Vital and Health Statistics

Reconsidering Age Adjustment Procedures: Workshop Proceedings

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This report contains papers presented at the Workshop on Age-Adjustment, March 7, 1991. Presentations are made by representatives of selected Federal, State, and international institutions dealing with issues in the use of the 1940 U.S. population as a standard for the age-adjustment of official statistics.

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Preface

This report contains papers presented at a workshop held at the National Center for Health Statistics (NCHS) on March 7, 1991. The workshop was held in order to address concerns arising from the use of the 1940 U.S. population as a standard for age adjustment of vital rates and to review issues surrounding the use of alternative standards from a variety of perspectives. Participants included representatives of selected Federal Government agencies, the National Committee on Vital and Health Statistics, the State of Michigan, and present and former NCHS staff.

Contents

Symbols

- - -	Data not available
. . .	Category not applicable
-	Quantity zero
0.0	Quantity more than zero but less than 0.05
Z	Quantity more than zero but less than 500 where numbers are rounded to thousands
*	Figure does not meet standard of reliability or precision
#	Figure suppressed to comply with confidentiality requirements

Part I

Introduction

Chapter 1
A reconsideration of age adjustment

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Introduction

During the last 150 years, there have been at least eight formal occasions that I have been able to identify on which experts have come together under the auspices of official statistical agencies or societies to discuss the issue of age adjustment. Undoubtedly, there have been innumerable other discussions that have not found their way into the literature. The need for this current workshop came about because of some adjustment issues that arose in formulating the health objectives for the Nation for the year 2000. We hope this workshop will provide a collegial discussion of these issues.

From another point of view, however, it is almost a court case with plaintiffs and defendants. The plaintiffs arguing that the current method has to be changed and offering reasons why, and the defendants arguing that the current method has been successful, or at least adequate, for its intended uses and should be maintained. At the end of this workshop, we will deliberate the claims and make recommendations as to how to adjudicate between them.

The crux of the issue is that we want to find out to what extent the current standard is truly inadequate—either not representing the true trends in a statistical sense or not communicating the intended message in a psychological or political sense. While age adjustment is used to enhance understanding of masses of data, it also conceals details; and we need to see examples of how this works in practice to the disadvantage of public health information, which will guide policies and inform the public.

As an introduction to these discussions, I would like to review briefly a few issues that have come up repeatedly in previous deliberations on age standardization and put them into a more modern perspective.

The distribution of the population and deaths by age

Figure 1 shows the number of deaths, the estimated midyear population, and the calculated death rates by age for the United States in 1986. Ten-year intervals are used except for ages less than 1 year, 1–4 years, and 85 years and over. Many demographers have been struck by the exponential nature of the mortality curve (for example, Gompertz), which ranges from 236 per million at ages 5–9 years to 153,989 per million at ages 85 years and over. Most age adjustment methods weight the individual age-specific death rates by a standard distribution of the population or of the number of deaths in order to provide a single index, which is to serve as a summary indicator of this broad range of death rates (See part II). Some causes for concern are immediately obvious. Since most deaths occur over 70 years of age, age adjustment methods based upon numbers of deaths will give great weight to this portion of the age range. Those based on population distributions will give more weight to the younger age groups.

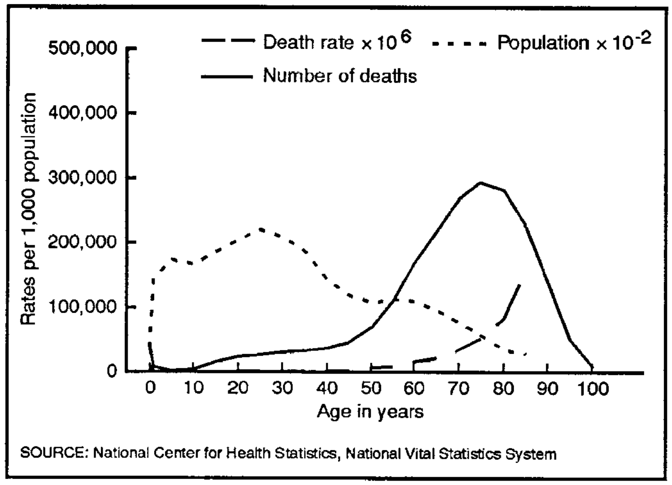

Figure 1. Number of deaths and death rates: United States, 1986

The current practice is to calculate a single death rate for the 85 years and over population. Currently, nearly 20 percent of all deaths are included in this single group. As the population ages and the mortality curve becomes flatter into older ages, more and more deaths will occur in this terminal open-ended stratum. A single death rate calculated for this group will not be sensitive to any changes in the age-specific death rates over the age of 85.

Historical perspective

The earliest reference to age adjustment that I have been able to find comes in an 1844 paper by F.G.P. Neison (1) presented to the Statistical Society of London (now the Royal Statistical Society). Neison was responding to an issue raised by Sir Edwin Chadwick concerning the measurement of the health of different communities. Chadwick had recommended the examination of the average age at death of those who had died during a particular year in the relevant communities as an indication of the comparative health conditions in those communities. Neison pointed out that the average age at death would depend to a large extent on the age distribution of the residents of the communities. While Chadwick's method may have had some merit if the populations of the communities had been closed and stable, Neison recognized that differing migration and birth patterns produced differences in the age distributions, which would have a profound effect on the average age at death.

In his paper Neison compared the mortality of two communities, Bethnal-green and St. George's Hanover-square, and proposed that in order to overcome the differences in age structure, ''. . . we shall suppose that the population of Bethnal-green is actually transferred to St. George's . . .'' and subject it to ''. . . exactly the same rate of mortality as that prevailed in St. George's Hanover-square''—the only change being a change in population. Bethnal-green is taken here to be the standard population.

Here we have—almost fully blown—the direct standardization method. As a matter of fact, later in the paper the indirect method of standardization is presented as well. One year later, Neison presented an even more detailed report using the same method comparing occupational classes (2).

A more complete historical review is presented in part II in a paper presented by Lester Curtin.

Age patterns of mortality by cause

As I have indicated, mortality rates vary considerably with age. The trends in mortality rates over time also vary by underlying cause of death. Figure 2 shows changes between 1940 and 1988 in age-specific mortality rates from accidents, cancer, and heart disease.

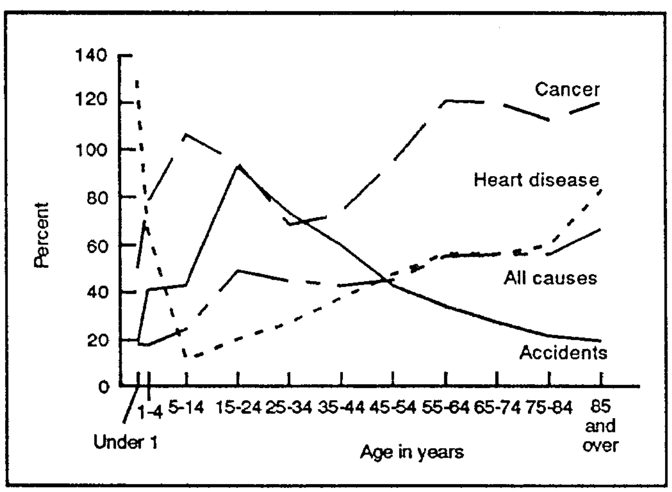

Figure 2. Age-specific mortality rates from selected causes, 1988 as percent of 1940

For all causes combined, there has been tremendous improvement at virtually all ages. At the youngest ages, mortality is only 20 percent of what it was 50 years ago—a tremendous improvement by any standard. Even at the older ages, mortality is only about 60 percent of what it was in 1940.

In the case of heart disease there has, at the youngest ages, actually been an increase due to better diagnosis of congenital conditions. At 5–14 years of age, mortality from heart disease is only about 10 percent of what it was. With advancing age, the improvement is progressively less impressive so that at age 85 years and over the 1988 rate is only 20 percent less than the rate for 1940.

In contrast, trends in mortality from accidents indicate that while young adults have just about the same rate they had 50 years ago, there have been great improvements among children and even more dramatic improvements among the elderly. We have made the environment much safer for elderly people. There have been great improvements in industrial and occupational accidents, and people who fall and break a hip will usually survive, whereas, 50 years ago it was virtually a death sentence.

The situation with cancer is more complicated. Significant progress has been made in infancy but we have not done as well among those 5–14 years of age. I imagine that some of the increase in mortality at these ages represents a postponement of deaths from younger ages. We have done well among young adults but after the age of 55 there has actually been a 20 percent increase since 1940.

The effect of using different standard populations

To show the effect of using different standard populations when employing the method of direct standardization, we have examined trends for six different populations (figure 3):

U.S. 1940. This population has been used for nearly 50 years in the United States. It emphasizes the age group 15–24 years, and then it has a nearly linear decline to ages 85 years and over.

WHO WORLD. WHO has estimated the world population for 1975, which is even younger than the U.S. 1940 population but has essentially the same structure (3).

WHO European. This standard is based upon the populations of the European countries in 1975 and is quite older than the WHO WORLD population. Between the ages of 5 and 64 years, there is virtually a uniform distribution of population and then a linear decline through the remaining ages (3).

U.S. 1990. Because of its recency, this has been proposed as a new standard. It is similar to the WHO European standard, except for distortions due to the baby boom.

World Bank 2020 and 2050. Using World Bank projections for nine industrialized countries (4), Dr. Alvan O. Zarate and I have developed standard populations for the year 2020 and 2050. The idea being that since the choice

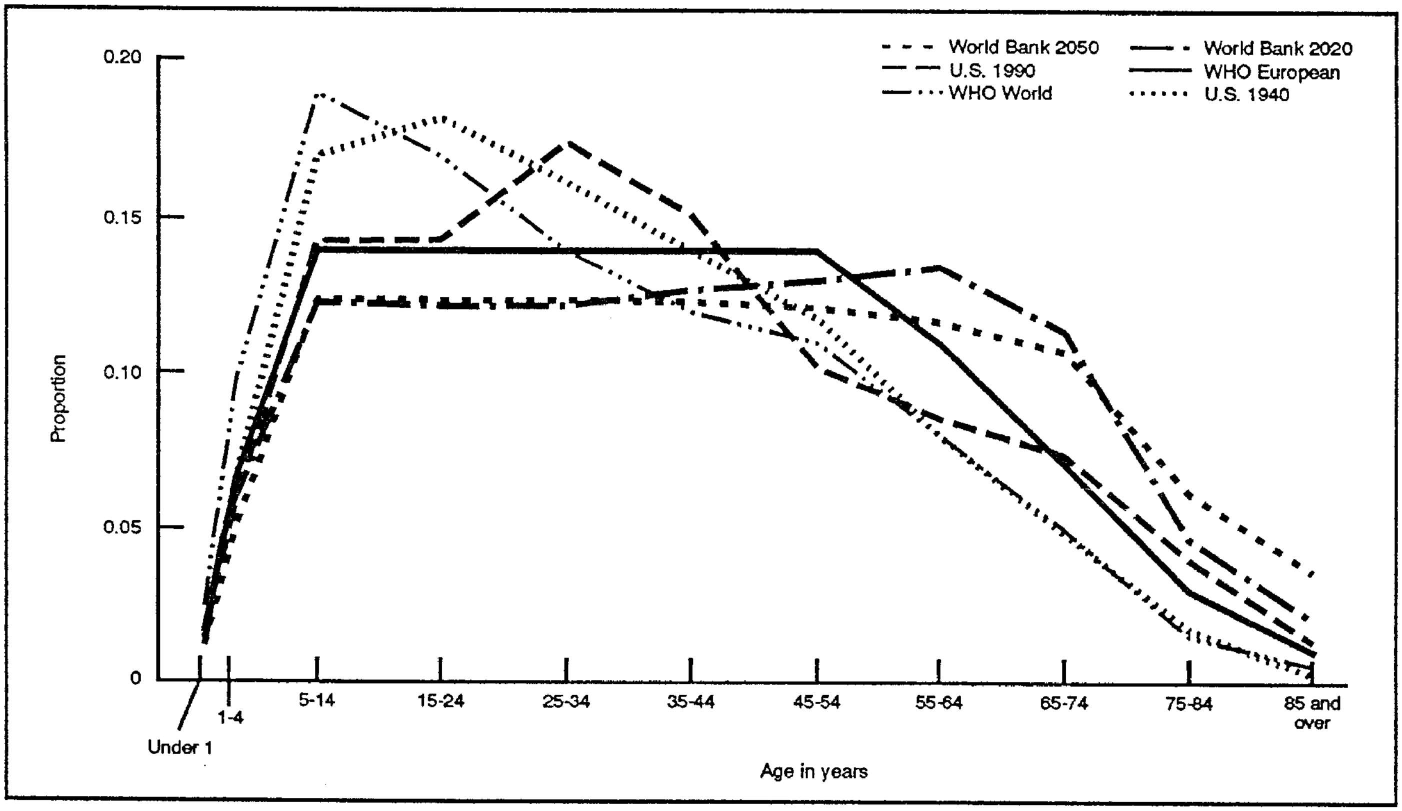

Figure 3. Age distribution of six standard populations

of the standard population is somewhat arbitrary, instead of looking back into the past we might look ahead to the standard population that we are aiming toward and that if the population changes as predicted, the age-adjusted rate might approximate the crude rate. The 2020 and 2050 standards are similar except that the 2020 standard reflects the lingering effects of the post-World War II baby boom while that for 2050 eliminates the baby boom and allows for some improvement in mortality at the older ages.

Now let us examine the effect of applying the six different standards to the three disease conditions mentioned previously.

Cancer

Using the U.S. 1940 population, the trend in cancer mortality shows about a 10 percent increase (figure 4). Because the other standards are based on older populations (the WHO WORLD is excluded), they all result in higher rates but the trends are quite similar, with increases ranging from 10 percent using the U.S. 1940 standard to 15 percent using the 2020 or 2050 populations. The unadjusted rate increased by 64 percent.

From the point of view of the long-term trend in cancer then, these rates are essentially equivalent—although the absolute rates themselves are quite different. None of the standard populations can reveal the differences in trends among the younger and older adults and, indeed, because of the grossly different time trends among

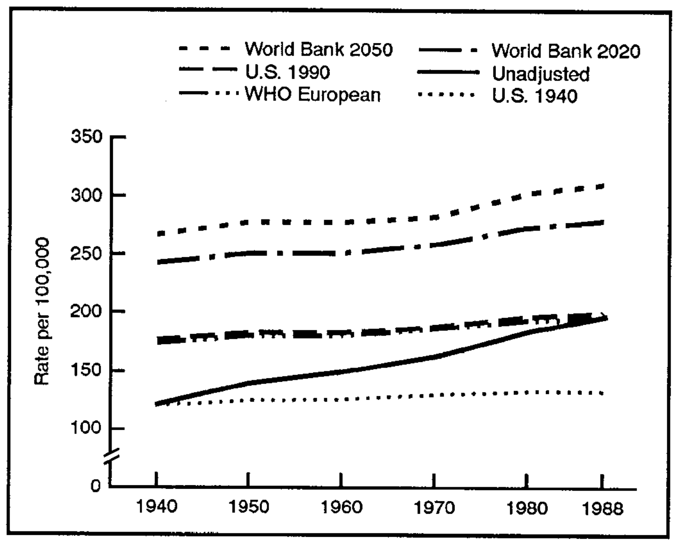

Figure 4. Age-adjusted death rates for cancer using alternate standards

these two different age segments, a single age-adjusted rate should probably not be used to summarize these trends.

Heart disease

Figure 5 shows that the unadjusted mortality rate for heart disease appears to have peaked sometime around 1960, while use of the 1940 standard results in a peak at about 1950. Again, all of the standards show similar trends

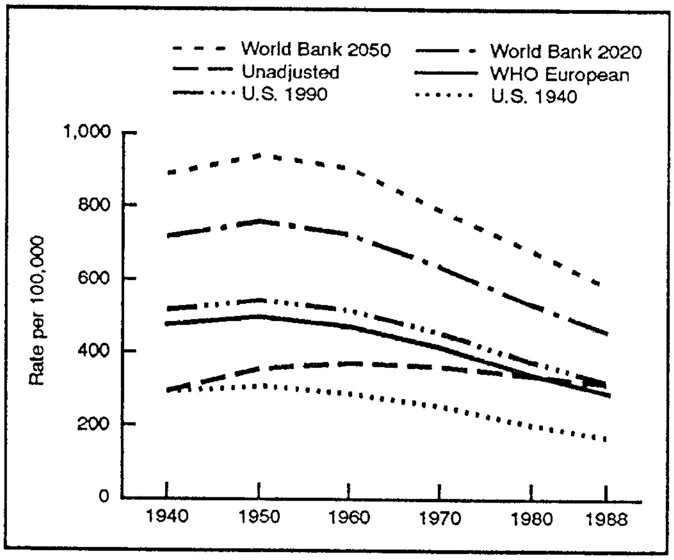

Figure 5. Age-adjusted death rates for heart disease using alternate standards

with declines ranging between 57 (1940) and 66 (World Bank 2050) percent. Whatever standard is used, the interpretation would be quite similar.

Accidents

Accidents present a paradoxical picture because as we indicated, mortality was extremely high among older age groups in 1940, and the most dramatic declines have occurred in these groups (figure 6). Yet, because the 1940 standard population is young compared with the other standards under examination, the smallest improvement in overall mortality results from its use.

While the trends are similar no matter which standard is used, the order of magnitude is quite different. Using the 1940 population, 1988 accident mortality is 48 percent of that for 1940. Using the 2050 standard, mortality is

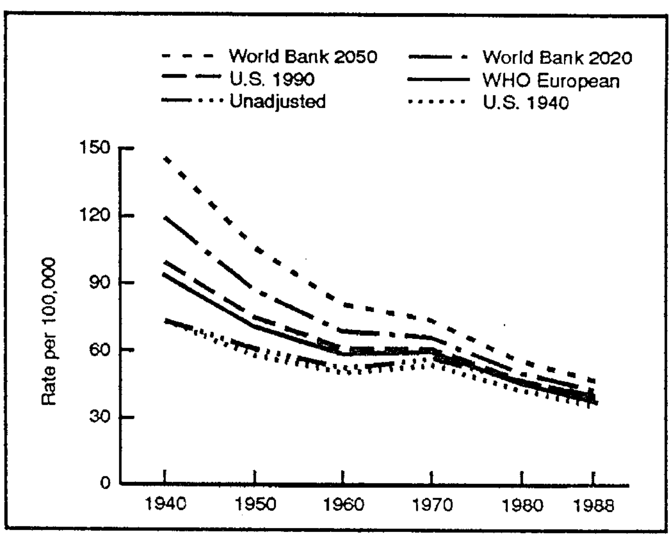

Figure 6. Age-adjusted death rates for accidents using alternate standards

32 percent of what it was in 1940, but again, there is an unmistakable decline.

This demonstrates some of the varied results that can be obtained by using different standards. While the trends are sometimes more dramatic using the older standards, the results are essentially the same.

The key dilemma that arises in using an age-adjusted rate is the impossibility of a single index being able to reflect nonhomogeneous effects. As long as the trends over time for different age groups are nearly the same, any reasonable choice of standard population will serve to reflect the overall trend adequately and permit comparison of different populations. The greater the disparity in trends by age, the more unsatisfactory will a single summary measure be. There is general consensus that serious investigations of trends should consider the trends in age-specific rates. But because such analyses become very detailed, it is still desirable to provide some simplifying summary. If a single measure is deemed unsatisfactory and detailed age-specific trends too complex, is it possible that a compromise can be struck by using a relatively small number, say 5 or 6, of broader age groups that will reflect the general trends, show major inhomogeneities, and yet be readily understandable by most data users?

For example, the following segmentation of the age range (with age adjustment within each strata, if necessary) may serve to accomplish these ends:

1. Infant mortality
2. Ages 1–14 years
3. Ages 15–34 years
4. Ages 35–64 years
5. Ages 65–84 years
6. Ages 85 years and over

It will be useful in our discussion to examine this concept and see if a consensus could be reached about appropriate age strata.

Charge to the workshop

With this as an introduction, I wish now to have the workshop participants review and make recommendations concerning the following:

1. The potential confusion among some data users in understanding the difference between crude and age-adjusted rates and the disparity between the magnitude of crude and age-adjusted rates.
2. The adverse ''psychological'' effect of current rates being adjusted by the 1940 population.
3. Differences in trends for certain causes of death when different standards are used.
4. The appropriateness of adjusting at all when trends differ markedly across age groups.
5. The impact of using different standards by different Federal agencies or in different reports.
6. The lack of information concerning the rationale for use of Federal standards.

Some of these issues I have already briefly touched on but I hope that in our presentations and discussions, we will give adequate consideration to all of these concerns and develop a set of recommendations for dealing with them.

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Part II

Historical and methodological perspectives

Chapter 2
A short history of standardization for vital events

by Lester R. Curtin, Ph.D., Office of Research and Methodology, National Center for Health Statistics

Introduction

In 1662, John Graunt published *Natural and Political Observations Mentioned in a Following Index and Made Upon the Bills of Mortality* (1). This analysis of the Bills of Mortality for London signaled the beginning of the development of analytic methods, such as the life table method, for using vital statistics and mortality data to examine public health issues.

A large variety of summary indexes for mortality have been proposed since the time of John Graunt. Most of these indexes consider the problem of standardization for differential age distributions. In the following, a brief history of two such summary indexes is presented that draws heavily on some previously published work.

Lilienfeld and Lilienfeld, in examining the history of epidemiology, took note of beginnings of age standardization for mortality data (2). That article, plus a later one by Lilienfeld (3), are the sources of much of the following information. In addition, more detailed history and discussion of mortality indexes can be found in chapter 4 by Woolsey in *Vital Statistics Rates in the United States, 1900–40* (4) and in the chapter by Pearl in *Medical Biometry and Statistics* (5).

Background

The development of analytic methods for vital statistics coincided with many of the initial developments in the field of mathematical statistics. Some time after Graunt, DeMoivre published his ‘‘Doctrine of Chances’’ in 1718 and is often credited with the discovery of the normal curve in 1733 (6). Laplace published ‘‘Theorie Analytique des Probabilites’’ in 1812, the same year Gauss published the ‘‘Theory of Least Squares’’ (5). Naturally, these theoretical developments were soon followed by new applications of the methods.

The Frenchman Pierre Charles-Alexandre Louis is attributed with the first vigorous applications of statistical methods to medical data, starting around 1830. Louis popularized the use of numerical methods in the study of medicine and was ‘‘responsible for the development of current concepts of epidemiologic reasoning’’ (3). Two of Louis’ students, William Guy and William Farr, were responsible for the development of the English school of statistics in the mid-1800’s. William Guy, a professor of medicine at King’s College, London, used statistical methods to study occupation diseases (7) and was probably the first person to employ Monte Carlo simulation to empirically examine statistical theories (8). William Farr’s contributions to epidemiology were numerous (2,3); his work has been collected in a memorial volume (9).

The growing science of statistics was still in its infancy when, at the suggestion of the British Association for the Advancement of Science, the Statistical Society of London was formed in 1834 (10). The Royal Actuarial Society was founded 14 years later, in 1848, and the London Epidemiological Society was formed March 6, 1850 (2). Thomas Malthus, Benjamin Gompertz, Auguste Quetelet, and Sir Edwin Chadwick were among the notable founders of the Statistical Society of London (10). Thomas Malthus is, of course, famous for his theories of population growth. Benjamin Gompertz developed the first mathematical model for mortality data. Auguste Quetelet, a Belgium statistician who trained briefly in France with Fourier and Laplace, was influential in the application of statistical thought to the social sciences (6). Sir Edwin Chadwick, a sanitary reformer, was indirectly responsible for the development of standardized rates. Because of the influence of these statistical pioneers, about one-third of the early papers presented at the Statistical Society of London were concerned with vital statistics (10).

During this period, English Public Health Practitioners, sometimes referred to as ‘‘sanitary physicians,’’ recognized the importance of mortality data as a means to describe and compare the health of various communities. These early public health practitioners also began to realize that the crude death rates were not appropriate to compare the health conditions for various small geographic areas. It was the issue of geographic comparisons of mortality that lead to the development of the present methods of direct and indirect standardization.

The beginning of the use of standardization

By the 1840’s, comparisons of crude rates were recognized to be inappropriate when the age distributions of the geographic areas differed greatly. Public health analysts wanted an index of mortality that would be free from the effect of age differences; they also wanted an index that would provide for an economy of expression and a simple summarization of mortality. While many different summary measures of mortality have been proposed over the last 150 years, two particular indexes remain as the most used.

These two widely used summary indexes for mortality data have become known as the direct standardized (age-adjusted) death rate and the indirect standardized death rate. Indirect standardization is often interpreted as an approximation to the method of direct standardization. That is, when data needed to compute a direct measure are not available, analysts may still have enough information to compute an indirectly standardized measure. However, the indirect standardization has intrinsic value and should be considered on its own merits, not solely as an approximation to direct standardization (4). Although demographic textbooks will often denote the direct measure as the preferred measure, this viewpoint is definitely not shared by everyone.

Interestingly, although the direct measure is now the preferred measure for vital statistics in the United States, it appears as though the indirect standardized death rate may have appeared first in (British) official government statistics. Benjamin and Pollard state:

> The first reference to a standard rate occurs in Farr's report of 1856 (Sixteenth Annual Report of the Registrar General for 1853) . . . The concept was later used (Twentieth Annual Report) to calculate a standard ''natural'' death rate for London in order to assess the excess mortality of the Metropolis. Essentially it represented ''indirect'' standardization. It appears that the direct method was due to Ogle who read a paper on the subject to the International Statistical Institute in 1891, recommending the use of an international standard population (though the direct method had in fact been employed in the Annual Report of the Registrar General for 1885) (11).

However, Benjamin and Pollard may be incorrect on both the first appearance of the direct standardized rate and as to who suggested the direct method. Several papers have attributed the first use of a standardized rate to Neison in 1844 (3,4).

Neison read a paper before the Statistical Society of London (now the Royal Statistical Society) on January 15, 1844. This paper was a response to a paper read by Sir Edwin Chadwick at the previous meeting of the Society. Subsequently, both papers were published in the Journal of the Royal Statistical Society (12,13).

Sir Edwin Chadwick was one of the early public health reformers in England. In particular, he was interested in the sanitary conditions of the laboring poor and the subsequent differences in health between urban and rural areas (14). Chadwick had written a report in 1842 that emphasized the link between disease and ''dirt'' due to insanitary conditions and overcrowding. His report stressed both the economic cost of ill-health and the social cost in terms of morals and habits (15,16). To support his conclusions, Chadwick examined mortality data for the different sanitation districts.

In a paper read before the Royal Statistical Society, Chadwick proposed the use of a mean age at death as an index of health that could be used to compare the health of the various ''sanitation districts'' around London. He argued that the mean age reflected a true summary of the age-specific risks of dying. Neison, a practicing actuary, took exception to the logic behind Chadwick's proposal and in a very brief period put together a rather remarkable article that introduced both the concepts of direct and indirect adjustment as well as introducing the term ''standard population.''

Basically, Neison recognized that the age distributions for the various community populations were very different. He reasoned that, because mortality increased with age, Chadwick's mean age at death for those communities with a relatively older population would tend to overstate the excess of death.

In order to account for the difference in age distribution of the communities to be compared, Neison states:

> We shall suppose that the population of Bethnal-green is actually transferred to St. George's, Hanover-square, but influenced by exactly the same rate of mortality (12).

That is, the age-specific rates for each community could be assumed to apply to exactly the same population distribution by age. Neison then used the expected deaths by age to compute an adjusted, or corrected, mean age at death; the method proposed is clearly the method of direct standardization.

Neison compared the crude mean age at death with the mean age computed by a method of direct standardization to illustrate the fallacy of Chadwick's comparisons. At that time, mortality rates were given as ''mortality percents,'' and Neison's table included a mortality percent for ''deaths transferred''—that is, Neison computed an age-adjusted rate by the direct method with the population of Bethnal-green as the standard. Neison even called the population a standard, viz. ''what would have been the result provided they had been under the Bethnal-green standard of population'' (12).

Neison goes on to state ''another method of viewing this question would be to apply the same rate of mortality to different populations'' (12). This, of course, is the method of indirect standardization. Neison again used the indirect method to compute an adjusted mean age at death; but he did not carry through on the method to compute what we would now call a standardized mortality ratio.

A short time after Neison had read his paper, William Farr entered the debate in a curious manner. Farr had been appointed compiler of abstracts in the office of the Registrar General in 1839. According to Lilienfeld (3), after Neison's paper had been presented, Chadwick had shown his analyses to Farr and Farr had apparently agreed with Chadwick. Chadwick then published his analysis along with Neison in the *Journal of the Royal Statistical Society*. But the *Lancet* published an editorial critical of

Chadwick's analysis. Much to Chadwick's surprise, the (unauthored) editorial was apparently written by Farr (3,17).

If this was indeed the sequence of events, then it is reasonable to assume that Farr was more in agreement with Neison; this is borne out by the subsequent use of the indirect adjustment procedure by Farr in 1853. Again, Neison had proposed both a direct and an indirect adjustment procedure, but Farr was the first to implement the indirect adjustment procedure. After the initial debate on standardization came to a close, Neison went on to become one of the founders of the Royal Actuarial Society; Chadwick continued to fight for reform of laws affecting the poor, and Farr became the leading epidemiologist of his time.

Use of direct standardization in England

Various mortality indices were published in reports of the Registrar General of England and Wales during the late 1800's (4). As mentioned, the indirect standardized rate was introduced in 1853. Woolsey, along with Benjamin and Pollard, states that the first use of the direct standardized rate was in 1883 in the Registrar General's report. The English reports continued to use direct standardization up to 1938. In 1946 the comparative mortality index was adopted, and then in 1958 the standardized mortality ratios were adopted (18,19).

When the first ''official'' direct standardized death rates were published in 1883, the standard population was based on the most current census population available, namely, the 1881 census population. The initial practice was to change the standard population every 10 years using each new census population. This was found to be problematic due to considerations of recomputing historical rates to assess current trends.

Because of the problems of changing standards every 10 years and the need for international comparisons as well, Ogle, one of Farr's successors, proposed the use of an international standard population (20). This standard was based on a composite of seven European country populations. However, the idea of one international standard never gained acceptance, even in England and Wales.

Around the turn of the century, England and Wales decided to adopt the 1901 population as ''the'' standard population and to use this standard even after a new decennial census. Note that at the time of its adoption, the 1901 population was the latest, most current census population.

Use of direct standardization in the United States

In the early 20th century, methods for the analysis of vital statistics in the United States often followed the lead of England and Wales. In *Mortality 1911*, standardized death rates were published for States and cities having populations of 100,000 or more (21). From 1921 to 1924 a similar form of the age-adjusted rate was shown for specific causes and for geographic areas. In *Mortality Rates 1910–20*, published by the Bureau of the Census in 1923, a number of ''adjusted'' rates were shown (22).

In these first United States mortality reports, the age-adjusted death rates were based on the England and Wales standard population of 1901. At that time, the standard population was chosen to provide comparability between the mortality measures produced by the two countries. For *Vital Statistics Rates in the United States, 1900–40* (23) as well as for *Vital Statistics Special Reports, 1900–53*, it was decided that the United States population was different enough from 1901 England that a new standard should be used. At the time, the 1940 U.S. population was the latest census population available and was thus used as the standard. Since that time, all age-adjusted rates produced as part of the official vital statistics that are published in the *Vital Statistics of the United States*, have used the 1940 population as the standard. Except for life tables, no other mortality summary rates have been published on an annual basis in the *Vital Statistics of the United States*.

Selection of standard population

In the early 1930's the Committee on Forms and Methods of Statistical Practice of the American Public Health Association

> . . . has addressed itself to the task of determining what, if anything, might conveniently be done to reduce the distortion and incomparability of rates due to varying proportions of young and old in the populations of different times and different geographic areas (24).

This committee presented two reports (4). The first report states ''. . . is it not unsound to confuse the health administrator with crude death rates and possibly to cause the public erroneously to infer that mortality is in general rising, at a time when health appropriations are greater than ever before?'' (25). The second report contained many recommendations, three of which Woolsey specified as:

a. That the use of the unadjusted total death rate be minimized . . . (and) referred to always as the ''crude death rate'';
b. that age-specific rates be used in place of the crude death rate whenever possible, even if broad age groups be used; and
c. that before any single death rate for all ages be adopted as standard, there should be further study (26).

Thus, the committee argued strongly in favor of adjusted rates but provided no recommendation for which index or which standard to use.

The issue of what standard population to use in direct standardization has been addressed by a number of authors in journals and in textbooks. One of the best summaries of the issues in selection of a standard population was given by Wolfenden:

> In connection with this problem of choosing an appropriate standard population, it is essential to remember that directly standardized rates are really index numbers which are constructed only for the purpose of comparison, so that no significance is to be attached to their absolute magnitudes; the main characteristic of the standard population consequently should be that it is not unnatural or clearly abnormal. In practice it will be found that various standard populations chosen within reason have insignificant effects upon the inferences to be drawn from comparisons of directly standardized rates for different geographical areas at all ages from all causes . . . Care, however, must of course be taken in drawing inferences from comparisons of standardized rates in respect of subdivisions of a general population, e.g., for certain causes of death or occupations, in which the age distributions of the populations exposed to risk may show peculiar characteristics sharply different from any normal general population (27).

There are three main points in this statement. First, the age-adjusted rate is an index number. Its magnitude has no meaning, and it should be used only for comparisons. Thus, in examining age-adjusted rates based on different standard populations, it is not really a valid argument to state that a particular standard population yields an age-adjusted death rate that looks ''too low.'' The only valid consideration is whether the comparisons between geographic areas, or between population subgroups (such as males compared with females), are valid.

Second, although selection of a standard is somewhat arbitrary, the standard selected should not be clearly abnormal. Thus, in the current debate, the issue of whether the current United States census population is *significantly* different from the 1940 population is a valid point of contention.

Third, when age-adjusted rates are computed and published in quantity, such as in the *Vital Statistics of the United States*, and a valid standard is chosen, there is still a certain amount of caution that needs to be exercised in the use of the age-adjusted rates. An analyst must still confirm that for any particular analyses, the subdomain comparisons are appropriate and the use of a summary measure is valid.

Returning to the issue of selecting a standard population, it should be noted that in examining official mortality statistics, it seems as though the initial selection of a standard population has almost always been the most current census population. Once used, however, the standard may remain in place for some time.

From time to time the question of changing the standard population is asked. Woolsey examined some alternative standards and concluded that there would be no significant change in age-adjusted rates among the standards examined (4).

When the American Public Health Association prepared its monographs around the 1950 census, Speigelman and Marks examined the questions of whether to change to the 1950 population as standard (28). They concluded that there was little reason to change.

Since that time, there have been periodic challenges to the use of 1940 population as the standard. These challenges seem to coincide with each new decennial census. For example, the issue was again examined by Curtin, Rosenberg, and Maurer in 1980 (29). They examined the effect of the 1940, 1970, and a life table population as a standard on such measures as black-white and male-female comparisons for selected causes of death. They also looked at overall mortality by State. They found that the ranking of States by age-adjusted death rate was not greatly affected by choice of standard population. The issue of selecting a standard population was then revisited by Robert Johnson at the 1990 annual meeting of the American Statistical Association (30).

Again, it seems that after every census, the question of changing the standard population arises. Perhaps it is a more important issue today because the 1940 census population is 50 years old and because of the increased emphasis on the analysis of chronic diseases and health issues for the elderly population.

Discussion

Although developed and widely used in England during the 19th century, the age-adjusted death rate was never accepted by everyone. In a discussion before the Royal Statistical Society, the age-adjusted rate was termed the ''despised standardized rate'' (31), and, 50 years later, the direct-standardized age-adjusted death rates are still despised by some illustrious persons (32). In Greenwood's time, such displeasures with the age-adjusted rate led to discussions of alternative summary measures, such as using the life table death rate (33), the equivalent average death rate (34), or measures developed by Yerushalmy (35), Kerridge (36), and others. Woolsey (4) examines some alternative summary measures as do numerous review articles (37–43).

Throughout the history of the use of the direct-standardized or age-adjusted death rate, the utility of the measure has often come into question. Nevertheless, the age-adjusted rate continues to be an integral part of the analysis of mortality trends and differentials.

Accepting this, the need for a summary index must be balanced by recognition of the limitations of summary measures. One hundred years after the founding of the Royal Statistical Society, Major Greenwood, in his discussion of Yule, stated:

> . . . the numerical statistical method, as distinct from the tabular statistical method of our ancestors, has been introduced precisely because the power of the human mind to grasp a number of particulars is limited, . . . It was not until the seventeenth century that it was realized that in seeking to grasp everything, one tended to grasp nothing (34).

This statement, either quoted directly or in a slightly different form, has continued to be prevalent in the multitude of published work on uses and limitations of summary measures of mortality.

Assuming the usefulness of the age-adjusted rate, the question of selection of the standard population remains. Clearly, the age-adjusted rate is a summary index, an index number whose magnitude has no meaning and should be used for comparisons only. Also, there can be delineated instances where it is inappropriate to use a standardized measure. This leads to a rather simple conclusion: If it is appropriate to use age adjustment, then the results should not be affected by the selection of a standard population; but if the results can be affected by the choice of a standard population, then it is not appropriate to use standardization at all.

In closing this historical overview, certain recurring issues may be mentioned:

- Standardization is not a substitute for the examination of age-specific rates, the age-adjusted rate in an index measure, whose magnitude has no intrinsic value, that is to be used for comparison purposes only.
- The standard population should not be considered ''abnormal'' or ''unnatural'' relative to the populations under study.
- Comparisons between alternative standards generally produce insignificant differences, but if significant differences do occur, one probably should not be using standardization in the first place.
- When a decision is made to change standards, the most current census population is usually selected.

Basically, there are few statistical reasons to guide the selection of a standard population for mortality data. In comparing several different populations, the variance of the direct-standardized measure is minimized when a ''pooled'' standard is used (46). If the interest is in comparing trends over time, the decomposition formula of Kitagawa seems to imply the use of the base-year population as a standard (47). That is, if the trend between 1950 and 1990 is of interest, then the difference between the crude rates for 1950 and 1990 can be decomposed into a difference of age-specific rates weighted by the 1950 population (thus a difference in two standardized rates with the 1950 population as the standard), a difference between the populations in the two years, and a rate-population interaction term.

In addition to the lack of a statistical reason to change standard populations, there are many practical reasons for official government statistics not to change the 1940 standard. The possibility of enormous resources spent to recompute historical figures and the confusion resulting from the publication of a set of numbers that would no longer be comparable to figures previously published are two reasons not to change the 1940 standard.

However, throughout the history of its use, the emphasis on selecting a standard population has been that the standard should not be greatly different or ''abnormal.'' With the 1940 population already 50 years out of date, the conceptual, not statistical, issue is whether the 1940 population should be considered abnormal when compared with today's United States population, and, if so, can the costs resulting from changing the standard population be justified.

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Chapter 3
Inadequacies of age adjustment as illustrated in cancer mortality

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Introduction

Over the years several different forms of age adjustment have been proposed as means of summarizing age-specific mortality rates for the purpose of comparing differences among groups or trends over time. Summary statistics allow comparisons among population groups or time periods whose populations have differing age structures, but they reflect age-specific differences reliably only if the differences are consistent across age groups. In the case of trends over time, if the age-specific mortality trends vary across age groups (that is, an age and calendar time interaction exists), summary statistics may conceal more than they reveal. Disease trends are, unfortunately, often subject to different patterns in different age groups. For example, this is true of cross-sectional data that are affected by birth cohort effects (such as lung cancer) and in the case where a period effect may decrease death rates in some age groups but not others (such as cervical cancer).

Each of the many summary statistics uses a different weighting scheme to summarize the age-specific mortality rates, and each of these different summary statistics is affected by any change in the choice of the standard population. This chapter concerns the weights used in several different standardization techniques. The need for homogeneity of age-specific mortality ratios to summarize age-specific death rates adequately is emphasized. An example of the different patterns of the summary statistics obtained by using different methods is illustrated.

Notation used in this chapter

In the notation, suffix i indicates the ith age interval (here 0–4, 5–9, . . . 80–84, 85 and over). Suffix j indicates the jth year, in the example 1950, 1955,. . . 1985. For each year j, the data consist of the i-specific population p_{ij}, deaths d_{ij}, and death rates r_{ij}. Capital letters are used to indicate the reference values. P_i and D_i are used for the reference population and number of deaths in the reference population (in the ith age interval); R_i indicates the death rate in the standard population. The ratio of the age-specific rate in the jth year to that in the reference population—that is, r_{ij}/R_i—is termed λ_{ij} in accordance with Liddell's usage (1).

Methods of standardization

Direct and indirect standardization are well known, but there are also several other methods of standardization, including the equivalent average death rate (2) and methods by Yerushalmy (3), Kerridge (4), and Liddell (1). These methods were reviewed by Liddell (1) in 1960.

Each of these methods of summarization can be seen as a weighted average of age-specific death rates. The similarity of the direct and indirect methods has been pointed out by Rothman (5). The weights for the age-specific death rates for direct and indirect standardization are in fact the distribution of the standard and specific-year populations, respectively (5). As a result, the direct and indirect methods show extremely similar trends in most instances. The equivalent average method, in contrast, weights death rates in each age group equally (2).

Conceptually one can think of standardization techniques as yielding a weighted average of either absolute death rates in each age group or as a weighted average of the ratios of age-specific death rates in a specific year to those of a standard population. The latter are termed mortality ratios, or λ_{ij} ($\lambda_{ij} = r_{ij}/R_i$). Age-specific mortality ratios are useful, as they compare each age-specific death rate in the specific population with the corresponding rate in the standard year to show the relative changes over time in each age group.

The weights that are applied to the age-specific mortality ratios can be obtained directly from the usual formula for the adjustment of age-specific death rates (1,6). For example, the comparative mortality figure (CMF), obtained from direct standardization, can be expressed as either a weighted average of age-specific mortality rates or age-specific mortality ratios (λ_{ij}).

Equations used to obtain selected statistics are shown below.

Directly standardized death rate $$\frac{\sum_i r_{ij} P_i}{\sum_i P_i} \qquad (1)$$

Comparative mortality figure $$\left(\frac{\sum_i r_{ij} P_i}{\sum_i P_i}\right) \Big/ \frac{\sum D_i}{\sum P_i} = \frac{\sum_i r_{ij} P_i}{\sum D_i} \qquad (2)$$

Substituting $\lambda_{ij} = r_{ij} \big/ R_i$

$$\frac{\sum_i r_{ij} P_i}{\sum_i D_i} = \frac{\sum_i \lambda_{ij} R_i P_i}{\sum D_i} = \frac{\sum_i \lambda_{ij} D_i}{\sum D_i} \qquad (3)$$

The directly standardized death rate (equation (1)), is a weighted average of age-specific death rates, and the weights are proportional to the population distribution. The CMF is this rate divided by the crude death rate in the standard population to form a ratio of rates. The CMF is also a weighted average of age-specific mortality ratios (λ_{ij}) where the weights are deaths in the standard population, as seen in equation (3). In a similar manner, one can calculate the weights used to average age-specific mortality ratios by the indirect method and by the Kerridge and person-weighted ratio (PWR) method presented by Liddell (1).

In the case of the indirect method, the age-specific mortality ratios are weighted by the deaths expected in the specific population. In the case of the methods of Kerridge and Liddell, the mortality ratios are weighted by the population distribution of the specific and standard populations, respectively (1).

Ideally, if we standardize only age-specific mortality ratios that are consistent over the age groups for any one year, the method of weighting of these ratios is not of major consequence. (The ratios in any one year are all similar and any summary statistic will suffice.) If mortality ratios in a particular year differ by age, the choice of method of standardization will affect the resulting summary statistic.

Cancer mortality trend for U.S. white males

As an example of the striking differences obtained by different methods of standardization, all cancer deaths of white males in the United States for the period 1950–85 have been analyzed using the CMF (directly standardized rate) and the Liddell method. Five-year age groups were used, and death rates for every fifth year were used to arrive at summary statistics for these years (figure 1). The standard used was a composite of the eight 5-year intervals during the period 1950–85. The trends are strikingly different. The CMF shows a steady increase up to 1980, whereas the PWR by Liddell shows a decline. The age-specific death rates for 1950 and 1985 are shown by 10-year age groups in table 1. The changes in these death rates over time are provided in the two right-hand columns. Both the absolute and relative change from the beginning to end of the time period are shown. Cancer mortality rates have decreased among those under 50 and increased for persons above this age. Thus the age-specific mortality ratios are not homogeneous across age groups, and any summary statistic will be a reflection of the particular weighting scheme used. For direct standardization, because the mortality ratios (λ_{ij}) are weighted by

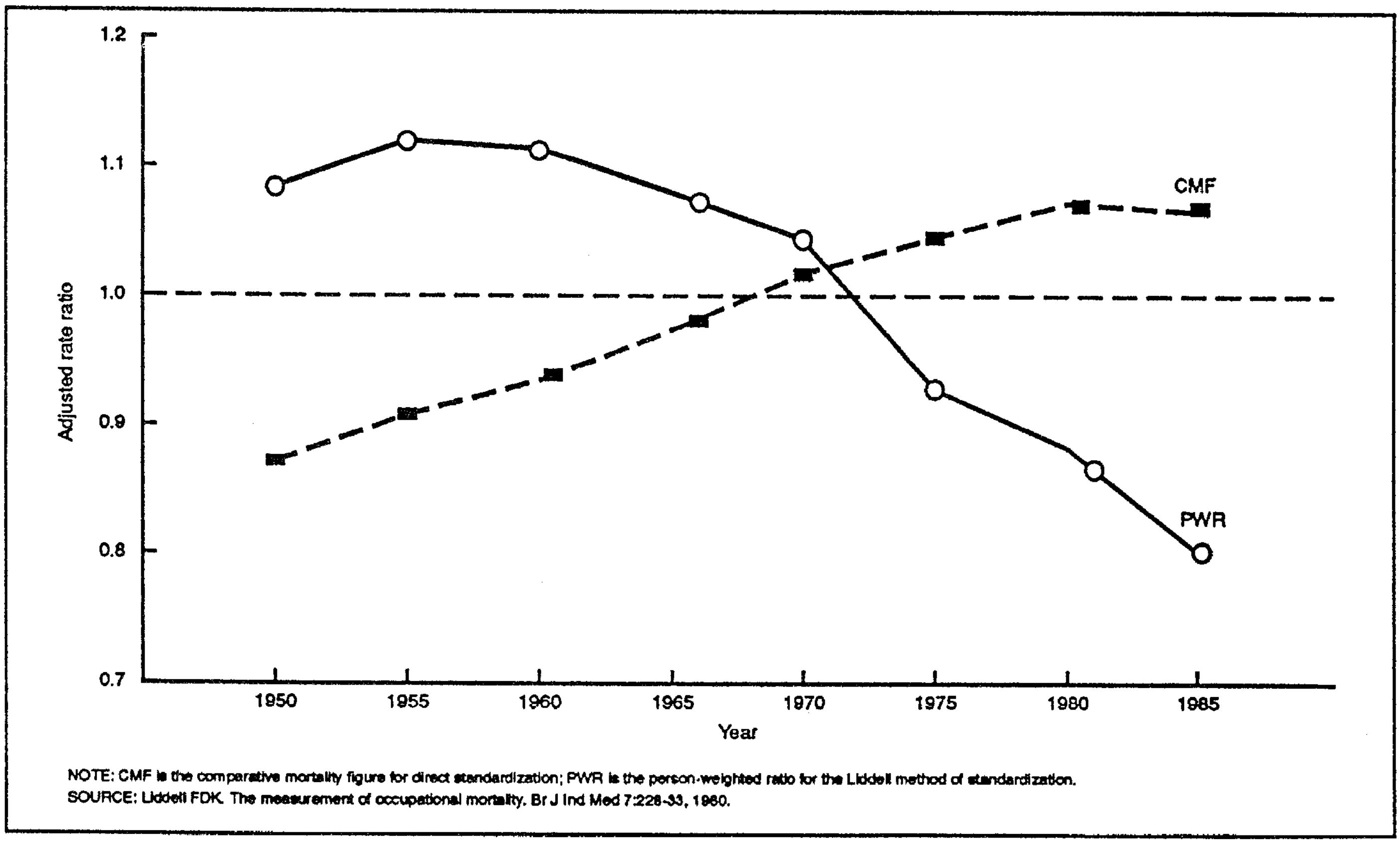

Figure 1. Age-adjusted ratios of cancer mortality for white males: United States, 1950–88

Table 1. Death rates for all cancers in white males, by age: United States, 1950 and 1985

Age	1950 (1)	1985 (2)	Absolute change column (2) minus column (1)	Relative change column (2) divided by column (1)
			Rate per 100,000 persons	
Under 10 years	11.64	4.67	–6.97	.40
10–19 years	8.66	5.00	–3.66	.57
20–29 years	13.47	9.15	–4.32	.68
30–39 years	28.59	22.19	–6.40	.78
40–49 years	87.79	80.99	–6.80	.92
50–59 years	269.69	309.62	+39.93	1.15
60–69 years	593.36	758.96	+165.60	1.28
70–79 years	1,064.04	1,445.88	+381.84	1.36
80 years and over	1,598.25	2,259.62	+661.37	1.41

deaths in the standard population, the summary measure will reflect the pattern at the ages where the highest proportion of deaths occur. In contrast, the Liddell method weights the death ratios by the population distribution of the standard, and hence reflects the changes in death rates in the largest population groups. Clearly in this example the message concerning the trend depends on the choice of method of standardization. Other examples of such varied mortality ratios are not difficult to find (6,7).

Aside from the method of standardization, the choice of standard population also may affect the comparison of summary indicators from year to year. The weights for the age-specific mortality ratios for both the direct method and Liddell method using two different standard populations for 1950 and 1985 are shown in table 2. For the direct method the weights are the number of deaths in each age group attributed to cancer in U.S. white males, and for the Liddell method the weights are the population distribution for U.S. white males. Using the direct method, 37 percent of the weight for the age-specific mortality ratios was given to those 70 years of age and over in 1950, whereas 50 percent of the weight was attributed to this age group in 1985. Using the Liddell method, the weights attributed to those 70 years of age and over for these two years were only 4.5 percent and 6.5 percent, respectively. Although the weights are different as a result of a change in the standard year, this difference is small compared with the difference resulting from the choice of the method of standardization.

The mortality ratios are weighted by deaths in direct standardization. Thus, where mortality ratios are not homogeneous, the summary statistic will reflect the mortality ratios in the age groups with the largest number of deaths. In the case of white male cancer mortality, the proportion of deaths in the oldest age groups continues to increase over time. Therefore, the use of a recent year as the standard (for instance, 1985) leads to an even greater emphasis on the trend in death rates among the elderly.

Conclusion

When age-specific death ratios are heterogeneous, the use of any summary statistic is not appropriate. In such cases, the choice of method of standardization, and to a lesser extent the choice of standard used, inevitably affects the pattern of the summary statistic. If mortality patterns vary by age, a closer examination of age-specific rates in both birth cohort and cross-sectional analyses can reveal far more pertinent and useful information.

Table 2. Percent distribution of relative weights used for comparative mortality figure and Liddell methods of age adjustment: United States, 1950 and 1985

Age	Proportion of deaths (all cancers)		Proportion of population (white U.S. males)	
	1950	1985	1950	1985
All ages	100.00	100.00	100.00	100.00
Under 10 years	1.60	0.31	19.98	14.63
10–19 years	0.87	0.34	14.66	15.00
20–29 years	1.44	0.76	15.47	18.25
30–39 years	2.92	1.64	14.89	16.41
40–49 years	7.72	4.08	12.82	11.08
50–59 years	19.22	14.03	10.38	9.06
60–69 years	29.67	29.30	7.28	8.49
70–79 years	25.68	32.06	3.51	4.77
80 years and over	10.88	18.12	0.99	1.76

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Part III

Advantages and disadvantages of age adjustment

Chapter 4
The use of multiple standards

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Age-adjusted death rates have been used extensively in mortality analyses for more than a century. Because the crude death rate is heavily influenced by the age composition of the population, it is not a useful measure for monitoring changes in mortality. For example, if there had been no changes in the age-specific death rates between 1980 and 1988, the aging of the population would have produced an 8 percent increase in the crude death rate. In fact, between 1980 and 1988 there was a 0.4 percent increase in the crude death rate even though every age-specific death rate declined.

To avoid the problems associated with crude death rates, age-adjusted death rates are often used to summarize mortality trends. However, as with any summary measure, essential details are often lost. In this presentation I will cover the main advantages and disadvantages of age adjustment, especially as they relate to the choice of the standard population. I will concentrate on the direct method of adjustment and the assessment of trends, although many of the points are relevant to indirect adjustment and the comparison of subpopulations or geographic areas.

The major advantage of age-adjusted rates is their simplicity as a summary measure of the set of age-specific rates. (In this presentation I will assume that the age-specific rates are expressed in the standard 11 age groups: under 1 year, 1–4 years, 5–14 years,. . . ,75–84 years, and 85 years and over.) When all the age-specific rates move in the same direction at the same relative magnitude, the age-adjusted rate is a valid summary measure in the sense that it will reflect that trend accurately—no matter what standard population is chosen.

Another advantage of the age-adjusted rate is that it has a smaller relative standard error than any of the age-specific rates; this is an important advantage when comparing subpopulations or geographic areas.

The disadvantages of age adjustment occur primarily when the age-specific rates move in different directions or at different relative magnitudes. When this occurs, the trend in the age-adjusted rate will reflect some sort of weighted average of the age-specific trends, where the weights depend upon the standard population chosen. In order to illustrate this problem, let us consider U.S. standard populations for three different years, 1940, 1980, and the projected population in 2050. Figure 1 shows that the population over 65 years accounted for about 5 percent of the total in 1940, 11 percent in 1980, and nearly 25 percent in 2050. Therefore, the 2050 standard will give the greatest weight to mortality changes among the elderly while the 1940 standard will give the least.

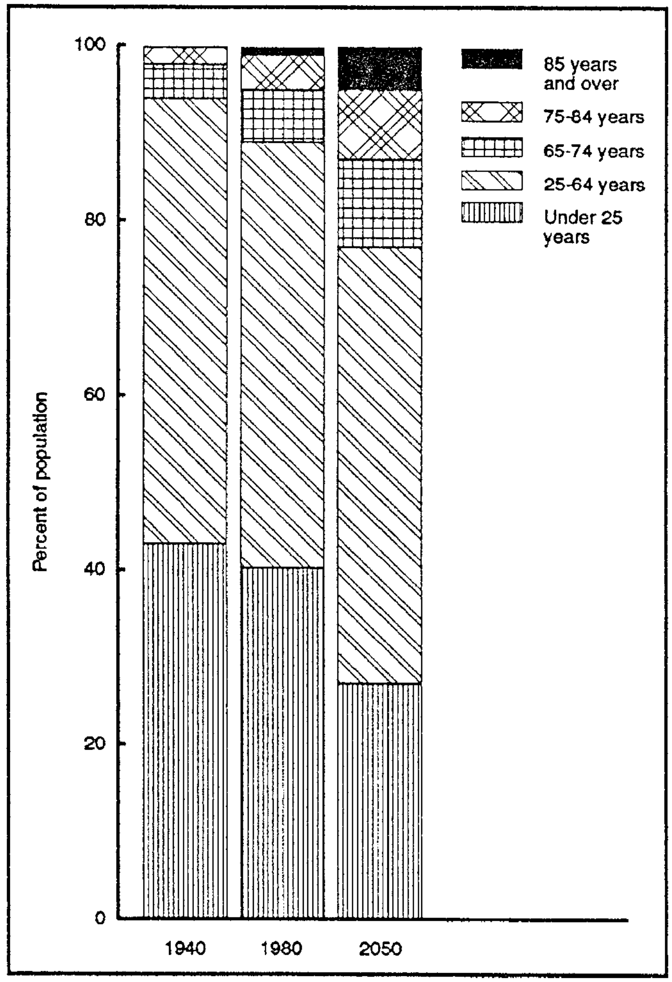

Figure 1. Age distribution of United States population: United States, 1940, 1980, and 2050

To illustrate the sensitivity of the adjusted rate to changes in age-specific rates, I started with the 1980 all causes death rate and tried four simple scenarios. Each scenario doubled the age-specific death rate for a portion of the age range while keeping the remaining rates constant. Figure 2 shows that for any standard population, doubling the rates at the older ages has a much larger effect on the age-adjusted rates than doubling at the

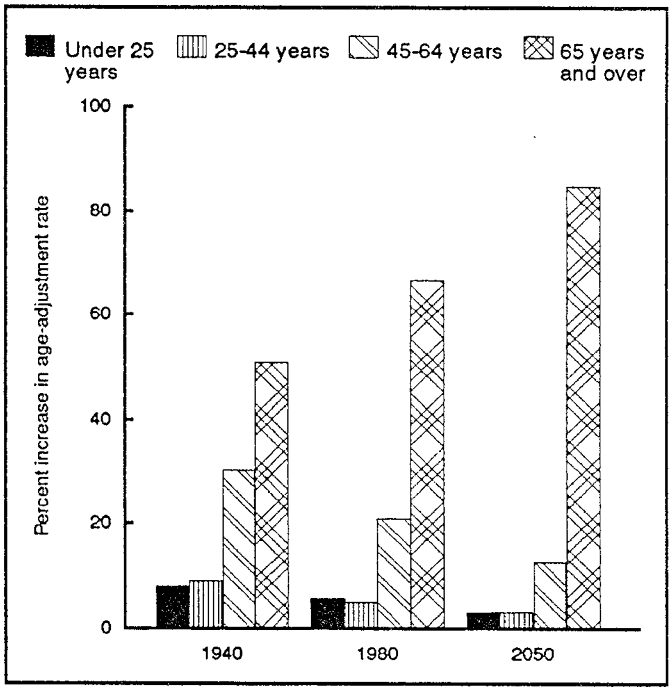

Figure 2. Increases in age-adjusted death rate after doubling age-specific death rates in selected age groups: United States, 1940, 1980, and 2050

younger ages. However, as the standard population becomes older this effect is magnified. If middle-aged (45–64 years) death rates are doubled, the 1940 adjusted rate would increase by 31 percent but the 2050 adjusted rate would increase by only 12 percent. On the other hand, if elderly (65 years and over) death rates are doubled, the 1940 adjusted rate would increase by 52 percent compared with an 84 percent increase for the 2050 adjusted rate. Thus, changes in mortality among the elderly have the largest impact on age-adjusted rates, even when using the standard population that gives least weight to the elderly (1940). This is due to the relatively large magnitude of the death rates among the elderly compared with those at younger ages.

One method for avoiding this emphasis on mortality among the elderly is the use of Years of Potential Life Lost (YPLL). YPLL weights each death according to the number of years of life lost to age 65. Death rates for the elderly are not used so that the YPLL rate summarizes mortality among those under 65 years of age. YPLL rates can be age adjusted in the usual way, which also requires the choice of a standard population. Let us consider the 1980 and 1988 age-specific death rates for the United States.

Figure 3 shows that there have been substantial reductions in most age groups. Yet the reduction in age-adjusted rates or YPLL differs considerably (figure 4). The reduction ranged from 5.5 percent for the age-adjusted rate using the 2050 standard to 12.4 percent for YPLL using the 1940 standard. Note that there is very little difference among the YPLL rates, including the crude. However, the age-adjusted rates differed much more and the crude death rate even showed a 0.4 percent increase.

The situation is even more complex when trends run in different directions as they do for cancer mortality. Figure 5 shows that cancer death rates have declined for those below 55 years of age while they have increased for those over 55 years of age. Figure 6 shows the resulting age-adjusted trends. The YPLL rates declined for all three standards chosen but among the age-adjusted death rates only the 1940 standard population shows a hint of a decrease.

Another difficulty with age-adjusted death rates is that the magnitude of the rates is totally arbitrary and depends upon the standard chosen. This can lead to confusion when comparing rates for different causes of death. For example, figure 7 shows the age-adjusted death rates using the 1940 standard for heart disease, cancer, stroke, and lung cancer. One might mistakenly conclude that lung cancer became a ''more important'' cause of death than stroke because of the crossover in 1982. Yet this is entirely a function of the standard population chosen. Figure 8 shows the same trends based on crude rates. Note that there were still more stroke deaths than lung cancer deaths in 1988, and that the gap between heart disease and cancer was substantially greater than was suggested by the age-adjusted rates. Because crude rates reflect the aging of the population as well as mortality trends, the declines in heart disease and stroke mortality are much less marked, and the increases in cancer much greater than was evident with the age-adjusted rates. Figure 9 shows the same trends using the 2050 population as the standard (the scale has been multiplied by 2.5 because of the greater magnitude of these rates; the relative scale is comparable to the previous figures). With this age distribution, stroke mortality appeared to be higher than cancer (and lung cancer) mortality until 1970 and considerably higher than lung cancer mortality in 1988. The trends in stroke mortality using the 2050 standard do not begin to decline until after 1960, compared with a noticeable decline between 1950 and 1960 when using the 1940 standard.

A reasonable compromise to the difficulties of using a single age-adjusted rate is to present more than one rate, but fewer than 11 age-specific rates. For example, one can compare trends in mortality for young people (under 25 years), middle-aged (25–64 years), and older persons (65 years and over). Figure 10 shows trends in age-adjusted rates for these three categories using both the 1940 and 2050 standard populations. Over these narrower age bands, the choice of standard population becomes much less critical. For the youngest age groups, the two standards are indistinguishable. The largest difference in magnitude occurs among the elderly but even here the trends are quite similar. Figure 11 shows the three sets of rates for cancer mortality. Both the magnitude of the rates and the trends are quite similar, regardless of which standard is used.

In summary, the choice of standard populations depends upon the purposes for which the age-adjusted rate is being used. Since the choice of standards is arbitrary, there is nothing inherently wrong or misleading about the 1940 standard—despite its being 50 years old. In fact, the large difference between the crude rates and the age-adjusted rates based on the 1940 standard is probably beneficial because it is less likely to lead to confusion than a more recent standard. The presentation of several age-adjusted rates based on different standard populations could lead to confusion and erroneous comparisons. A reasonable compromise is to present tables of age-adjusted rates for three broad age groups (under 25 years, 25–64 years, and 65 years and over). The choice of standard population for these rates is less critical since both the trends and magnitudes will be similar over a wide range of standards.

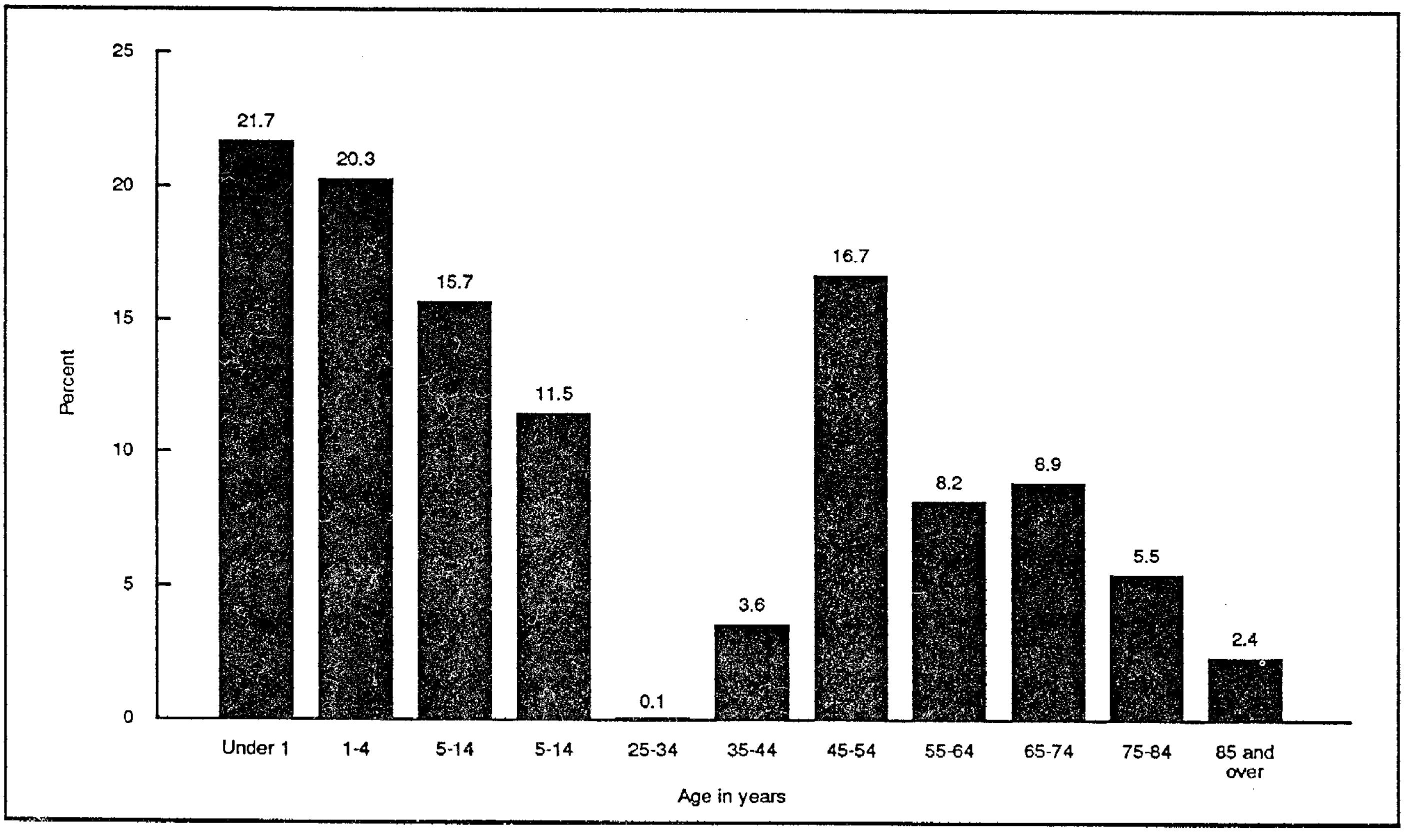

Figure 3. Percent decrease in age-specific death rates: United States, 1980–88

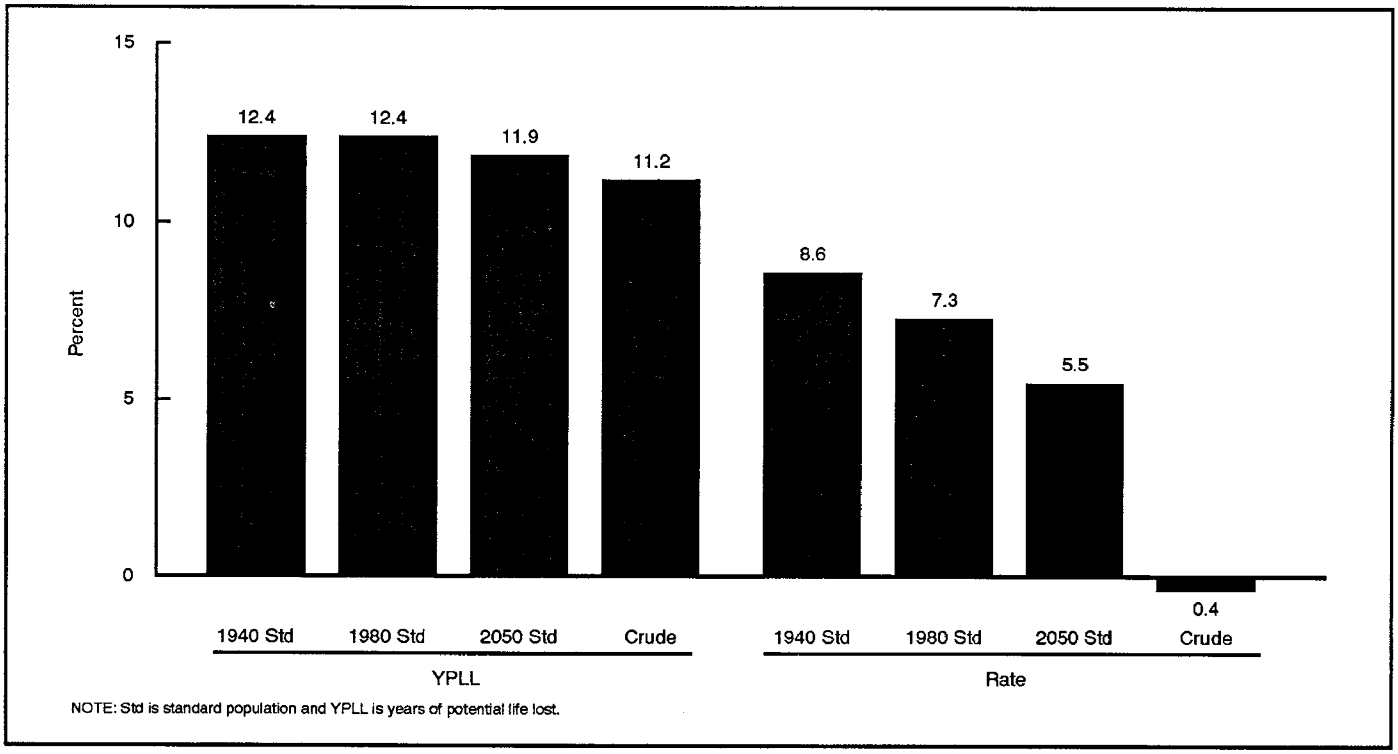

Figure 4. Percent decrease in age-adjusted YPLL and death rates: United States, 1980–88

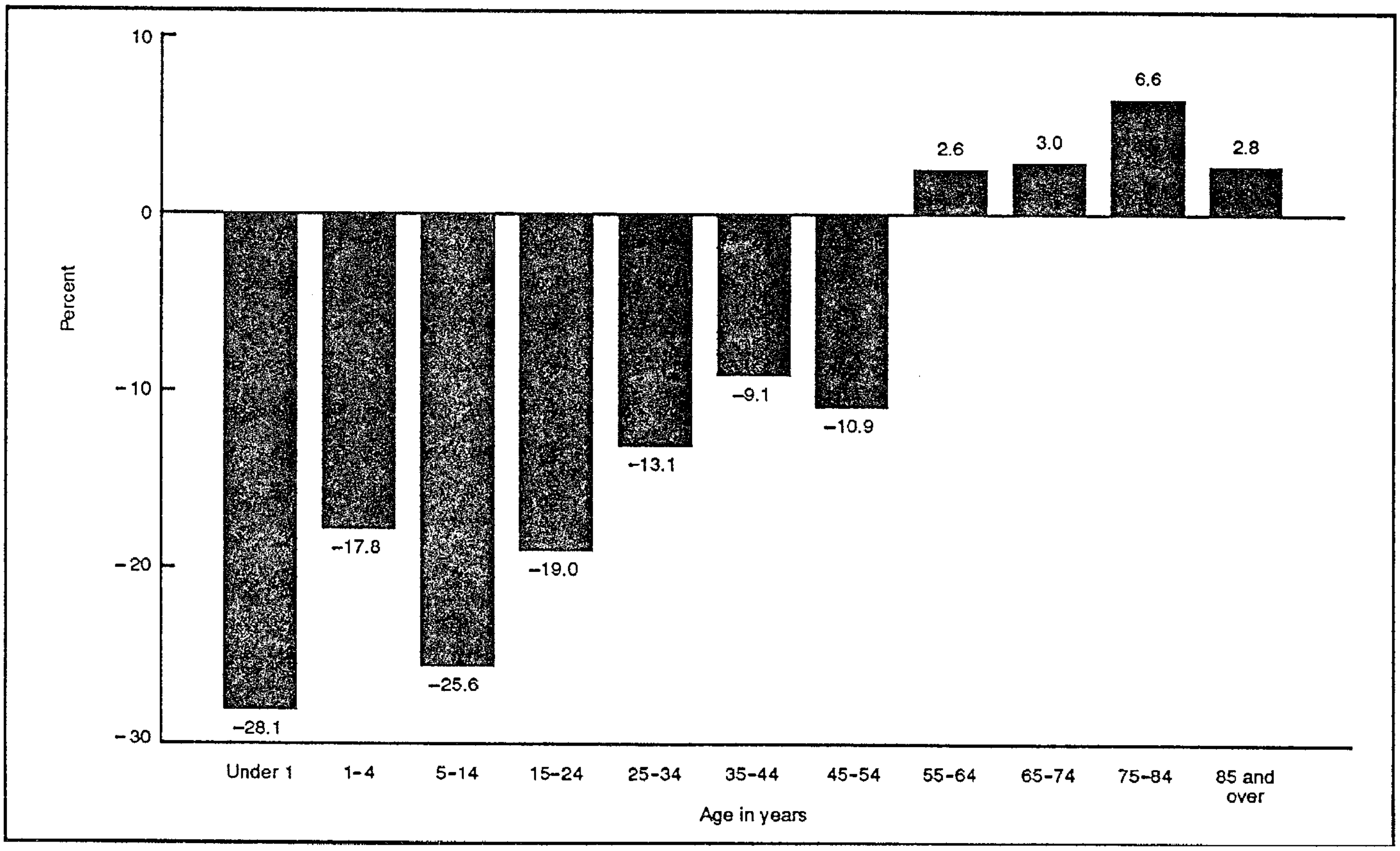

Figure 5. Percent change in age-specific cancer death rates: United States, 1980–88

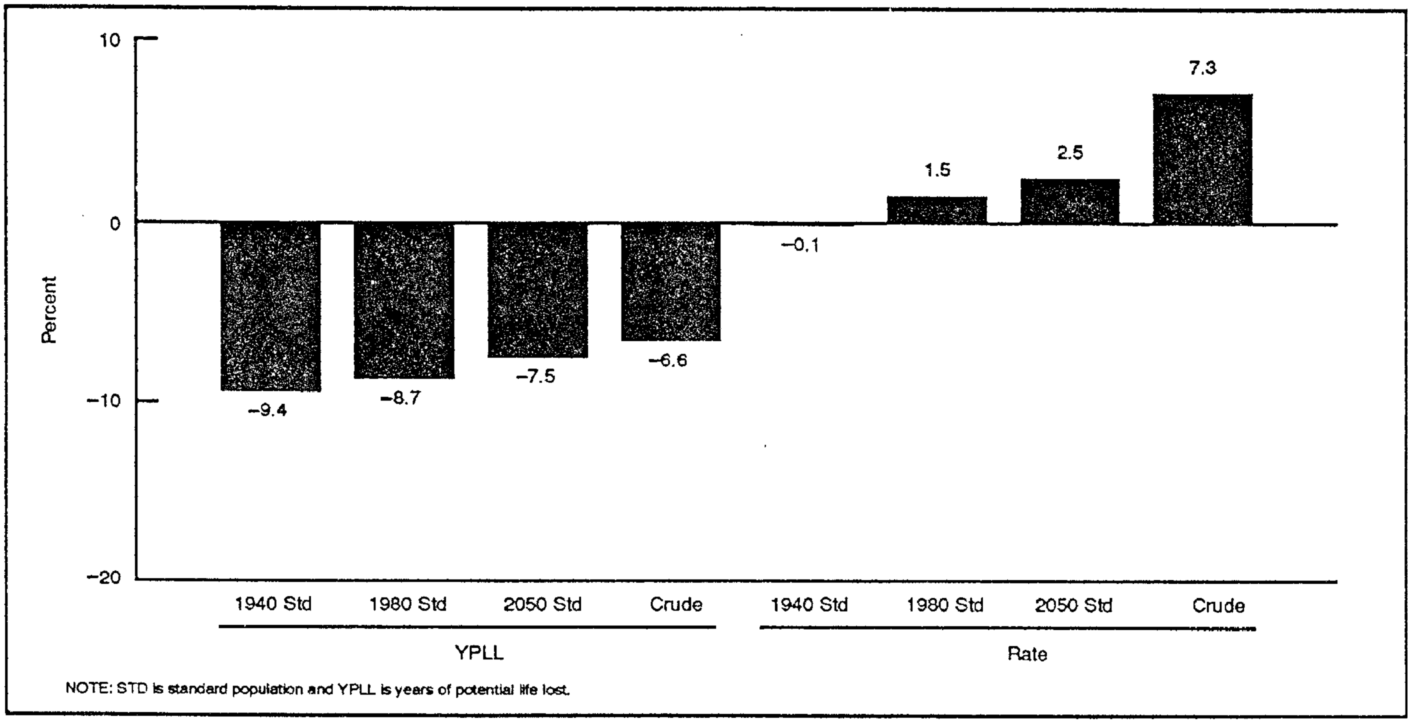

Figure 6. Percent change in age-adjusted YPLL and death rates for cancer: United States, 1980–88

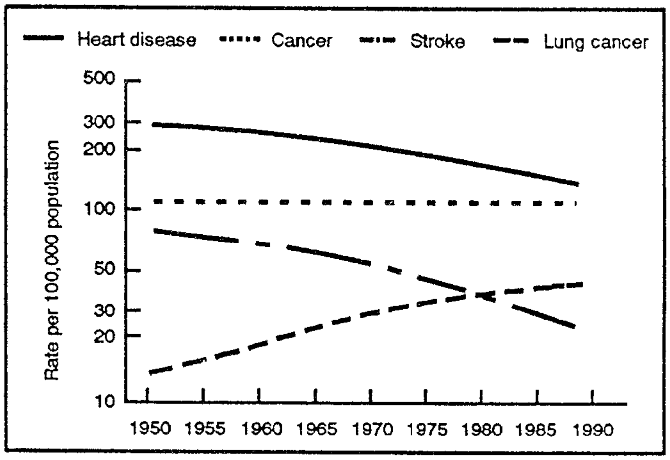

Figure 7. Mortality trends, age-adjusted death rates (1940 Standard): United States, 1950–88

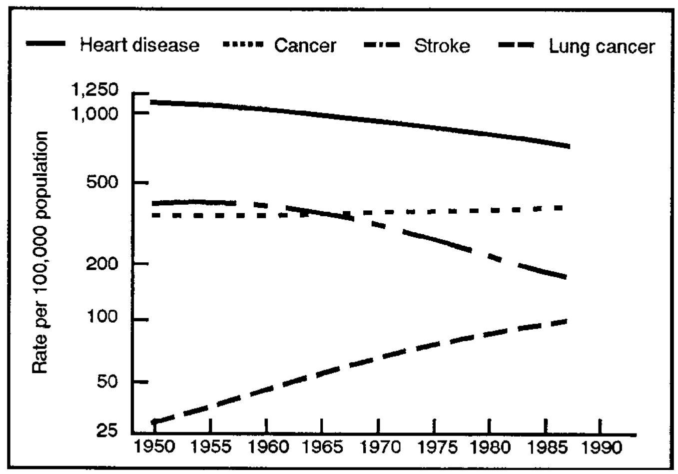

Figure 9. Mortality trends, age-adjusted death rates (2050 Standard): United States, 1950–80

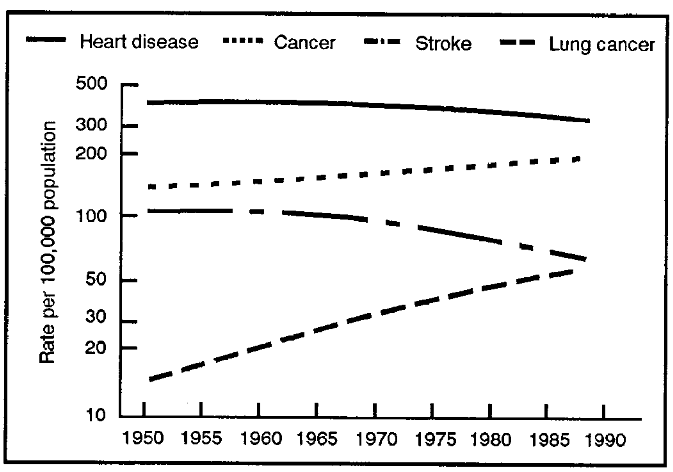

Figure 8. Mortality trends, crude death rates: United States, 1950–88

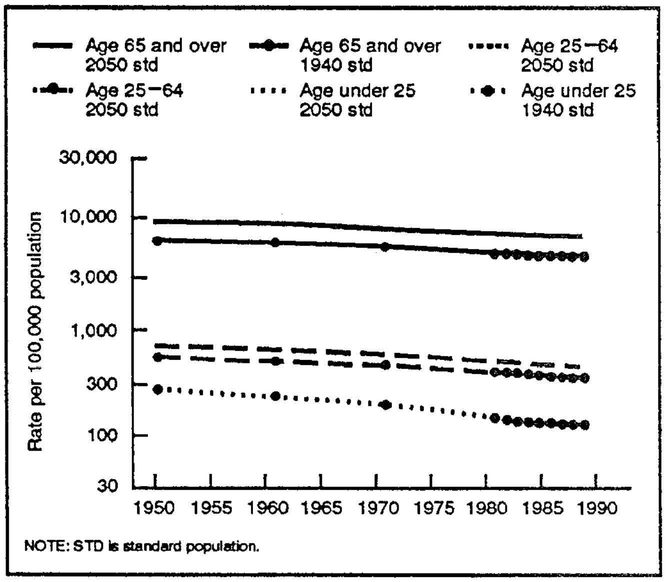

Figure 10. Age-adjusted death rates in three age groups, all causes of death: United States, 1950–88

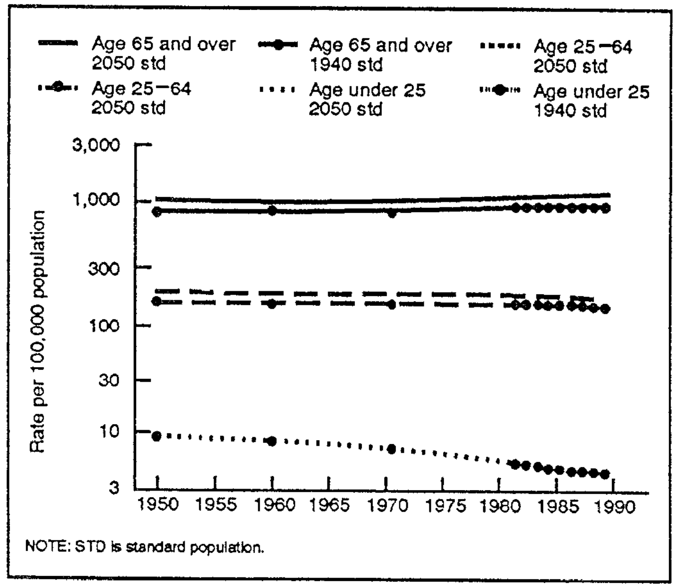

Figure 11. Age-adjusted cancer death rates in three age groups: United States, 1950–88

Chapter 5
Choosing a standard population: Some statistical considerations

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Introduction

The issue of alternative standard populations for age adjusting death rates surfaces into open debate from time to time. This may even have been an issue in the 19th century, when age-adjusted death rates were first regularly published in the English official reports of vital statistics. It certainly was in the 1930's when G. Udny Yule presented a paper on standardization at the meeting of the Royal Statistical Society (1) and, again, in the early 1940's when Linder and Grove prepared their classic compilation of historic vital statistics rates (2).

In discussions of which population standards to use for England, it was argued that the 1901 population of England would give too much weight to the younger population, which at the time was experiencing rapid reductions in mortality. In current discussions, it is often argued that the 1940 population also gives too much weight to the younger population in comparison with the 1990 population that is more heavily weighted by the elderly. In her review of the early history of age adjustment, Klebba notes that the 1901 population of England and Wales was initially adopted as a standard by the U.S. Bureau of the Census (3). But the 1940 population was selected as the standard by Linder and Grove for vital statistics, and it has remained the standard for almost 50 years in presenting mortality data by the National Center for Health Statistics (NCHS), its predecessor agencies, and by the States.

Use of the 1940 standard by NCHS has not gone without challenge in recent years. The issue was raised in the media in 1979 when Harry Schwartz of the Columbia University College of Physicians and Surgeons wrote in the *Wall Street Journal* (4) that the increase in cancer mortality between 1968 and 1978 was due in large measure to the aging of the U.S. population rather than to increases in age-specific mortality risk. In challenging Schwartz's conclusions, Samuel Epstein of the University of Illinois School of Public Health wrote that had the 1970 population instead of the 1940 population been used as a standard population, the change in mortality during the period would have been 5.5 percent rather than 2.5 percent (5).

The issue of which population standard to use for age-adjusting death rates has been raised in recent years within the Federal Government. A recent instance resulted from the use of a standard population other than 1940 in a series of articles on chronic diseases that appeared in the *Morbidity and Mortality Weekly Report,* a widely read publication of the Centers for Disease Control (CDC). Rates presented in the articles for selected chronic diseases by State differed from rates prepared by NCHS and by the States, which were based on the 1940 standard. The issue was also raised in designing CDC's ''State Profiles,'' which present a number of health indicators for individual States.

Again, the issue was addressed in developing the statistical methodology for the Nation's health objectives for the year 2000 (6). It was recognized that the methodology for the Year 2000 Health Objectives would have broad implications for the statistical measures used at both the National and State level for many years; the 1940 standard was selected.

In the future, which standard to use will no doubt be raised time and time again in not only a national but also an international context, as efforts are made to promote international comparability in health statistics methodology, following the model of international comparability in cause-of-death classification through the International Classification of Diseases of the World Health Organization (7).

Nonstatistical considerations

A review of the literature on age standardization reveals the complexity of the issue of alternative standards, which involves not only statistical but also nonstatistical considerations. While the present paper focuses on statistical aspects of the issue, it may be useful to review some nonstatistical considerations in choosing population standards for age-adjusting death rates.

Among these are the uses to which age-standardized measures are put, that is, whether principally for in-depth epidemiological research, or whether, instead, for routine presentation of data. In the former case, there are opportunities for augmenting summary measures such as age-adjusted death rates, where necessary, with more in-depth analyses of age-specific rates, and even introducing controls for demographic characteristics such as race, sex, and geographic area. In-depth research provides unique opportunities for exploring alternatives and for examining factors contributing to change over time and to demographic differentials in mortality. In contrast, in routine data production and dissemination, the requirements of continuity and uniformity are powerful and, indeed, may be of the overriding considerations in the selection of population standards for age adjustment.

Policy considerations can play a role in the type of statistical index chosen for data presentation. For example, a public health program whose focus is youth may be inclined to select measures that give greater emphasis or statistical weight to the younger population than a program whose target is the adult or elderly population. An example of a standardized index that emphasizes youth is the ''Years of Potential Life Lost'' (YPLL), a measure widely favored in injury prevention programs. This is a measure in which age-specific mortality is weighted by a factor representing the difference between an arbitrary end point age, usually 65 or 70 years, and the midpoint of a population group. Under such a scheme, the age group 20, for example, has a weight of 50—the difference between 70 years and 20 years—while the age group 50 would get a weight of only 20—the difference between 70 years and 50 years. The ratio of these weights is 50 to 20, or 2.5 as compared with a ratio of 1.5 when the weights of the standard 1940 population are used. The YPLL is widely used in injury research, whose program targets tend to be the younger population.

Another nonstatistical consideration in selecting a standard population is purely administrative, such as the initiation of a new public health program. Thus, the selection of the 1970 population standard for cancer data is roughly coincident with the beginnings of the cancer tumor registry program of the National Cancer Institute. The 1970 population also coincidentally gives greater weight to the older population than the 1940 standard, with the statistical result, shown below, that the age-adjusted death rate for all cancers combined shows a later inflection point signaling the beginning of a downward trend than when the 1940 standard is used.

Once a population standard becomes identified with a particular series of statistical data as, say, in the case of cancer data, widely used and accepted, the standard assumes a kind of ''verity'' and historic momentum as is the case with the 1940 population as the standard for mortality data in the United States and the 1901 population used for England and Wales.

An important nonstatistical consideration is ease of use and interpretation, particularly by the public and lay users. Thus, a single standard is less likely to confuse than multiple standards, and the retention of a standard is less likely to confuse than changing standards. Changing standards, moreover, means that statistical results prepared under one regimen may not be comparable with those prepared under a different set of population standards, giving possible rise to confusion. While Johansen has argued that the statistical discontinuities associated with revisions in cause-of-death classification are already part of the accepted statistical apparatus in mortality presentation (8), the problems created by these revisions—technical, administrative, and interpretive—should not be minimized. It is not clear, moreover, that the issue of age-standardization is comparable to that of cause-of-death classification which must capture as accurately as possible medical terminology that is rapidly evolving as a result of changes in medical technology, medical knowledge, and medical practice.

If multiple standards were used to avoid the problem of discontinuing a time series but yet initiating a new one, the multiple standards would also have the potential of confusion in both the presentation and interpretation of data. Data users find consistency and simplicity of presentation appealing and intelligible. Multiple choices, as in population projections prepared by the U.S. Bureau of the Census (for example, high, medium, and low series) can put an unnecessary burden on the data user, while a change in statistical practice and standards—without a compelling justification—may raise questions in the minds of the public as to whether the change is motivated by other than technical considerations.

Statistical considerations

The purpose of this paper is to provide some statistical perspective on the question of alternative population standards. As such, the paper approaches the problem in much the same way as a number of earlier papers, such as Spiegelman and Marks (9), Curtin, Maurer, and Rosenberg (10), Metropolitan Life Insurance Company (11), and most recently Johansen (8). All these papers have in common the empirical exercise of comparing age-adjusted death rates using alternative population standards. They differ mainly in the types of standards used and in the cause-of-death categories and demographic groups to which the alternative standards are applied.

The nature of age-adjusted death rates

As an introduction to the empirical comparisons, it may be helpful to review the meaning of an age-adjusted death rate. It is a weighted average death rate, where the weights w^i of the corresponding age-specific death rates r^i range from 0.0 to 1.0. The crude death rate, under this conceptualization, is an average rate whose population weights are those representing the current population. Clearly, a variety of weights can be used, including the 1940 standard that is now widely used by NCHS and the States in their vital statistics programs, or the 1970 standard used in much cancer research, or the YPLL weights, or the 1980 population used by parts of CDC other than NCHS.

Once the population weights have been selected, they are multiplied by the age-specific rates under consideration and the results summed to achieve a weighted average. In this paper, the age-adjusted death rate for the first population group is R_1 and for the second group it is R_2.

The characteristic that distinguishes one group from another may be cause of death, that is, the rate for cancer as compared with the rate for heart disease; or it may be race, that is, white persons as compared with black persons; or it may be sex, males as compared with females; or it may be time, that is, 1980 as compared with 1988. And, finally, the comparison may represent any combination of characteristics, such as the cancer death rate for females in 1980 as compared with their rate in 1988.

The comparison of two age-standardized rates R_1 and R_2 using the same standard population as a percent change

$$\frac{R_2 - R_1 \times 100}{R_1}$$

or as ratio R_2 to R_1 would be a measure of the comparison of the entire set of age-specific rates for the two population groups. Under ideal circumstances, the percent change or ratio for R_1 and R_2 should reflect exactly the same percent change or ratio for every age group.

Graphically, as shown in panel A of figure 1, this is presented by parallelism in the two lines. In practice, however, age-specific ratios in the death rates of two population groups are rarely the same. They differ from one age group to the next, sometimes extremely, such that the rate for one population group may be higher for one age group but lower for the adjacent age group, or there may be other more general patterns such as those illustrated in panels B and C. In panel B, the general pattern is one in which the age-specific death rates tend to ''converge'' with increasing age. This is a widely observed general pattern for many causes of death; also shown is a less common diverging pattern of age-specific rates. In panel C, the age-specific rates are depicted in a pattern of ''crossover,'' where the relationship of the rates, age by age, crosses over from higher to lower as has been observed in age-specific comparisons between the white and black population groups. Under the circumstances of convergence and crossover, comparisons based on a single average measure such as the age-adjusted death rate, may not represent well the complex pattern of age-specific variation, although they do show the ''average'' ratio between the two groups.

As comparisons depart increasingly from parallelism, the less appropriate it is to use age-adjusted death rates for making comparisons; and the comparisons of age-adjusted death rates become highly dependent upon the particular standard selected. Thus, if the comparisons are about the same for each age group, it does not make much difference if the standard is 1940 or 1990. But if the age-specific ratios are not uniform, the choice of standards is likely to make a difference.

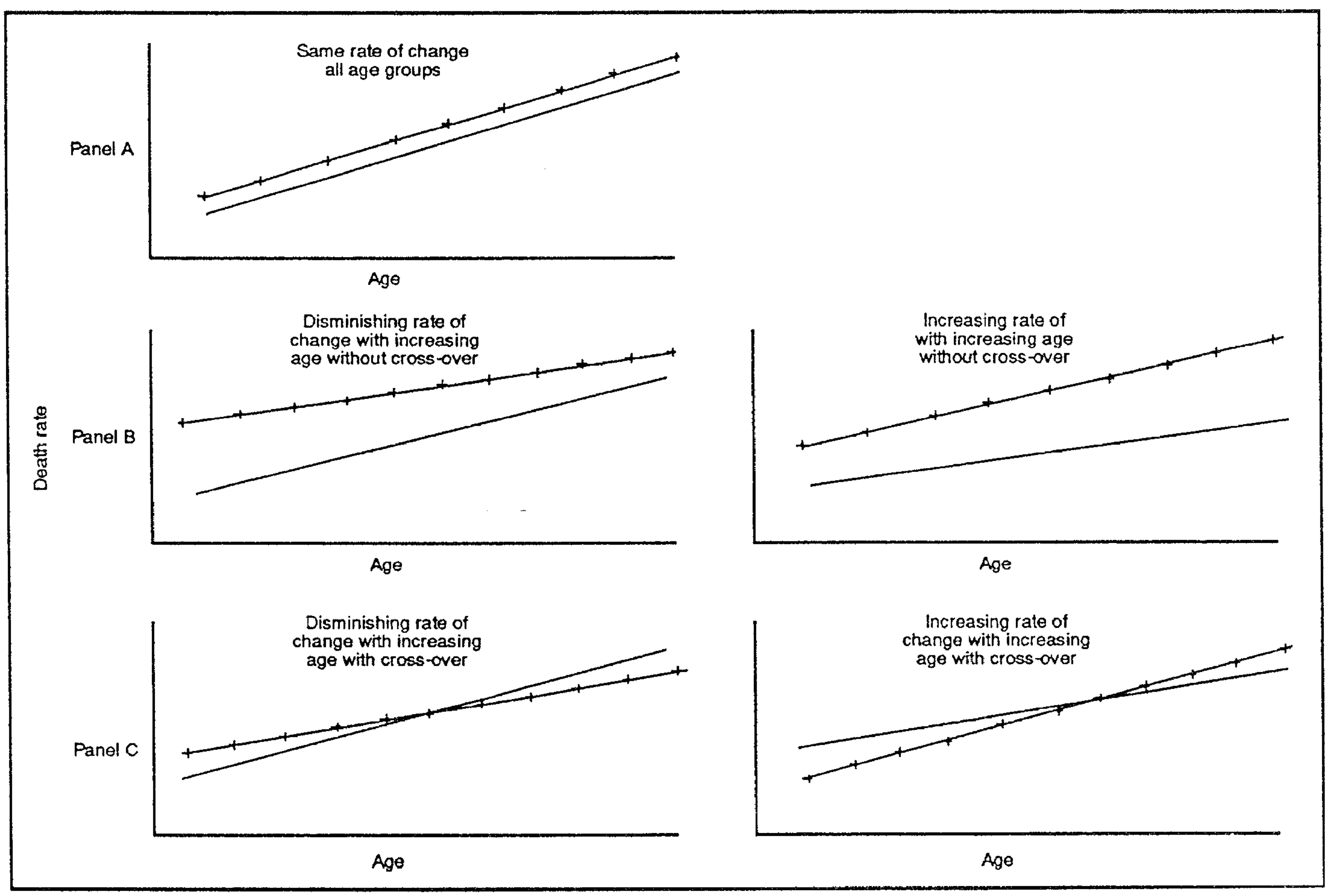

Figure 1. Comparison of hypothetical age-specific death rates for two population groups

Methods

Nature and sources of data

To illustrate the sensitivity of age-adjusted death rates to alternative population distributions, several causes of death were selected with contrasting age structures of mortality. These causes were as follows: (1.) All causes of death combined. (2.) Malignant neoplasms, including neoplasms of lymphatic and hematopoietic tissues, ICD–9 Nos. 140–208, hereinafter referred to as ''all cancers.'' (3.) Malignant neoplasms of respiratory and intrathoracic organs, ICD–9 Nos. 160–165, referred to as ''respiratory cancer''; Cerebrovascular diseases, ICD–9 Nos. 430–438, referred to as ''stroke; and Homicide and legal intervention, ICD–9 Nos. E960-E978, referred to as ''homicide.''

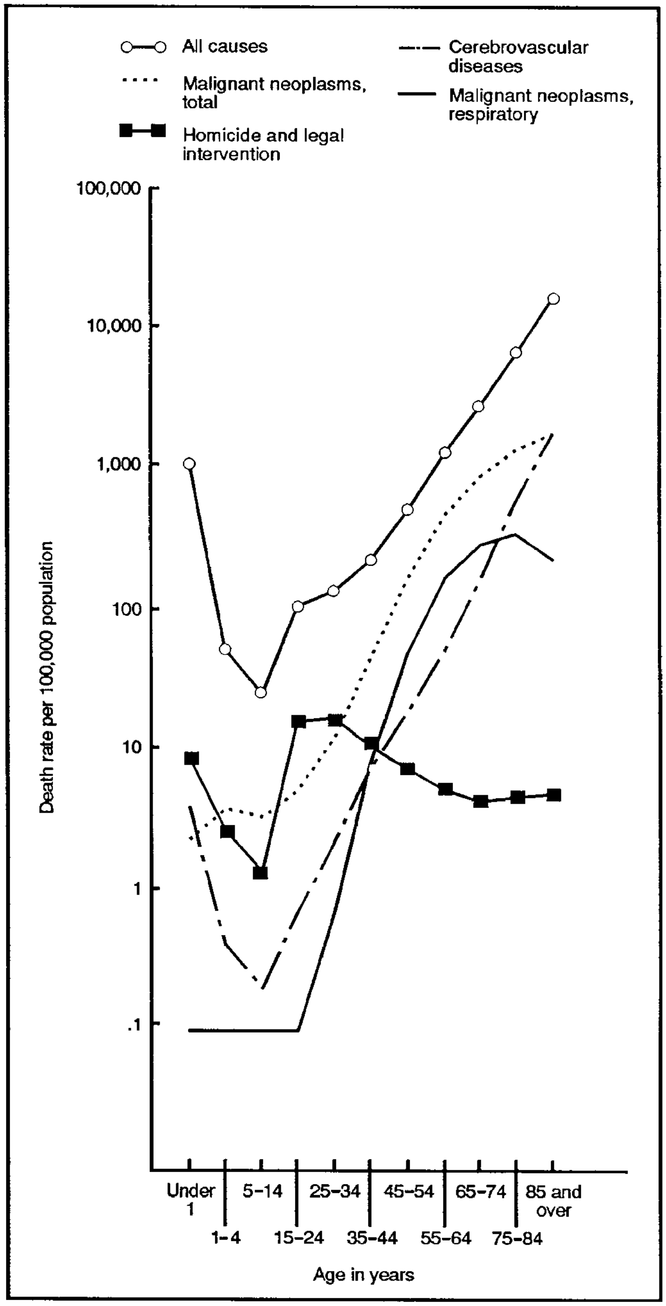

Figure 2. Death rates by age for selected causes of death: United States, 1988

For each of these causes of death, age-specific death rates were estimated separately for the white and black population and for males and females for each of the years 1968, 1980, and 1988. Age-adjusted death rates were calculated for each of these groups using two alternative standard populations, that of 1940—the standard currently used in mortality time series of NCHS—and that for 1988, referred to, for convenience, as the standard for 1990, which it closely approximates. For each of these groups, percent changes in mortality were calculated for the periods 1980–88 and 1968–88. For the latter period, the classification of the selected causes of death were sufficiently comparable between the Eighth and Ninth Revisions of the International Classification of Diseases to calculate percent change without adjustment for comparability. Mortality sex ratios and mortality race ratios were also calculated.

These rates, ratios, and percent changes are shown in detail in tables 1–5. In addition, for each of the cause-sex or cause-race groups, estimates were made of standard errors and relatively standard errors for the alternative age-adjusted death rates. These are shown in detail in tables 6–10.

To simplify the presentation in this paper, patterns of mortality for the total population are approximated by using the white population, whose deaths in 1988 accounted for 87 percent of all deaths.

Age patterns of mortality

The diversity of the age patterns of mortality for the selected causes of death is illustrated in figure 2, using death rates for 1988, which are similar to those of other years. For all causes of death combined, the age schedule of mortality shows the well-known ''J-shaped'' pattern with slightly elevated rates for infants, the lowest rates at ages 5–14 years and gradual increases beyond that age group. Indeed, this general pattern is characteristic of most ''natural'' causes of death, in contrast to those causes by external trauma—such as accidents, homicides, and suicides whose age pattern of mortality reflects predominantly social and behavioral factors rather than biological factors related to aging.

The pattern for all causes is heavily influenced by, and indeed reflects, the pattern for heart disease, which in 1988 accounted for about one-third of all deaths. For all cancers and cancers of the respiratory system, the pattern of age-specific mortality follows this general pattern, although with later onset and somewhat attenuated increase with increasing age. The pattern for stroke is similar but with a higher proportion of deaths at advanced ages.

In contrast to the characteristic increasing death rates with increasing age for the natural causes, the age pattern of mortality for homicide is essentially flat; that is, rates are relatively uniform throughout the age distribution, although with somewhat higher rates for young adults.

Not only do causes of death have somewhat different patterns of age-specific mortality for 1988, they also show different age-specific patterns of change over time, illustrated by percent change during 1968–88. For all causes of death combined, the greatest reductions in mortality were all cancers and respiratory cancer, there were decreases for age groups under 55–64 and 45–54 years, respectively, and increases thereafter, examples of the ''crossover'' that make age-adjusted death rates for all cancers and respiratory cancer especially sensitive to alternative standard populations.

The age pattern of mortality change for stroke differs from the other causes in having relatively uniform reductions in mortality at each age. This pattern should result in little difference in change based on either of the alternative population standards. For homicides, the pattern of change is a mirror image to that for all causes, that is, the greatest increases at the younger age with generally smaller increases at the older ages.

Age distribution of standard populations

The alternative populations used as standards have somewhat different age structures, as illustrated in figure 3. The 1940 population is ''younger,'' that is, it has a greater proportion of the population concentrated at younger ages. This reflects both the effects of higher fertility, which tend to spread out the population base, as well as the higher mortality at almost every age than the 1990 population standard. In contrast, the 1990 population is ''older,'' and appears to be moving toward the European model of population structure with an ever-increasing proportion of the population at the older ages.

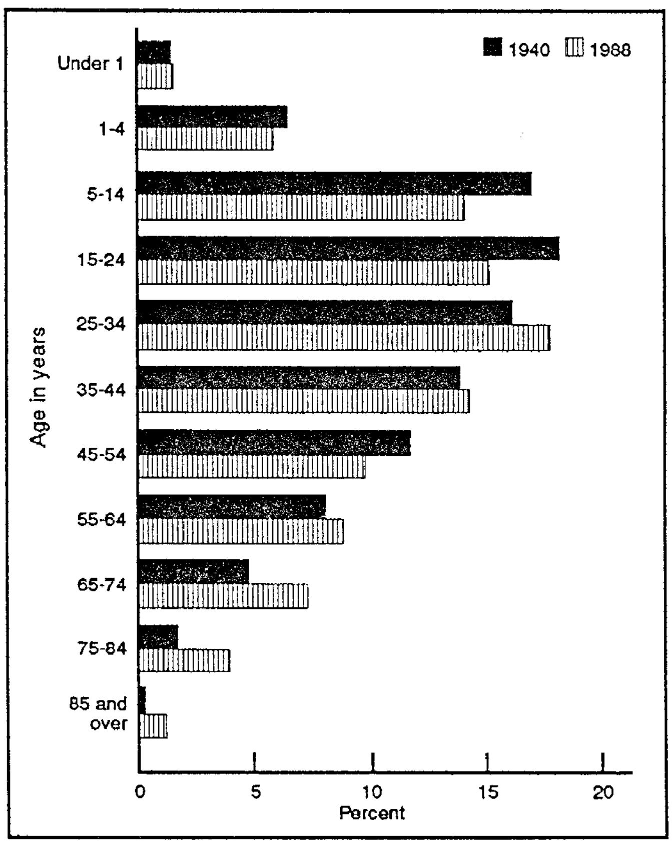

Figure 3. Comparison of age distributions of the 1940 and 1988 populations of the United States, expressed as percents

The alternative structure of the two standard populations can be expected to have consequences for the age-adjusted death rates in which the population at each age group serves as a weight. Accordingly, the 1940 population weights give relatively greater emphasis to the younger population and to the causes of death that are more closely associated with the younger population, namely, the external causes of death; while the 1990 standard will give greater emphasis to the natural causes, for which the highest rates are at the advanced ages.

Results

Causes of death

The effect of alternative population standards on death rates for selected causes is shown in table A. The top two panels show, respectively, absolute and relative levels of mortality in 1988 under the assumptions of either a 1940 or a 1990 standard population, while the lowest panel shows the effect of alternative standards on changes in mortality for the selected causes during 1968–88.

In terms of comparisons between causes of death, use of the 1990 standard tends to increase the absolute level of mortality for the natural causes (deaths from diseases rather than from trauma) and all causes of death combined, since the 1990 standard gives more weight to rates in the older age categories. As a result, the age-adjusted death rates based on the 1990 population more closely resemble the unadjusted death rates for these causes of death. The greatest differences in magnitude are for those causes with the greatest concentration of mortality at the older ages such as stroke, whose age-adjusted death rate more than doubled when the 1990 standard is used as compared with the 1940 standard. Age-adjusted death rates for the other natural causes are from 40 to 70 percent higher using the 1990 standard. In contrast, the age-adjusted death rate for homicide, whose rates are relatively evenly distributed throughout the age range, is about the same under the two standards.

While the absolute levels of mortality tend to be affected by the choice of standards, the relative dispersion of the rates, shown in the first panel (columns 3 and 4), is not highly affected. For example, cancer risk is about one-quarter that of all causes of death combined under either assumption. More generally, comparisons of risk among the causes seem to be only marginally affected by the choice of population standards.

The middle panel shows changes in age-adjusted death rates during 1968–88, based on the alternative population standards. For both the white and black populations, there are differences in the magnitude of change when different

Table A. Comparison of age-adjusted death rates based on the standard populations of 1940 and 1990, for selected causes of death: United States, 1988; and expressed as ratio to All causes of death combined; and comparison of percent change in rates, by race and sex, 1968–88

Cause of death	Age-adjusted death rate (rate per 100,000 population) 1940 (1)	1990 (2)	Ratio of rates (All causes=1.00) 1940 (3)	1990 (4)
All causes	509.8	841.6	1.00	1.00
Malignant neoplasms, total	130.0	191.4	0.26	0.27
Malignant neoplasms, respiratory	39.4	55.0	0.08	0.07
Cerebrovascular diseases	27.5	57.5	0.05	0.07
Homicide and legal intervention	5.3	5.2	0.01	0.01
	Percent change in rates, 1968–88			
	White		Black	
All causes	–10.5	–7.9	–5.2	–1.7
Malignant neoplasms, total	2.4	6.0	9.8	17.9
Malignant neoplasms, respiratory	49.6	58.8	63.7	79.2
Cerebrovascular diseases	–58.4	–57.4	–59.0	–56.4
Homicide and legal intervention	25.6	23.8	–19.3	–19.4
	Male		Female	
All causes	–27.8	–25.1	–7.5	-5.0
Malignant neoplasms, total	4.5	9.6	2.2	6.0
Malignant neoplasms, respiratory	24.6	35.1	175.7	190.7
Cerebrovascular diseases	–58.4	–58.1	–57.8	–56.6
Homicide and legal intervention	60.5	+60.6	2.3	3.1

standards are used but not in direction. Under the 1990 standard, decreases in mortality by cause of death are reduced in size while increases tend to be amplified, except for homicide which remains about the same.

The largest differences in percent change between the two standards are for white mortality from all causes of death combined, from a decrease of 10.5 to one of 7.9 percent; and for all cancers, an increase from 2.4 to 6.0 percent. While the absolute magnitudes of rates are different for the black population, the effect of the alternative standards is proportionately similar to that of the white population.

The bottom panel of table A shows the effect of alternative standards on trends for the selected causes by sex. Again, absolute magnitudes of change differ between the two standards, but the direction of change and the general order of magnitude of change are the same.

Sex comparisons

Because mortality analyses often examine patterns and trends by sex, the effect of alternative standards on death rates of males and females was examined, as shown in table B. The ratio of male-to-female age-adjusted death rates in 1988 is slightly but not consistently affected by the choice of the standard population. When the 1990 standard population is used, the resulting ratio is smaller for all causes of death combined and for stroke; but it is larger for all cancers and for cancer of respiratory system; and it is relatively unchanged for homicides. However, the trend in the ratio, which represents the convergence or divergence in mortality between the sexes over time, appears to be about the same regardless of the choice of standard.

Race comparisons

Race comparisons of mortality are of great interest and are widely used to monitor and evaluate the health of the minority populations. Table C compares mortality between the two race groups in 1988 in terms of the ratio of black to white age-adjusted death rates based on the standard populations for 1940 and 1990. Ratios by cause of death differ depending on which standard is used. The 1990 standard tends to reduce the race differential,

Table B. Comparison of the ratio of male to female age-adjusted death rates based on the standard populations of 1940 and 1990, for selected causes of death: United States, 1988; and comparison of percent change in ratios, 1968–88

Cause of death	Ratio, 1988 (male/female) 1940	1990	Percent change in ratio, 1968–88 1940	1990
All causes	1.72	1.62	21.9	21.1
Malignant neoplasms, total	1.46	1.57	2.2	3.4
Malignant neoplasms, respiratory	2.44	2.62	–54.8	–53.5
Cerebrovascular diseases	1.18	1.11	–2.3	–3.3
Homicide and legal intervention	1.27	1.26	–18.1	–18.8

Table C. Comparison of the ratio of black to white age-adjusted death rates based on the standard populations of 1940 and 1990, for selected causes of death: United States, 1988; and comparison of percent change in ratios, 1968–88

Cause of death	*Ratio, 1988 (black/white)*		*Percent change in ratio, 1968–88*	
	1940	*1990*	*1940*	*1990*
All causes	1.55	1.36	5.9	6.7
Malignant neoplasms, total	1.32	1.27	7.2	11.3
Malignant neoplasms, respiratory	1.26	1.21	9.4	12.9
Cerebrovascular diseases	1.87	1.50	4.0	3.9
Homicide and legal intervention	6.45	6.42	–35.8	–34.9

although the extent of the reduction varies by cause of death. Thus, for all causes of death combined, the mortality race ratio using the 1990 standard is 1.36 compared with 1.55 for the 1940 standard; for cancer, 1.27 compared with 1.32; for respiratory cancer, 1.26 compared with 1.21; and for stroke, 1.50 compared with 1.87. For homicide, the ratio is virtually unchanged, 6.42 compared with 6.45.

Trends in mortality race ratios are shown in the second panel of the table. For some of the causes of death, the 1990 ratio increases somewhat the percent change in the ratio. This represents a greater widening in the mortality differential between the white and black population than depicted when the 1940 population is used as a standard. For stroke and homicide, the rate of change in the ratio is about the same, regardless of which standard population is used.

Stochastic variation

Another issue examined in comparing alternative population standards is statistical significance. Because the numbers of deaths reported through the vital statistics system are a complete count of events, they are not subject to sampling error—although they are subject to errors in the registration process. However, when the figures are used for analytical purposes, such as comparison of rates over time or among groups and geographic areas, the number of events that actually occurred may be considered as one of a large series of events that could have arisen under the same circumstances, as indicated by Chiang (12). The probable range of values may be estimated from the actual figures according to certain statistical assumptions.

In general, distributions of vital events may be assumed to follow the binomial distribution. Estimates of standard error and tests of significance under this assumption are described in most standard statistics texts. When the number of events is large, the standard error expressed as a percent of the number or rates is usually small.

When the number of events is small (perhaps less than 100) and the probability of such an event is small, considerable caution must be observed in interpreting the conditions described by the figures. This is particularly true for infant mortality rates, cause-specific rates, and death rates for small areas such as counties. Events of a rare nature may be assumed to follow a Poisson probability distribution.

For aggregate mortality indexes such as crude death rates and age-adjusted death rates, the variances can be thought of as a weighted average of the variances for the individual age groups, where the weights reflect the square of the proportion of the standard population at each age. In general, the larger the number of deaths on which an age-adjusted death rate is based, the smaller the variance, and, therefore, the standard error.

To determine if the standard errors and relative standard errors are affected by the choice of the standard population, these statistics were estimated for the selected causes of death by race and sex for 1988. It could be predicted that the standard errors would increase using the 1990 population roughly in proportion to the increases that occur in the age-adjusted death rate. It could also be expected that the relative standard error would change relatively little if the change in the standard error and the rate were about the same.

The results shown in table D are generally consistent with expectations, that is, the standard errors for the natural causes increased by up to 50 percent, except for homicide, for which the standard error did not change. In

Table D. Comparison of standard error and relative standard error of the age-adjusted death rates based on the standard populations of 1940 and 1990, for selected causes of death: United States, 1988

Cause of death	*Standard error*		*Relative standard error (in percent)*	
	1940	*1990*	*1940*	*1990*
All causes	0.4	0.6	0.1	0.1
Malignant neoplasms, total	0.2	0.3	0.2	0.2
Malignant neoplasms, respiratory	0.1	0.2	0.3	0.3
Cerebrovascular diseases	0.1	0.2	0.3	0.3
Homicide and legal intervention	0.1	0.1	1.0	1.0

Table E. Comparison of standard error and relative standard error of the age-adjusted death rates based on standard populations of 1940 and 1990, for different sample sizes: United States, 1988

Size of sample	Number of deaths	Standard error		Relative standard error (percent)	
		1940	1990	1940	1990
100 percent	1,876,979	0.4	0.6	0.1	0.1
10 percent	187,697	1.3	1.9	0.3	0.2
1 percent	18,770	4.1	6.0	0.8	0.7

contrast, the relative standard errors for all the causes of death were similar for both the 1990 and the 1940 standard populations.

Also examined was the effect of reducing the number of observations on the variance under alternative assumptions of the standard population. For each of the causes of death, the number of deaths and population were reduced successively to 10 percent, then 1 percent of their observed size to assess the effect on the respective variances. The results of this exercise are shown in table E for all causes of death combined, results that are essentially the same for the other causes of death.

With successive reductions in the size of the sample, the standard error increased as did the relative standard error; the reduction in the sample to 1 percent of the original size resulted in tenfold increases in standard errors and relative standard errors. The increases were the same in the standard errors and relative standard errors as sample size was reduced for the two population standards.

Discussion

This paper has examined the effect of using alternative population standards on age-adjusted death rates using methods similar to those of earlier studies by Spiegelman and Marks; Curtin, Maurer, and Rosenberg; Metropolitan Life Insurance Company; Johansen; and others. The results of this study are generally consistent with those of the previous studies, while use of the more recent (1990) standard greatly affects the absolute levels of mortality, bringing them into close alignment with the observed unadjusted death rates for the current period. Their effect on relative levels and on trends are far less marked, with a few exceptions, similar to those noted in previous studies.

Mortality sex ratios are somewhat affected by the use of the more recent population standard but trends in these ratios are not. Mortality race ratios are affected, as are trends in the ratios for a number of the selected causes of death, a finding that definitely needs to be considered if a change in standards is contemplated. The impact of alternative standards on stochastic variation was also examined, as it was in the earlier study by Curtin (10). It was shown that while standard errors were considerably larger when the 1990 standard was used, relative standard errors remained the same.

While the effect of alternative standards on geographic comparisons was not explored in the present study, it was by Curtin and his colleagues (10). They found that the ranking of States in terms of their average mortality levels tended to remain relatively stable regardless of whether the 1940 or the 1970 population was used as the standard. Further, the rankings of the States in terms of their age-adjusted death rates were highly correlated with rankings based on life expectancy. In the few instances where the State rankings changed considerably, the age-specific mortality patterns or age structures of the States (Alaska and Hawaii) were unusual, suggesting the need to augment aggregate measures with more detailed measures.

The conclusions drawn by this study are also generally consistent with those of earlier studies, namely, that there is no compelling statistical basis for selecting one standard population over another. Instead, the arguments pro and con tend to emphasize, instead, symbolic or nonstatistical criteria. These are exemplified by the opposing views of Johansen on the one hand and Chiazze on the other. In arguing for a more current standard, Johansen states ‘‘we should want to know what is happening in terms of our current population, not what would have happened to a population living 50 years ago’’ (8). Chiazze has taken an altogether different view of using an old versus a current standard population. He notes than an earlier standard helps remind us that age-adjusted death rates are constructs or indexes that are useful for comparative purposes, ‘‘but whose absolute magnitude are not indicative of the actual situation,’’ (13) and have the additional advantage of retaining continuity with historic time series.

The arguments we hear today regarding alternative population standards remind us of the arguments in the 1930’s over the appropriate population standard for England and Wales. The issues and the considerations have not changed much. The complexity of the issue, the importance of the issue for promoting uniformity and comparability of major health indicators domestically and internationally, and the consequences of making changes for the production of tabular data suggest the wisdom of proceeding on the matter in a deliberative and cautious way, seeking consultation and consensus to either stay with the existing standard or to embrace a new standard when both the statistical and nonstatistical considerations for change are sufficiently compelling.

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Table 1. Age-adjusted death rates based on the 1940 and 1990 standards and death rates by 10-year age groups for All causes, by selected characteristics: United States, 1968, 1980, and 1988

[Rates per 100,000 population]

Characteristic	*Age-ajusted death rate*												
	1940 standard	*1990 standard*	*Under 1 year*	*1–4 years*	*5–14 years*	*15–24 years*	*25–34 years*	*35–44 years*	*45–54 years*	*55–64 years*	*65–74 years*	*75–84 years*	*85 years and over*
Race													
White:													
1968	569.5	913.9	1,169.2	61.2	31.5	111.6	114.9	206.3	559.2	1,318.5	2,945.8	6,734.8	15,761.1
1980	559.4	906.3	1,099.9	57.9	29.1	112.0	118.4	197.2	531.6	1,276.7	2,921.1	6,664.9	16,220.0
1988	509.8	841.6	832.0	45.7	23.9	95.1	116.2	188.0	438.8	1,173.0	2,667.6	6,282.9	15,875.6
Percent change:													
1968–88	(10.5)	(7.9)	(28.8)	(25.3)	(24.1)	(14.8)	1.1	(8.9)	(21.5)	(11.0)	(9.4)	(6.7)	0.7
1980–88	(8.9)	(7.1)	(24.4)	(21.1)	(17.9)	(15.1)	(1.9)	(4.7)	(17.5)	(8.1)	(8.7)	(5.7)	(2.1)
Black:													
1968	831.8	1,162.6	2,596.1	104.6	43.2	136.1	262.5	508.2	1,105.3	2,159.9	3,876.0	6,569.2	12,550.7
1980	842.5	1,201.3	2,356.6	97.6	39.0	138.3	269.5	489.9	1,087.6	2,146.6	3,932.9	7,382.6	13,610.8
1988	788.8	1,142.6	1,996.6	80.8	36.0	145.2	275.4	499.3	924.6	1,923.9	3,649.7	7,440.9	13,482.5
Percent change:													
1968–88	(5.2)	(1.7)	(23.1)	(22.8)	(16.7)	6.7	4.9	(1.8)	(16.3)	(10.9)	(5.8)	13.3	7.4
1980–88	(6.4)	(4.9)	(15.3)	(17.2)	(7.7)	5.0	2.2	1.9	(15.0)	(10.4)	(7.2)	0.8	(0.9)
Ratio (black/white):													
1968	1.46	1.27	2.22	1.71	1.37	1.22	2.28	2.46	1.98	1.64	1.32	0.98	0.8
1980	1.51	1.33	2.14	1.69	1.34	1.23	2.28	2.48	2.05	1.68	1.35	1.11	0.8
1988	1.55	1.36	2.40	1.77	1.51	1.53	2.37	2.66	2.11	1.64	1.37	1.18	0.8
Percent change:													
1968–88	5.9	6.7	8.1	3.4	9.8	25.2	3.7	7.8	6.6	0.1	4.0	21.4	6.6
1980–88	2.7	2.4	12.0	4.9	12.4	23.6	4.1	6.9	3.0	(2.5)	1.6	6.9	1.2
Sex													
Male:													
1968	965.2	1,482.1	2,562.6	98.2	52.3	182.8	214.0	406.0	988.7	2,344.1	5,049.1	10,215.2	21,732.0
1980	777.2	1,217.7	1,428.5	72.6	36.7	172.3	196.1	299.2	767.3	1,815.1	4,105.2	8,816.7	18,801.1
1988	696.7	1,110.7	1,113.7	56.5	30.9	151.0	196.7	301.4	629.0	1,606.9	3,573.8	8,223.2	18,370.8
Percent change:													
1968–88	(27.8)	(25.1)	(56.5)	(42.5)	(40.9)	(17.4)	(8.1)	(25.8)	(36.4)	(31.4)	(29.2)	(19.5)	(15.5)
1980–88	(10.4)	(8.8)	(22.0)	(22.2)	(15.8)	(12.4)	0.3	0.7	(18.0)	(11.5)	(12.9)	(6.7)	(2.3)
Female:													
1968	437.4	723.3	1,222.7	58.8	25.6	59.6	77.5	168.6	431.7	948.2	2,125.3	5,444.1	14,245.0
1980	432.6	723.7	1,141.7	54.7	24.2	57.5	75.9	159.3	412.9	934.3	2,144.7	5,440.1	14,746.9
1988	404.4	687.2	897.7	45.0	20.4	52.1	74.0	140.0	350.9	904.7	2,056.1	5,173.3	14,508.1
Percent change:													
1968–88	(7.5)	(5.0)	(26.6)	(23.5)	(20.3)	(12.6)	(4.5)	(17.0)	(18.7)	(4.6)	(3.3)	(5.0)	1.8
1980–88	(6.5)	(5.1)	(21.4)	(17.7)	(15.7)	(9.4)	(2.5)	(12.1)	(15.0)	(3.2)	(4.1)	(4.9)	(1.6)
Ratio (male/female):													
1968	2.21	2.05	2.10	1.67	2.04	3.07	2.76	2.41	2.29	2.47	2.38	1.88	1.53
1980	1.80	1.68	1.25	1.33	1.52	3.00	2.58	1.88	1.86	1.94	1.91	1.62	1.27
1988	1.72	1.62	1.24	1.26	1.51	2.90	2.66	2.15	1.79	1.78	1.74	1.59	1.27
Percent change:													
1968–88	(21.9)	(21.1)	(40.8)	(24.8)	(25.9)	(5.5)	(3.7)	(10.6)	(21.7)	(28.2)	(26.8)	(15.3)	(17.0)
1980–88	(4.1)	(3.9)	(0.8)	(5.4)	(0.1)	(3.3)	2.9	14.6	(3.5)	(8.6)	(9.2)	(1.9)	(0.7)

Table 2. Age-adjusted death rates based on the 1940 and 1990 standards and death rates by 10-year age groups for Cancer, by selected characteristics: United States, 1968, 1980, and 1988

[Rates per 100,000 population]

	Age-adjusted death rate												
Characteristic	*1940 standard*	*1990 standard*	*Under 1 year*	*1–4 years*	*5–14 years*	*15–24 years*	*25–34 years*	*35–44 years*	*45–54 years*	*55–64 years*	*65–74 years*	*75–84 years*	*85 years and over*
Race													
White:													
1968	126.9	180.6	4.9	8.4	6.6	8.3	16.8	58.0	175.2	402.0	742.2	1,142.5	1,509.7
1980	129.6	187.8	3.1	4.5	4.5	6.3	13.5	46.0	170.8	422.2	807.2	1,227.6	1,600.8
1988	130.0	191.4	2.2	3.8	3.2	5.1	11.5	41.6	152.3	437.1	833.8	1,305.6	1,640.2
Percent change:													
1968–88	2.4	6.0	(55.1)	(54.8)	(51.5)	(38.6)	(31.5)	(28.3)	(13.1)	8.7	12.3	14.3	8.6
1980–88	0.3	1.9	(29.0)	(15.6)	(28.9)	(19.0)	(14.8)	(9.6)	(10.8)	3.5	3.3	6.4	2.5
Black:													
1968	155.9	205.5	4.7	6.2	4.9	7.8	21.9	89.8	266.7	546.6	845.5	1,035.9	1,079.3
1980	172.1	236.0	3.7	4.5	3.5	6.8	16.4	73.7	276.3	612.0	981.1	1,352.5	1,571.1
1988	171.3	242.2	3.0	3.6	2.9	5.6	15.8	69.7	243.8	588.1	1,029.2	1,542.8	1,720.1
Percent change:													
1968–88	9.8	17.9	(36.2)	(41.9)	(40.8)	(28.2)	(27.9)	(22.4)	(8.6)	7.6	21.7	48.9	59.4
1980–88	(0.4)	2.6	(18.9)	(20.0)	(17.1)	(17.6)	(3.7)	(5.4)	(11.8)	(3.9)	4.9	14.1	9.5
Ratio (black/white):													
1968	1.23	1.14	0.96	0.74	0.74	0.94	1.30	1.55	1.52	1.36	1.14	0.91	0.71
1980	1.33	1.26	1.19	1.00	0.78	1.08	1.21	1.60	1.62	1.45	1.22	1.10	0.98
1988	1.32	1.27	1.36	0.95	0.91	1.10	1.37	1.68	1.60	1.35	1.23	1.18	1.05
Percent change:													
1968–88	7.2	11.3	42.2	28.4	22.1	16.8	5.4	8.2	5.2	(1.0)	8.4	30.3	46.7
80–88	(0.7)	0.7	14.3	(5.3)	16.5	1.7	13.1	4.6	(1.0)	(7.2)	1.6	7.3	6.9
Sex													
Male:													
1968	155.5	227.4	4.7	8.8	6.9	10.0	17.3	53.7	183.0	497.9	998.2	1,520.1	1,936.1
1980	165.5	249.2	3.7	5.2	4.9	7.8	13.4	44.0	188.7	520.8	1,093.2	1,790.5	2,369.5
1988	162.4	249.2	2.3	3.8	3.6	5.9	11.7	39.7	166.3	526.7	1,072.7	1,861.0	2,527.9
Percent change:													
1968–88	4.5	9.6	(51.1)	(56.8)	(47.8)	(41.0)	(32.4)	(26.1)	(9.1)	5.8	7.5	22.4	30.6
1980–88	(1.8)	(0.0)	(37.8)	(26.9)	(26.5)	(24.4)	(12.7)	(9.8)	(11.9)	1.1	(1.9)	3.9	6.7
Female:													
1968	108.8	149.3	5.1	7.3	5.7	6.5	17.2	67.9	183.0	337.2	553.1	869.4	1,223.6
1980	109.2	152.5	2.7	3.7	3.6	4.8	14.0	53.1	171.8	361.7	607.1	903.1	1,255.7
1988	111.2	158.2	2.3	3.7	2.7	4.2	12.2	48.5	154.9	376.6	659.2	982.6	1,292.8
Percent change:													
1968–88	2.2	6.0	(54.9)	(49.3)	(52.6)	(35.4)	(29.1)	(28.6)	(15.4)	11.7	19.2	13.0	5.7
1980–88	1.8	3.8	(14.8)	0.0	(25.0)	(12.5)	(12.9)	(8.7)	(9.8)	4.1	8.6	8.8	3.0
Ratio (male/female):													
1968	1.43	1.52	0.92	1.21	1.21	1.54	1.01	0.79	1.00	1.48	1.80	1.75	1.58
1980	1.52	1.63	1.37	1.41	1.36	1.63	0.96	0.83	1.10	1.44	1.80	1.98	1.89
1988	1.46	1.57	1.00	1.03	1.33	1.40	0.96	0.82	1.07	1.40	1.63	1.89	1.96
Percent change:													
1968–88	2.2	3.4	8.5	(14.8)	10.1	(8.7)	(4.7)	3.5	7.4	(5.3)	(9.8)	8.3	23.6
1980–88	(3.6)	(3.6)	(27.0)	(26.9)	(2.0)	(13.6)	0.2	(1.2)	(2.3)	(2.9)	(9.6)	(4.5)	3.6

Table 3. Age-adjusted death rates based on the 1940 and 1990 standards and death rates by 10-year age groups for Cancer of respiratory system, by selected characteristics: United States, 1968, 1980, and 1988

[Rates per 100,000 population]

Characteristic	*Age-adjusted death rate*												
	1940 standard	*1990 standard*	*Under 1 year*	*1–4 years*	*5–14 years*	*15–24 years*	*25–34 years*	*35–44 years*	*45–54 years*	*55–64 years*	*65–74 years*	*75–84 years*	*85 years and over*
Race													
White:													
1968	26.3	34.7	0.2	0.0	0.1	0.2	1.0	10.2	41.2	106.6	168.3	161.3	117.4
1980	35.6	48.2	0.1	0.0	0.0	0.1	0.7	9.0	53.6	140.4	242.7	252.9	185.6
1988	39.4	55.0	0.1	0.0	0.0	0.1	0.7	7.0	47.6	160.0	279.7	325.7	228.3
Percent change:													
1968–88	49.6	58.8	(43.2)	(100.0)	(100.0)	(43.2)	(31.9)	(31.3)	15.4	50.1	66.2	101.9	94.5
1980–88	10.6	14.1	0.0	0.0	0.0	0.0	0.0	(22.2)	(11.2)	14.0	15.2	28.8	23.0
Black:													
1968	30.4	37.1	0.2	0.0	0.0	0.1	1.4	18.5	66.3	124.5	149.5	130.2	98.9
1980	46.5	59.0	0.4	0.1	0.0	0.2	1.3	16.5	89.7	198.3	263.9	243.3	172.9
1988	49.8	66.5	0.2	0.0	0.0	0.2	0.9	13.1	77.7	206.3	320.9	340.2	234.5
Percent change:													
1968–88	63.7	79.2	(5.4)	0.0	(100.0)	55.0	(37.8)	(29.2)	17.2	65.7	114.7	161.2	137.1
1980–88	7.1	12.7	(50.0)	(100.0)	0.0	0.0	(30.8)	(20.6)	(13.4)	4.0	21.6	39.8	35.6
Ratio (black/white):													
1968	1.16	1.07	1.20	0.00	0.58	0.73	1.41	1.82	1.61	1.17	0.89	0.81	0.84
1980	1.31	1.22	4.00	0.0	0.0	2.00	1.86	1.83	1.67	1.41	1.09	0.96	0.93
1988	1.26	1.21	2.00	0.0	0.0	2.00	1.29	1.87	1.63	1.29	1.15	1.04	1.03
Percent change:													
1968–88	9.4	12.9	66.5	0.0	0.0	173.1	(8.6)	3.1	1.5	10.4	29.2	29.4	21.9
80–88	(3.1)	(1.2)	(50.0)	0.0	0.0	0.0	(30.8)	2.1	(2.5)	(8.7)	5.5	8.6	10.3
Sex													
Male:													
1968	47.9	64.1	0.2	0.0	0.1	0.2	1.6	16.1	69.6	192.1	324.4	313.7	217.0
1980	59.7	83.8	0.3	0.0	0.0	0.2	1.0	12.6	79.8	223.8	422.0	511.5	386.3
1988	59.7	86.6	0.1	0.0	0.0	0.2	0.9	9.6	65.7	229.5	425.4	579.8	492.8
Percent change:													
1968–88	24.6	35.1	(42.7)	(100.0)	(100.0)	(16.0)	(42.7)	(40.3)	(5.6)	19.4	31.2	84.9	127.0
1980–88	0.0	3.4	(66.7)	0.0	0.0	0.0	(10.0)	(23.8)	(17.7)	2.5	0.8	13.4	27.6
Female:													
1968	8.9	11.4	0.2	0.1	0.1	0.1	0.6	6.1	18.8	31.6	41.9	53.9	61.8
1980	18.3	23.5	0.1	0.1	0.1	0.0	0.6	6.8	34.8	74.5	106.1	98.0	96.3
1988	24.4	33.0	0.1	0.0	0.0	0.1	0.5	5.6	35.0	102.2	164.1	169.9	125.7
Percent change:													
1968–88	175.7	190.7	(45.1)	(100.0)	(100.0)	(6.3)	(17.0)	(8.5)	86.6	223.8	291.8	215.0	103.6
1980–88	33.9	40.6	0.0	(100.0)	(100.0)	0.0	(16.7)	(17.6)	0.6	37.2	54.7	73.4	30.5
Ratio (male/female):													
1968	5.40	5.64	0.96	0.16	0.82	2.23	2.61	2.63	3.71	6.09	7.74	5.82	3.51
1980	3.27	3.56	3.00	0.00	0.00	0.0	1.67	1.85	2.29	3.00	3.98	5.22	4.01
1988	2.44	2.62	1.00	0.0	0.0	2.00	1.80	1.71	1.88	2.25	2.59	3.41	3.92
Percent change:													
1968–88	(54.8)	(53.5)	4.2	0.0	0.0	(10.3)	(30.9)	(34.8)	(49.4)	(63.1)	(66.5)	(41.3)	11.5
1980–88	(25.3)	(26.5)	(66.7)	0.0	0.0	0.0	8.0	(7.5)	(18.1)	(25.2)	(34.8)	(34.6)	(2.3)

Table 4. Age-adjusted death rates based on the 1940 and 1990 standards and death rates by 10-year age groups for Cerebrovascular diseases, by selected characteristics: United States, 1968, 1980, and 1988

[Rates per 100,000 population]

Characteristic	*Age-adjusted death rate*												
	1940 standard	*1990 standard*	*Under 1 year*	*1–4 years*	*5–14 years*	*15–24 years*	*25–34 years*	*35–44 years*	*45–54 years*	*55–64 years*	*65–74 years*	*75–84 years*	*85 years and over*
Race													
White:													
1968	66.2	134.9	4.5	0.8	0.7	1.5	3.6	12.0	35.1	101.3	375.0	1,312.5	3,698.6
1980	38.0	79.5	3.6	0.4	0.2	0.8	2.0	6.6	20.2	56.0	202.1	776.2	2,328.4
1988	27.5	57.5	3.0	0.3	0.2	0.7	1.7	5.0	14.9	43.3	142.3	542.0	1,739.4
Percent change:													
1968–88	(58.4)	(57.4)	(33.3)	(62.5)	(71.4)	(53.3)	(52.8)	(58.3)	(57.5)	(57.3)	(62.1)	(58.7)	(53.0)
1980–88	(27.7)	(27.6)	(16.7)	(25.0)	0.0	(12.5)	(15.0)	(24.2)	(26.2)	(22.7)	(29.6)	(30.2)	(25.3)
Black:													
1968	125.8	198.0	9.3	1.3	0.8	3.6	14.7	56.4	139.4	339.5	795.9	1,442.4	2,676.1
1980	68.5	114.8	8.8	0.6	0.4	1.9	7.3	25.0	71.0	161.5	408.9	976.4	1,888.6
1988	51.5	86.3	8.8	0.6	0.3	1.0	6.0	21.9	53.6	124.2	290.6	736.5	1,445.4
Percent change:													
1968–88	(59.0)	(56.4)	(5.4)	(53.8)	(62.5)	(72.2)	(59.2)	(61.2)	(61.5)	(63.4)	(63.5)	(48.9)	(46.0)
1980–88	(24.8)	(24.9)	0.0	0.0	(25.0)	(47.4)	(17.8)	(12.4)	(24.5)	(23.1)	(28.9)	(24.6)	(23.5)
Ratio (black/white):													
1968	1.90	1.47	2.07	1.63	1.14	2.40	4.08	4.70	3.97	3.35	2.12	1.10	0.72
1980	1.80	1.44	2.44	1.50	2.00	2.37	3.65	3.79	3.51	2.88	2.02	1.26	0.81
1988	1.87	1.50	2.93	2.00	1.50	1.43	3.53	4.38	3.60	2.87	2.04	1.36	0.83
Percent change:													
1968–88	(1.6)	2.3	41.9	23.1	31.2	(40.5)	(13.6)	(6.8)	(9.4)	(14.4)	(3.8)	23.6	14.8
1980–88	4.0	3.9	20.0	33.3	(25.0)	(39.8)	(3.3)	15.6	2.3	(0.5)	0.9	8.0	2.4
Sex													
Male:													
1968	78.7	151.4	5.6	0.8	0.7	1.8	4.8	16.4	47.9	144.2	483.1	1,418.2	3,591.6
1980	44.9	88.4	5.0	0.4	0.3	1.1	2.6	8.7	27.3	74.7	259.2	868.3	2,199.2
1988	32.4	63.5	4.2	0.4	0.2	0.8	2.4	7.5	21.0	59.5	176.5	603.2	1,625.6
Percent change:													
1968–88	(58.8)	(58.1)	(25.0)	(50.0)	(71.4)	(55.6)	(50.0)	(54.3)	(56.2)	(58.7)	(63.5)	(57.5)	(54.7)
1980–88	(27.7)	(28.2)	(16.0)	0.0	(33.3)	(27.3)	(7.7)	(13.8)	(23.1)	(20.3)	(31.9)	(30.5)	(26.1)
Female:													
1968	65.3	131.4	4.9	0.9	0.6	1.7	4.9	16.6	41.5	101.4	351.6	1,248.8	3,618.3
1980	37.6	78.0	3.8	0.5	0.3	0.8	2.6	8.4	23.3	56.9	189.0	741.6	2,328.2
1988	27.6	57.0	3.7	0.4	0.2	0.7	2.1	6.2	17.4	44.0	137.3	523.7	1,738.4
Percent change:													
1968–88	(57.8)	(56.6)	(24.5)	(55.6)	(66.7)	(58.8)	(57.1)	(62.7)	(58.1)	(56.6)	(60.9)	(58.1)	(52.0)
1980–88	(26.8)	(26.9)	(2.6)	(20.0)	(33.3)	(12.5)	(19.2)	(26.2)	(25.3)	(22.7)	(27.4)	(29.4)	(25.3)
Ratio (male/female):													
1968	1.21	1.15	1.14	0.89	1.17	1.06	0.98	0.99	1.15	1.42	1.37	1.14	0.99
1980	1.19	1.13	1.32	0.80	1.00	1.38	1.00	1.04	1.17	1.31	1.37	1.17	0.94
1988	1.18	1.11	1.14	1.00	1.00	1.14	1.14	1.21	1.21	1.35	1.29	1.15	0.94
Percent change:													
1968–88	(2.3)	(3.3)	(0.7)	12.5	(14.3)	7.9	16.7	22.4	4.6	(4.9)	(6.4)	1.4	(5.8)
1980–88	(1.3)	(1.7)	(13.7)	25.0	0.0	(16.9)	14.3	16.8	3.0	3.0	(6.3)	(1.6)	(1.0)

Table 5. Age-adjusted death rates based on the 1940 and 1990 standards and death rates by 10-year age groups for Homicide, by selected characteristics: United States, 1968, 1980, and 1988

[Rates per 100,000 population]

	Age-adjusted death rate												
Characteristics	*1940 standard*	*1990 standard*	*Under 1 year*	*1–4 years*	*5–14 years*	*15–24 years*	*25–34 years*	*35–44 years*	*45–54 years*	*55–64 years*	*65–74 years*	*75–84 years*	*85 years and over*
Race													
White:													
1968	4.2	4.2	4.0	1.1	0.5	4.8	6.9	6.3	5.0	4.0	3.3	2.9	3.3
1980	6.9	6.9	4.3	1.7	0.9	10.1	11.6	9.7	7.3	4.8	4.4	4.4	4.8
1988	5.3	5.2	5.8	1.9	0.9	7.8	8.9	6.8	5.0	3.9	3.1	3.4	3.5
Percent change:													
1968–88	25.6	23.8	45.0	72.7	80.0	62.5	29.0	7.9	0.0	(2.5)	(6.1)	17.2	6.1
1980–88	(23.8)	(23.8)	34.9	11.8	0.0	(22.8)	(23.3)	(29.9)	(31.5)	(18.8)	(29.5)	(22.7)	(27.1)
Black:													
1968	42.3	41.8	9.5	3.8	2.2	49.8	83.7	70.2	49.1	30.2	16.0	10.1	8.7
1980	40.6	40.3	15.7	6.8	2.6	50.6	81.2	59.7	44.5	29.7	19.3	14.8	11.3
1988	34.1	33.7	21.4	6.9	3.6	59.1	64.8	44.0	24.5	16.9	16.4	17.6	18.3
Percent change:													
1968–88	(19.3)	(19.4)	125.3	81.6	63.6	18.7	(22.6)	(37.3)	(50.1)	(44.0)	2.5	74.3	110.3
1980–88	(16.0)	(16.4)	36.3	1.5	38.5	16.8	(20.2)	(26.3)	(44.9)	(43.1)	(15.0)	18.9	61.9
Ratio (black/white):													
1968	10.05	9.85	2.38	3.45	4.40	10.38	12.13	11.14	9.82	7.55	4.85	3.48	2.64
1980	5.85	5.85	3.65	4.00	2.89	5.01	7.00	6.15	6.10	6.19	4.39	3.36	2.35
1988	6.45	6.42	3.69	3.63	4.00	7.58	7.28	6.47	4.90	4.33	5.29	5.18	5.23
Percent change:													
1968–88	(35.8)	(34.9)	55.4	5.1	(9.1)	(27.0)	(40.0)	(41.9)	(50.1)	(42.6)	9.1	48.6	98.3
1980–88	10.2	9.7	1.1	(9.2)	38.5	51.2	4.0	5.1	(19.6)	(30.0)	20.6	53.9	122.1
Sex													
Male:													
1968	13.4	13.3	4.7	1.5	0.9	16.4	25.3	20.8	15.1	10.5	7.6	5.4	5.9
1980	6.9	6.9	4.3	1.7	0.9	10.1	11.6	9.7	7.3	4.8	4.4	4.4	4.8
1988	5.3	5.2	5.8	1.9	0.9	7.8	8.9	6.8	5.0	3.9	3.1	3.4	3.5
Percent change:													
1968–88	(60.5)	(60.6)	23.4	26.7	0.0	(52.4)	(64.8)	(67.3)	(66.9)	(62.9)	(59.2)	(37.0)	(40.7)
1980–88	(23.8)	(23.8)	34.9	11.8	0.0	(22.8)	(23.3)	(29.9)	(31.5)	(18.8)	(29.5)	(22.7)	(27.1)
Female:													
1968	4.1	4.0	4.9	2.3	1.1	5.8	6.2	5.4	3.7	2.6	2.7	3.4	3.7
1980	4.5	4.4	5.6	2.2	1.1	6.6	7.0	5.7	4.1	2.8	3.0	3.5	4.3
1988	4.2	4.2	8.7	2.3	1.1	6.0	7.3	4.6	3.1	2.5	2.9	3.5	3.7
Percent change:													
1968–88	2.3	3.1	77.6	0.0	0.0	3.4	17.7	(14.8)	(16.2)	(3.8)	7.4	2.9	0.0
1980–88	(6.9)	(6.1)	55.4	4.5	0.0	(9.1)	4.3	(19.3)	(24.4)	(10.7)	(3.3)	0.0	(14.0)
Ratio (male/female):													
1968	3.29	3.30	0.96	0.65	0.82	2.83	4.08	3.85	4.08	4.04	2.81	1.59	1.59
1980	1.55	1.55	0.77	0.77	0.82	1.53	1.66	1.70	1.78	1.71	1.47	1.26	1.12
1988	1.27	1.26	0.67	0.83	0.82	1.30	1.22	1.48	1.61	1.56	1.07	0.97	0.95
Percent change:													
1968–88	(61.4)	(61.8)	(30.5)	26.7	0.0	(54.0)	(70.1)	(61.6)	(60.5)	(61.4)	(62.0)	(38.8)	(40.7)
1980–88	(18.1)	(18.8)	(13.2)	6.9	0.0	(15.0)	(26.4)	(13.1)	(9.4)	(9.0)	(27.1)	(22.7)	(15.3)

Table 6. Deaths, age-adjusted death rates based on the 1940 and 1990 standards, standard errors, and relative standard errors in percent for All causes, by selected characteristics: United States, 1988

Characteristic	Deaths	*Age-adjusted death rates* 1940 standard	*Age-adjusted death rates* 1990 standard	*Standard errors* 1940 standard	*Standard errors* 1990 standard	*Relative standard errors (percent)* 1940 standard	*Relative standard errors (percent)* 1990 standard
White							
Observed number . . . . .D	1,876,969	509.8	841.6	0.4	0.6	0.1	0.1
Ten-percent sample 0.1D	187,697	509.8	841.6	1.3	1.9	0.3	0.2
One-percent sample 0.01D	18,770	509.8	841.6	4.1	6.0	0.8	0.7
Black							
Observed number . . . . .D	264,026	788.8	1,142.6	1.6	2.2	0.2	0.2
Ten-percent sample 0.1D	26,403	788.8	1,142.6	5.0	7.0	0.6	0.6
One-percent sample 0.01D	2,640	788.8	1,142.6	15.8	22.0	2.0	1.9
Male							
Observed number . . . . .D	1,125,537	696.7	1,110.7	0.7	1.0	0.1	0.1
Ten-percent sample 0.1D	112,554	696.7	1,110.7	2.1	3.2	0.3	0.3
One-percent sample 0.01D	11,255	696.7	1,110.7	6.8	10.2	1.0	0.9
Female							
Observed number . . . . .D	1,042,465	404.4	687.2	0.5	0.7	0.1	0.1
Ten-percent sample 0.1D	104,246	404.4	687.2	1.5	2.1	0.4	0.3
One-percent sample 0.01D	10,425	404.4	687.2	4.7	6.6	1.2	1.0

Table 7. Deaths, age-adjusted death rates based on the 1940 and 1990 standards, standard errors, and relative standard errors in percent for Cancer, by selected characteristics: United States, 1988

Characteristic	Deaths	*Age-adjusted death rates* 1940 standard	*Age-adjusted death rates* 1990 standard	*Standard errors* 1940 standard	*Standard errors* 1990 standard	*Relative standard errors (percent)* 1940 standard	*Relative standard errors (percent)* 1990 standard
White							
Observed number . . . . .D	425,123	130.0	191.4	0.2	0.3	0.2	0.2
Ten-percent sample 0.1D	42,512	130.0	191.4	0.7	0.9	0.5	0.5
One-percent sample 0.01D	4,251	130.0	191.4	2.2	2.9	1.7	1.5
Black							
Observed number . . . . .D	53,971	171.3	242.2	0.8	1.0	0.4	0.4
Ten-percent sample 0.1D	5,397	171.3	242.2	2.4	3.3	1.4	1.4
One-percent sample 0.01D	540	171.3	242.2	7.6	10.5	4.4	4.3
Male							
Observed number . . . . .D	258,035	162.4	249.2	0.3	0.5	0.2	0.2
Ten-percent sample 0.1D	25,804	162.4	249.2	1.0	1.6	0.6	0.6
One-percent sample 0.01D	2,580	162.4	249.2	3.3	4.9	2.0	2.0
Female							
Observed number . . . . .D	226,924	111.2	158.2	0.3	0.3	0.2	0.2
Ten-percent sample 0.1D	22,692	111.2	158.2	0.8	1.1	0.7	0.7
One-percent sample 0.01D	2,269	111.2	158.2	2.6	3.3	2.3	2.1

Table 8. Deaths, age-adjusted death rates based on the 1940 and 1990 standards, standard errors, and relative standard errors in percent for Cancer of the respiratory system, by selected characteristics: United States, 1988

Characteristic	Deaths	Age-adjusted death rates		Standard errors		Relative standard errors (percent)	
		1940 standard	1990 standard	1940 standard	1990 standard	1940 standard	1990 standard
White							
Observed number . . . . .D	121,938	39.4	55.0	0.1	0.2	0.3	0.3
Ten-percent sample 0.1D	12,194	39.4	55.0	0.4	0.5	1.0	0.9
One-percent sample 0.01D	1,219	39.4	55.0	1.2	1.6	3.0	2.9
Black							
Observed number . . . . .D	14,950	49.8	66.5	0.4	0.5	0.8	0.8
Ten-percent sample 0.1D	1,495	49.8	66.5	1.3	1.7	2.7	2.6
One-percent sample 0.01D	149	49.8	66.5	4.2	5.5	8.4	8.2
Male							
Observed number . . . . .D	91,839	59.7	86.6	0.2	0.3	0.3	0.3
Ten-percent sample 0.1D	9,184	59.7	86.6	0.6	0.9	1.1	1.1
One-percent sample 0.01D	918	59.7	86.6	2.0	2.9	3.4	3.3
Female							
Observed number . . . . .D	46,393	24.4	33.0	0.1	0.2	0.5	0.5
Ten-percent sample 0.1D	4,639	24.4	33.0	0.4	0.5	1.6	1.5
One-percent sample 0.01D	464	24.4	33.0	1.2	1.5	5.0	4.7

Table 9. Deaths, age-adjusted death rates based on the 1940 and 1990 standards, standard errors, and relative standard errors in percent for Cerebrovascular diseases, by selected characteristics: United States, 1988

Characteristic	Deaths	Age-adjusted death rates		Standard errors		Relative standard errors (percent)	
		1940 standard	1990 standard	1940 standard	1990 standard	1940 standard	1990 standard
White							
Observed number . . . . .D	130,025	27.5	57.5	0.1	0.2	0.3	0.3
Ten-percent sample 0.1D	13,003	27.5	57.5	0.3	0.5	1.0	0.9
One-percent sample 0.01D	1,300	27.5	57.5	0.9	1.6	3.1	2.8
Black							
Observed number . . . . .D	18,484	51.5	86.3	0.4	0.6	0.8	0.7
Ten-percent sample 0.1D	1,848	51.5	86.3	1.3	2.0	2.5	2.3
One-percent sample 0.01D	185	51.5	86.3	4.0	6.4	7.8	7.4
Male							
Observed number . . . . .D	59,749	32.4	63.5	0.1	0.3	0.4	0.4
Ten-percent sample 0.1D	5,975	32.4	63.5	0.4	0.8	1.4	1.3
One-percent sample 0.01D	597	32.4	63.5	1.4	2.6	4.3	4.1
Female							
Observed number . . . . .D	90,770	27.6	57.0	0.1	0.2	0.4	0.3
Ten-percent sample 0.1D	9,077	27.6	57.0	0.3	0.6	1.3	1.1
One-percent sample 0.01D	908	27.6	57.0	1.1	1.9	4.0	3.3

Table 10. Deaths, age-adjusted death rates based on the 1940 and 1990 standards, standard errors, and relative standard errors in percent for Homicide, by selected characteristics: United States, 1988

Characteristic	Deaths	*Age-adjusted death rates*		*Standard errors*		*Relative standard errors (percent)*	
		1940 standard	*1990 standard*	*1940 standard*	*1990 standard*	*1940 standard*	*1990 standard*
White							
Observed number . . . . .D	10,991	5.3	5.2	0.1	0.1	1.0	1.0
Ten-percent sample 0.1D	1,099	5.3	5.2	0.2	0.2	3.1	3.0
One-percent sample 0.01D	110	5.3	5.2	0.5	0.5	9.7	9.5
Black							
Observed number . . . . .D	10,389	34.1	33.7	0.3	0.3	1.0	1.0
Ten-percent sample 0.1D	1,039	34.1	33.7	1.1	1.1	3.1	3.1
One-percent sample 0.01D	104	34.1	33.7	3.4	3.3	9.9	9.9
Male							
Observed number . . . . .D	16,763	5.3	5.2	0.1	0.1	1.3	1.3
Ten-percent sample 0.1D	1,676	5.3	5.2	0.2	0.2	4.0	4.0
One-percent sample 0.01D	168	5.3	5.2	0.7	0.7	12.6	12.5
Female							
Observed number . . . . .D	5,295	4.2	4.2	0.1	0.1	1.4	1.4
Ten-percent sample 0.1D	529	4.2	4.2	0.2	0.2	4.5	4.4
One-percent sample 0.01D	53	4.2	4.2	0.6	0.6	14.1	13.8

Part IV
Areas of application

Chapter 6
The choice of the standard for age adjustment

by Richard Rothenberg, M.D., Center for Chronic Disease Prevention and Health Promotion, Centers for Disease Control, and Robert Hahn, Ph.D., Epidemiology Program Office, Centers for Disease Control

For five decades, the National Center for Health Statistics (NCHS) has used the population of the United States in 1940 as the standard for age adjustment of mortality statistics. Any choice of standard is arbitrary, a convenient construct for making comparisons. However, as 1940 recedes, its relevance has been questioned, because the current population structure differs markedly from that of 1940. It is tempting casually to dismiss the 1940 standard as outmoded, but the issue is complex and its resolution difficult for several reasons. Theoretically, is there a best or most appropriate standard? Empirically, does a change in standard make a difference in the perception of disease burden or the ranking of public health problems? Economically, what effort and cost are engendered by a change? Socially, what is the impact of discontinuity on public perception?

These issues have been revisited on several occasions during the last 30 years. In 1966, Spiegelman and Marks compared mortality data using the populations of 1940, 1950, and 1960 as standards (1). In 1981, Curtin, Maurer, and Rosenberg compared standardization using the 1940 and 1970 populations (2). Although their methods differed in detail (table 1), their results were similar. Spiegelman and Marks noted a major change in the absolute level of the age-adjusted rate (AAR) and that the amount of change varied by disease (major change for stroke, moderate change for diabetes, insignificant change for motor vehicle accidents and homicide). The choice of standard had little influence on the AAR for the population 65 years of age and over. The standard exerted no influence on the male-female or the black-white ratios. There was little difference in observed trends using any of the three standards.

Curtin, Maurer, and Rosenberg demonstrated a high correlation between the AAR (1940 standard) and life expectancy at birth (using 1969–72 life tables), between the AAR (1970 standard) and life expectancy at birth, and between the two standards. They noted that the AAR is higher when using the 1970 standard for total mortality and for causes for which the average age at death is higher than that for total mortality. The AAR (1970 standard) is lower, however, for causes for which the average age at death is lower than the overall average age at death. Using the percent change as a measurement of trend, they observed a small effect of a change in standard. Using annual average percent change, however, they noted an important effect of the change in standard for suicide and for cancer. By comparing two time periods for cancer, whose mortality increases were accelerating, they were able to demonstrate that the 1970 standard revealed a greater increase for cancer than the 1940 standard. In this subanalysis, they concluded that a change in standard may affect the perception of trend because of variable changes in age-specific trends—a situation for which age standardization is not optimal. Finally, they demonstrated that the change of standard had little effect on the male-female ratio and that the relative standard error of the AAR and the coefficient of variation were unaffected. Both groups of researchers concluded that a shift from the 1940 standard was not warranted at the time.

Methods

In the current analysis (table 2), we compared the effects of eight standard populations: the populations determined at each census from 1940 to 1980; an estimate of the 1990 population (3); the standard population used by the World Health Organization, referred to here as WORLD (mentioned in (4)); and a uniform standard, referred to here as UNIFORM, for which each of *n* age groups receives 1/*n*th of the weight. (A uniform standard is equivalent to the mean age-specific rate.)

Numerator data for total mortality were derived from the underlying-cause-of-death (UCD) tapes for 1968–88 supplied by NCHS (5). Numerator data for the 15 leading causes of death were taken from the UCD data for 1987. In a separate analysis, four causes of death—ischemic heart disease, cancer, chronic obstructive pulmonary disease (COPD), and Alzheimer's disease—were examined in greater detail. For them, data were extracted from the multiple-cause-of-death tapes for 1968–87 supplied by NCHS (6). A death was included if there was mention of these four conditions anywhere on the original death certificate (the ''record axis'' in the electronic format). Intercensal population estimates for 1968–79 were provided by the U.S. Bureau of the Census (3), and estimates for 1980–88 were provided by a private contractor (7). These denominators differ slightly from those currently used by NCHS, which incorporate the periodic updates of intercensal estimates supplied by the Bureau of the Census and do not use the private contractor. Nonetheless, the rate estimates generated in this analysis differ only in a minor way from those published by NCHS.

In addition to a comparison of U.S. decennial population, WORLD, and UNIFORM standards, a set of artificial weights was constructed to examine the particular effect of different types of population structures on the AAR. Four different population pyramids were examined: predominance of the young, predominance of the elderly, predominance of the middle-aged, and a population with predominance of both young and old with deemphasis of the middle-aged. In each subset, the degree of predominance was varied over a range of values.

The major factors examined were the relative change in the AAR, trends, sex and race ratios, rankings of States for ischemic heart disease, rankings of major causes of death, effect of alternative age groupings, and difference between the crude rate and the AAR. Four methods, similar in their nomenclature but somewhat different in their statistical approach, were used to examine trends: the overall percent change, which uses the first and last values to compute the change ((*Pn–Po)/Po*) (8); the average annual percent change, which also uses the first and last values and assumes uniform change in each interval (((*Pn*/*Po*)**1/*n*)–1) (8); the slope of a line fitted by linear regression through all the data points; and the corrected slope (slope/intercept), which is equivalent to the average annual percent change for the fitted line. For simple and multiple linear regression, year was converted so that the 0 point was at 1977.5, thereby centering the intercept at the midpoint of the data, which equates the intercept with the mean. For each State, a separate multiple regression analysis was performed using rank as the dependent variable and year and standard as independent variables. In these multiple regressions, the 1940–90 standards were coded 0–5. The average change in rank for each State was calculated by substituting in the regression equation.

Results

Relative effect on AAR

The choice of standard has a dramatic effect on the size of the AAR, as expected (table 3). Using the 1950–70 standards, the AAR drifts slowly upward, but there is a sharp increase with 1980 and a subsequent small fall with 1990. The rate ratios for each of the standards compared with the 1940 standard increase slightly over time; this effect is most marked for the UNIFORM to 1940 ratio.

The WORLD standard, although quite different in structure from the 1940 standard (table 4), produces a similar AAR. For instance, for 1988 the rate ratio for AAR (WORLD) to AAR (1940) was 1.045. The 1990 standard, as expected, produces a value for 1988 that is closest to the crude rate. (Obviously, if a 1990 standard were used for 1990 data, the crude rate and AAR would be identical.)

The UNIFORM standard, which gives greater total emphasis to older age groups than does any of the others, produces a very large AAR. As noted, it is equivalent to the mean age-specific rate, and in fact it corresponds most closely to the age-specific rate for persons aged 65–69 years for the period 1968–88. Thus, it may be viewed as providing information usually not incorporated in the AAR.

Trends

For total mortality, the overall percent change and the average annual percent change do not vary appreciably with the standard chosen (table 5). The slope of mortality decline, however, is accentuated by the more recent standards. Although the slope is a larger negative number using the 1990 standard than using the 1940 standard, it is actually a smaller percent of the intercept (mean AAR). The WORLD standard produces results similar to those for the 1940 standard. The UNIFORM standard is considerably different. The two measures of percent change are smaller, the slope is steeper, and the slope is a smaller proportion of the mean AAR.

The specific causes of mortality exhibit different trend patterns with different standards. For ischemic heart disease, which has undergone dramatic declines, the trends are similar to those for overall mortality. There is less evidence of decline with more recent standards using either percent measure. The slope is increasingly negative for the later standards, but the slope is also a smaller percent of the mean AAR.

In the case of cancer, for which there have been small increases in overall mortality, the opposite occurs. The percent measures are magnified by using more recent standards; using 1990, the overall percent increase is 5.5 percent, compared with 2.4 percent for 1940. The slope also increases, but more importantly, the slope is a greater proportion of the mean AAR with more recent standards (1980 and 1990) than with the 1940 standard. Again, the WORLD standard produces results similar to those for 1940. The UNIFORM standard accentuates these increases to an even greater extent than do the 1980 and 1990 standards.

A similar phenomenon occurs for Alzheimer's disease, whose increases have been among the most dramatic for any cause of death, including AIDS. A change of standard from 1940 to 1990 more than doubles the percent change and produces large increases for all the other parameters. If the UNIFORM distribution is used, the overall percent increase is elevated almost fourfold.

Chronic obstructive pulmonary disease is a condition for which there has been no significant mortality trend during the period of observation. It is of interest that the choice of standard can actually alter the perceived direction of change. The overall percent change is -1.1 percent using 1940 and 8.3 percent using 1990, although it is important to remember that none of the slopes is significant.

Thus, standards that reflect more recent population structures have a small but consistent influence on the perception of trends. It is reasonable to generalize that, for diseases with decreasing mortality, the decline will be less pronounced using a standard that reflects the current population composition than using the 1940 standard. For diseases with increasing mortality, the increase will be more pronounced. In the examples cited (with the exception of Alzheimer's disease), these differences are small to moderate. For Alzheimer's disease, the change in standard produces a marked alteration in the perception of trend.

Sex and race ratios

As with the total population, more recent standards alter the actual level of the AAR for each sex, race, and sex-race group. This alteration is not uniform across the groups or across years. The ratio of the AAR using the 1990 standard to the AAR using the 1940 standard increases from 1968 to 1988 for each of the sex, race, and sex-race groups (table 6). It is greatest for black females (9.5 percent) and smallest for white females (2.2 percent). In general, the change is greater for black than white persons and greater for men than women.

The male-female ratio, the black-white ratio, and the sex-specific black-white ratios all are smaller when more recent standards are used (table 7). The amount of change differs with each comparison and over the years. For example, the 1990 standard produces a ratio of black to white mortality among women in 1968 that is 20.1 percent less than that produced by the 1940 standard. In 1988, the ratio using the 1990 standard was only 12.9 percent lower than that using the 1940 standard.

State rankings

Each standard alters the relative rankings of States for ischemic heart disease mortality. The degree of alteration is greater with more recent standards than with the 1940 standard (table 8) and is greatest with the 1990 standard. Comparing 1990 with 1940, there is a mean movement of 2.4 ranks, with a range of 0–23 ranks. For 1987, only three States had no change in rank over all the standards: Utah (48th), Hawaii (49th), and New York (1st).

Change in rank is, of course, a function not only of standardization but of varying secular trends within States. A shift in population structure or a shift in true risk can make a State more susceptible to the effect of a change in standard. Using multiple regression analyses for each State to compare the 1990 standard with the 1940 standard, the largest negative change occurred for Georgia (-8.6) and the largest positive change for Connecticut (7.5) (table 9). The average change over all the States was 2.4 ranks. These values represent the effect of the change in the standard while controlling for secular trends, and they suggest that secular trend did not confound the change in ranks produced by different standards.

Disease rankings

The leading causes of death have different ranking patterns depending on the standard used (table 10). These changes do not affect the two major causes of death (heart disease and malignant neoplasms), but they do create generally small perturbations in the ordering of the remaining diseases. The rank order correlation coefficient for the ranks produced by the 1990 standard compared with those for the 1940 standard was 0.93 ($p<0.01$), indicating a high degree of correlation. The change in ranks was not statistically significant, but it does alter to some extent the perception of disease importance.

Relationship of crude rate and AAR

The percent difference between the crude rate and the AAR is a rough measure of the difference in structure between the population under consideration and the standard (table 11). Averaged over the years, the 1970 standard keeps the AAR closest to the crude rate. The 1940 standard provides the greatest disparity between the two measures. The 1990 standard is midway between but, as noted, provides the closest approximation of the current crude rate.

Effect of age intervals

Mortality has been significantly postponed over the period of observation. As a result, if 10-year age groups are used, each 10-year age group has a larger proportion of individuals in its upper portion than was the case 20 years ago. Use of 5-year age groups for standardization, instead of the 10-year age groups employed by NCHS, has little or no effect on the age-adjusted rate with any standard, however.

Constructed standards

A series of 16 constructed standards, each emphasizing different portions of the population, confirmed most intuitive notions of how the standards affect the relative perception of rate. A weighting system that stresses younger groups tends to magnify downward trends; conversely, a system that stresses older persons diminishes downward trends. Intermediate weighting systems have less effect in either direction. A system that stresses the middle years shows the greatest consistency over time but, under the conditions examined, elevates the AAR by a factor of 3.5 to 4.0. (The data generated by this analysis are extensive and are not presented in detail here.)

Discussion

The purpose of age standardization is to permit comparison of populations that differ in their age structure. In usual epidemiologic circumstances, several populations are compared using some intuitively acceptable standard (for instance, counties are compared using the State population as a standard, or a study and control group are compared by standardizing each to their combined population). The choice of standard is, as noted, arbitrary. However, once a standard is chosen, there is obvious value in using it consistently, particularly in the context of long-term trend data. A change in standard is not undertaken lightly. Theoretical considerations aside, an important part of the justification of standard change rests on the empirical demonstration of important (and desirable) differences in the results generated by the new standard.

Previous analyses (1,2) that compared the 1940 standard with a 1950, 1960, or 1970 standard demonstrated some differences, and these were deemed relatively unimportant. The current study confirms that the perception of disease burden is altered relatively little by use of the 1950, 1960, or 1970 standard. The data suggest, however, that a larger change occurs with 1980; this change, although slightly attenuated, continues with the 1990 standard. (Final judgment on the 1990 standard cannot be made until the official population counts are available. These analyses were based on estimates from the U.S. Bureau of the Census (3).)

Compared with the 1940 standard, the 1990 standard places the AAR in close proximity to the current crude rate. It causes attenuation of the rate of decline of total mortality and of diseases whose mortality is declining; conversely, it accentuates the rate of increase for diseases that are increasing. In general, the 1990 standard diminishes sex, race, and sex-race ratios but does so to differing degrees, depending on the groups being compared. The 1990 standard alters the relative ranking of States for the leading cause of death (ischemic heart disease). For most States, this effect is small to moderate; for several States, the effect is large; and for three States at either end of the ranking, there is no effect. It is unclear whether States in the middle of the distribution would be concerned about the alterations. There is a change in the rank ordering for the leading causes of death, but it is not statistically significant.

Given that these changes are real, the subjective question as to whether they are important remains. Several theoretical issues may be raised in this regard. First, the magnitude of the difference between the crude rate and the AAR is related to the perceived difference in trend. An adjusted trend eliminates the effect of change in population structure and provides a better perception of the ''true'' rate of change than does the crude rate. It may be argued that standards can be constructed to manipulate this rate of change at will, and the best standard is one that reports a minimum difference between the crude rate and the adjusted rate over the whole range of the data. This is likely to be a standard that emphasizes a population from the center of the chronologic distribution rather than one at either extreme. Empirically, the actual changes in the perception of trend with any standard are small (table 5), so this ''theoretical'' advantage may be helpful in decisionmaking. If the notion of a central population is pursued, its centrality should be related to the overall timespan contemplated; 1990, for example, is the central point in the 100 years of data that begin in 1940.

Dr. Kleinman has argued (9) that the use of a standard such as the 1990 population introduces an element of ''bias'' by weighting the standard toward an older population. The 1940 standard counterbalances this effect. It is unlikely that Dr. Kleinman was using the term ''bias'' in its statistical sense but rather in its more generic sense: the introduction of a preference. Again, we are dealing with subjective choice. It may well be worthwhile in some instances to blunt the effect of aging in the population by using a younger population as the standard. On the other hand, judgment could dictate that a population that reflects the current one provides the best public health perspective. An AAR that is close to the crude rate has an air of verisimilitude of which the 1940 standard AAR, by its distance from the crude rate, is deprived. If Dr. Kleinman's argument were to be pursued, however, it would appear that an ''unbiased'' standard would weight all age groups equally. The UNIFORM standard employed here has, as noted, the advantage of providing a piece of information not present with any other standard—the mean age-specific rate, which, in these data, is closest to the rate for persons aged 65–69 years. This may well be an argument for using the UNIFORM standard in some capacity.

These considerations do not appear to provide an incontrovertible argument for or against changing the current 1940 standard. One point that does emerge, however, is that there is no ''standard'' standard. It is likely that a standard can outlive its usefulness and that the same data should be approached with different standards for different purposes. Perhaps the notion under severest scrutiny is not whether 1940 is appropriate but whether a single standard is the optimum policy.

The data that NCHS acquires and subsequently publishes are really of three logical types: observations, estimates, and constructs. The observations (counts of the number of deaths) may be viewed as incontrovertible, or at least difficult to challenge, because they represent reports from the only collection mechanism available. Although perhaps estimates in the statistical sense, the numbers are usually accepted as the truth. The estimates (crude rates and age-specific rates) require the addition of denominators. Such population estimates are altered periodically and may be challenged. (The Bureau of the Census is in court at this very moment.) Estimates command a somewhat different type of belief from that required for observations. Third, the constructs (age-adjusted rates) depend on several subjective choices (standard, age interval). Constructs have considerable epidemiologic and statistical utility, but they are not to be believed in the same sense as observations or estimates. This line of reasoning suggests that alternative standards may be useful.

Finally, in addition to empirical and theoretical issues, a number of economic and social factors influence the choice of standard. Following is a summary of some theoretical, empirical, economic, and sociopolitical arguments that have been raised for and against change of the current standard.

Arguments for change

1. Even though the AAR is a construct, it should be of the same order of magnitude as the crude rate in order to minimize the difference between the crude and adjusted rates. The most appropriate compromise is a population that is central to the populations being compared.
2. Changing the standard produces small but consistent changes in the empirical results. The most appropriate measure of trend (the slope/intercept) changes with more recent standards, as do sex and race ratios, rankings of States, and rankings of diseases.
3. Because it is generally agreed that the choice of standard is to a large extent arbitrary and subjective, it makes little sense to have a ''standard'' standard. The AAR is not the same ''logical type'' as a crude rate, which in turn is different from the reported number of deaths. Taken in reverse order, these measures represent a progression from counting to construction, and the degree of tenacity in maintaining their inviolability should decrease accordingly.
4. The cost of conversion is considerable only if the decision is made to retrofit the data. Concurrent new standards, which would run parallel with and eventually replace 1940, would require minimal expense. The ultimate goal would be to provide electronic access to the data so that users could employ a standard that they deem appropriate to the work that they are doing.
5. As noted, the 1940 standard is viewed by many as antiquated (even if for the wrong reasons). The standard may be perceived as inappropriate, and NCHS must deal with the perception. A change of standard would align most diseases with their current crude rate and perhaps imbue the actual number with a bit more relevance.
6. If the 1940 standard were not abandoned but used in parallel with another standard and then replaced after a suitable period of time, social and political reaction to the discontinuity could be minimized.

Arguments against change

1. There is no theoretically correct standard. The chosen standard should provide a balance that minimizes the effect of population trends, thereby avoiding ''bias'' in estimation of disease impact. The 1940 standard minimizes the bias imposed by the current aging population.
2. Observed differences produced by using different standards are small, with minor exceptions. The changes usually affect the magnitude but not the direction of change. Many of the differences that result from changing standards occur in situations where age adjustment may not be an appropriate tool. For example, in cancer mortality, divergent age-specific rates make age adjustment inappropriate, and this is one of the conditions for which changing the standard makes a real difference.
3. The costs of changeover are considerable, both in personnel and other resources. In addition, the added burden on State data centers would be poorly tolerated.
4. On the social and political levels, a change in standard would produce a dramatic discontinuity, and the abrupt change would generate considerable confusion. For researchers, the loss of continuity would have a substantial effect on prior and contemplated work.
5. Although there is no ''right'' standard, NCHS has the responsibility to choose a de facto standard. Despite possible limitations, codification of the AAR with a single standard serves a vital social and political function.
6. The introduction of other standards contemporaneously with the 1940 standard would create disruption and cumbersome presentations in NCHS publications, whose year-to-year continuity is one of their great strengths. It might be simple enough to present alternate AAR's, but a table of the top 15 causes of death would be confusing.

Summary and recommendations

There is reasonable argument on both sides of this issue. We suggest that the main issue does not hinge on the use of 1940 as a standard but on whether it is appropriate to have an absolute standard. The standardized rate that NCHS produces is an important epidemiologic measure, but not an incontrovertible number. We recommend that NCHS attach two new standards to a portion of its data (the 1990 population, when it becomes available, and the WORLD standard); that it publish the UNIFORM standard (mean age-specific rate); that it not attempt to retrofit data; and that it establish a new continuum. For several years, there should be considerable overlap—perhaps even dual publication of the major tables—with eventual changeover to another standard that more closely approximates the population structure of the past 20 and the coming 50 years.

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Table 1. Summary of methods from prior studies of standards for age adjustment of mortality statistics

Comparison	*Spiegelman and Marks*	*Curtin, Maurer, and Rosenberg*
Standards	1940, 1950, 1960	1940, 1970
Conditions	Total mortality Tuberculosis Diabetes Vascular central nervous system lesions Congenital malformation Motor vehicle accidents Homicides	Total mortality Diseases of the heart Malignant neoplasms Respiratory cancer Cerebrovascular disease Suicides Homicides
Factors examined	Relative change in AAR AAR for persons 65 years and over Sex ratio Race ratio Trends (percent change)	Correlation of AAR and life expectancy Rank order correlation Relative change in AAR Trends (percent change, average annual percent change) Ratio of change over 2 time periods Sex ratio Relative standard error of covariance
Time periods studied	1956, 1940, 1920	1940, 1970, 1977

NOTE: AAR is age-adjusted rate.
SOURCES: Spiegelman and Marks, 1966 (1); Curtin, Maurer, and Rosenberg, 1981 (2).

Table 2. Summary of methods from current study of standards for age adjustment of mortality statistics

Comparison	*Items studied*
Standards	1940, 1950, 1960, 1970, 1980, 1990, WORLD, UNIFORM, and a series of artificially constructed standards
Conditions	Total mortality (18 5-year age groups) Total mortality (11 10-year age groups) Ischemic heart disease Cancer (malignant neoplasms) Chronic obstructive pulmonary disease Alzheimer's disease
Factors examined	Relative change in AAR Trends (percent change, average annual percent change, slope) Relative difference between crude rate and AAR Sex ratio Race ratio Sex-race ratio State rankings (effect of standard on Ischemic heart disease ranking) Disease rankings (for 1988) Effect of alternative age groupings
Time periods studied	1962–88 (total mortality) 1968–87 (cause-specific mortality) 1988 (disease rankings)

NOTE: AAR is age-adjusted rate.

Table 3. Age-adjusted rate for total mortality, by standard used or age adjustment: United States, 1968–88

[Rate per 100,000 population]

Year	*1940*	*1950*	*1960*	*1970*	*1980*	*1990*	*WORLD*	*UNIFORM*
1968	743.1	849.8	926.3	995.8	1,290.1	1,232.9	793.2	3,524.1
1969	705.9	807.0	879.3	944.6	1,221.6	1,169.0	753.4	3,327.0
1970	714.0	814.1	884.9	948.4	1,211.8	1,166.9	757.4	3,227.3
1971	679.9	775.5	844.4	909.2	1,174.7	1,125.9	721.0	3,196.0
1972	698.2	795.6	865.6	931.4	1,198.3	1,150.0	738.4	3,226.9
1973	687.6	783.7	853.0	919.0	1,186.9	1,136.4	727.8	3,217.9
1974	659.8	752.0	818.6	881.6	1,137.8	1,089.7	698.5	3,080.5
1975	630.8	718.2	780.8	840.3	1,079.2	1,036.2	665.9	2,894.7
1976	618.9	705.6	768.5	828.8	1,071.9	1,025.3	654.8	2,913.5
1977	600.9	684.0	744.3	803.1	1,036.4	992.4	634.0	2,805.1
1978	592.7	675.0	735.0	794.2	1,028.7	983.2	625.6	2,802.1
1979	577.6	657.5	715.7	773.1	1,000.5	956.9	609.2	2,716.4
1980	583.7	665.1	725.1	785.4	1,023.8	976.2	616.0	2,814.7
1981	566.5	645.3	703.2	761.5	993.4	946.2	597.6	2,729.3
1982	554.0	632.0	689.5	747.1	973.3	929.0	583.9	2,674.0
1983	551.0	629.4	687.6	746.5	976.5	930.9	580.8	2,704.6
1984	546.1	623.9	681.7	740.9	971.7	925.4	575.5	2,701.5
1985	546.7	624.9	683.2	743.2	978.3	930.3	576.6	2,736.4
1986	542.1	618.8	675.9	735.3	968.4	920.9	570.9	2,705.2
1987	536.0	611.9	668.3	727.3	959.2	911.8	564.5	2,685.9
1988	536.2	612.3	669.0	728.6	964.0	915.2	565.2	2,712.4

Table 4. Weights derived from alternative standards for age adjustment of mortality statistcs, by age: United States, 1988

Age	*1940*	*1950*	*1960*	*1970*	*1980*	*1990*	*WORLD*	*UNIFORM*
Under 5 years	0.0801	0.1073	0.1133	0.0844	0.0717	0.0769	0.120	0.0556
5–9 years	0.0811	0.0876	0.1042	0.0982	0.0724	0.0745	0.100	0.0556
10–14 years	0.0892	0.0738	0.0935	0.1023	0.0795	0.0673	0.090	0.0556
15–19 years	0.0937	0.0705	0.0737	0.0938	0.0920	0.0680	0.090	0.0556
20–24 years	0.0880	0.0763	0.0602	0.0806	0.0932	0.0744	0.080	0.0556
25–29 years	0.0843	0.0813	0.0606	0.0663	0.0858	0.0862	0.080	0.0556
30–34 years	0.0778	0.0765	0.0666	0.0562	0.0774	0.0881	0.060	0.0556
35–39 years	0.0725	0.0746	0.0696	0.0547	0.0613	0.0801	0.060	0.0556
40–44 years	0.0667	0.0677	0.0647	0.0590	0.0511	0.0715	0.060	0.0556
45–49 years	0.0627	0.0601	0.0607	0.0596	0.0481	0.0560	0.060	0.0556
50–54 years	0.0551	0.0548	0.0536	0.0546	0.0510	0.0457	0.050	0.0556
55–59 years	0.0444	0.0479	0.0470	0.0491	0.0506	0.0418	0.040	0.0556
60–64 years	0.0359	0.0401	0.0398	0.0424	0.0442	0.0425	0.040	0.0556
65–69 years	0.0289	0.0331	0.0349	0.0344	0.0384	0.0400	0.030	0.0556
70–74 years	0.0195	0.0226	0.0264	0.0268	0.0298	0.0322	0.020	0.0556
75–79 years	0.0114	0.0143	0.0170	0.0189	0.0210	0.0251	0.010	0.0556
80–84 years	0.0059	0.0074	0.0088	0.0112	0.0128	0.0164	0.005	0.0556
85 years and over	0.0028	0.0038	0.0052	0.0074	0.0198	0.0133	0.005	0.0556

Table 5. Measures of trend for total mortality and mortality from selected conditions, by standards used for age adjustment: United States, 1968–88

Condition and measure	1940	1970	1980	1990	WORLD	UNIFORM
Total mortality						
Percent change	–27.9	–27.0	–25.6	–26.0	–28.2	–24.3
Annual percent change[1]	–1.6	–1.6	–1.5	–1.5	–1.6	–1.4
Slope[2]	–10.6	–13.5	–16.1	–16.0	–11.1	–32.8
Slope/intercept (percent)	1.7	1.6	1.5	1.5	1.7	1.4
Ischemic heart disease						
Percent change	–51.7	–50.5	–49.1	–49.7	–51.1	–48.0
Annual percent change[1]	–3.6	–3.5	–3.3	–3.4	–3.5	–3.2
Slope[2]	–8.3	–12.0	–15.9	–15.4	–8.6	–38.1
Slope/intercept (percent)	4.1	4.0	3.8	3.9	4.0	3.7
Cancer						
Percent change	2.4	4.6	5.6	5.5	2.9	8.3
Annual percent change[1]	0.1	0.2	0.3	0.3	0.1	0.4
Slope[2]	0.2	0.5	0.7	0.7	0.3	2.2
Slope/intercept (percent)	0.1	0.3	0.3	0.3	0.2	0.5
Alzheimer's disease						
Percent change	2,212.5	3,347.4	4,716.6	4,523.3	2,405.2	8,360.3
Annual percent[1]	17.0	19.4	21.4	21.1	17.5	24.8
Slope[2]	0.2	0.4	0.5	0.5	0.2	1.6
Slope/intercept (percent)	16.9	18.3	19.4	19.2	17.2	20.6
Chronic obstructive pulmonary disease						
Percent change	–1.1	4.9	7.8	8.3	–1.0	16.0
Annual percent change[1]	–0.1	0.2	0.4	0.4	–0.1	0.7
Slope[3]	–0.2	–0.1	0.0	0.0	–0.2	0.8
Slope/intercept (percent)	0.5	0.1	0.0	0.0	0.5	0.5

[1]Assuming uniform change over years.
[2]All slopes were statistically significant, $p < 0.01$.
[3]No slopes were statistically significant, $p > 0.05$.

Table 6. Ratio of age-adjustment rate using 1990 standard to age-adjustment rate using 1940 standard for total mortality, by sex, race, and sex-race group: United States, 1968 and 1988

Characteristic	Ratio 1968	Ratio 1988	Percent difference between 1940 and 1990 standards
Female	1.78	1.82	2.3
Male	1.62	1.70	4.9
White	1.72	1.76	2.3
Black	1.42	1.52	7.0
White female	1.84	1.86	2.2
White male	1.66	1.74	4.8
Black female	1.47	1.61	9.5
Black male	1.40	1.49	6.4

Table 7. Sex, race, and sex-race ratios produced by 1990 and 1940 standards for age-adjustment of mortality statistics: United States, 1968–88

Ratio and year	*Standard* 1940	*Standard* 1990	*Difference between 1940 and 1990 standards*
	Ratio		Percent
Black-white			
1968	1.55	1.29	17.1
1988	1.56	1.35	13.4
Male-female			
1968	1.74	1.59	8.7
1988	1.74	1.62	6.8
Black-white, male			
1968	1.48	1.23	15.8
1988	1.57	1.35	14.1
Black-white, female			
1968	1.67	1.34	20.1
1988	1.57	1.35	12.9

Table 8. Mean and maximum change in ranking of States for Ischemic heart disease mortality for each standard used for age adjustment compared with 1940 standard: United States, 1968–87

Year	*1950 standard*		*1960 standard*		*1970 standard*		*1980 standard*		*1990 standard*	
	Mean	*Maximum*	*Mean*	*Maximum*	*Mean*	*Maximum*	*Mean*	*Maximum*	*Mean*	*Maximum*
1968	0.6	2	1.1	5	1.6	6	3.0	10	2.6	8
1969	0.6	4	1.0	5	1.5	6	2.6	13	2.3	13
1970	0.4	1	0.7	3	1.3	8	2.7	13	2.1	10
1971	0.8	3	1.3	5	1.9	5	3.2	10	2.5	9
1972	0.5	3	1.0	4	1.5	7	2.7	11	2.2	11
1973	0.6	3	1.2	4	1.6	7	3.0	12	2.5	8
1974	0.7	5	1.1	5	1.6	6	2.8	12	2.2	8
1975	0.8	3	1.4	6	1.8	7	2.9	12	2.6	10
1976	0.7	2	1.0	3	1.5	6	2.9	12	2.2	10
1977	0.4	2	0.7	4	0.9	6	2.2	8	1.6	7
1978	0.3	2	0.7	3	1.1	3	2.4	8	1.9	8
1979	0.5	3	1.1	6	1.6	6	3.4	11	2.9	11
1980	0.5	3	1.1	4	1.7	5	3.0	12	2.6	8
1981	0.7	3	1.4	4	2.1	6	4.0	11	3.2	9
1982	0.5	2	1.1	5	1.9	7	3.6	11	2.7	8
1983	0.5	3	1.0	5	1.5	7	3.1	11	2.4	9
1984	0.5	3	1.0	4	1.5	8	3.4	13	2.5	10
1985	0.6	3	1.1	4	1.6	5	3.5	12	2.7	8
1986	0.5	3	1.0	4	1.4	6	3.1	18	2.5	15
1987	0.5	3	1.2	7	2.2	10	4.2	15	3.5	12

Table 9. Multiple regression results on effect of standard used for age adjustment and year on ranking of States for Ischemic heart disease mortality, by State: United States, 1968–87

State	*Intercept*	*Slope for standard*	*Slope for year*	*Calculated change in rank*
Alabama	36.419	0.836	0.473	–4.2
Alaska	45.214	0.824	0.594	–4.1
Arizona	44.179	–0.331	0.510	1.7
Arkansas	37.795	0.599	0.339	–3.0
California	28.074	–1.123	–0.187	5.6
Colorado	43.681	–0.816	0.103	4.1
Connecticut	25.633	–1.490	0.287	7.5
Delaware	17.831	0.384	–2.822	–1.9
Washington, D.C.	34.576	0.923	–2.209	–4.6
Florida	34.074	–0.253	0.562	1.3
Georgia	19.457	1.727	0.057	–8.6
Hawaii	44.550	–0.230	–0.709	1.2
Idaho	45.433	–0.390	0.174	2.0
Illinois	7.726	–0.417	–0.143	2.1
Indiana	14.710	0.223	0.883	–1.1
Iowa	29.219	–0.254	0.043	1.3
Kansas	29.836	–0.434	0.171	2.2
Kentucky	13.764	0.144	0.357	–0.7
Louisiana	12.848	1.054	–0.332	–5.3
Maine	9.636	0.006	0.074	0.0
Maryland	25.931	–0.046	–2.912	0.2
Massachusetts	24.160	–0.887	1.072	4.4
Michigan	8.381	–0.236	0.461	1.2
Minnesota	33.783	–0.080	0.032	0.4
Mississippi	29.910	0.853	–0.053	–4.3
Missouri	21.333	–0.580	0.555	2.9
Montana	45.598	0.044	0.447	–0.2
Nebraska	36.941	–0.433	0.754	2.2
Nevada	32.302	0.286	–0.398	–1.4
New Hampshire	19.948	–0.076	0.240	0.4
New Jersey	2.821	–0.099	–0.002	0.5
New Mexico	50.714	–0.076	–0.021	0.4
New York	5.069	–0.474	0.378	2.4
North Carolina	11.545	0.889	0.203	–4.4
North Dakota	35.050	–0.370	0.308	1.9
Ohio	7.279	0.059	0.416	–0.3
Oklahoma	23.824	0.207	1.255	–1.0
Oregon	37.438	–0.229	0.668	1.1
Pennsylvania	7.357	–0.053	–0.398	0.3
Rhode Island	4.531	–0.336	0.062	1.7
South Carolina	12.524	1.477	–0.546	–7.4
South Dakota	29.943	–0.857	0.695	4.3
Tennessee	19.002	0.286	0.096	–1.4
Texas	45.121	0.061	0.109	–0.3
Utah	48.445	–0.311	0.002	1.6
Vermont	20.071	0.021	–0.597	–0.1
Virginia	17.850	0.710	–0.770	–3.6
Washington	36.645	–0.451	–0.729	2.3
West Virginia	4.812	0.389	0.318	–1.9
Wisconsin	19.748	–0.986	0.519	4.9
Wyoming	33.269	0.316	–0.386	–1.6

NOTE: Fitted values are shown for average change in rank using 1990 standard compared with 1940 standard, controlling for year.

Table 10. Ranking of leading causes of death, by standard used for age adjustment: United States, 1988

Cause	*1990*	*1980*	*1970*	*1960*	*1950*	*1940*	*WORLD*	*UNIFORM*
Diseases of the heart	1	1	1	1	1	1	1	1
Malignant neoplasm	2	2	2	2	2	2	2	2
Cerebrovascular disease	3	3	3	4	3	4	4	3
Accidents	4	4	4	3	4	3	3	6
Chronic obstructive pulmonary disease	5	6	5	5	5	5	5	5
Pneumonia and influenza	6	5	6	6	6	6	6	4
Diabetes	7	7	7	7	8	8	8	8
Suicide	8	8	8	8	7	7	7	12
Chronic liver disease	9	10	9	9	9	9	9	11
Atherosclerosis	10	9	12	13	14	14	14	7
Nephritis	11	11	11	11	11	12	11	9
Homicide	12	13	10	10	10	10	10	13
Septicemia	13	12	13	12	13	13	13	10
Human immunodeficiency virus	14	14	14	14	12	11	12	14

Table 11. Percent difference between crude rate and age-adjusted rate, for total mortality by standard used for age adjustment: United States, 1968–88

Year	*1940*	*1950*	*1960*	*1970*	*1980*	*1990*	*WORLD*	*UNIFORM*
				Percent difference				
1968	23.2	12.2	4.2	–2.9	–33.4	–27.5	18.0	–264.3
1969	23.0	12.0	4.1	–3.0	–33.3	–27.5	17.8	–263.0
1970	24.3	13.7	6.2	–0.5	–28.4	–23.7	19.7	–242.1
1971	26.4	16.1	8.6	1.6	–27.2	–21.9	22.0	–246.0
1972	25.7	15.3	7.9	0.8	–27.6	–22.4	21.4	–243.5
1973	26.4	16.1	8.7	1.7	–27.0	–21.6	22.1	–244.3
1974	27.3	17.2	9.8	2.9	–25.3	–20.0	23.1	–239.4
1975	28.3	18.3	11.2	4.5	–22.7	–17.8	24.3	–229.1
1976	29.6	19.7	12.6	5.7	–22.0	–16.7	25.5	–231.5
1977	30.6	21.0	14.1	7.3	–19.7	–14.6	26.8	–223.9
1978	31.7	22.2	15.3	8.5	–18.5	–13.3	27.9	–222.8
1979	32.3	23.0	16.2	9.4	–17.2	–12.1	28.6	–218.3
1980	33.5	24.2	17.3	10.5	–16.7	–11.3	29.8	–220.9
1981	34.3	25.2	18.5	11.7	–15.2	–9.7	30.7	–216.4
1982	35.1	25.9	19.2	12.4	–14.1	–8.9	31.6	–213.4
1983	36.2	27.1	20.3	13.5	–13.1	–7.8	32.7	–213.3
1984	36.7	27.7	20.9	14.1	–12.7	–7.3	33.3	–213.3
1985	37.4	28.5	21.8	14.9	–12.0	–6.5	34.0	–213.2
1986	37.9	29.1	22.5	15.7	–11.0	–5.5	34.6	–210.0
1987	38.5	29.8	23.3	16.5	–10.1	–4.6	35.2	–208.2
1988	39.2	30.5	24.1	17.3	–9.4	–3.8	35.9	–207.8

Chapter 7
Use of age-adjusted disease rates for cancer

by Edward J. Sondik, Ph.D., Division of Cancer Prevention and Control, National Cancer Institute

In a recent report commissioned by the Senate Appropriations Committee, the adequacy of measures of progress against cancer was assessed (1,2). The report, written by an extramural committee and facilitated by the National Cancer Institute (NCI), divided cancer measures into two types, direct and indirect. Cancer incidence, mortality, and survival were considered direct measures because they measure different dimensions of the extent of the disease in the population. Indirect measures include a variety of other measures such as smoking and other risk factor prevalence, screening rates, and dietary patterns. The Committee felt that mortality is the most important of these measures; in essence, it is the bottom line of the fight against the disease. In turn, it is the trend in mortality—and in incidence and survival—that chronicles the impact of the National Cancer Program.

Influence of age on direct measures

Age is closely tied to cancer incidence and mortality, and as the higher ages predominate in the population, the crude rate of cancer incidence and mortality will rise, all other factors remaining constant. Because cancer incidence and mortality are so strongly linked to age (table 1), as we analyze trends in the direct measures of cancer, it is essential to ''decouple'' the effect of age from all other effects, particularly the effects of cancer prevention and control programs and the effects of known (and unknown) etiologic agents. As noted in the report on measures of cancer (1,2), there are several issues with respect to the use of age adjustment of cancer data, including:

- The choice of base year, the topic of this workshop.
- Whether the adjustment procedure should include period and cohort effects, some procedure is essential to account for the influence of population size and the aging of the population. To not account for these factors may lead to very different conclusions. Table 2 shows the quantitative effect on percent change in mortality of using the number of deaths, the crude rate, and the age-adjusted (to 1970) rate to assess change over time. Clearly all three are valid measures, but each measures something different.

NCI uses of age-adjusted cancer rates

NCI uses age-adjusted cancer data for a number of different purposes. For example:

- Each year NCI publishes an extensive statistical review that examines trends in the incidence, mortality, and survival of cancer (3). The incidence and mortality data are all age adjusted to 1970.
- We have stated our goals for the year 2000 (developed in 1985) in terms of age-adjusted rates, in this case age adjusted to the 1980 U.S. population.
- NCI makes a number of comparisons among States, regions, socioeconomic groups, etc., almost always doing so using age-adjusted rates. For the recently published atlases of U.S. cancer mortality among white persons and persons of other races for the period 1950–80, 1960 was used as the base year (4,5).

In summary, age-adjusted incidence and mortality rates coupled with relative survival rates (not age adjusted) are the primary measures NCI uses to report trends in cancer and thereby assess changes in the patterns and burden of cancer.

Desirable characteristics of measures of cancer

In general, the desirable characteristics of cancer measures are as follows:

- We seek measures that will remove, to the greatest extent possible, the influence of a changing age distribution.
- Secondly, measures of cancer should reflect the current magnitude of the problem as much as possible. We would like to be able to compare age-adjusted rates across cancer sites and obtain an assessment of the relative impact of different cancers. The same holds true for comparing cancer rates with the rates of other diseases. Therefore, one would hope that if age adjustment is used, the base year would be as close to the current year as practical.

Clearly, the absolute numbers of cases and deaths provide some of the best measures of the direct impact of the disease, but trends in cases and deaths are confounded by the changing age distribution.

Rationale for using 1970 as the base year

As noted, NCI uses 1970 as the standard for age adjustment of incidence and mortality trends. Our rationale is that 1970 was the most recent census year prior to the start of the SEER (Surveillance, Epidemiology, and End Results) Program. The SEER Program is a set of population-based cancer registries collecting information on cancer incidence and survival from a selected set of regions comprising about 10 percent of the U.S. population. NCI uses the series of data collected from SEER, coupled with national mortality data, as the data base for trends on incidence and mortality.

Age adjustment of cancer-related data

Choice of base year

The following figures show the impact of the choice of a base year on cancer mortality rates per 100,000 persons:

1986 mortality rate:	
Crude	194.7
Adjusted to 1970	171.3
Adjusted to 1940	133.2

The deemphasis on the older populations in the 1940 base year is particularly troublesome to NCI. Because persons 65 and over account for more than 50 percent of cancer cases and deaths from cancer, changes in the age-specific rates for those 65 and over (either increases or decreases) are not fairly reflected through the 1940 base year measure. One also could argue that those 65 and over are not fully accounted for through the 1970 base year measure as well. I would not debate that point. In fact, a more recent year, 1980, is a more appropriate base year at this time.

Relative survival

In the past NCI has not adjusted relative survival data for age. The definition of relative survival and the methods used by NCI to calculate the measure estimate an essentially age-independent measure of the force of mortality resulting solely from a particular form of cancer. Yet we know from analyzing data by specific age groups that relative survival may differ significantly by age for some cancers. For example, recent 5-year relative and observed survival rates for kidney and renal pelvis cancer are shown in table 3. As NCI extends its series of survival data, the question of whether to adjust for age effects may become an issue.

Rates of change

Over the last few years NCI has made considerable use of the percent change in incidence and mortality calculated from the age-adjusted rates. The percent change is usually calculated over the full range of the period for which the SEER data are available, 1973–88 in the latest report. We have also used the equivalent measure of the estimated annual percent change. The choice of base year for age adjustment will influence the magnitude of change of these measures.

Use of age-adjusted figures in establishing disease prevention and control objectives

In 1985 NCI set cancer prevention and control objectives for the year 2000 for smoking prevalence, dietary change, screening rates, and the adoption of state-of-the-art treatment regimens. Our analysis of the impact on cancer incidence and mortality rates of achieving these objectives was based on rates age adjusted to the base year 1980. The reason for selecting 1980 was not only to remove the effects of the changing age distribution of the population, but at the same time, to keep the rates related as much as possible to the current magnitude of the problem.

Use of age-adjusted figures in reporting smoking data

Smoking is the cause of some 30 percent of all cancer deaths. Therefore, a key measure of the Nation's progress toward reducing the burden of cancer is the smoking prevalence rate. Several years ago I was surprised to see age-adjusted figures reported as the primary measure of trends in smoking. The question I would raise is whether these figures should be age adjusted at all, at least as a primary measure. We age adjust cancer incidence and mortality rates to eliminate an uncontrollable factor driving the trends in the cancer rates. It is not in our power to change the age distribution of the population and thereby bring cancer incidence rates down. On the other hand, it is within the realm of possibility to drastically change the smoking rates in the United States. A smoke-free or nearly smoke-free society is a distinct possibility. Because we can affect smoking behavior, or at least individuals can affect their own smoking behavior, regardless of age, the use of age-adjusted figures masks an important aspect of smoking data. When we at NCI report smoking data, we generally do not age adjust the rates. I would make the same conclusion for other behaviors that, although tied to age, are not dictated by age.

Summary

The use of 1940 as the base year for age adjustment in these NCI applications seems problematic. It is more than a half century away from today and 60 years from the year 2000. The age distribution today is very different from the age distribution of the 1940's in terms of implications for the burden of cancer. If cancer control or disease prevention objectives are to stimulate actions toward prevention, the associated measurements must reflect the magnitude of the problem and changes in this magnitude as accurately as possible. Age adjustment to the year 1940 will not reflect changes in incidence or mortality rates as accurately as an adjustment to a more recent base year.

In some discussions prior to the publication of *Healthy People 2000* (6), it was suggested that the crude rate would be the most appropriate measure in which to couch the objectives. Although this may seem an anathema to some, it may have been the most appropriate solution. A quick study would be sufficient to assess the impact of expected changes in the age distribution of the United States from 1990 to 2000 on measures of the various objectives outlined in *Healthy People 2000*. It may turn out that any change in the age distribution has minimal effect on the measures of the objectives compared with the effect of changes projected from the various prevention regimens.

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Table 1. Age-specific incidence and mortality cancer rates, by age: United States, 1983–87

[All rates per 100,000 persons]

Age	Incidence	Mortality
Under 5 years	18.8	3.9
5–9 years	11.1	3.9
10–14 years	11.4	3.4
15–19 years	20.0	4.9
20–24 years	30.3	5.9
25–29 years	47.7	9.1
30–34 years	79.1	16.1
35–39 years	129.1	29.9
40–44 years	211.0	58.8
45–49 years	335.0	114.9
50–54 years	514.3	210.0
55–59 years	795.3	346.0
60–64 years	1,148.9	514.3
65–69 years	1,574.2	735.9
70–74 years	1,967.1	966.9
75–79 years	2,286.6	1,187.2
80–84 years	2,500.5	1,432.0
85 years and over	2,383.3	1,618.0

SOURCE: National Center for Health Statistics, National Cancer Institute.

Table 2. Number of deaths, crude death rate, and age-adjusted death rate, by age: United States, 1970–87

Year	Number of deaths[1]	Crude death rate	Age-adjusted death rate[2]
1970	331,000	162.8	162.8
1980	417,000	183.9	168.1
1987	477,000	195.9	171.5
Percent change			
1970–87	+44.1	+20.3	+5.4

SOURCE: National Center for Health Statistics, National Cancer Institute.

Table 3. Five-year relative and observed survival rates for kidney and renal pelvis cancer, by age: United States, 1982–87

[All rates per 100,000 persons]

Age	Relative	Observed
All ages	53.2	44.3
Under 45 years	71.9	71.2
45–54 years	57.9	55.7
55–64 years	56.0	51.2
65–74 years	48.1	39.6
75 years and over	39.7	24.0

SOURCE: National Center for Health Statistics, National Cancer Institute.

Chapter 8
Age adjustment for the year 2000 health objectives

by Michael A. Stoto, Ph.D., Institute of Medicine

Introduction

Choosing the proper procedure for age adjustment of vital rates is complex. The choice involves both scientific and practical issues. Moreover, vital rates constitute an important aspect of communication with the public and decisionmakers about the health status of the American population.

In *Healthy People 2000* (1), for instance, the vast but often hidden potential of health promotion and disease prevention is recognized by presenting in concrete statistical terms the health status gains that can be expected from health promotion and disease prevention activities. Stating objectives for the future in quantitative terms portrays the benefits of prevention in a way that can lead to action now. If this process is to be successful, statistical presentations of progress toward the objectives must be meaningful and accurate. In considering whether and how to standardize, therefore, it is important to have in mind a few points about the purpose of age adjustment, especially as it might be used in assessing progress toward the Year 2000 Health Objectives.

Reasons for adjustment

Overall population death rates are essentially weighted averages of a series of death rates for different age and sex groups. With ''crude,'' or unstandardized, death rates, the weights change as the population ages, so it is impossible to disentangle changes in age structure from changes in underlying death rates. For instance, even if there were no changes in the age-specific cancer rates from 1987 to 2000, we would expect the death rate to rise from 195.9 to 217.1 per 100,000, an increase of 10.8 percent (assuming the Census Bureau's median population projection for the United States). Such a change does not indicate progress toward the objectives, and no one would want to represent it as such. The problem is not so clear cut when the age-specific rates change, however. We will likely see a decrease in the overall cancer mortality rate that reflects a combination of decreases in age-specific rates plus an increase corresponding to the aging of the population in the 1990's. Because the objectives are aimed at preventing death and disability, not the aging of the population, we would like to somehow ''subtract out'' the changes associated with population aging. This is one of the main purposes of age adjustment, or direct standardization.

Standardization serves this purpose well. Applying the age-specific rates from various years to the 1940 U.S. population, for instance, shows that while the cancer death rate increased by 20 percent in crude terms from 1970 to 1987, it increased by only 2 percent when standardized to the 1940 population. This is illustrated in figure 1. During the same period, ischemic heart disease fell by 50 percent in standardized terms but only 36 percent with crude rates.

Another way of looking at this is to see how standardization affects the year 2000 targets. One early draft of the target for coronary heart disease mortality called for a 33-percent reduction in the rate—that is, a decrease in the age-adjusted rate from 135.2 to 90.0 per 100,000. Suppose that this same percentage applied to the ischemic heart disease death rate, which was 113.9 per 100,000 in 1987 (when adjusted to the 1940 population). If this 33-percent decrease applied at every age, the standardized target would be 75.8 per 1,000, and the crude target using the projected year 2000 population would be 165.6 per 1,000. The targeted 33-percent decrease at each age is masked by population aging and looks like only a 21-percent decrease overall. The adjusted figures thus seem to represent the anticipated mortality gains more ''accurately'' and certainly represent them in a way that is more compelling to policymakers.

Standardization, however, serves a second and very different purpose at the same time. Because States and other geographic areas differ in the age, race, and sex composition of their population, States with the same age-, race-, and sex-specific death rates will have different crude death rates (both overall and cause specific). Similarly, some of the differences that we find among States and other areas reflect differences in population composition rather than differences in underlying rates. In setting their own targets for the year 2000, States will want to look at the national target as well as current rates of other States. This comparison makes sense only if differences in the composition of the national and State populations are ''removed.'' If all States are adjusted to the same standard

NOTE: The views expressed in this paper are those of the author, not necessarily those of the Institute of Medicine or the National Academy of Sciences.

population, standardization provides a bridge from the national targets to State and local targets.

Finally, we should note that, for some purposes, standardization might lead to difficulties. Some States and other areas will want to set priorities among the objectives. Many factors go into such choices, but the current level of mortality associated with a disease or other health problem is a major one. Standardized rates can and do lead to different priorities than the crude rates do. For example, accidents and adverse effects have a somewhat higher mortality rate than cerebrovascular diseases when adjusted to the 1940 population (35.0 versus 29.7 per 100,000), but in absolute terms the cerebrovascular mortality rate is more than 50 percent higher than the accident mortality rate (61.2 versus 39.5) One might argue that crude rates accurately reflect the burden of illness in a public health sense; they are proportional to the number of deaths per cause. There are, however, other indexes of the burden associated with each cause, such as years of potential life lost.

Choice of a standard population

If death rates are to be standardized, the choice of a standard can make a substantial difference. Figure 1, for example, shows the overall cancer death rate in crude terms and standardized to the 1940 and the estimated 1990 populations. The largest difference is in the level of the rates; the 1987 rate is fully 50 percent higher (199.9 compared with 132.9 per 100,000) when the 1990 population rather than the 1940 population is chosen as the standard. The choice of standard affects trends as well. Using the 1990 standard, the cancer death rate increased by 6.2 percent from 1970 to 1987, but using the 1940 standard, it increased by only 2.3 percent. We cannot say that either of these standards is ''correct'' in some absolute sense, but it is important to note that they are different. We can say that the 1990 standard more closely reflects the current burden of mortality by cause.

Whatever decision is made about adjustment and choice of standard, it is important that the decision be applied consistently to all of the mortality objectives. Without a common standard, it is impossible to compare death rates for different causes to get some sense of priority. For instance, at one point during the drafting of the Year 2000 Health Objectives, the cancer rates were adjusted to 1970 and heart disease rates to 1940. The result was that the overall cancer death rate was higher than that of coronary heart disease, although the relationship is reversed when using any reasonable standard.

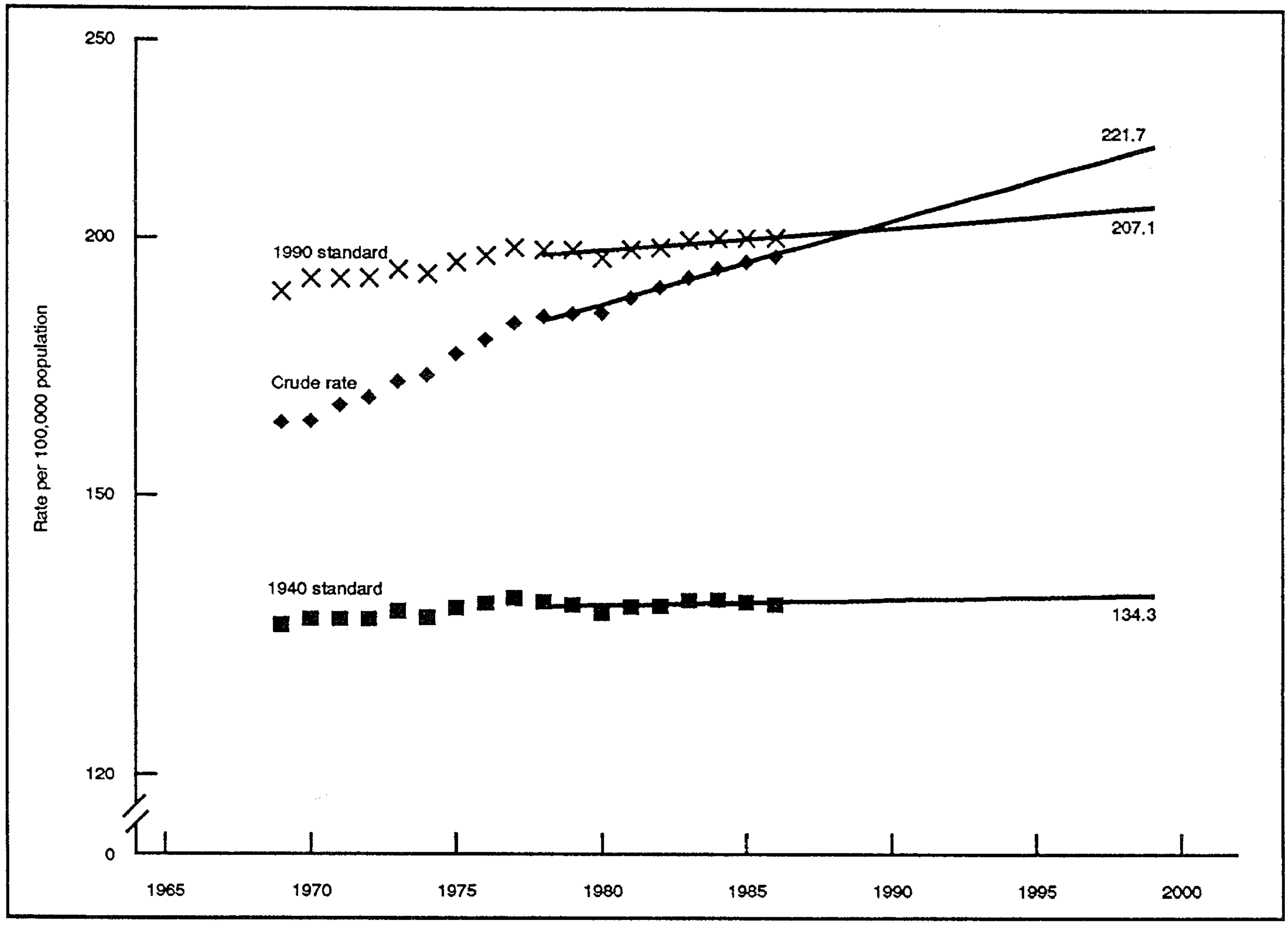

Figure 1. Crude and adjusted cancer mortality rates for 1970–87 and projected to 2000: United States

Furthermore, the statisticians who will have to monitor progress on the objectives at the national, State, and other levels will have much more difficulty in doing so if different methods of standardization are used in different priority areas.

A group of statisticians from different Public Health Service agencies who met last year seemed to approach some agreement that the death rates should be presented age adjusted and that the 1940 standard should be used. Two arguments were put forward. First, the 1940 adjustment would be consistent with the long-term practice of the National Center for Health Statistics and widespread use by other groups in reporting death rates. Using this standard would facilitate the efforts of States trying to monitor their own progress on the objectives. Second, using the 1940 population, with its younger age structure, helps emphasize the levels of preventable mortality that exist at younger ages. Personally, I am concerned about this second argument. Although I too would like to see more attention paid to children's health problems, I would like to get there through the front door and not introduce value arguments into the technical choice of a statistical standard.

Others argued against adjusting, especially to the 1940 population, because it masks the public health impact of the levels seen in crude death rates. Note in figure 1 that the standardized and crude rates agree when a standard close to the year of the crude rate is chosen. Using the 1940 standard, the relationship among adjusted cause-specific death rates is different from that among the crude rates.

Conclusions

One compromise is to adjust the rates using a more recent standard population, such as 1990. This would give a better picture of the current public health impact of the various diseases (as measured by the relative numbers of deaths) and would provide the analytical benefits of age adjustment. The difficulty with using a new standard is that special calculations would be needed each year to monitor changes in these rates. Calculating targets and monitoring changes for States and other subpopulations probably would be made more complicated by using a new reference population. However, if the Centers for Disease Control and National Center for Health Statistics are planning to set up a system to report on progress on the Year 2000 Health Objectives on a regular basis at the State (and perhaps lower) level, the introduction of this system by itself is a major change and a major effort. Now might be just the time to switch all mortality reporting to a more current standard.

The *Healthy People 2000* process will be successful if local newspapers occasionally run on their front pages a small number of statistical charts illustrating progress in their areas toward meeting the Year 2000 Health Objectives. Such charts, often in the form of time series of mortality rates, perhaps for a small number of causes, will provide a rare opportunity to present public health information to the public. Thus, it is important that they convey as much information as accurately as possible. The trend information will be the same regardless of the standard population chosen, but the relative importance of the causes of death will be reasonably accurate only if a near-current standard population is used as the basis of the adjustment.

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Part V

Considerations for the future

Chapter 9
Age adjustment in National Center for Health Statistics mortality data: Implications of a change in procedures

by John E. Patterson, Division of Vital Statistics, National Center for Health Statistics

I have been asked to examine some of the practical implications of changing National Center for Health Statistics (NCHS) procedures for producing age-adjusted mortality data. I am very pleased to have this opportunity, because our division will have the responsibility for implementing any such changes. We also will be responsible for releasing the data through our annual volumes of *Vital Statistics of the United States* and such widely disseminated publications as the ‘‘Advance Report of Final Mortality Statistics.’’ In addition, we respond to a large number of inquiries regarding our mortality data from Congress, other components of the Public Health Service, the academic community, the media, advocacy groups, and the lay public. Finally, we work closely with our colleagues in the State health departments in developing standards and uniform procedures for vital statistics. Whatever the outcome of our deliberations, the Division of Vital Statistics will have an important role in implementing, justifying, and explaining the results.

Three practical considerations are involved in any possible change in NCHS procedures for producing age-adjusted mortality data: the level of effort required to make the change, the price we may pay in terms of confusing our data users, and the need to prepare a sound rationale for any change in order to dispel any possible suspicion that it was motivated by other than scientific considerations.

Level of effort

If the l990 census population or a projected population were substituted for the 1940 standard, NCHS would need to prepare a *Vital and Health Statistics* series report and a *Monthly Vital Statistics Report* (MVSR) supplement to explain the rationale for the change and its effect on the data. This would require a total of about 2.5 person-years of effort if a new annual series of age-adjusted rates were prepared using the standard NCHS summary cause-of-death categories going back to 1960. The level of effort would be substantially higher if the new rates were prepared for years prior to 1960, because the required data for the earlier years are not available in machine-readable form. If NCHS were to implement a new series of rates based upon a new population standard while retaining and continuing to publish the series based upon the 1940 standard, it also would be necessary to prepare a series report and periodic MVSR supplements to provide our users with ongoing guidance and information relating to the two series of rates. This would require a total of approximately 2.75 person-years of effort, assuming the same level of detail going back to 1960.

Confusion

Modification of current NCHS practices in age-adjusted mortality data can be expected to result in considerable confusion among our data users. If the traditional time series of age-adjusted death rates based on the 1940 standard population is discontinued and a new standard is instituted, many data users are likely to compare current rates based on the new standard with earlier rates based on the old standard. The practice of mixing rates based on the two different standard populations may be widespread and persistent, even with strong cautionary notes in NCHS publications. Our data users will need to be careful to carry out trend analyses within the time period for which a single standard population is used but not across time periods that result in the use of two different standard populations. Our users also will find that the results of studies based on the new standards may not be comparable with the results of earlier studies based on the old standards.

If a second population standard is adopted while maintaining the time series based on the 1940 standard, we will have an even greater potential for confusion. In addition, our data users are likely to ask us to indicate which is the ‘‘official’’ or ‘‘preferred’’ series of rates. In presenting descriptive analyses in our summary publications such as the ‘‘Advance Report of Final Mortality Statistics,’’ we will have to decide which standard will be used for presenting trends and comparisons in order to avoid having a lengthy, highly redundant text. The choice of one over the other may suggest to many of our users that one is better than the other.

We can anticipate that having two NCHS time series would lead to the accidental mixing of the two series in the same analysis, or to the selection of the standard that will give greater emphasis to one set of patterns and trends than the other. It is known, for example, that the 1940 standard population—which is younger than the current population—results in greater emphasis on causes of death associated with youth, specifically, deaths from homicide and accidents rather than deaths from chronic diseases.

With a new standard, there probably would be a transitional period during which some users would continue to use the older age standard while others would use the new one. Some State vital statistics offices may be eager to make the change; others may be reluctant to do so.

To mitigate confusion, NCHS will have to devote considerable resources and effort to clearly describe any change in practices and its consequences for analysis and interpretation of mortality data by a broad range of data users, from those in the media to academicians with training in biostatistics, demography, and epidemiology.

Motives and rationale

Questions may also be asked regarding our motives for making a change in our age-adjustment practices. Some users may be uncomfortable using a population standard that is more than 50 years old, but others may be bothered even more by a change that does not have obvious scientific advantages. These users may wonder if the data are being ‘‘manipulated’’ because of an ulterior motive.

One effect of changing from the 1940 to a more current standard such as 1990 is on comparisons of mortality by race. A new standard will tend to narrow the differences in mortality between the white and black populations for all causes of death combined and probably for most causes of death. For example, for all causes of death combined, the reduction will be from a 50 percent differential using the 1940 standard to a 33 percent differential using the 1990 standard. A change in the presentation of NCHS mortality data could easily raise questions as to motives for the change.

The public can interpret a change in longstanding statistical practices as possibly manipulative, obfuscatory, or politically inspired. For this reason, any change in practice will require considerable effort on the part of NCHS to provide a clear and compelling rationale for the change in order to reassure the public that the reasons for change are solely of a technical nature.

Chapter 10 Summary and recommendations

by Manning Feinleib, M.D., Dr.P.H., National Center for Health Statistics

The workshop on age adjustment proved to be a stimulating presentation and review of the major problems in age adjustment that have been discussed on numerous occasions during the past 150 years.

We have been reminded that because unadjusted rates can be seriously misleading, there is a clear need for age adjustment.

It has been demonstrated that the choice of standard for age adjustment inevitably affects the pattern of any summary statistic. Nonetheless, while there may be great differences in the magnitude of various rates, an overall similarity is manifested in long-term trends regardless of the standard employed.

We have reviewed statistical as well as nonstatistical considerations in the selection of standard populations and discussed the practical implications for implementing new standards.

Examples were presented to show that for several causes of death, somewhat different interpretations would result from different standard populations but the use of broad age groups might be used to show the differences in trends that lead to these disparities.

Naturally, individual investigators are free to choose whatever standard population they feel would most accurately reflect the import of their analyses. In the case of official statistics, however, there is a need for a common method and to minimize confusion on the part of data users, and so we must return to the original question—what standard population best serves the interest of the majority of users.

Subsequent to the formal workshop session, a subgroup of participants (Joel Kleinman, John Patterson, and Alvan Zarate) volunteered to review the discussions of the workshop and to prepare a set of recommendations. These recommendations were then circulated to all of the participants for comment. Although everyone felt that the workshop had clarified the important issues, as might have been anticipated, there was no unanimity on the recommended standard population. Going with the majority and trying to balance the cogent minority arguments, the following recommendations were adopted.

1. NCHS will continue to use the 1940 U.S. population as the basis for calculating age-adjusted death rates. This population will be converted into a relative distribution totalling 1,000,000 and will be referred to as the ‘‘U.S. Standard Million Population.’’
2. NCHS will study the following issues that may lead to the introduction of a new or an additional standard by the year 2000:
   a. The effects on age-adjusted death rates of using rates for ages 85–94 years and 95 years and over, in place of 85 years and over in their calculation.
   b. The feasibility of producing tables of trends for leading causes of death from 1960 to the present for broad age groupings, and the desirability of finer age-adjustment within the broad age groups.
   c. The utility and timeliness of producing age-adjusted rates based on the latest decennial census.
3. NCHS shall develop suitable technical notes and expository material concerning the appropriate use of age adjustment, differences in interpretation from crude and other rates used in the scientific literature, and clarification of issues expressed by data users.
4. Other official agencies should use the standard million population when publishing age-adjusted mortality rates. Researchers examining unique issues might consider the use of other standard populations when appropriate and, to minimize confusion, point out this departure from standard practice.

Part VI
Appendixes

Appendix I
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Appendix II
Age-specific weights of age-specific percent changes assumed in the computation of percent changes based on age-adjusted death rates

by Jeffrey Maurer, M.S., Division of Vital Statistics, National Center for Health Statistics

Introduction

While not presented at the workshop, this paper was developed in conjunction with that prepared by Rosenberg, Curtin, Maurer, and Offutt (part III, chapter 5) and considers issues closely related to those discussed by Gray-Donald (part II, chapter 3).

It is common practice in the National Center for Health Statistics (NCHS) to compute percent changes between two data years based on age-adjusted death rates by cause of death, race, and sex. This paper demonstrates that the percent changes based on age-adjusted death rates are weighted averages of the age-specific percent changes. The paper also shows that these weights are the product of the age-specific weights of the standard population and age-specific death rates for the base year divided by the sum of these products. The implication is that the implicitly used weights for computing percent changes based on age-adjusted death rates differ by race, sex, cause of death, and the standard population. Some comparisons using different weighting schemes of the age-specific percent changes are made by race and cause of death using the 1940 and 1990 standard populations. The results show that percent changes based on age-adjusted death rates tend to minimize the white-to-black ratios of the percent changes as compared with other weighting schemes. There are, also, other differences among the weighting schemes. Discussions of these implications may be warranted. Furthermore, and perhaps more importantly, it is discovered that the weights of the age-specific percent changes may be used to determine which age groups contributed the most to the percent change of two age-adjusted death rates.

Determination of the weights

Let C be the percent change for two age-adjusted death rates as follows:

$$C = \frac{R_n - R_0}{R_0} \cdot 100$$

where R_n=age-adjusted rate for the n^{th} year and R_0= the age-adjusted rate for the base year. Then

$$C = \frac{\sum w_i R_{in} - \sum w_i R_{i0}}{\sum w_i R_{i0}} \cdot 100$$

where R_{in}=age-specific rate for n^{th} year, R_{i0}=age-specific rate for base year, and w_i=age-specific proportion for standard population (say 1940), where $\sum w_i = 1$.

Assume C* is a weighted average of ‘‘age-specific percent changes’’ as follows:

$$C^* = \sum w^*_i \frac{R_{in} - R_{i0}}{R_{i0}} \cdot 100$$

As shown below, the following weights (w_i*) make C* equal to C:

$$\boxed{w^*_i = \frac{w_i R_{i0}}{\sum w_i R_{i0}}}$$

by substitution,

$$C^* = \sum \frac{w_i R_{i0}}{\sum w_i R_{i0}} \cdot \frac{R_{in} - R_{i0}}{R_{i0}} \cdot 100$$

$$C^* = \frac{\sum w_i (R_{in} - R_{i0})}{\sum w_i R_{i0}} \cdot 100$$

$$C^* = \frac{\sum w_i R_{in} - \sum w_i R_{i0}}{\sum w_i R_{i0}} \cdot 100$$

$$C^* = C$$

therefore, the w^*_i are the age-specific weights such that if the age-specific percent changes were multiplied by these weights and those results summed over all the age groups, this would give the same results as computing a percent change based on two age-adjusted death rates. The w^*_i are the age-specific weights for the standard population

(w_i) times the corresponding age-specific death rate for the base year (R_{io}) divided by the sum of those products.

The same formula is applicable to sex and race ratios based on age-adjusted death rates, except that the weights are applied to the age-specific sex and race ratios.

Implication of the weights

What is the implication of this finding? The implication is that for percent changes based on age-adjusted death rates, the weights of the age-specific percent changes will be different for every percent-change comparison made between races, sexes, or causes of death. This is the case since in the formula, $w^*_i=w_iR_{io}/\sum w_iR_{io}$, the base-year age-specific death rates (R_{io}) are different for each race, sex, and cause of death.

The next question is, ‘‘Are the weights so different as to produce different results?’’ The mortality data presented in the paper by Rosenberg, Curtin, Maurer, and Offutt (Part III, Chapter 5) are used for comparing four different weighting schemes applied to age-specific percent changes (table 1). (The percent changes shown in Rosenberg, et al may differ slightly from those in this paper due to rounding.) These four schemes were used in conjunction with the 1940 and the 1988 (hereinafter referred to as 1990) standard populations. The first weighting scheme is the ‘‘usual method,’’ which computes percent changes based on age-adjusted death rates and, therefore, implicitly uses different weights for the age-specific percent changes. The second and third schemes, ‘‘white weights’’ and ‘‘black weights,’’ use the 1968 age-specific death rates (R_{io}) for the white and black populations, respectively, and the weights for the standard population. The fourth weighting scheme uses the weights for the 1940 or 1990 standards only.

This paper examines the effects of these four schemes on the percent changes for all causes, cerebrovascular diseases, cancer, and homicide for the white and black populations (table 1). It should be noted that for all causes for the white population, the ‘‘usual method’’ and the ‘‘white weights’’ produce the same percent changes (–10.5), which empirically corroborates the formula for the w^*_i. Similarly, for the black population, the ‘‘usual method’’ and the ‘‘black weights’’ have the same percent change (–5.2). These same results occur for the other causes of death for both the 1940 and 1990 standards.

In general, the ‘‘usual method’’ (based on different weights) tends to minimize the white-to-black ratio of the percent changes when compared with the other weighting schemes (table 1). For example, for the 1940 standard for all causes, the ‘‘usual method’’ produces a ratio of 2.02 followed by ‘‘black weights’’ (2.23), ‘‘1940 weights’’ (2.44), and ‘‘white weights’’ (3.75).

It may be noted that for all causes and the 1990 standard, the percent change using ‘‘white weights’’ for black persons is positive (1.1), while the corresponding changes for the other three weighting schemes are negative. This positive percent change occurred because the percent distribution of the ‘‘white weights’’ for the age groups 75–84 years and 85 years and over (28 and 20 percent, respectively) were much higher than for the other three weighting schemes and these weights were applied to relatively high positive percent changes for those two age groups. (Data are based on detailed tables not shown in this paper.)

The white-to-black ratios differ comparatively little among the four weighting schemes for cerebrovascular diseases. This result occurs since the age-specific percent changes are relatively uniform across all age groups for white and black persons and, therefore, different weighting schemes have very little effect (tables 1,2).

For cancer, on the other hand, the weighting scheme can have a major impact on the resulting summary percent changes. For example, using the 1940 standard, the ‘‘1940 weights’’ produce negative percent changes for white persons (–29.2 percent) and black persons (–21.3 percent), while the other three weighting schemes produce positive percent changes. These results occur mainly because the percent changes for cancer declined for every age group under age 55 years and increased for every age group 55 years and over, and because the age groups under 55 years are weighted heavily by the ‘‘1940 weights’’ (accounting for 85 percent of the weights). (Data are based on detailed tables not shown in this paper.) In contrast, the ‘‘white weights’’ and ‘‘black weights’’ for the age groups under 55 years account for only 27 and 32 percent, respectively, of the weights and, therefore, heavier weights are applied to the increasing percent changes of the age groups 55 years and over.

In addition, the ‘‘usual method’’ for cancer using the 1940 standard produces a percent change for black persons (9.8) that is about four times that for white persons (2.4), while the ‘‘white weights’’ and ‘‘black weights’’ produce percent changes for black persons (13.4 and 9.8, respectively) that are almost six and nine times those for white persons (2.4 and 1.1, respectively). Comparing these weighting schemes for the 1940 standard with the 1990 standard for cancer produces similar results, but at a lower level. The percent changes for black persons are three to four times the corresponding changes for white persons.

Similar to cancer, the weighting scheme for homicide can have a large impact on the summary percent changes. For example, using the 1940 standard, the ‘‘1940 weights’’ produced a positive percent change for black persons while the other three weighting schemes produced negative percent changes. These results occurred mainly because the age groups 1–4 years and 5–14 years had very large percent increases (81.6 and 63.6 percent, respectively), and these age groups are weighted more heavily by the ‘‘1940 weights’’ than the other weighting schemes. (Data are based on detailed tables not shown in this paper.) The results using the ‘‘1990 weights’’ for white persons are similar. The white-to-black ratio of the percent changes is somewhat higher using the ‘‘white weights’’ (–1.77) than the ‘‘usual method’’ (–1.33) or the ‘‘black weights'' (–1.33). Similar results occur using the 1990 standard.

Application of weights

Also, it is discovered that there is an important application of the weights, w_i*. Using these weights, it is possible to determine which age groups contributed the most to a percent change based on age-adjusted death rates. The basic principle is that the product of the ''white weights'' or ''black weights'' and the age-specific percent changes are additive. Since these products are additive, the percent contribution for an age group can be determined.

An example that examines the percent change between 1968 and 1988 of age-adjusted death rates based on the 1940 standard population for cerebrovascular diseases by race is shown in table 2. Based on the age-adjusted death rate, cerebrovascular diseases for white persons declined 58.4 percent. Table 2 shows that the sum of the products of the age-specific ''white weights'' and the age-specific percent changes gives the same percent change (–58.4). If each of the age-specific products is divided by –58.4 and multiplied by 100, the results show the percent contribution of each age group. Thus, for white persons the age group 75–84 years contributed the most (35 percent, rounded to the nearest percent) to this decline, followed by 65–74 years (29 percent), 85 years and over (14 percent), 55–64 years (12 percent), 45–54 years (6 percent), and other ages (4 percent). For black persons, the age group 65–74 years contributed the most (33 percent), followed by 55–64 years (23 percent), 75–84 years (16 percent), 45–54 years (14 percent), 35–44 years (7 percent), 85 years and over (5 percent), and other ages (3 percent).

Discussion

This paper uncovers the age-specific weights implicitly used when computing percent changes based on age-adjusted death rates. The weights are the age-specific weights for the standard population times the age-specific death rate for the base year divided by the sum of those products. The implication is that for percent changes based on age-adjusted death rates, the weights of the age-specific percent changes will be different for every percent-change comparison made between races, sexes, or causes of death. In other words the percent changes based on age-adjusted death rates are not standardized. The weights are different because the age-specific death rates for the base year are different for each race, sex, and cause of death. Mortality sex and race ratios based on age-adjusted death rates are affected in the identical way. Using four different weighting schemes based on both the 1940 and 1990 standards, somewhat different results are produced. The author recommends that there be some discussion on whether or not the differing results are of practical significance. If it is determined that the contrasting results are of practical significance, then a standard set of weights would need to be agreed upon. The prospect of coming to an agreement on such a standard would probably be as arduous and controversial as agreeing on a standard for computing the age-adjusted death rate.

There is, however, a less controversial, and, perhaps even more important, finding in this paper. By discovering the weights associated with the age-specific percent changes, it is possible to ascertain the percent contribution of every age group to the percent change of two age-adjusted death rates. Thus, for any percent change based on two age-adjusted death rates, one can determine those age groups that contributed the most to that change.

Table 1. Summary of percent changes for selected causes of death using various age-specific weighting schemes of the age-specific percent changes, by race: United States, 1968–88

Weighting scheme and cause	*Percent change* White	*Percent change* Black	*Ratio of percent changes (white/black)*
All causes			
1940 standard:			
Using usual method[1]	–10.5	–5.2	2.02
Using white weights[2]	–10.5	–2.8	3.75
Using black weights[3]	–11.6	–5.2	2.23
Using 1940 weights	–13.9	–5.7	2.44
1990 standard:			
Using usual method[1]	–7.9	–1.7	4.65
Using white weights[2]	–7.9	1.1	–7.18
Using black weights[3]	–9.4	–1.7	5.53
Using 1990 weights	–12.7	–4.8	2.65
Cerebrovascular diseases			
1940 standard:			
Using usual method[1]	–58.4	–59.0	0.99
Using white weights[2]	–58.4	–55.5	1.05
Using black weights[3]	–58.8	–59.0	1.00
Using 1940 weights	–58.6	–61.8	0.95
1990 standard:			
Using usual method[1]	–57.4	–56.3	1.02
Using white weights[2]	–57.4	–52.4	1.10
Using black weights[3]	–58.3	–56.3	1.04
Using 1990 weights	–58.3	–61.1	0.95
Cancer			
1940 standard:			
Using usual method[1]	2.4	9.8	0.24
Using white weights[2]	2.4	13.4	0.18
Using black weights[3]	1.1	9.8	0.11
Using 1940 weights	–29.2	–21.3	1.37
1990 standard:			
Using usual method[1]	5.9	17.9	0.33
Using white weights[2]	5.9	22.7	0.26
Using black weights[3]	4.5	17.9	0.25
Using 1990 weights	–25.9	–17.2	1.51
Homicide			
1940 standard:			
Using usual method[1]	25.6	–19.3	–1.33
Using white weights[2]	25.6	–14.5	–1.77
Using black weights[3]	25.6	–19.3	–1.33
Using 1940 weights	36.0	4.9	7.35
1990 standard:			
Using usual method[1]	23.6	–19.6	–1.20
Using white weights[2]	23.6	–13.3	–1.77
Using black weights[3]	24.2	–19.6	–1.23
Using 1990 weights	32.2	4.8	6.71

[1]Percent change is based on age–adjusted death rates. As a result, the age–specific weights of the age–specific percent changes for the white and black populations are different.

[2]The white age–specific weights are $w_{i40}R_{i68}/\Sigma w_{i40}R_{i68}$ and $w_{i90}R_{i68}/\Sigma w_{i90}R_{i68}$ for the 1940 and 1990 standard populations, respectively. The R_{i68} are the death rates for the white population.

[3]The black age–specific weights are $w_{i40}R_{i68}/\Sigma w_{i40}R_{i68}$ for the 1940 standard and $w_{i90}R_{i68}/\Sigma w_{i90}R_{i68}$ for the 1990 standard. The R_{i68} are the death rates for the black population.

Table 2. Percent contribution by age of percent changes based on age-adjusted death rates for cerebrovascular diseases, by race: United States, 1968–88

[Rates per 100,000 population. Age-adjusted death rate based on 1940 standard population]

Rate, weighting scheme, and race	*Age-adjusted rate*	*Total*	*Under 1 year*	*1–4 years*	*5–14 years*	*15–24 years*	*25–34 years*	*35–44 years*	*45–54 years*	*55–64 years*	*65–74 years*	*75–84 years*	*85 years and over*
Rate													
White:													
Rates for 1968 (R_{i68})	66.2	. . .	4.5	0.8	0.7	1.5	3.6	12.0	35.1	101.3	375.0	1,312.5	3,698.6
Rates for 1988	27.5	. . .	3.0	0.3	0.2	0.7	1.7	5.0	14.9	43.3	142.3	542.0	1,739.4
Percent change	. . .	–58.4	–33.3	–62.5	–71.4	–53.3	–52.8	–58.3	–57.5	–57.3	–62.1	–58.7	–53.0
Black:													
Rates for 1968 (R_{i68})	125.8	. . .	9.3	1.3	0.8	3.6	14.7	56.4	139.4	339.5	795.9	1,442.4	2,676.1
Rates for 1988	51.5	. . .	8.8	0.6	0.3	1.0	6.0	21.9	53.6	124.2	290.6	736.5	1,445.4
Percent change	. . .	–59.0	–5.4	–53.8	–62.5	–72.2	–59.2	–61.2	–61.5	–63.4	–63.5	–48.9	–46.0
Using 1940 as a standard													
1940 standard weights (w_{i40})	. . .	1.000000	0.015343	0.064718	0.170355	0.181677	0.162066	0.139237	0.117811	0.080294	0.048426	0.017303	0.002770
Percent distribution	. . .	100.00	1.53	6.47	17.04	18.17	16.21	13.92	11.78	8.03	4.84	1.73	0.28
White weights:													
(w_{i40}•white R_{i68}/(Σw_{i40}•white R_{i68}))	66.2	. . .	0.069044	0.051774	0.119249	0.272516	0.583438	1.670844	4.135166	8.133782	18.159750	22.710188	10.245122
Distribution of weights	. . .	1.000000	0.001044	0.000783	0.001803	0.004120	0.008820	0.025258	0.062511	0.122958	0.274520	0.343309	0.154875
Percent distribution	. . .	100.00	0.10	0.08	0.18	0.41	0.88	2.53	6.25	12.30	27.45	34.33	15.49
Black weights													
(w_{i40}•blackR_{i68}/(Σw_{i40}•blackR_{i68}))	125.8	. . .	0.142690	0.084133	0.136284	0.654037	2.382370	7.8529671	6.4228532	7.2598133	8.5422532	4.957847	7.412797
Distribution of weights	. . .	1.000000	0.001134	0.000669	0.001083	0.005197	0.018931	0.062400	0.130497	0.216609	0.306260	0.198317	0.058903
Percent distribution	. . .	100.00	0.11	0.07	0.11	0.52	1.89	6.241	3.052	1.66	30.63	19.83	5.89
White (using white weights)													
Contribution to percent change	. . .	–58.4	–0.03	–0.05	–0.13	–0.22	–0.47	–1.47	–3.60	–7.04	–17.03	–20.15	–8.20
Percent contribution	. . .	100.0	0.1	0.1	0.2	0.4	0.8	2.5	6.2	12.1	29.2	34.5	14.0
Black (using black weights)													
Contribution to percent change	. . .	–59.0	–0.01	–0.04	–0.07	–0.38	–1.12	–3.82	–8.03	–13.74	–19.44	–9.71	–2.71
Percent contribution	. . .	100.0	0.0	0.1	0.1	0.6	1.9	6.5	13.6	23.3	32.9	16.4	4.6

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