rapid declines in age-specific rates over age 35, comparable in rate of change to the impact of the "Other" category in period one.

3 Since 1954, for those 15–24, mortality due to violence has exhibited an upward trend, countering the depressing effect on mortality of other components in this age group, and producing a net increase in mortality. This countervailing role of violence as a component is somewhat apparent also at ages 25–44, but the forces making for decline in mortality prevail at these older ages.

4 For infants, mortality due to causes largely or wholly peculiar to this group has declined at a fairly steady rate in all periods.

Factors influencing cause-specific trends, with an emphasis on recent trends

Before turning to the implications of these trends in mortality for future mortality levels, let us examine briefly the factors that are responsible for the trends in these categories of cause of death. Because we are interested in the future, we concentrate our discussion on factors influencing the trend in the most recent period and the groundwork they lay for the future. At present, the state of knowledge permits only qualitative judgments.

Cardiovascular diseases

It is difficult to attribute the decline in cardiovascular disease death rates, which dominates the recent mortality decline, to any one factor or set of factors. Many factors, grouped here into two categories—life-style and medical factors—have been suggested as partially responsible for this decline.

Changes in life-style include reduction in cigarette smoking, reduction in the intake of animal fats, and increased leisure-time physical activity. Among these factors, smoking is most clearly linked to cardiovascular mortality (Public Health Service, 1979a). In general, cigarette use declined between 1968 and 1977, although no clear downward trend characterizes the entire period and reductions do not characterize all age and sex groups (Public Health Service, 1979a; 1976). The intake of high levels of animal fats has been linked less clearly to cardiovascular mortality, but it is generally assumed that, if there is an effect, it would work through serum cholesterol concentration and obesity. During recent years there have been declines both in the intake of animal fats (Board of Agriculture and Renewable Resources, 1976) and in serum cholesterol levels (National Center for Health Statistics, 1977a; H. Taylor et al., 1975). Action-oriented leisure-time activity appears to be on the increase. Although it is difficult to document this increase and to determine which age,

FIGURE 6   Death rates for specified age groups by major causes of
death, 1940–77 (per 100,000)
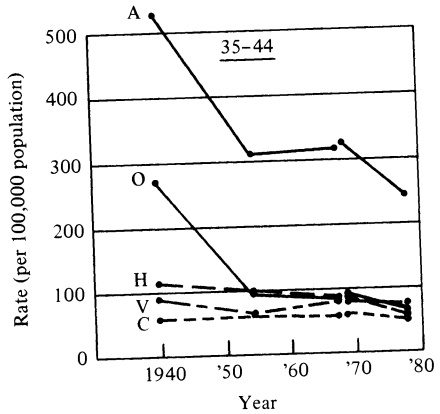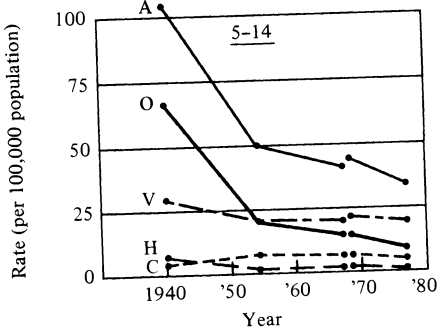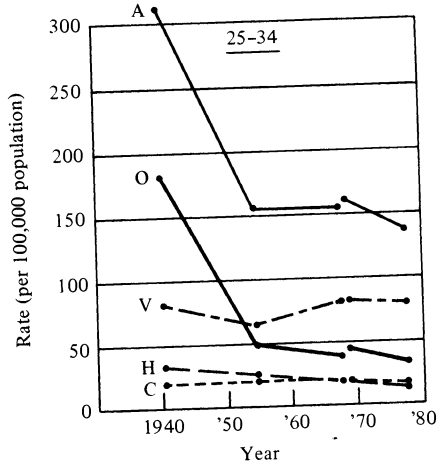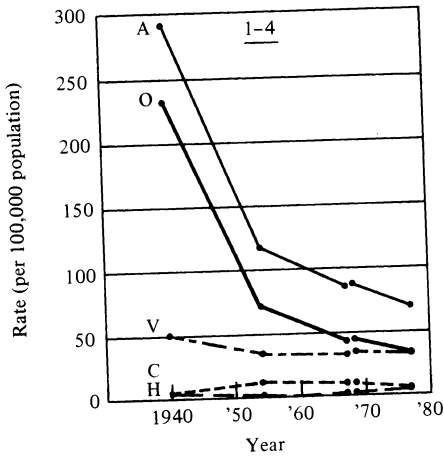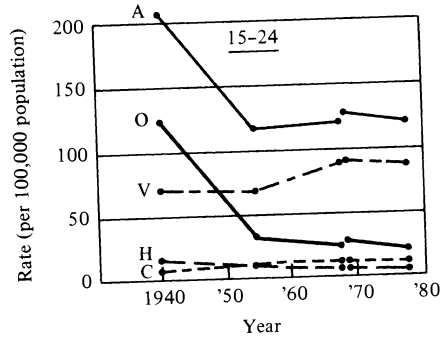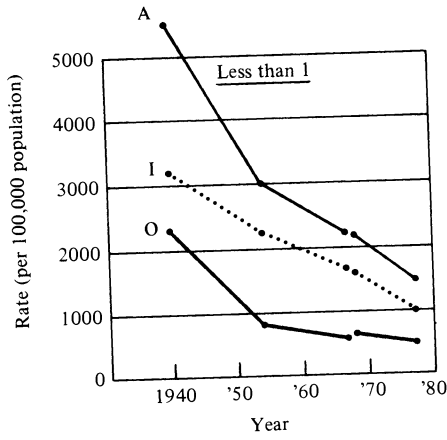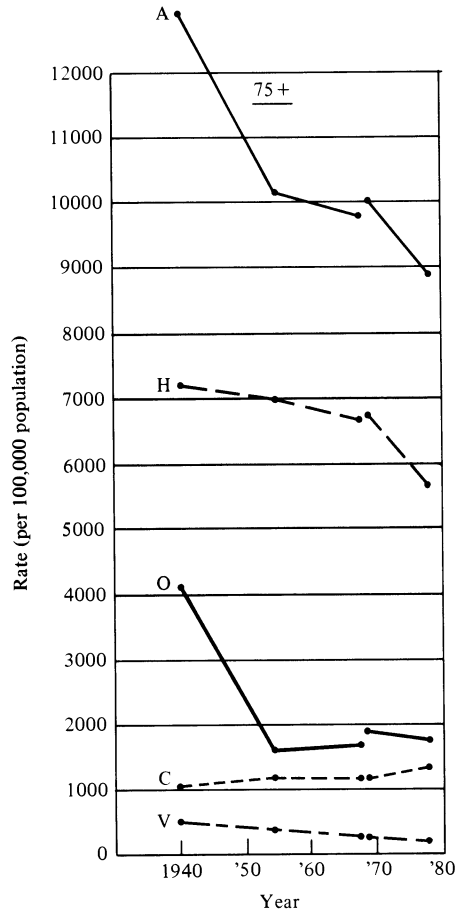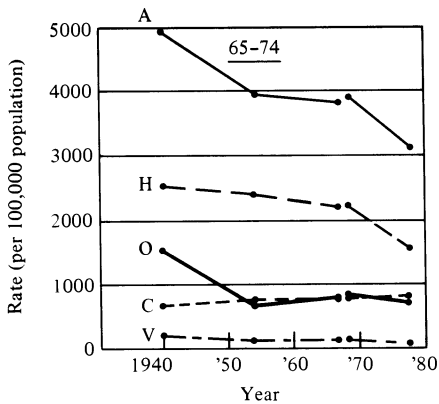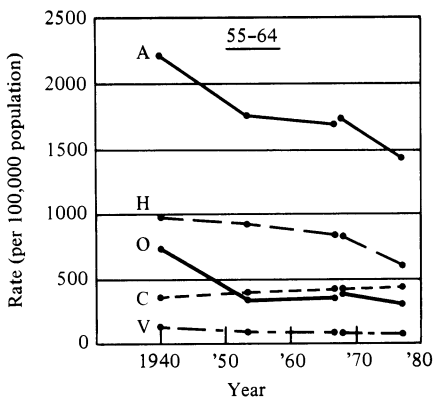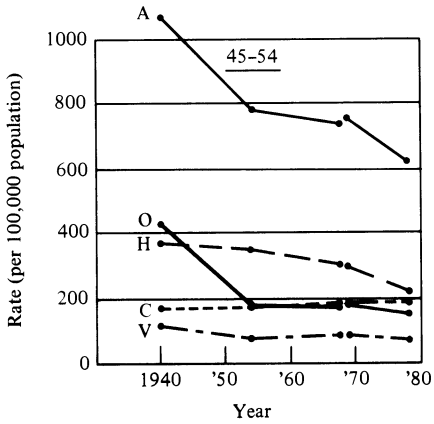
Legend

A———all causes
I ···· diseases of infancy and
      congenital malformations
V—·—violence
H——cardiovascular diseases
C----malignant neoplasms
O———all other causes

sex, and race groups it characterizes, it is clear that large numbers of Americans are now regularly engaged in leisure-time physical activity (National Center for Health Statistics, 1978).

These changes in life-style may have played some significant role in reducing the death rates from cardiovascular diseases, but they do not appear to have occurred among all age, sex, and race groups that have experienced large declines in cardiovascular mortality. Also the timing of changes in these behaviors does not always clearly coincide with changes in mortality rates. Moreover, it is generally believed that life-style changes may only affect mortality substantially after a lag. These considerations have led some researchers to emphasize the importance of medical factors over life-style changes as a cause of the recent cardiovascular mortality decline.

Medical influences on mortality include both diagnostic and therapeutic factors. During the period in which mortality rates from cardiovascular diseases fell so markedly, the availability of low or no cost medical care was extended to the old and the poor through government programs. There is evidence that among these segments of the population visits to physicians increased during these years (National Center for Health Statistics, 1975; D. Rogers and R. Blendon, 1977). It is possible that this increased use of medical facilities among these groups could have affected mortality from cardiovascular diseases by identifying people in need of treatment and providing that treatment. This would be especially true for conditions that may exhibit few symptoms, such as hypertension.

Information diffusion campaigns and community-based screening programs may also have aided in increasing the proportion of people at high risk of a cardiovascular death who were undergoing treatment (J. Stamler et al., 1976; D. M. Berkson et al., 1977). There is evidence that the proportion of persons with hypertension who were undergoing treatment increased during this period (N. Borhani, 1979; National Center for Health Statistics, 1977b), although the prevalence of hypertension among American adults appears not to have changed, at least up to 1974 (National Center for Health Statistics, 1977b).

Techniques of diagnosing coronary artery disease have been substantially improved through advances in fields such as radiology. In addition to these advances, several "noninvasive" methods of diagnosing this disease, such as the treadmill electrocardiogram, have been developed during this period (Braunwald, 1979).

Drug and surgical treatment for cardiovascular conditions has also changed rapidly in the past 15 years. New drugs have been introduced to accomplish such aims as controlling hypertension, regulating heart rates, and decreasing heart mechanical activity (Braunwald, 1980). New surgical techniques to repair and replace parts of the heart and blood vessels, including coronary bypass surgery, have been diffused during the period also. While the effectiveness of coronary bypass surgery remains under question (European Coronary Surgery Study Group, 1979; H. Hiatt, 1977; *New England Journal*

of Medicine, 1977; H. McIntosh and Jorge Garcia, 1978; J. W. Hurst et al., 1978), there is general agreement that the number of people who have actually had this surgery is so small that it could not have played a very significant role in the recent mortality decline (M. Stern, 1979). New treatment facilities such as coronary intensive care units and mobile coronary units may also have played some role in the decline in mortality from heart disease. While the coronary intensive care units certainly aid in monitoring patients and have equipment to resuscitate the patient and regulate heart rhythms, their role in preventing death is still being debated (M. Stern, 1979). Since many heart attacks occur outside of hospitals, mobile coronary units can prevent death by providing treatment in the crucial time before a patient reaches the hospital. However, mobile units are not regarded as being sufficiently widespread in the United States at this time to have had much effect on the death rate (M. Stern, 1979).

This review should indicate that while it is difficult to establish the relative weights of the above-mentioned causes, many factors—particularly medical factors—probably have contributed to the recent decline in cardiovascular mortality rates.

"Other" causes

As noted, in the first period, the category ''Other'' causes was largely dominated by influenza and pneumonia and other infectious and parasitic diseases, many of which respond to treatment with antibiotics and sulfa drugs. Thus, it is not surprising that decline in mortality due to this set of causes accounts for most of the mortality decline during this period, which was marked by the introduction and diffusion of many of these ''wonder drugs.'' It is also not surprising that after these drugs had been widely diffused and deaths from diseases that respond to this treatment had been largely eliminated, the rate of decline in this category slowed.

Influenza and pneumonia are still a major component of this category, along with such diseases as bronchitis, diabetes, peptic ulcer, cirrhosis of the liver, and kidney disease. Between 1968 and 1977 declines occurred in death rates from these diseases at every age group (the one exception being the death rate from cirrhosis for those aged 65 to 84) for a variety of reasons, which include improved use of medical care, diagnosis, and treatment. Reduction in cigarette use has also affected death rates from some of these causes.

Diseases of infancy

The rate of decline in deaths from diseases of infancy, which are largely due to prematurity and congenital malformations and occur in the neonatal period, has increased in recent years. A number of factors may have played a role in increasing the rate of decline. Some of these worked to reduce the proportion of high risk births; others increased the survival rate of these births. Declines in fertility rates, starting in the early 1960s, led to a decrease in the percentages of births to older mothers and of higher order births, both of which have a

greater risk of mortality. Some researchers have estimated that as much as 25 percent of the recent decline in infant mortality could be due to the reduction in higher order births (N. Morris et al., 1975; N. Wright, 1975). Most of this reduction would, of course, be in the diseases of infancy. More reliable methods of contraception and liberalized abortion laws may have increased the proportion of wanted births during the last decade. Assuming a lower rate of mortality among wanted births, this would lead to a decrease in infant mortality (V. Fuchs, 1974, p.33). Increasing the availability of medical care to the poor who have high infant death rates could have worked through prenatal care to decrease the number of high risk infants born and through postnatal care to decrease the death rate among those born. "The evidence mounts that properly organized and appropriate care of pregnant women before and at the time of delivery can make substantial inroads on infant mortality" (D. Rogers and R. Blandon, 1977).

In recent years, many advances have been made in the treatment and the delivery of care to premature infants, whose rate of infant death is ten times that of infants mature at birth. Treatment advances have developed with the science of neonatology. An example of new methods of delivering care to premature infants can be found in the intensive care units for the premature available in some parts of the country—particularly urban areas. A number of these have developed extensive transfer networks so that they are able to serve a large number of hospitals and a correspondingly large population base.

Violence

While changes in death rates from violence have been relatively unimportant in causing change in the age-adjusted mortality rate, they have been important in determining the trend in adolescent and young adult mortality. In 1968 at least half of the deaths for the age groups 5 to 34 were due to violent causes.

In the first period, deaths from violence were also reduced by the spread of antibiotics and sulfa drugs, since infection often accompanied injury. While medical and surgical techniques and emergency room medical care improved throughout the entire 1940–77 period, mortality rates did not continue to decline because the number of accidental injuries increased. Deaths from violence are primarily the result of accidents—motor vehicle accidents being the most common cause of mortality. As the number of cars per capita has increased, the percentage of people involved in motor vehicle accidents has also increased. However, between 1968 and 1977 accidental death rates in general and death rates from motor vehicle accidents declined in all age groups. Motor vehicle accident death rates did not decline steadily throughout the period but, rather, dropped sharply from 1973 to 1974 when speed limits were reduced to conserve fuel. After this initial reduction, the rates rose again in some age groups.

Working against the decline in accidental death rates, death rates from homicide increased in all age groups during the 1968–77 period. In the age

groups 5 to 44 and 65 to 84, increases in the rate of suicide supplemented the increases in homicide. Young adult mortality failed to decline at the same rate as mortality of other age groups because of increases in deaths from suicide and homicide among young adults. Easterlin (1980) has argued that increases in death rates from these causes among these age groups resulted from the pressures generated by their large cohort size.

Cancer

Cancer is another cause of death for which the trends across age groups have varied. This has occurred largely because cancer is not one disease that takes one form and for which there is one prescribed treatment; rather it takes many forms and has many treatments. Much of the variation in trends by age results from the fact that the site of cancer varies by age group and techniques of diagnosis and treatment differ by site. As noted there have been major advances in the treatment of the cancers most common to children. Programs emphasizing early diagnosis have led to declines in cancers among young adult women. In ages where death rates from cancer increased between 1968 and 1977 (above 45), the increase can be largely explained by increases in lung cancer and would not have occurred in most age groups had this type not increased. The trend in lung cancer for an age group is largely determined by the trend in cigarette consumption, with a 20- to 30-year lag. It is estimated that more than 80 percent of all lung cancer could be prevented if people stopped smoking (Public Health Service, 1979b, p. 65).

While lung cancer has been increasing in recent years, cancer of the digestive organs has been decreasing and quite significantly in some age groups. Changes in cancers of the digestive organs can be related to changes in food consumption and methods of preservation and preparation (American Cancer Society and National Cancer Institute, 1975).

While death rates from most other forms of cancer have not changed much in recent years, treatment and diagnosis have changed. Advances have been made in both radiation therapy and chemotherapy, while surgical techniques continue to evolve.

Actually, the stability in cancer death rates is, from one point of view, surprising. Even if the risk of dying of cancer remained unchanged one would expect increases in the cancer death rate due to decreases in death rates from other causes, because the survivors of these diseases would then be exposed to death from cancer. For instance, if the risk of dying from cancer had remained constant in the 1968 to 1977 period, one would have expected to observe increases in the cancer death rate over the age range due to this fact. The actually observed increases in the age groups 45–54 and 65–74 are not as large as would be expected if all other causes changed as they actually did and the force of cancer mortality remained unchanged. In the age groups below 45 the small increases in cancer that would be expected under this assumption are not observed. However, the observed increase between 1968 and 1977 in

cancer death rates for the 55–64 year olds is larger than that which would be expected under these same assumptions.

Projections of mortality to the year 2000

Let us turn from the past to the future. Current mortality projections substantially discount the pace of recent mortality declines and project only mild future mortality declines (F. Bayo, H. Shiman, B. Sobus, 1977; S. Mushkin and D. Wagner, 1978). Presently we know too little about the forces responsible for the cause-of-death pattern of mortality decline apparent since 1968 to project it into the future with much confidence. It is interesting to speculate, however, that we are witnessing the beginning of a new phase of mortality decline in which advances in regard to the treatment of cardiovascular diseases take up the role played from 1940 to 1954 by antibiotics in reducing mortality due to infectious diseases. This is an idea that has been promoted by some experts in the field. A noted medical researcher said at the 1979 Conference on Heart Disease, "In the history of every disease a critical moment occurs when major advances become possible. I believe we have reached this critical moment with respect to coronary artery disease" (Braunwald, 1979, p. 144).

To explore the implications of this hypothesis, age-specific mortality rates are projected here to the year 2000 on the assumption that within each age group the annual percentage rate of change from 1968 to 1977 for each of the causes identified in Figure 6 continues from 1977 to 2000. Such a projection, based on a model of principal causes within each age group, is more plausible than a simple extrapolation of the total rate for each age group because trends in specific causes are affected by different underlying factors.[3]

In effect, such a projection explores the implications of assuming the continuation of recent mortality improvements in regard to cardiovascular diseases, "other diseases," and infant deaths, and of deterioration in some age groups with regard to deaths by violence and cancer. Before considering the results of the projection, let us assess the plausibility of this assumption.

While it is difficult to assess the role of each factor in the recent cardiovascular mortality decline, the increasing knowledge in recent years about the prevention, treatment, and diagnosis of these diseases can serve as a foundation for future declines. Life-style changes made to prevent cardiovascular disease should continue to take place, and those that have already occurred may have more effect after a longer period of time. Diffusion of current medical techniques can still cause substantial mortality decline in this area. While the percentage of people with undiagnosed hypertension has declined since the early 1960s, a national survey in the first half of the 1970s indicated that over half (54.9 percent) of those with hypertension still remain undiagnosed (National Center for Health Statistics, 1977b, p. 19). More universal diagnosis and treatment of this condition should continue to decrease cardiovascular mortality for years to come.

Experts on cancer are not nearly as optimistic or unified on the outlook

for cancer death rates as heart disease experts are on the outlook for heart disease. Some experts predict substantial increases, others predict substantial decreases, but on the average they predict little change (S. Mushkin and D. Wagner, 1977). That the 1968 to 1977 trends of small decreases in the young adult years and small increases in the older adult years would continue into the future is not implausible. Most experts do not predict significant decreases for cancer death rates in the near future because comparatively little is known about its causes and prevention. Even as cancer treatment is developed it is possible that cancer death rates may not decline and could increase as exposure to carcinogenic substances is increased. What happens to death rates from respiratory cancer is largely a function of what happens to cigarette smoking and cigarette development. There are many other carcinogenic substances in the environment, however, that may have yet to show their effects on mortality rates, such as synthetic chemicals developed in the past 25 years to which people have not yet had extended exposure. Substantial exposure to these substances currently occurs in the workplace. It is estimated that now 20 percent of all cancers may be related to carcinogens encountered in the work-place (Public Health Service, 1979b, p. 107). The effect of this exposure may not be fully felt for some time to come.

If dramatic therapeutic advances in immunotherapy and chemotherapy were made, it is possible that current trends in cancer mortality could change, but because cancer takes so many forms and invades so many systems of the body this is unlikely to occur in the near future.

Continued declines in diseases of infancy seem probable, as prenatal and postnatal care continues to be extended to subgroups of the population and as methods of preventing and treating prematurity advance. "Other" diseases will probably also continue to decline at their current rate, as advances are made in the treatment and prevention of diabetes, influenza and pneumonia, and kidney diseases. The trend in the cirrhosis death rate may not be down, as this is largely determined by the trend in alcohol consumption.

What will happen to deaths from violent causes is probably most difficult to predict. Emergency medical treatment can continue to advance and the death rate from these causes continue to increase if the number of violent occurrences increases. While we assume that death rates for these causes will continue upward in the young adult ages for our projection, it is worth noting that Easterlin has predicted a downturn in these death rates in the 1980s (Easterlin, 1980).

From this analysis of factors affecting the recent decline in mortality, it seems reasonable to conclude that projection of current trends may present a plausible picture of the future. Let us turn then to the specifics of the projection. The expectations of life at various ages from the life table con-structed from age- and cause-specific death rates based on the assumptions mentioned above are shown in Table 2. Life tables for the other dates in this analysis and for 1901 are also shown for comparison. If current trends continue, life expectancy at birth (for the two sexes combined) in the year 2000 will be

TABLE 2   United States: expectation of life (both sexes) at selected ages: 1901, 1940, 1954, 1968, 1977, and projected for 2000

Age	1901	1940	1954	1968	1977	2000 (Projected)
0	49.2	63.6	69.6	70.2	73.2	80.4
15	46.8	53.1	57.1	57.2	59.6	66.2
45	24.8	26.9	29.4	29.6	31.8	37.9
65	11.9	12.8	14.4	14.6	16.3	21.8
75	7.1	7.6	9.0	9.1	10.4	15.3

SOURCES: For 1901, U.S. *Life Tables, 1890, 1901, 1910, and 1901-1910*, Department of Commerce (Washington, D.C.: US Government Printing Office, 1921), pp. 52–53. Data for more recent years—through 1977—are from *Vital Statistics of the United States* (Hyattsville, Maryland: National Center for Health Statistics, DHEW, selected years).

80.4 years, an increase of 7.2 years from 1977. Perhaps the most interesting feature of the projected life table is the increase in the length of life at the oldest ages. Between 1977 and 2000 life expectancy would increase 5.5 years at 65 and 4.9 years at 75. This would create a novel situation in which about three-fourths of the increased life expectancy at birth would be due to mortality declines at the oldest ages. From the beginning of the century until 1977 life expectancy at age 65 only increased 4.4 years. During this same period expectation of life at birth increased 24 years. If current trends continue until 2000, life expectancy for those over 65 will increase over 1977 levels by about one-third (33.7 percent) and for those over 75, by almost one half (47.1 percent).

   This projection is made assuming that yearly rates of change continue at the 1968 to 1977 pace for each of the five disease categories. Since the rate of change in cardiovascular diseases is overwhelmingly important in determining the projected expectation of life, mortality rates are also projected assuming the yearly rate of decline between 1977 and 2000 for cardiovascular diseases is only half of that experienced between 1968 and 1977. Under this assumption expectation of life at birth (e_0^0) would be 77.8 and expectation of life at age 65 (e_{65}^0) would be 19.3 at the turn of the century. These numbers indicate that even with a radically reduced rate of improvement in cardiovascular mortality in the coming years, there would still be substantial improvement in life expectancy.

   It should be noted that projecting age-cause-specific mortality rates produces results that differ from projection based solely on total age-specific rates not divided into cause groups. If the projection from 1977 to 2000 were made assuming that the age-specific rates of change experienced between 1968 and 1977 continued to 2000, the projected mortality rates would be lower at every age and the projected e_0^0 for 2000 would be 1.3 years greater than that projected from the component causes. Projecting total age-specific rates does not recognize that unless all causes change at the same rate, causes within the total will become more or less important as mortality changes; hence, to generate constant change by age over time one has to assume a changing pattern of cause-specific rates of change over time.

    This component-causes method of projection presents a much more optimistic picture of mortality conditions for the year 2000 than the Census Bureau projection. The present projection of e_0^0 of 80.4 compares with a census projection of 74.1. For e_{65}^0 the difference is between 21.8 and 16.8 (Siegel, 1978, p. 16).

    The projected improvement in mortality for those over 65 made by the Census Bureau is very low relative to current rates of change. The census projection was made in 1976 when e_0^0 was 73.1 and e_{65}^0 was 16.0 (Siegel, 1978, p. 16). It projects that between 1976 and the year 2000, life expectancy at birth will increase by 1.0 years and life expectancy at age 65 by 0.8 years. Between 1976 and 1977 (the year that is the base for the component-cause method), the actual increases in e_0^0 and e_{65}^0 were 0.4 and 0.3 respectively.

    The Census Bureau projection is currently used as the basis for estimating the population in the year 2000 aged 65 and over eligible for certain government programs. If the projection here is closer to the truth, the actual number of people over 65 enumerated in the year 2000 will be approximately 35.7 million rather than 31.9 million as officially projected (Siegel, 1978, p. 17).

    If projected trends continue until the year 2000, mortality improvement beyond that date will be much more dependent on the medical and life-style innovations that affect the death rate from cancer than those that affect heart disease. The percent distribution by cause of the projected total age-standardized death rate for the year 2000 is shown below.

Cause	Percent
Diseases of infancy	1.1
Cardiovascular diseases	33.9
Cancer	33.8
Violence	12.3
"Other"	18.9
Total	100.0

If current trends continue—increases in cancer and decreases in heart disease—in the year 2000, cancer will be as important a cause of death as cardiovascular disease.

    To recapitulate our argument, the trend in US mortality rates during 1940–77 can be divided into three distinct periods—two periods of rapid decline surrounding a period of little decline. The two periods of rapid decline, although somewhat similar in rate, were caused by different factors. In the first period, much of the decline was due to a reduction in deaths from diseases that were cured with antibiotics and similar drugs. Much of the recent decline is accounted for by decreases in cardiovascular diseases. This is the first time in history that mortality declines have been dominated by decreases in diseases of old age or degenerative diseases. Because this is so, we may be beginning a new era of mortality decline, which, if it continues, will lead to large increases in life expectancy at older ages.

Notes

This is a revised version of a paper presented at the 1980 meetings of the Population Association of America. The author is grateful to Harry Rosenberg of the NCHS for supplying unpublished data and to John D. Durand and Richard A. Easterlin for comments.

1 Because comparability ratios and/or death rates were not available for 1940 and 1954, it is impossible to compute comparable rates for three of the 15 leading causes (i.e., influenza and pneumonia; bronchitis, emphysema, and asthma; and nephritis).

2 The four nonresidual cause categories here correspond to the following categories in the *Eighth Revision of the International Classification of Diseases*.

— cancer (malignant neoplasms 140–209)
— cardiovascular diseases (diseases of heart 390–398, 402, 404, 410–429; cerebrovascular diseases 430–438; arteriosclerosis 440)
— violence (accidents EOO–E949; homicide E960–E978; suicide E950–E959)

— diseases of infancy (certain causes of mortality in early infancy 760–769.2, 769.4–772, 774–778; congenital anomalies 740–759)

3 An almost identical projection technique was used by Harold Dorn in 1952. After examining mortality change over the 1920–1947 period he projected mortality rates by assuming that the annual rates of decrease experienced for the years 1936–38 to 1946–48 continued up to 1960 and 1970 for accidents, cancer, cardiovascular-renal diseases, and all other causes as a group. His estimated expectations of life at birth for 1970 were lower than those calculated from the year's actual mortality experience by 1.0 year for white females and 2.1 years for white males. He more severely underestimated the expectation of life of the black population. For black males his estimate was 6 years below that actually experienced. For black females the projected value fell short of the actual value by 2.4 years. His projection was for a more optimistic mortality outlook, however, than others made about the same time and thus was closer to actual experience (H. Dorn, 1952).

References

American Cancer Society and National Cancer Institute. 1975. "Symposium: Nutrition in the causation of cancer," *Cancer Research* 35, no. 11, part 2.

Bayo, Francisco R., Howard W. Shiman, and Bruce R. Sobus. 1977. *United States Population Projections for OASDHI Cost Estimates*. Actuarial Study no. 76 (Social Security Administration: Office of the Actuary).

Berkson, David M., et al. 1977. "The current improved status of hypertension detection and treatment in Chicago," *Circulation* 56: III-170 (abstract).

Board of Agriculture and Renewable Resources, Commission on Natural Resources and Food and Nutrition Board, Assembly of Life Sciences. 1976. *Fat Content and Composition of Animal Products* (Washington, D.C.: National Academy of Sciences).

Borhani, Nemet O. 1979. "Mortality trend in hypertension, United States, 1950–1976," in *Proceedings of the Conference on the Decline in Coronary Heart Disease Mortality*, ed. Richard J. Havlik and Manning Feinleib (Washington, D.C.: Public Health Service).

Braunwald, Eugene. 1979. "Statement," in *Proceedings of the 1979 Conference on Heart Disease* (Washington, D.C.: National Academy of Sciences).

———. 1980. "Treatment of the patient after myocardial infarction," *New England Journal of Medicine* 302:290–293.

Dorn, Harold F. 1952. "Prospects of further decline in mortality rates," *Human Biology* 24:235–261.

Easterlin, Richard A. 1980. *Birth and Fortune* (New York: Basic Books).

European Coronary Surgery Study Group. 1979. "Coronary-artery bypass surgery in stable angina pectoris: Survival at two years," *Lancet* 1:889–893.

Fuchs, Victor R. 1974. *Who Shall Live? Health Economics and Social Choice* (New York: Basic Books).

Hiatt, H. H. 1977. "Lessons of the coronary-bypass debate," *New England Journal of Medicine* 297:1462–1464.

McIntosh, Henry D., and Jorge A. Garcia. 1978. "The first decade of aortocoronary bypass grafting, 1967–1977," *Circulation* 57:405–430.

Morris, Naomi M., J. Richard Udry, and Charles L. Chase. 1975. "Shifting age parity distribution of births and decrease in infant mortality," *American Journal of Public Health* 65:359–362.

Mushkin, Selma J., and Douglas P. Wagner. 1977. *Projected Mortality in the Year 2000 Due to Cancer* (Washington, D.C.: Public Services Laboratory, Georgetown University).

———. 1978. *Expected Mortality as a Criterion in Health Policy Evaluation* (Washington, D.C.: Public Services Laboratory, Georgetown University).

National Center for Health Statistics. 1964. *The Change in Mortality Trend in the United States*, Series 3, no. 1 (Washington, D.C.: US Government Printing Office).

———. 1975. *Physician Visits: Volume and Interval Since Last Visit, United States, 1971*, Series 10, no. 97 (Washington, D.C.: US Government Printing Office).

———. 1977a. "A comparison of levels of serum cholesterol of adults 18–74 years of age in the United States in 1960–62 and 1971–74," Advance data, no. 5.

———. 1977b. *Blood Pressure Levels of Persons 6–74 Years: United States, 1971–74* (Hyattsville, Md.: US Department of Health, Education, and Welfare).

———. 1978. *Exercise and Participation in Sports Among Persons 20 Years of Age and Over: United States, 1975* (Washington, D.C.: US Department of Health, Education, and Welfare).

New England Journal of Medicine. 1977. "Special correspondence: A debate on coronary bypass," *New England Journal of Medicine* 297:1464–1470.

Public Health Service. 1976. "Adult use of tobacco, 1975," unpublished manuscript.

———. 1979a. *Smoking and Health: A Report of the Surgeon General* (Washington, D.C.: US Government Printing Office).

———. 1979b. *Healthy People: The Surgeon General's Report on Health Promotion and Disease Prevention* (Washington, D.C.: US Government Printing Office).

Rogers, David E., and Robert J. Blendon. 1977. "The changing American health scene: Sometimes things get better," *Journal of the American Medical Association* 237:1710–1714.

Siegel, Jacob S. 1978. "Prospective trends in the size and structure of the elderly population, impact of mortality trends, and some implications," *Current Population Reports*, Series P-23, no. 78 (Washington, D.C.: US Government Printing Office).

Stamler, Jeremiah, et al. 1976. "Hypertension screening of 1 million Americans:

Community Hypertension Evaluation Clinic (CHEC) Program, 1973 through 1975," *Journal of the American Medical Association* 235:2299–2306.

Stern, Michael P. 1979. "The recent decline in ischemic heart disease mortality," *Annals of Internal Medicine* 91:630–640.

Taylor, Henry L., et al. 1975. "Secular changes in coronary heart disease risk factors," *Circulation* 52:II-96 (abstract).

Wright, Nicholas H. 1975. "Family planning and infant mortality rate decline in the United States," *American Journal of Epidemiology* 101:182–187.