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Age Standardization of Death Rates: Implementation of the Year 2000 Standard

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Abstract

This report discusses the rationale for and implications of the implementation of a new population standard for the age standardization (age adjustment) of death rates. The new standard is based on the year 2000 population and beginning with data year 1999, will replace the existing standard based on the 1940 population. This report also includes a technical discussion of direct and indirect standardization and statistical variability in age-adjusted death rates. Currently, at least three different standards are used among Department of Health and Human Services agencies. Implementation of the year 2000 standard will reduce confusion among data users and the burden on State and local agencies. Use of the year 2000 standard will also result in age-adjusted death rates that are substantially larger than those based on the 1940 standard. Further, the new standard will affect trends in age-adjusted death rates for certain causes of death and will narrow race differentials in age-adjusted death rates. Although age standardization is an important and useful tool, it has some limitations. As a result the examination of age-adjusted death rates should be the beginning of an analysis strategy.

Introduction

The purpose of this report is to provide the rationale for and the implications of implementing a new population standard for age-adjusting death rates. Based on the year 2000 population, the new standard replaces the existing 1940 standard million population that has been used for over 50 years. The change will be implemented by the National Center for Health Statistics (NCHS), effective with deaths occurring in 1999. This report also includes a technical discussion of direct and indirect standardization and statistical variability in age-adjusted death rates (see "Technical notes").

The crude death rate is a widely used measure of mortality. However, crude death rates are influenced by the age composition of the population. As such, comparisons of crude death rates over time or between groups may be misleading if the populations being compared differ in age composition. This is relevant, for example, in trend comparisons of U.S. mortality given the aging of the U.S. population (1). The crude death rate for the United States rose from 852.2 per 100,000 population to 880.0 during 1979–95. This increase in the crude death rate was due to the increasing proportion of the U.S. population in older age groups that have higher death rates. Age standardization, often called "age adjustment," is one of the key tools used to control for the changing age distribution of the population, and thereby to make meaningful comparisons of vital rates over time and between groups. In contrast to the rising crude death rate, the age-adjusted death rate for the United States dropped from 577.0 per 100,000 U.S. standard population to 503.9 during 1979–95. This age-adjusted comparison is free from the confounding effect of changing age distribution and therefore, better reflects the trend in U.S. mortality. To use age adjustment requires a "standard population," which is a set of arbitrary population weights (see "Methods").

Since 1943 NCHS and the States have used a standard based on the 1940 U.S. population termed the "U.S. standard million population" for age-adjusting rates. Although the 1940 standard is widely used, at least three different standards are currently used by Federal and State agencies (2,3,4).

It has been recognized that the use of a single age-adjustment standard by Federal agencies would help to alleviate confusion and misunderstanding among data users and the media. Multiple standards also create burdens for the States, who attempt to make their data consistent with Federal statistics. In recent years the 1940 standard has been perceived as outdated and incompatible with the current and "older" age structure of the population. NCHS sponsored two national workshops (1991, 1997) to examine these issues. Participants of the

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first workshop on age adjustment examined technical issues and problems related to the calculation and interpretation of age-adjusted death rates. Participants included representatives from NCHS, other components of the Centers for Disease Control and Prevention, the National Institutes of Health, the National Academy of Sciences, State health departments, and academia (5). Recommendations were made to continue the use of the 1940 standard by NCHS, to encourage other Federal and State governmental agencies to use this standard when publishing official mortality statistics, and to have NCHS study issues that might lead to the introduction of a new or additional standard by the year 2000 (6).

The second workshop focused on policy issues related to a coordinated approach to age standardization within the Department of Health and Human Services (DHHS) (7). Workshop participants concluded that although there were no compelling technical reasons to change population standards, the public health community might be better served by a new, uniform, and more contemporary standard. Additionally, workshop participants recommended that the new standard for age-adjusting rates be based on the year 2000 U.S. population (see "Technical notes" for the recommendations of the second workshop). These recommendations were subsequently approved as policy by the Secretary, DHHS.

Methods

Data

Mortality data in this report are from annual statistical files of the National Vital Statistics System, which is a compilation of statistics from all death certificates filed in the 50 States and the District of Columbia (8). The projected population age distribution for the year 2000 standard was prepared by the U.S. Bureau of the Census (9) and converted by NCHS to a standard million population by dividing the age-specific populations by the total population and multiplying by 1 million (see "Technical notes").

Death rates

The burden of disease in a population is typically denoted by the total number of health events (such as deaths). However, the absolute number of events is seldom useful for making comparisons between groups or examining changes over time, because it depends largely on population size. That is, a large population tends to generate more health events than a smaller population simply because of its larger size. Consequently, to compare differences in mortality among groups or across time periods, the number of events must be related to the size of the "population at risk" of experiencing the event. In this way, one can compare the relative risk of death between groups or time periods. The most informative method of making comparisons of mortality risk between groups is to examine differences in age-specific death rates. The age-specific death rate is defined as the number of deaths occurring in a specified age group divided by the midyear population of that age group, usually expressed per 1,000 or 100,000 population. Age-specific death rates allow one to compare mortality risk among groups or over time specific for a particular age group. Although effective in eliminating the effect of age composition, age-specific comparisons can be cumbersome, because they require a relatively large number of comparisons, one for each age group.

The crude death rate is a summary measure or average defined as the total number of deaths divided by the total midyear population and is often expressed per 1,000 or 100,000 population. Although it is the simplest way to express relative mortality risk, the crude death rate is often inadequate because many health outcomes such as death vary substantially by age. Because the risk of dying is much greater at older than at younger ages, populations with older age distributions tend to have higher crude death rates than younger populations. Table A illustrates a comparison between two hypothetical groups of the same population size, 10,000 persons, but with different age compositions and different age-specific death rates. Group A has proportionately more elderly persons; sixty percent are aged 65 years and over (column 2) compared with 10 percent for group B (column 6). Further age-specific death rates for each age group in group A are lower than those for group B. Group A has a crude death rate of 50 deaths per 1,000 population (column 3 all ages), and group B has a crude death rate of 40 deaths per 1,000 population (column 7 all ages).

At first glance the relative risk of mortality appears to be greater for group A than for group B. However, close examination shows that the substantially older age distribution of group A resulted in the higher crude death. An examination of the age-specific death rates in table A shows that death rates increase sharply with age, and that the age-specific rates of group B are higher (column 7) than those of group A (column 3) at every age. Contrary to what the comparison of crude death rates revealed, the mortality risk was higher for each age group in group B than in group A. Thus, to make meaningful comparisons of mortality risk between the two groups, the effect of variation in the age distribution between groups (or time periods) must be taken into account.

Table A. Group comparison of crude and age-adjusted death rates

Age	Group A				Group B				Standard population (9)	Standard weight[3] (10)
	Deaths (1)	Population (2)	Rate[1] (3)	Weighted rate[2] (4)	Deaths (5)	Population (6)	Rate[1] (7)	Weighted rate[2] (8)		
All ages	500	10,000	50	. . .	400	10,000	40	. . .	10,000	1.0
0–24 years	20	1,000	20	6	180	6,000	30	9	3,000	0.3
25–64 years	120	3,000	40	12	150	3,000	50	15	3,000	0.3
65 years and over	360	6,000	60	24	70	1,000	70	28	4,000	0.4
Age-adjusted death rate[1]	. . .	. . .	. . .	42	. . .	. . .	. . .	52	. . .	. . .

. . . Category not applicable.
[1]Rate per 1,000 population.
[2]The weighted rate is calculated by multiplying the age-specific rate by the standard weight.
[3]The standard weight for each age group is calculated by dividing the standard population at each age by the total standard population.

To overcome the effect of population age composition on comparisons of crude death rates, as well as the unwieldiness of multiple comparisons of age-specific death rates, a summary measure of mortality risk that controls for variation in age distributions was needed. The age-adjusted death rate is such a summary measure. Age-adjusted rates were first used in 1841 for the analysis of mortality data (10). The age-adjusted death rate is defined as the death rate that would occur if the observed age-specific death rates were present in a population with an age distribution equal to that of a standard population. The age-adjusted death rate is typically computed by the method of direct standardization. Indirect standardization may also be used to control for differences in age composition (see "Technical notes"). However, direct standardization is the most widely used method. The age-adjusted death rate computed by the direct method is a weighted average of the age-specific death rates. The weights represent standard population proportions by age and are applied to the age-specific death rates of each comparison group or time period (11). In table A the standard population of 10,000 is shown in column 9 and as relative weights summing to 1.0 in column 10. The age-adjusted death rate is calculated by multiplying each age-specific rate (columns 3 and 7) by the standard weight (column 10) and summing the weighted age-specific death rates (see "Technical notes"). Because each group or time period shares a common age distribution represented by the age-specific standard population weights, the effects of variation in age distribution are eliminated. In table A the age-adjusted death rate of group A is 42 (column 4) compared with 52 for group B (column 8), reflecting the effect of the lower age-specific rates at each age in group A. Thus, group B has a higher relative mortality risk measured by the age-adjusted death rate than group A, despite having a lower crude death rate.

Age adjustment by the direct method requires a standard age distribution or "standard population." Selection of an appropriate standard population is to some extent arbitrary because no "correct" standard population exist, although there are statistical reasons to guide the selection of a standard (12–14). The principal guidance in the statistical literature is that the standard population selected should not be considered "abnormal" relative to the populations being studied. That is, the standard population should reflect a reasonable age distribution (15). The selection of the standard population will not substantially affect comparisons among groups or time periods if the age-specific rates in the populations being compared have a roughly consistent relationship. That is, the relative differences are constant from one age group to the next. If the age-specific rates are not consistent, comparisons will be dependent on the standard selected. The most commonly used standard in the United States is based on the age distribution of the 1940 U.S. population (8). This standard is expressed in terms of a "standard million" (i.e., the relative age distribution of the 1940 population of the United States totaling 1 million) in 10-year age groups.

Two important caveats apply when age adjusting rates. First, considered alone, the age-adjusted death rate does not reflect the mortality risk of a "real" population. The average risk of mortality of a real population is represented by the crude death rate. The numerical value of an age-adjusted death rate depends on the standard used and, therefore, is not meaningful by itself. Age-adjusted death rates are appropriate only when comparing groups or examining trends across multiple time periods (13). A comparison of age-adjusted death rates among groups or time periods does reflect differentials in the average risk of mortality.

Second, age standardization may mask important information if the age-specific rates in the populations being compared do not have a consistent relationship (13, 16). This problem arises in cancer mortality. Table B shows 1979–95 cancer death rates for three broad age groups and the age-adjusted death rate. The trend in the age-specific death rate for the youngest age group (0–24 years) decreased by 33 percent during this period, while the rate for the oldest age group (65 years and over) increased by 15 percent. In contrast, the age-adjusted death rates (based on the 1940 standard) changed very little. Thus, the trend in the age-adjusted death rate for cancer does not reflect the complexities in the underlying age-specific rates. As averages, age-adjusted rates, like other averages, may lose information shown in their components, especially when age-specific rates reflect divergent trends over time. More often, however, age-specific rates move roughly in parallel. Thus, age-adjusted death rates are a widely accepted and useful convention for analyzing trends (17–19). Age-adjusted death rates are also highly effective for making comparisons among population groups (18) and among geographical areas (20) because age distribution often varies substantially between such comparison groups. In sum, thorough mortality analyses should include examination of age-adjusted rates as well as age-specific rates. In cases where age standardization may mask important age-specific trends or differences, presentation of age-adjusted rates should be supplemented with age-specific rates.

Effects of changing to the year 2000 standard

Changing from the 1940 standard population to the year 2000 standard will affect the magnitude of age-adjusted death rates, and in some cases, trends in mortality. This is because the age structures of the 1940 and year 2000 populations differ. From 1940 to year 2000, the U.S. population "aged" considerably. This occurred for two reasons: Fertility declined and age-specific death rates declined, particularly among the elderly population, resulting in greater survival at older ages. Figure 1 shows population pyramids for the 1940 U.S.

Table B. Age-specific, crude, and age-adjusted death rates for cancer: United States, 1979–95

[Age-specific rates per 100,000 population in specified age group; age-adjusted rates per 100,000 standard population (1940); cancer includes *Ninth Revision, International Classification of Diseases, 1975* categories 140–208, including malignant neoplasms of lymphatic and hematopoietic tissues]

Year	Age-specific rates			
	0–24 years	25–64 years	65 years and over	Age-adjusted rate
1979	5.1	142.7	986.6	130.8
1980	5.2	142.9	1,011.3	132.8
1981	4.8	139.4	1,008.6	131.7
1982	5.0	138.4	1,023.9	132.8
1983	4.8	136.6	1,034.0	133.1
1984	4.4	136.2	1,045.2	134.1
1985	4.4	134.6	1,051.1	134.4
1986	4.3	131.0	1,062.4	134.2
1987	4.1	128.8	1,067.3	134.0
1988	4.0	127.0	1,076.3	134.0
1989	4.0	124.5	1,095.9	134.5
1990	3.9	123.4	1,111.3	135.0
1991	3.9	121.3	1,117.3	134.5
1992	3.8	118.6	1,121.8	133.1
1993	3.7	117.1	1,133.7	132.6
1994	3.6	115.6	1,134.5	131.5
1995	3.4	113.7	1,136.6	129.9

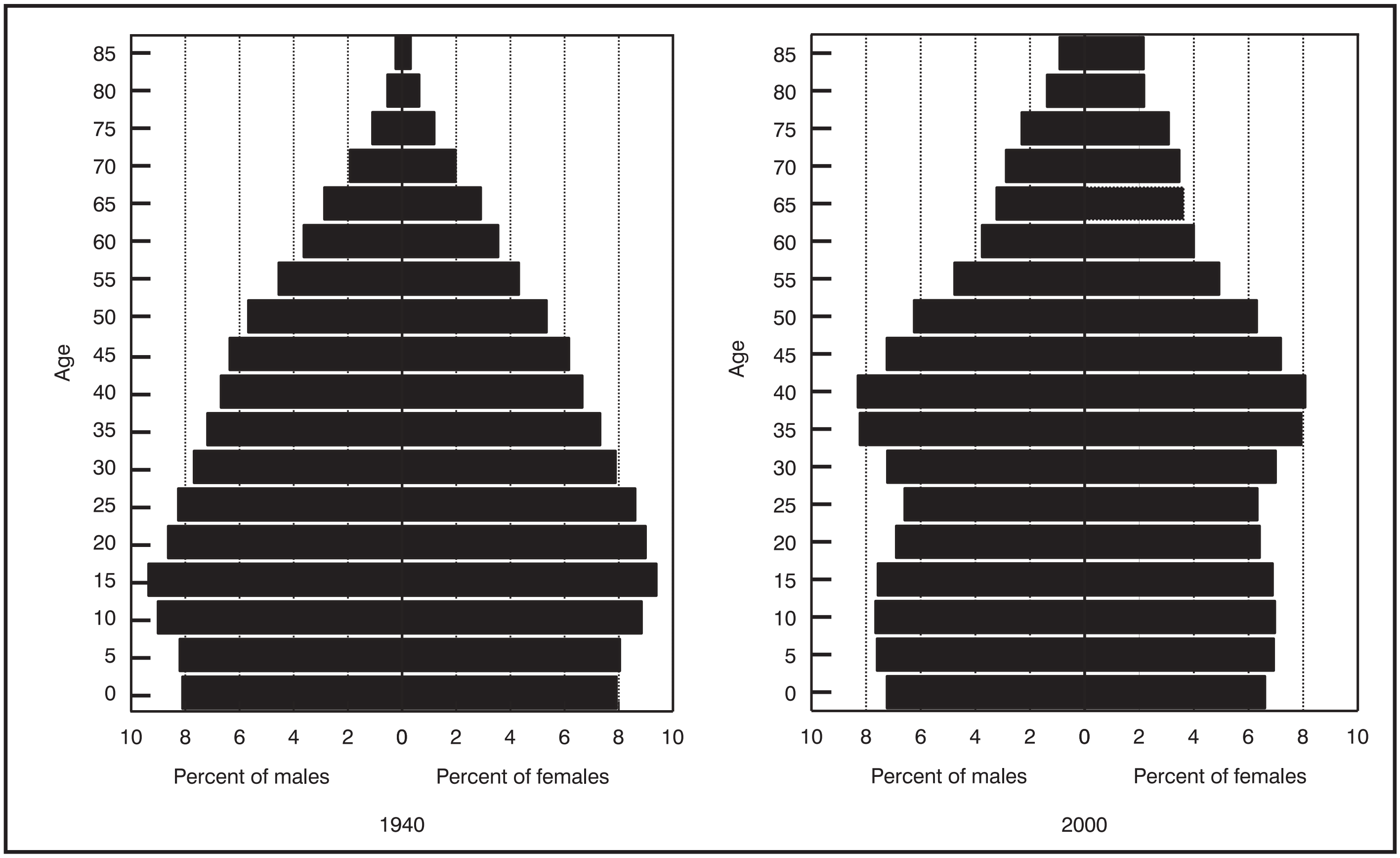

Figure 1. Population pyramids for the 1940 and 2000 U.S. populations expressed as a percent of total population

population and the projected year 2000 U.S. population. The 1940 population is more tapered, having a wider base and narrowed tip. The year 2000 population shows a higher concentration of population in the middle and older age groups, such as between 35 to 45 years of age and 65 years of age and over. The proportion of the population for these age groups increased from 0.139 to 0.163 and 0.068 to 0.124, respectively (table C). Thus, the population aged 65 years and over essentially doubled during this period. Because the standard populations serve as the weights for calculating age-adjusted rates, the differences in the age structure of the populations between 1940 and year 2000 translate directly into a change in the weights used for age standardization. Table C shows the 1940 and year 2000 standard populations with their corresponding age-specific weights. The difference in age distribution between the 1940 and year 2000 standards has implications for the presentation and interpretation of mortality statistics regarding age-adjusted death rates.

Magnitude of the age-adjusted death rate

Change in the population standard from 1940 to the year 2000 will affect the magnitude of the age-adjusted death rate for the United States. The rate based on the year 2000 standard will be much larger than that based on the 1940 standard. As noted earlier, the magnitude of the age-adjusted rate is largely dependent on the age distribution of the applied standard. Figure 2 shows the trend in mortality in terms of the crude death rate along with age-adjusted death rates based on the 1940 and the year 2000 standards. The 1995 age-adjusted death rate based on the 1940 standard was 503.9 deaths per 100,000 standard population. The age-adjusted death rate for 1995 based on the year 2000 standard was 918.5, nearly double that based on the 1940 standard and much closer in magnitude to the crude death rate. Thus, the age-adjusted death rate based on the year 2000 standard much more closely reflects the observed average risk of mortality in 1995—represented by the crude death rate—than the age-adjusted rate based on the 1940 population. The age-adjusted rate based on the year 2000 standard is larger because the year 2000 population standard, which has an older age structure, gives more weight than the 1940 standard to death rates at the older ages where mortality is higher.

Although many studies have emphasized correctly that the choice of standard makes relatively little difference in terms of the relative trend

Table C. The 1940 and year 2000 U.S. standard populations

Age	1940		2000	
	Number	Weight	Number	Weight
All ages.	1,000,000	1.000000	1,000,000	1.000000
Under 1 year.	15,343	0.015343	13,818	0.013818
1–4 years.	64,718	0.064718	55,317	0.055317
5–14 years	170,355	0.170355	145,565	0.145565
15–24 years	181,677	0.181677	138,646	0.138646
25–34 years	162,066	0.162066	135,573	0.135573
35–44 years	139,237	0.139237	162,613	0.162613
45–54 years	117,811	0.117811	134,834	0.134834
55–64 years	80,294	0.080294	87,247	0.087247
65–74 years	48,426	0.048426	66,037	0.066037
75–84 years	17,303	0.017303	44,842	0.044842
85 years and over. . . .	2,770	0.002770	15,508	0.015508

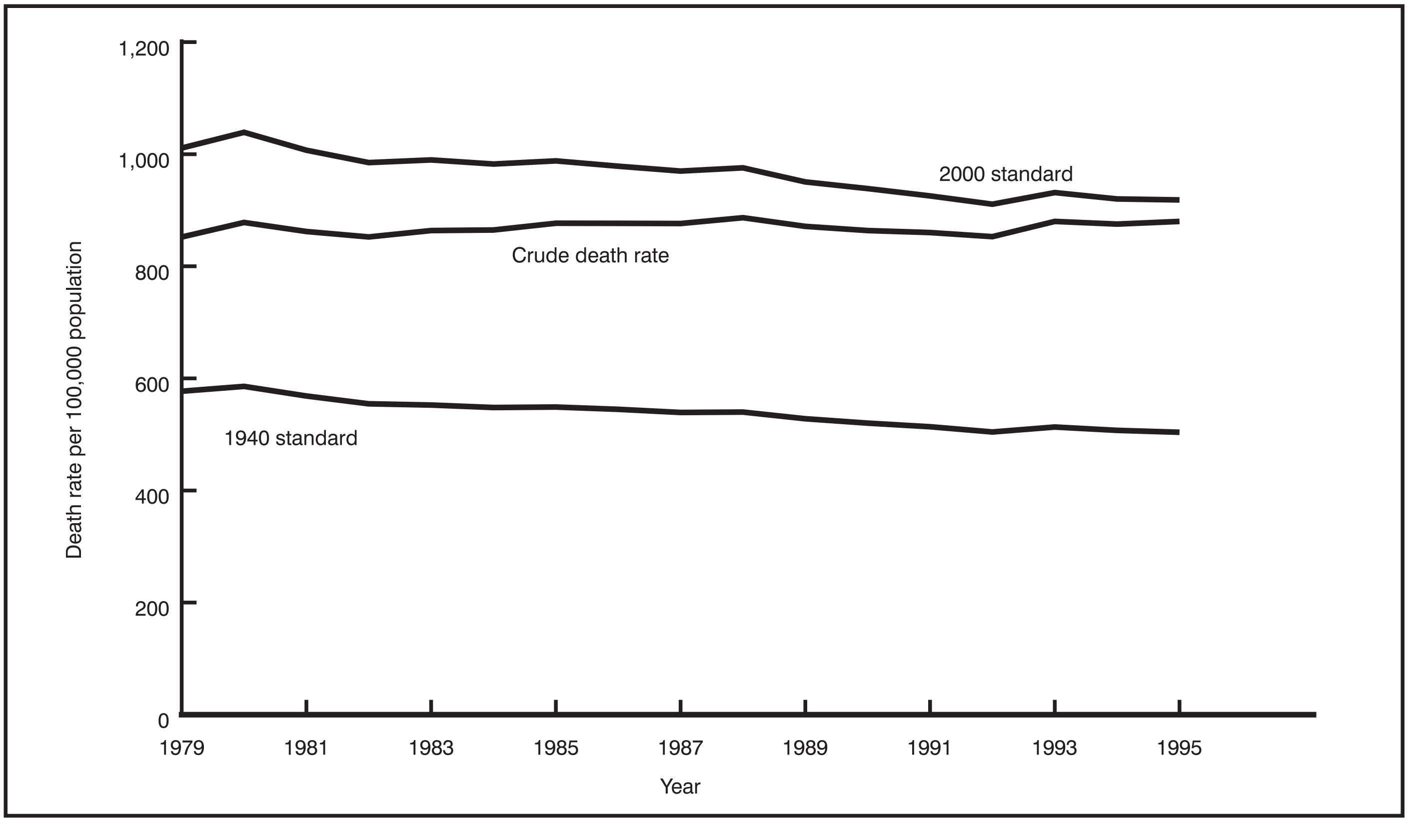

Figure 2. Crude and age-adjusted death rates based on the 1940 and 2000 standard populations: United States, 1979–95

(13,21), the choice can make a difference in some cases, when age-specific rates trace divergent trends, or when the age structure of the alternative standard populations differ. The crude death rate changed very little from 1979 to 1995, from a rate of 852.2 per 100,000 population to 880.0, an increase of 3.3 percent. In contrast, during this period the age-adjusted death rate based on the 1940 standard decreased by 12.6 percent, from 577.1 per 100,000 standard population to 503.9, while the rate based on the year 2000 standard decreased by 9.2 percent from 1011.1 to 918.5. Tracing a similar pattern over time (figure 2), the decline using the year 2000 standard is attenuated compared with the decline using the 1940 standard because age-specific declines have been smaller at the older ages, to which the year 2000 standard gives proportionately more weight than the 1940 standard. Nevertheless, the trend lines in figure 2 for the age-adjusted rates based on the year 2000 standard and the 1940 standard are roughly parallel, showing that the decrease in the age-adjusted death rate from 1979 to 1995 is similar regardless of the standard used.

Leading causes of death

Changing to the year 2000 standard affects age-adjusted death rates for specific causes of death largely in terms of the magnitude of the rate and much less in terms of the trend. However, the effect varies greatly among the leading causes of death. Table D shows trends from 1979 to 1995 in age-adjusted death rates using the 1940 and year 2000 standards for each of the 15 leading causes of death in the United States in 1995. For those causes where risk increases sharply with age, chronic diseases in particular, the change in magnitude is up threefold. For cerebrovascular diseases (stroke), for example, the age-adjusted death rate is 26.7 deaths per 100,000 standard population using the 1940 standard but is 63.9 using the year 2000 standard, a 2.4-fold difference. Large differences also occur for heart disease, malignant neoplasms (cancer), chronic obstructive pulmonary disease, pneumonia and influenza, diabetes, nephritis (kidney disease), septicemia, Alzheimer's disease, and atherosclerosis. Age-specific death rates for all of these causes of death are higher in older age groups, and, as a result, these causes are more affected by the larger weights of the year 2000 standard.

In contrast for those causes where risk is more uniform among the age groups, the differences in rates based on the two standards are much smaller. These causes include accidents, Human immunodeficiency virus (HIV) infection, suicide, chronic liver disease, and homicide, which are more concentrated in the younger and middle-age groups and consequently are much less affected by the disparity in weights between the two population standards.

Choice of the age standard does affect trends in some of the leading causes of death. The effect is least when changes in age-specific rates are parallel and is greater when age-specific trends diverge over time. For most of the leading causes, trends in age-adjusted death rates are virtually parallel regardless of the standard. Thus, trends for heart disease, stroke, diabetes, HIV infection, suicide, chronic liver disease, homicide, and atherosclerosis are approximately the same using the year 2000 standard and the 1940 standard. For example, for heart disease the age-adjusted death rate based on the 1940 standard declined by 30 percent from 1979 to 1995 and by 26 percent based on the year 2000 standard. The difference reflects the greater emphasis that the year 2000 standard weights give to the less rapid decline in the heart disease death rates at the older ages than at the younger ages. Specifically, age-specific death rates for heart disease among those aged 25–64 years declined by 43 percent, while

Table D. Age-adjusted death rates and percent change based on the 1940 and year 2000 standard populations for 15 leading causes of death: United States, 1979–95

[Age-adjusted rates are per 100,000 standard population. The asterisks preceding the categories indicate that they are not part of the *Ninth Revision, International Classification of Diseases, 1975*; the categories were added by the National Center for Health Statistics in 1987]

Cause of death (Based on the *Ninth Revision, International Classification of Diseases, 1975*) and year	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	Percent change 1979–95
All causes																		
1940	577.1	585.1	568.6	554.7	552.5	548.1	548.8	544.8	539.2	539.9	528.0	520.2	513.8	504.5	513.3	507.4	503.9	–12.7
2000	1,011.1	1,039.1	1,007.2	985.0	989.8	982.5	988.1	978.6	970.0	975.7	950.6	938.7	925.5	910.9	931.5	920.2	918.5	–9.2
Diseases of heart (390–398,402,404–429)																		
1940	199.6	202.0	195.3	190.9	189.6	184.3	181.4	176.0	170.8	167.7	157.5	152.0	148.2	144.3	145.3	140.3	138.3	–30.7
2000	401.7	412.1	397.0	389.0	388.8	378.8	374.9	365.1	355.9	352.5	332.1	321.8	313.8	306.1	310.0	299.7	296.3	–26.2
Malignant neoplasms, including neoplasms of lymphatic and hematopoietic tissues (140–208)																		
1940	130.8	132.8	131.7	132.8	133.1	134.1	134.4	134.2	134.0	134.0	134.5	135.0	134.5	133.1	132.6	131.5	129.9	–0.7
2000	204.0	207.9	206.4	208.3	209.1	210.8	211.3	211.5	211.7	212.5	214.2	216.0	215.8	214.3	214.6	213.1	211.7	3.8
Cerebrovascular diseases (430–438)																		
1940	41.6	40.8	38.2	35.9	34.5	33.6	32.5	31.1	30.5	30.0	28.3	27.7	26.8	26.2	26.5	26.5	26.7	–35.8
2000	97.3	85.3	89.7	84.4	81.3	78.9	76.6	73.3	71.8	70.8	67.1	65.5	63.4	62.1	63.2	63.3	63.9	–34.3
Chronic obstructive pulmonary diseases and allied conditions (490–496)																		
1940	14.6	15.9	16.3	16.2	17.5	17.8	18.8	18.9	18.9	19.6	19.6	19.7	20.1	19.8	21.4	21.0	20.8	42.9
2000	25.5	28.3	29.0	29.0	31.6	32.4	34.5	34.8	35.0	36.5	36.6	37.2	38.0	37.9	40.9	40.6	40.5	58.7
Accidents and adverse effects (E800–E949)																		
1940	42.8	42.3	39.7	36.6	35.3	35.1	34.8	35.2	34.7	35.0	33.9	32.5	31.0	29.4	30.3	30.3	30.5	–28.8
2000	47.9	47.7	44.7	41.4	40.3	40.1	39.9	40.0	39.6	40.2	39.0	37.5	36.0	34.6	35.7	35.7	36.0	–24.8
Pneumonia and influenza (480–487)																		
1940	11.2	12.9	12.3	10.9	11.9	12.2	13.5	13.6	13.2	14.3	13.8	14.0	13.4	12.7	13.5	13.0	12.9	15.6
2000	26.1	31.4	30.0	26.5	29.7	30.6	34.5	34.8	33.8	37.3	35.9	36.8	34.9	33.1	35.2	33.9	33.8	29.4
Diabetes mellitus (250)																		
1940	9.8	10.1	9.8	9.6	9.9	9.5	9.7	9.7	9.9	10.2	11.6	11.7	11.8	11.8	12.5	12.9	13.3	36.1
2000	17.5	18.1	17.6	17.2	17.6	17.2	17.4	17.2	17.5	18.0	20.5	20.7	20.7	20.8	22.0	22.7	23.4	33.8
Human immunodeficiency virus infection (*042–*044)																		
1940	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	5.5	6.7	8.7	9.8	11.3	12.6	13.8	15.4	15.6	184.2
2000	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	5.6	6.9	9.0	10.2	11.8	13.2	14.5	16.2	16.4	189.8
Suicide (E950–E959)																		
1940	11.7	11.4	11.5	11.6	11.4	11.7	11.6	11.9	11.7	11.5	11.3	11.5	11.4	11.1	11.3	11.2	11.2	–3.9
2000	12.6	12.2	12.3	12.5	12.4	12.6	12.5	13.0	12.8	12.5	12.3	12.5	12.3	12.1	12.2	12.0	12.0	–4.6
Chronic liver disease and cirrhosis (571)																		
1940	12.1	12.2	11.4	10.6	10.2	10.0	9.7	9.3	9.2	9.1	9.0	8.6	8.3	8.0	7.9	7.8	7.6	–37.0
2000	14.8	15.1	14.2	13.2	12.8	12.7	12.3	11.8	11.7	11.6	11.6	11.1	10.7	10.5	10.3	10.2	10.0	–32.8
Nephritis, nephrotic syndrome, and nephrosis (580–589)																		
1940	4.4	4.5	4.5	4.5	4.6	4.8	4.9	4.9	4.8	4.8	4.5	4.3	4.3	4.3	4.5	4.3	4.3	–1.1
2000	8.6	9.1	9.1	9.3	9.6	10.0	10.4	10.4	10.4	10.4	9.6	9.3	9.3	9.4	9.7	9.4	9.5	10.0
Homicide and legal intervention (E960–E978)																		
1940	10.2	10.8	10.4	9.7	8.6	8.4	8.3	9.0	8.6	9.0	9.4	10.2	10.9	10.5	10.7	10.2	9.4	–7.8
2000	9.9	10.5	10.1	9.4	8.4	8.1	8.0	8.6	8.3	8.5	8.8	9.5	10.1	9.6	9.8	9.3	8.5	–13.6

See footnotes at end of table.

Table D. Age-adjusted death rates and percent change based on the 1940 and year 2000 standard populations for 15 leading causes of death: United States, 1979–95—Con.

[Age-adjusted rates are per 100,000 standard population. The asterisks preceding the categories indicate that they are not part of the *Ninth Revision, International Classification of Diseases, 1975*; the categories were added by the National Center for Health Statistics in 1987]

Cause of death (Based on the *Ninth Revision, International Classification of Diseases, 1975*) and year	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	Percent change 1979–95
Septicemia (038)																		
1940	2.3	2.6	2.9	3.0	3.4	3.7	4.1	4.4	4.5	4.6	4.2	4.1	4.1	4.0	4.1	4.0	4.1	76.0
2000	4.3	5.0	5.4	5.9	6.7	7.4	8.3	9.0	9.3	9.7	8.8	8.6	8.6	8.4	8.6	8.3	8.4	94.7
Alzheimer's disease (331.0)																		
1940	0.3	0.4	0.5	0.7	1.0	1.3	1.6	1.8	2.0	2.1	2.2	2.2	2.1	2.1	2.3	2.5	2.7	980.0
2000	0.4	0.7	0.9	1.3	2.2	3.1	4.1	4.6	5.5	5.8	6.1	6.4	6.3	6.3	7.2	7.8	8.4	1,862.8
Atherosclerosis (440)																		
1940	5.7	5.7	5.2	4.9	4.7	4.2	4.0	3.7	3.6	3.5	3.0	2.8	2.6	2.4	2.4	2.3	2.3	–59.4
2000	17.9	18.0	16.5	15.3	14.6	13.2	12.6	11.7	11.2	10.9	9.3	8.5	7.9	7.5	7.4	7.2	6.9	–61.5

. . . Category not applicable.

Table E. Age-specific death rates and percent change for 15 leading causes of death by three broad age categories: United States, 1979–95

[Rates are per 100,000 population in specified age group. The asterisks preceding the categories indicate that they are not part of the *Ninth Revision, International Classification of Diseases, 1975*. The categories were added by the National Center for Health Statistics in 1987]

Cause of death (Based on the *Ninth Revision, International Classification of Diseases, 1975*) and age	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	Percent change 1979–95
All causes																		
0–24 years	121.0	121.0	114.0	109.6	104.5	103.2	103.0	104.4	102.1	103.1	101.9	99.5	97.1	91.3	91.3	88.1	84.9	–29.8
25–64 years	500.2	498.0	481.9	462.7	453.7	445.7	441.4	434.1	426.9	423.2	414.1	406.2	400.7	394.7	400.1	398.6	697.3	39.4
65 years and over	5,060.5	5,252.0	5,117.3	5,056.4	5,134.5	5,118.7	5,174.9	5,130.2	5,095.8	5,146.3	5,012.3	4,963.2	4,924.0	4,880.6	5,047.7	5,014.1	5,052.8	–0.2
Diseases of heart (390–398,402,404–429)																		
0–24 years	2.5	2.9	2.7	2.7	2.9	3.0	2.9	3.0	2.9	2.9	2.5	2.5	2.5	2.4	2.4	2.5	2.4	–5.1
25–64 years	155.2	151.9	146.0	139.6	135.7	130.0	125.6	119.5	113.7	109.0	101.6	96.9	94.0	91.9	91.8	89.4	88.4	–43.1
65 years and over	2,256.1	2,330.4	2,253.5	2,227.2	2,240.1	2,193.3	2,182.1	2,133.9	2,089.3	2,083.2	1,968.6	1,914.0	1,881.0	1,844.5	1,891.0	1,840.7	1,835.3	–18.6
Malignant neoplasms, including neoplasms of lymphatic and hematopoietic tissues (140–208)																		
0–24 years	5.1	5.2	4.8	5.0	4.8	4.4	4.4	4.3	4.1	4.0	4.0	3.9	3.8	3.8	3.7	3.6	3.4	–33.1
25–64 years	142.7	142.9	139.4	138.4	136.6	136.2	134.6	131.0	128.8	127.0	124.5	123.4	121.3	118.6	117.1	115.6	113.7	–20.4
65 years and over	986.6	1011.3	1008.6	1023.9	1034.0	1045.2	1051.1	1062.4	1067.3	1076.2	1095.8	1111.3	1117.3	1121.8	1133.7	1134.5	1136.6	15.2
Cerebrovascular diseases (430–438)																		
0–24 years	0.7	0.8	0.7	0.6	0.7	0.7	0.6	0.5	0.5	0.6	0.5	0.6	0.6	0.5	0.6	0.5	0.6	–22.6
25–64 years	22.6	21.5	20.6	19.2	18.4	17.9	17.0	16.4	16.0	15.5	14.7	14.3	13.8	13.7	13.6	13.8	13.8	–39.1
65 years and over	576.6	573.1	534.7	506.5	489.7	477.0	465.7	445.9	438.1	434.1	412.8	403.5	394.1	388.5	401.4	405.2	413.8	–28.2
Chronic obstructive pulmonary diseases and allied conditions (490–496)																		
0–24 years	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.4	0.4	0.4	0.5	0.4	0.5	0.5	0.5	48.6
25–64 years	10.8	11.3	11.3	10.7	11.4	11.3	11.6	11.3	11.1	11.2	11.1	10.7	10.7	10.2	10.7	10.5	10.3	–4.4
65 years and over	152.2	170.6	175.8	177.0	193.4	199.5	213.4	216.0	217.5	227.8	228.0	234.1	240.6	242.2	263.7	262.5	263.9	73.4
Accidents and adverse effects (E800–E949)																		
0–24 years	39.1	38.3	34.9	32.2	30.4	30.1	29.7	30.8	29.5	29.3	27.1	25.7	24.7	22.1	22.6	22.3	21.8	–44.1
25–64 years	42.1	41.8	40.3	36.7	35.5	35.1	34.9	34.9	34.7	35.1	34.6	33.3	31.2	30.4	31.5	31.5	32.2	–23.5
65 years and over	95.6	97.2	90.5	86.0	87.2	87.5	87.9	86.6	87.2	89.6	87.5	84.3	83.3	82.5	84.8	85.4	86.8	–9.3
Pneumonia and influenza (480–487)																		
0–24 years	2.1	1.9	1.6	1.5	1.5	1.4	1.4	1.4	1.4	1.3	1.4	1.3	1.3	1.2	1.2	1.1	1.1	–49.2
25–64 years	6.1	6.8	6.5	5.7	5.8	5.9	6.3	6.4	6.1	6.5	6.3	6.2	6.0	5.4	5.9	5.7	5.6	–8.2
65 years and over	145.6	178.1	171.8	153.2	174.7	182.0	207.0	209.6	204.4	226.9	219.7	226.8	217.2	209.1	225.3	219.4	221.6	52.1
Diabetes mellitus (250)																		
0–24 years	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	–29.7
25–64 years	8.5	8.8	8.4	8.2	8.4	7.9	8.1	8.1	8.2	8.6	9.4	9.5	9.5	9.6	10.0	10.4	10.8	26.5
65 years and over	95.3	98.7	96.0	94.1	96.6	95.0	96.0	94.0	95.8	98.1	113.4	114.3	115.0	115.7	123.6	128.5	132.6	39.1
Human immunodeficiency virus infection (*042–*044)																		
0–24 years	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.8	0.9	1.0	0.9	1.1	1.0	1.1	1.2	1.2	–
25–64 years	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	10.2	12.5	16.5	18.8	21.7	24.5	26.9	30.1	30.4	–
65 years and over	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	1.1	1.2	1.3	1.4	1.7	1.9	2.0	2.1	2.3	–
Suicide (E950–E959)																		
0–24 years	5.7	5.7	5.7	5.6	5.5	5.7	5.9	5.9	5.7	5.7	5.6	5.6	5.5	5.4	5.6	5.7	5.5	–4.8
25–64 years	16.2	15.8	16.2	16.2	15.8	15.9	15.5	16.0	15.7	15.2	15.0	15.3	15.1	14.8	14.9	14.8	14.8	–8.4
65 years and over	18.7	17.8	17.1	18.4	19.3	19.8	20.4	21.6	21.8	21.1	20.3	20.6	19.7	19.1	18.9	18.1	18.1	–3.5
Chronic liver disease and cirrhosis (571)																		
0–24 years	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	–57.0
25–64 years	19.5	19.5	17.7	16.1	15.5	14.9	14.3	13.5	13.3	13.2	12.8	12.1	11.6	11.3	11.2	11.2	11.0	–43.6
65 years and over	35.6	37.3	37.0	35.4	34.7	35.6	34.5	34.1	33.2	33.0	34.3	33.5	32.8	32.4	31.5	31.2	30.5	–14.4

See footnotes at end of table.

Table E. Age-specific death rates and percent change for 15 leading causes of death by three broad age categories: United States, 1979–95—Con.

[Rates are per 100,000 population in specified age group. The asterisks preceding the categories indicate that they are not part of the *Ninth Revision, International Classification of Diseases, 1975*. The categories were added by the National Center for Health Statistics in 1987]

Cause of death (Based on the *Ninth Revision, International Classification of Diseases, 1975*) and age	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	Percent change 1979–95
Nephritis, nephrotic syndrome, and nephrosis (580–589)																		
0–24 years	0.5	0.4	0.5	0.4	0.4	0.5	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	–41.7
25–64 years	3.2	3.2	3.0	3.0	2.9	2.9	3.0	2.9	2.8	2.9	2.6	2.5	2.4	2.4	2.5	2.3	2.4	–24.2
65 years and over	47.6	50.8	51.8	53.6	55.8	58.5	61.2	61.5	61.6	61.3	57.1	55.7	56.6	58.0	60.2	59.3	60.2	26.4
Homicide and legal intervention (E960–E978)																		
0–24 years	7.5	8.1	7.7	7.2	6.4	6.3	6.3	7.2	7.0	7.6	8.2	9.4	10.4	10.2	10.7	10.2	9.2	22.7
25–64 years	13.4	14.2	13.8	12.7	11.4	11.0	10.9	11.5	10.9	11.1	11.3	11.8	12.1	11.4	11.2	10.6	9.7	–27.5
65 years and over	5.2	5.6	5.0	4.9	4.5	4.3	4.3	4.5	4.6	4.4	4.2	4.0	4.1	3.8	3.7	3.5	3.2	–38.6
Septicemia (038)																		
0–24 years	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.5	0.6	0.5	0.5	0.5	0.5	0.5	0.5	–1.5
25–64 years	1.8	2.0	2.2	2.2	2.4	2.6	2.8	2.9	2.9	2.9	2.7	2.6	2.6	2.6	2.5	2.6	2.7	50.0
65 years and over	22.7	26.8	28.8	31.9	37.2	41.2	47.2	51.1	53.6	56.0	50.3	49.4	50.0	49.2	51.4	49.6	50.4	122.3
Alzheimer's disease (331.0)																		
0–24 years	–	–	–	0.0	–	0.0	0.0	–	–	–	–	0.0	–	–	0.0	0.0	0.0	–
25–64 years	0.2	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.2	0.3	0.3	0.3	44.9
65 years and over	2.6	4.1	5.6	8.4	14.8	21.0	27.5	31.0	36.7	39.3	41.5	43.1	43.4	43.8	50.1	54.9	60.3	2221.6
Atherosclerosis (440)																		
0–24 years	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	–49.7
25–64 years	1.2	1.3	1.2	1.1	1.1	1.0	1.0	0.9	0.9	0.8	0.7	0.7	0.7	0.6	0.6	0.6	0.6	–48.6
65 years and over	109.5	109.9	101.9	95.3	91.7	83.7	80.1	74.3	72.1	69.9	60.0	55.2	52.2	49.6	50.2	49.2	47.4	–56.7

. . . Category not applicable.

0.0 Quantity more than zero but less than 0.5.

– Quantity zero.

the decline among those older than 65 years was only 19 percent (table E).

For other leading causes of death, trends using the two different standards are less consistent. The previously described case of cancer (table B) is illustrative because of the clear pattern of divergent age-specific trends. Based on either standard, the trend in age-adjusted death rate for cancer increased gradually from 1979 reaching a peak in 1990 and declining steadily thereafter (table D). However, based on the 1940 standard, the 1995 rate is 0.7 percent below the rate for 1979; while using the year 2000 standard, the 1995 rate is 3.8 percent above that for 1979. The relatively higher 1995 rate based on the year 2000 standard reflects the greater emphasis that the year 2000 standard gives to increases in age-specific death rates at the older ages than the decreases at the younger ages; while the 1940 standard gives more emphasis to the decreases at the younger ages.

Race differences in mortality

The year 2000 standard has implications for race and ethnic differentials in mortality. In particular, the difference between mortality for the black and white populations will be affected as will that for the Hispanic and non-Hispanic populations. One way of showing the differential in mortality between population groups is the "mortality race ratio," which is the ratio of the age-adjusted death rate for one group (e.g., the black population) to that of another group (the white population). The mortality race ratio for the black and white populations in 1995 is reduced from 1.6 using the 1940 standard to 1.4 using the year 2000 standard (see table F). Using the 1940 standard, the black population has an age-adjusted death rate that is 60 percent higher than that for the white population (18). In contrast, the year 2000 standard results in a rate for the black population that is only 40 percent higher. The explanation for the narrowing of the differential lies in the age-specific death rates and the population structure of the two race groups. Table F shows age-specific death rates by race for three broad age groups. The mortality ratio is highest for the youngest age group (0–24 years), where the black population has double the mortality of the white population. For the oldest age group (65 years and over), however, the mortality ratio is 1.1, denoting only 10 percent higher mortality between the elderly black and white populations. The reduction in the overall (all ages combined) mortality ratio from the 1940 to the year 2000 standard reflects the greater weight that the year 2000 standard gives to the older population, where race differentials in mortality are smaller. Because the age-specific rates in the black and white populations being compared do not have a consistent relationship, the single ratio of age-adjusted rates masks the important age-specific differences in the mortality race ratio. To better understand race differentials in mortality, it is essential to augment analyses of age-adjusted death rates with analyses of age-specific rates.

Table F. Age-specific and age-adjusted death rates by race: United States, 1995

[Age-adjusted death rates are per 100,000 standard population. Age-specific rates are per 100,000 population in specified age group]

Rate	White death rate	Black death rate	Ratio
Age-adjusted rates			
1940 standard	476.9	765.7	1.6
2000 standard	890.0	1,224.5	1.4
Age-specific rates			
0–24 years	73.0	149.1	2.0
25–64 years	365.4	691.1	1.9
65 years and over	5,049.3	5,679.2	1.1

While the magnitude of the mortality race ratio is affected by the change in standard, the trend in the ratio over time is not seriously affected. Figure 3 shows the trend in the mortality race ratio for 1979–95 based on the 1940 and year 2000 standards. The trends in the mortality race ratio based on both standards are nearly parallel. Thus, regardless of the standard used, the *widening* or *narrowing* of the race gap in mortality will be approximately the same even if the magnitude of the gap itself is different.

Another widely used measure of mortality risk is the expectation of life at birth, which is derived from life tables. Like the age-adjusted death rate, the life expectancy measure is standardized so that comparisons over time or between groups are not affected by the actual age distributions of the respective populations. However, unlike the age-adjusted death rate, life table measures are entirely free of assumptions about the structure of the populations being compared. Instead, life tables generate their own "life table population" and thus, are not weighted by an arbitrary, externally imposed standard population. As a result comparisons of life expectancy at birth are unaffected by the change from the 1940 to the year 2000 standard.

Discussion

Participants of two national workshops reviewed the technical and policy issues associated with alternative population standards. Participants of the second workshop recommended changing to the year 2000 standard from the 1940 standard, which has been used for over 50 years. They also recommended that all health agencies use the year 2000 standard for routine presentation of mortality statistics. These recommendations will be become policy of DHHS, effective September 1998.

The adoption of a single standard will reduce confusion among data users and will reduce the burden on State and local agencies, who now must produce multiple data series to be consistent with the rates based on different standards used by DHHS agencies. A new standard means, however, that mortality time series at all geographical levels must be recomputed using the new standard. Further, long-range goal setting efforts such as "Healthy People" must recalibrate their health goals measured in terms of age-adjusted rates.

Age-adjusted death rates calculated before implementation of the year 2000 standard will not be comparable to rates using the new standard. Comparisons of age-adjusted death rates based on different standards can lead to erroneous conclusions regarding trends in health and mortality. Use of the year 2000 standard will result in age-adjusted death rates that are often substantially larger than those based on the 1940 standard. The new standard will affect trends in age-adjusted death rates for certain causes of death and will narrow race differentials in age-adjusted death rates. However, use of the year 2000 standard will result in race differentials in mortality that more closely approximate those of the "real" population than mortality race differentials based on the 1940 standard. These effects will require explanation to data users and the media.

The two workshops underscored the strengths and weaknesses of age-adjusted death rates. Although age standardization is an important and useful tool, some of its limitations become apparent when changing the population standard. The numerical value of the age-adjusted rate

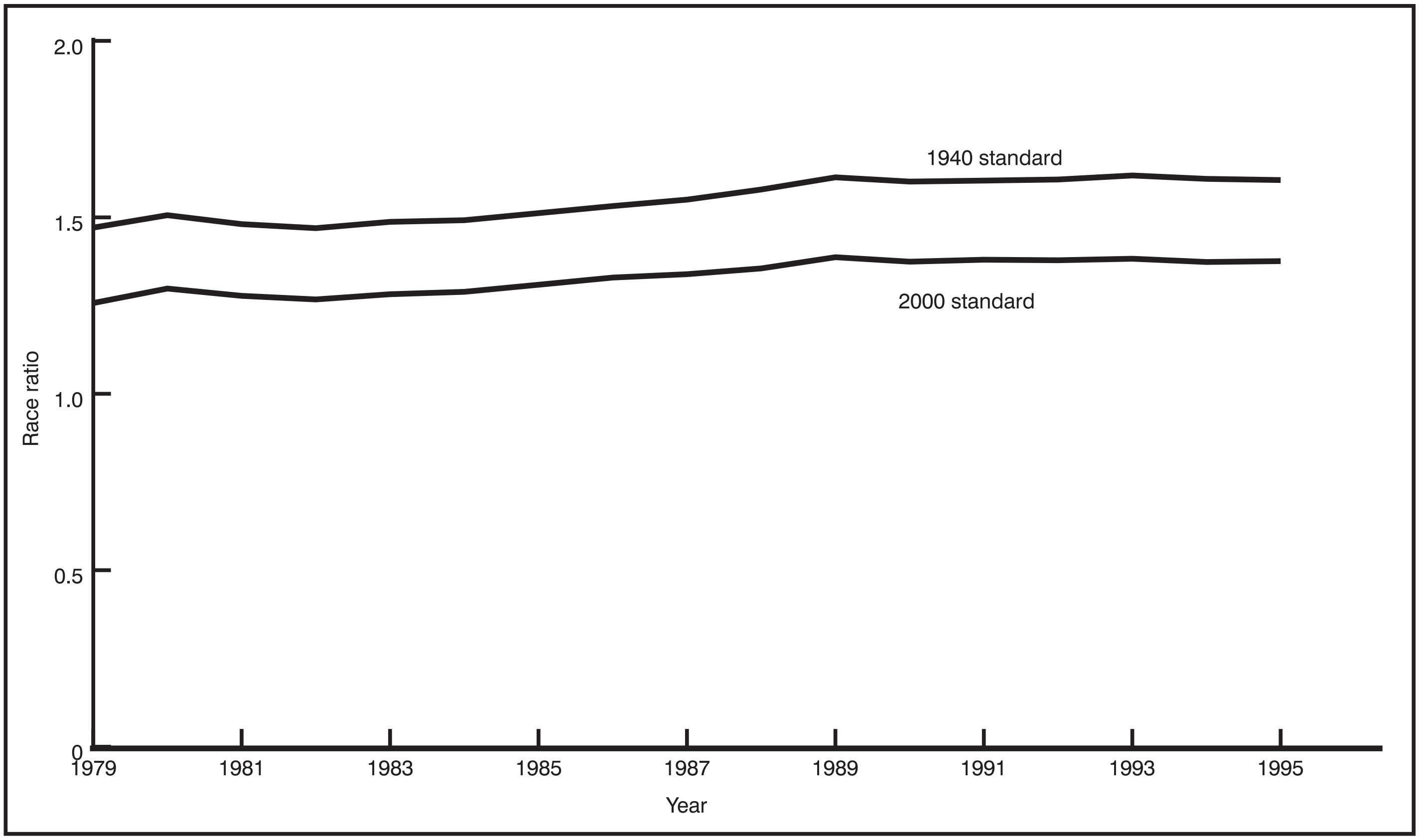

Figure 3. Mortality race ratio based on the 1940 and 2000 standard populations: United States, 1979–95

depends on the standard used and is meaningful by itself only for comparing groups or trends. Further, age standardization is less useful when age-specific rates in the populations being compared do not have a consistent relationship. Finally, because age-adjusted death rates are averages, they represent merely the beginning of an analysis strategy that should proceed to age-specific analyses and then to examination of additional sociodemographic, temporal, and geographical variables.

References

1. Treas JT. Older Americans in the 1990s and beyond. Population Bulletin 50(2). 1995.
2. Sondik EJ. Use of age-adjusted disease rates for cancer. In: Feinleib M, Zarate AO, eds. Reconsidering age adjustment procedures: Workshop proceedings. National Center for Health Statistics. Vital Health Stat 4(29). 1992.
3. Ries LAG, Miller BA, Hankey BF, Kosary CL, Harras A, Edwards BK, et al., eds. SEER Cancer Statistics Review, 1973–1991. Bethesda, Maryland: National Cancer Institute. 1994.
4. Centers for Disease Control and Prevention. Trends in ischemic heart disease deaths—United States, 1990–1994. Morbidity and Mortality Weekly Report, 46(7): 146–150. 1997.
5. Feinleib M, Zarate AO, eds. Reconsidering age adjustment procedures: Workshop proceedings. National Center for Health Statistics. Vital Health Stat 4(29). 1992.
6. Feinleib M. Summary and recommendations. In: Feinleib M, Zarate AO, eds. Reconsidering age adjustment procedures: Workshop proceedings. National Center for Health Statistics. Vital Health Stat 4(29). 1992.
7. Anderson RN. Report of the second workshop on age adjustment. In preparation.
8. National Center for Health Statistics. Technical appendix. Vital statistics of the United States, 1994, vol II, mortality, part A. Washington: Public Health Service. 1998. Available at http:// www.cdc.gov/nchswww
9. Day, JC. U.S. Bureau of the Census. Population projections of the United States by age, sex, race, and Hispanic origin: 1995 to 2050. Current population reports; series P-25, no 1130. U.S. Government Printing Office. Washington, DC. 1996.
10. Neison FGP. On a method recently proposed for conducting inquiries into the comparative sanatory condition of various districts. Journal of the Royal Statistical Society of London 7: 40–68. 1844.
11. Shryock HS, Siegel JS. The methods and materials of demography. San Diego: Academic Press. 1976.
12. Curtin LR. A short history of standardization for vital events. In: Feinleib M, Zarate AO, eds. Reconsidering age adjustment procedures: Workshop proceedings. National Center for Health Statistics. Vital Health Stat 4(29). 1992.
13. Curtin LR, Klein RJ. Direct standardization (age-adjusted death rates). National Center for Health Statistics. Healthy People 2000: Statistical notes, no 6—revised. 1995.
14. Curtin LR, Maurer J, Rosenberg HM. On the selection of alternative standards for the age-adjusted death rate: Proceedings of the social statistics sections, American Statistical Association. 218–23. 1980.
15. Wolfenden HH. On the methods of comparing the mortalities of two or more communities and the standardization of death rates. Journal of the Royal Statistical Society. 86:399–411. 1923.
16. Fleiss, JL. Statistical methods for rates and proportions. New York: John Wiley and Sons. 1973.
17. National Center for Health Statistics. Vital Statistics of the United States, vol II, mortality. Washington: Public Health Service. 1992.

18. National Center for Health Statistics. Health United States 1996–97 and Injury Chartbook. Hyattsville, Maryland. 1997.
19. Anderson RN, Kochanek KD, Murphy SL. Report of final mortality statistics, 1995. Monthly vital statistics report; vol 45 no 11, supp 2. Hyattsville, Maryland: National Center for Health Statistics. 1997.
20. Pickle LW, Mungiole M, Jones GK, White AA. Atlas of United States Mortality. Hyattsville, Maryland: National Center for Health Statistics. 1996.
21. Spiegelman M, Marks HH. Empirical testing of standards for the age adjustment of death rates by the direct method. Human Biology 38:280–92. 1966.
22. Chiang CL. Standard error of the age-adjusted death rate. Vital statistics–Special reports; vol 47 no 9. National Center for Health Statistics. Washington: Public Health Service. 1961.
23. Fay MP, Feuer EJ. A semi-parametric estimate of extra-Poisson variation for vital rates. Statistics in Medicine 16:2389–2401. 1997.
24. Brillinger DR. The natural variability of vital rates and associated statistics. Biometrics 42:693–734. 1986.
25. Seal HL. Mortality data and the binomial probability law. Skandinavisk Aktuarietidskrift 33: 188–216. 1949.
26. Arnold SF. Mathematical statistics. Englewood Cliffs, New Jersey: Prentice Hall. 1990.
27. Fay MP, Feuer EJ. Confidence intervals for directly standardized rates: A method based on the gamma distribution. Stat Med 16:791–801. 1997.

Technical notes

Year 2000 standard weights

The year 2000 standard million population is constructed from the projected year 2000 population prepared by the U.S. Bureau of the Census (9). The projections shown in this report are from the middle series calculated based on the July 1, 1994, population estimated from the 1990 Decennial Census. The projected year 2000 age-specific populations, their proportion distribution, and the standard million are shown in table I. The standard million is simply calculated by multiplying the proportion distribution rounded to six decimal places by 1,000,000. The standard weights (w_{si}) are equal to the proportion distribution of the standard million.

Direct standardization

The age-adjusted death rate is most often computed using the direct method as it is the simplest and most straightforward method of standardization (10). Let

D_i = the number of deaths in age interval i, and
P_i = the midyear population in age interval i.

The age-specific death rate (R_i) is then given by

$$R_i = \frac{D_i}{P_i} \qquad (1)$$

which is usually expressed per 1,000 or 100,000 population.

The age-adjusted death rate is a weighted average of the age-specific death rates where the age-specific weights represent the relative age distribution of the standard population. Let

P_{si} = the population in age interval i in the standard population.

The standard weights (w_{si}) are then given by

$$w_{si} = \frac{P_{si}}{\sum_i P_{si}} \qquad (2)$$

Table I. Projected year 2000 U.S. population and proportion distribution by age

Age	Population	Proportion distribution (weights)	Standard million
Total	274,634,000	1.000000	1,000,000
Under 1 year	3,795,000	0.013818	13,818
1–4 years	15,192,000	0.055317	55,317
5–14 years	39,977,000	0.145565	145,565
15–24 years	38,077,000	0.138646	138,646
25–34 years	37,233,000	0.135573	135,573
35–44 years	44,659,000	0.162613	162,613
45–54 years	37,030,000	0.134834	134,834
55–64 years	23,961,000	0.087247	87,247
65–74 years	18,136,000	0.066037	66,037
75–84 years	12,315,000	†0.044842	44,842
85 years and over	4,259,000	0.015508	15,508

† Figure is rounded up instead of down to force total to 1.0.

where $0 < w_{si} < 1$ and the w_{si} sum to 1. The age-adjusted death rate (AADR) is then given by

$$\text{AADR} = \sum_i w_{si} \bullet \frac{D_i}{P_i} = \sum_i w_{si} \bullet R_i \qquad (3)$$

Indirect standardization

Indirect standardization is less commonly used, but is useful especially when age-specific numbers of deaths are unavailable (11,13). For indirect standardization, a standard set of age-specific death rates are applied to the overall mortality experience of the observed population. This technique yields an "expected" number of deaths in the observed population, assuming that the age-specific death rates of the standard population apply to the observed population. The indirect standardized death rate (ISDR) is computed from the expected number of deaths and is given by

$$\text{ISDR} = \frac{R_s \bullet D}{\sum_i R_{si} \bullet P_i} \qquad (4)$$

where R_s is the crude rate of the standard population, D is the total number of deaths in the observed population, R_{si} is the age-specific death rate in age interval i in the standard population, and P_i is the population of age interval i in the observed population. Most often, however, the ratio of observed deaths to expected deaths is presented. This ratio is called the standardized mortality ratio (SMR) and is given by

$$\text{SMR} = \frac{\text{observed deaths}}{\text{expected deaths}} = \frac{D}{\sum_i R_{si} \bullet P_i} \qquad (5)$$

Variability

Age-adjusted death rates, with the exception of preliminary estimates, are typically based on complete counts and are not subject to sampling error. However, mortality data, including age-adjusted death rates, may be subject to random variation. That is, the number of deaths that actually occurred may be considered as one of a large series of possible results that could have arisen under the same circumstances (22). When the number of deaths is small, random variation may be relatively large, and thus, caution must be used in interpreting age-adjusted death rates and other mortality data. Random variation is typically measured in terms of variance or standard error (the square root of the variance). The calculation of the standard error of the age-adjusted death rate is shown below.

The age-adjusted death rate is a weighted average of the age-specific death rates (equation 3). Because the age-specific standard weights are invariant and the probability of death in one age interval is independent of the probability of death in any other age interval, the variance of the age-adjusted death rate is given by

$$\text{var (AADR)} = \sum_i w_{si}^2 \text{ var } (R_i) \qquad (6)$$

To calculate the variance of the age-specific death rate (R_i), one must make certain assumptions about the process of death. The first assumption is that all persons in age interval i have the same risk of death (homogeneity). This assumption allows for simplicity in the calculation of the variance and is typically applied although the risk of death is distinctly heterogeneous within age intervals. Although beyond the scope of this report, the extra variation in vital rates due to within-age-group heterogeneity in the risk of death can be estimated and applied to statistical tests (23). The second assumption involves the underlying distribution used to calculate the variance. The number of deaths occurring in a population has typically been assumed to follow a binomial distribution (22, 24, 25). However, critical assumptions of the binomial are not very realistic when applied to an open population (24). As a result, variance estimates based on the binomial tend to underestimate the variance associated with the death rate. Death in open populations can be alternatively viewed as deriving from a Poisson distribution. The Poisson is much simpler conceptually and computationally and provides reasonable, conservative estimates of the variance of the death rate (24). Using the properties of the Poisson distribution, the variance of the age-specific death rate is given by

$$\mathrm{var}(R_i) = \mathrm{var}\left(\frac{D_i}{P_i}\right) = \frac{1}{P_i^2}\,\mathrm{var}(D_i) = \frac{D_i}{P_i^2} = \frac{R_i^2}{D_i} \tag{7}$$

Substituting equation 7 into equation 6, the standard error of the age-adjusted death rate S(AADR) is given by

$$\mathrm{S(AADR)} = \sqrt{\mathrm{var(AADR)}} = \sqrt{\sum_i w_{si}^2 \bullet \frac{R_i^2}{D_i}} \tag{8}$$

Confidence intervals

For an age-adjusted death rate X, let $E(X) = x$ be given by equation 3 and $\mathrm{var}(X) = v$ be given from equation 8. The age-adjusted death rate is a linear combination of Poisson random variables. However, it is clear that the age-adjusted death rate X is not a Poisson random variable itself because $E(X)$ is not equal to $\mathrm{var}(X)$. Indeed, a linear combination of independent Poisson random variables does not have a simple form (26). However, it can be placed in the more general family of gamma distributions of which the Poisson is a member. Given a gamma distribution with parameters a and b, let $X \sim \Gamma(a, b)$. Then $E(X) = x = a / b$ and $\mathrm{var}(X) = v = ab^2$. Describing a and b in terms of x and v gives a distribution for X such that

$$X \sim \Gamma\left(\frac{x^2}{v}, \frac{v}{x}\right) \tag{9}$$

A useful property of the gamma distribution is that one can divide X by b (25) such that

$$\frac{X}{b} \sim \Gamma(a,1) \tag{10}$$

This converts the gamma distribution into its standard form, i.e., where $b = 1$. This greatly simplifies calculations. Expressing equation 9 in its standard form gives

$$\frac{X}{\frac{v}{x}} = \frac{x^2}{v} \sim \Gamma\left(\frac{x^2}{v},1\right) \tag{11}$$

The lower 100(1–α)-percent confidence limit for x^2 / v is given by

$$L\left(\frac{x^2}{v}\right) = \Gamma^{-1}_{\left(\frac{x^2}{v},1\right)}(\alpha / 2) \tag{12}$$

The upper 100(1–α)-percent confidence limit is given by

$$U\left(\frac{x^2}{v}\right) = \Gamma^{-1}_{\left(\frac{(x+k_M)^2}{v+k_M^2},1\right)}(1-\alpha / 2) \tag{13}$$

where $k = k_M = \max_{i\in\{1,...,I\}}(k_i)$ is a continuity correction made necessary by the fact that we are using a continuous distribution to estimate confidence limits for a discrete random variable.
From equation 3, increasing the number of deaths by 1 in age interval i results in a $k_i = w_i / p_i$ increase in the age-adjusted death rate. If k_i is constant for all age intervals, $k_i = k$. However, given that the values for w_i and p_i typically used in calculating age-adjusted death rates are variable across age intervals, it is unclear what value of k is appropriate. A conservative upper confidence limit can be obtained by using the maximum value of $k_i = k_M$ (27).

A close approximation of equation 14 that alleviates the need to calculate k_M is

$$U\left(\frac{x^2}{v}\right) = \Gamma^{-1}_{\left(\frac{x^2}{v}+1,1\right)}(1-\alpha / 2) \tag{14}$$

For $x^* = cx$, it can be shown that $L(x^*) = c\ L(x)$ and $U(x^*) = c\ U(x)$ (26). Let $x^* = x^2 / v$ and let $c = x / v$.

Then

$$L(x) = \frac{L\left(\frac{x^2}{v}\right)}{\frac{x}{v}} \tag{15}$$

and

$$U(x) = \frac{U\left(\frac{x^2}{v}\right)}{\frac{x}{v}} \tag{16}$$

These results can easily be calculated using statistical packages such as SAS, which have a function to calculate the inverse gamma distribution (or the inverse chi-square distribution, see 27). Table II shows a set of factors that may be applied to age-adjusted death rates to calculate 95-percent confidence intervals. These factors are derived from the standard gamma distribution such that for any value of x^2 / v rounded to the nearest integer the lower confidence factor (LCF) is

$$LCF\left(\frac{x^2}{v}\right) = \frac{L\left(\frac{x^2}{v}\right)}{\frac{x^2}{v}} \tag{17}$$

The upper confidence factor (UCF) for any integer value of x^2 / v is calculated in the same way substituting $U(x^2 / v)$ into equation 17. These factors can then be multiplied by the age-adjusted death rate (x) such that $L(x) = x \bullet \text{LCF}$ and $U(x) = x \bullet \text{UCF}$. As the $L(x)$ and $U(x)$ based on factors in table II are restricted to integer values of x^2 / v, they will differ slightly from values of $L(x)$ and $U(x)$ calculated in SAS where there is no such restriction. The SAS code used to generate table II is shown at the end of the table.

The Poisson distribution and its gamma family members are asymmetrical distributions with zero as the lower bound. However, for $X \sim \Gamma(a, b_{-1})$, when a is large, X is approximately normally distributed and thus, nearly symmetrical. Therefore, when constructing confidence intervals for the age-adjusted death rate a normal approximation may be applied when x^2 / v is large to simplify calculations. In practice, 95-percent confidence intervals are reasonably symmetrical when x^2 / v is greater than or equal to 100, although this cutoff point is somewhat arbitrary. As a result values for x^2 / v in table II are limited to integer values from 1 to 99. The normal approximations of the 95-percent confidence limits are given by $L(x) = x - 1.96\sqrt{v}$ and $U(x) = x + 1.96\sqrt{v}$.

Recommendations of the second workshop on age adjustment

1. The population standard for age-adjusting death rates should be changed from the 1940 standard million population to the projected U.S. 2000 population to be published by the Census Bureau in the spring of 1998. A single standard should be used by all agencies for official presentation of data. For special analyses, alternative standards may be used as appropriate to the research.
2. Agencies should implement the new population standard by data year 1999.
3. Agencies should continue to use and publish their standards until the new standard is officially adopted (beginning with data year 1999). To avoid confusion, agencies implementing the new standard before data year 1999 should simultaneously publish rates adjusted to the old and new standards.
4. After the implementation date, agencies should use the new standard in all press releases and other communication with the public.
5. NCHS will be responsible for selecting a name for the new standard and will determine the number of significant digits.
6. Agencies should continue to use the current 11 age groups (less than 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, and 85 years and over) for calculating age-adjusted rates using the new standard.
7. NCHS will convene an implementation committee that will be responsible for developing a time table and strategies for implementation and for commissioning papers to publicize the change in standard.
8. NCHS will publicize the new standard in NCHS publications, the *Morbidity and Mortality Weekly Report, Public Health Reports,* and appropriate professional newsletters. Scholarly papers could also be published in appropriate professional and technical journals.
9. NCHS will convene a work group to evaluate the age-adjustment standard at least every 10 years.

Table II. Lower and upper 95-percent confidence limit factors for age-adjusted death rates based on a gamma distribution with parameter x^2 / v, where x is the age-adjusted death rate and v is the variance of the age-adjusted death rate

x^2/v	Lower confidence factor	Upper confidence factor	x^2/v	Lower confidence factor	Upper confidence factor
1	0.02532	5.57164	51	0.74457	1.31482
2	0.12110	3.61234	52	0.74685	1.31137
3	0.20622	2.92242	53	0.74907	1.30802
4	0.27247	2.56040	54	0.75123	1.30478
5	0.32470	2.33367	55	0.75334	1.30164
6	0.36698	2.17658	56	0.75539	1.29858
7	0.40205	2.06038	57	0.75739	1.29562
8	0.43173	1.97040	58	0.75934	1.29273
9	0.45726	1.89831	59	0.76125	1.28993
10	0.47954	1.83904	60	0.76311	1.28720
11	0.49920	1.78928	61	0.76492	1.28454
12	0.51671	1.74680	62	0.76669	1.28195
13	0.53246	1.71003	63	0.76843	1.27943
14	0.54671	1.67783	64	0.77012	1.27698
15	0.55969	1.64935	65	0.77178	1.27458
16	0.57159	1.62394	66	0.77340	1.27225
17	0.58254	1.60110	67	0.77499	1.26996
18	0.59266	1.58043	68	0.77654	1.26774
19	0.60207	1.56162	69	0.77806	1.26556
20	0.61083	1.54442	70	0.77955	1.26344
21	0.61902	1.52861	71	0.78101	1.26136
22	0.62669	1.51401	72	0.78244	1.25933
23	0.63391	1.50049	73	0.78384	1.25735
24	0.64072	1.48792	74	0.78522	1.25541
25	0.64715	1.47620	75	0.78656	1.25351
26	0.65323	1.46523	76	0.78789	1.25165
27	0.65901	1.45495	77	0.78918	1.24983
28	0.66449	1.44528	78	0.79046	1.24805
29	0.66972	1.43617	79	0.79171	1.24630
30	0.67470	1.42756	80	0.79294	1.24459
31	0.67945	1.41942	81	0.79414	1.24291
32	0.68400	1.41170	82	0.79533	1.24126
33	0.68835	1.40437	83	0.79649	1.23965
34	0.69253	1.39740	84	0.79764	1.23807
35	0.69654	1.39076	85	0.79876	1.23652
36	0.70039	1.38442	86	0.79987	1.23499
37	0.70409	1.37837	87	0.80096	1.23350
38	0.70766	1.37258	88	0.80203	1.23203
39	0.71110	1.36703	89	0.80308	1.23059
40	0.71441	1.36172	90	0.80412	1.22917
41	0.71762	1.35661	91	0.80514	1.22778
42	0.72071	1.35171	92	0.80614	1.22641
43	0.72370	1.34699	93	0.80713	1.22507
44	0.72660	1.34245	94	0.80810	1.22375
45	0.72941	1.33808	95	0.80906	1.22245
46	0.73213	1.33386	96	0.81000	1.22117
47	0.73476	1.32979	97	0.81093	1.21992
48	0.73732	1.32585	98	0.81185	1.21868
49	0.73981	1.32205	99	0.81275	1.21746
50	0.74222	1.31838			

```
* Program to compute 100(1- alpha)-percent confidence limit factors;
*   for a gamma or Poisson-distributed variable with parameter n;

Percent let alpha=0.05; * For 95-percent confidence limit factors;
data CI;
   alo = &alpha/2;
   ahi = 1-&alpha/2;

do n = 1 to 99;
   LCF = gaminv ( alo, n)/n;
   UCF = gaminv (ahi, n+1)/n;
output;
end;
proc print data=CI;
   var n LCF UCF;
run;
```

Contents

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