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Age-Adjusted Death Rates

by

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Introduction

Mortality or death rates are often used as measures of health status for a population. Population-based incidence or morbidity data are available in North Carolina in a few areas such as cancer and certain communicable diseases, but for many chronic diseases we know only how many people died from the disease and not how many are living with it. Given the importance of data from death certificates in measuring the health of populations, it is important that valid comparisons of death rates are made. Many factors affect the risk of death, including age, race, gender, occupation, education, and income. By far the strongest of these factors affecting the risk of death is age, with persons in the oldest age groups having a much higher risk of death. Populations often differ in age composition. A "young" population has a higher proportion of persons in the younger age groups, while an "old" population has a higher proportion in the older age groups and is expected to have higher crude (unadjusted) death rates than a "young" population. Therefore, it is often important to control for differences among the age distributions of populations when making comparisons among death rates to assess the relative risk of death. This *Statistical Primer* describes how age-adjusted death rates are calculated and discusses some related issues.

The methods for adjusting death rates for age that are shown here could also be applied to other characteristics of a population, such as income or gender, if it were considered desirable to adjust for such characteristics before comparing death rates. Also, disease incidence rates, birth rates, or other types of rates could be adjusted for age, or other factors, using the general approach presented here.

Crude and Age-Specific Death Rates

A crude or unadjusted death rate is simply the number of deaths divided by the population at risk, often multiplied by some constant so that the result is not a fraction.

✐ *Formula:*

$$\text{Crude death rate} = \frac{\text{\# deaths}}{\text{population at risk}} \quad \text{X } 1{,}000$$

For example, for Hertford County, North Carolina, during the period 1991 through 1995, there were 1,336 deaths to residents of the county. To get an annualized death rate for this five-year period, the estimated mid-year resident population is summed over the five years. For Hertford County, the sum of the population of those five years is 112,419. The crude death rate is 1,336 divided by 112,419 which equals .01188. This is the average annual proportion of residents who died during the period 1991–95 (slightly more than 1 percent). When multiplied by 1,000, which is sometimes used as a multiplier for a death rate for all causes of death, the rate is 11.9 deaths per 1,000 population per year (see last row of **Table 1**). For death rates for specific causes of death, a multiplier of 100,000 is often used so that the rate is not less than 1.0. For smaller geographic areas or when using cause-specific death rates, it is often desirable to calculate multi-year death rates to decrease random variation in the rates due to small numbers of deaths in a single year. These multi-year death rates are essentially average annual rates.

The crude death rate is a good measure of the overall magnitude of mortality in a population. If a population is old and has a high mortality rate as a result, then the crude rate is useful information for some purposes, such as planning for the delivery of health care services.

An age-specific death rate is simply a crude death rate for a specific age group. One can also calculate rates specific for race, gender, or other factors. Table 1 shows age-specific death rates for Hertford County residents for the period 1991–95, with 10 commonly used age groupings. Note that the death rate for ages 0–4 is substantially higher than the death rates for the other younger age groups (primarily due to a high death rate during infancy); only at ages 45–54 does the death rate exceed that for ages 0–4. It can

Table 1. Age-Specific Death Rates for All Causes of Death: Hertford County, North Carolina Residents (1991–95 Combined)

Age Group	1 Number of Deaths (1991–95)	2 Total Population (1991–95)	3 Percent of Population in Each Age Group	4 Proportion Who Died	5 Age-Specific Death Rates per 1,000 Population
0–4	30	8,150	7.3	.00368	3.68
5–14	2	17,109	15.2	.00012	0.12
15–24	24	16,601	14.8	.00145	1.45
25–34	34	14,872	13.2	.00229	2.29
35–44	59	16,199	14.4	.00364	3.64
45–54	85	12,381	11.0	.00687	6.87
55–64	147	10,277	9.2	.01430	14.30
65–74	305	9,370	8.3	.03255	32.55
75–84	406	5,631	5.0	.07210	72.10
85+	244	1,829	1.6	.13341	133.41
Total	1,336	112,419	100.0	.01188	11.9

be immediately seen that the death rates are many times higher in the oldest age groups. Therefore, a geographic area or demographic group with an older population will automatically have a higher overall death rate just because of the age distribution. **The main purpose of age-adjusting death rates is to control for differences in the age distribution of various populations before making mortality comparisons.**

For some causes of death, such as injuries (i.e., work-related or from automobile crashes) and AIDS, older persons do not have the highest death rates. But even in these cases it is important to standardize for age when comparing death rates across different populations, since some populations may have a higher proportion of persons in the age groups with the highest death rates.

Another *Statistical Primer* by the State Center for Health Statistics discusses the issue of random error in vital rates and presents formulas for quantifying this error and calculating confidence intervals around the measured rates (reference #1). Those formulas are applicable to the crude and age-specific rates presented here, and to any simple or unadjusted rate.

Note: Random error may be substantial when a rate or percentage has a small number of events in the numerator (e.g., less than 20).

Age-Adjusted Death Rates

Direct Method

The direct method of age adjustment is frequently used to compare the death rates of different populations, by controlling for differences in age distribution. The age-specific death rates of the population of interest (sometimes called the "study" population) are applied to the age distribution of a "standard" population in order to calculate "expected deaths." The expected deaths are the deaths that would occur in the standard population IF it had the same death rates of the study population in each age group. These expected deaths for each age group are then summed and divided by the total standard population to arrive at the age-adjusted death rate. **Stated another way, this is the death rate that the study population would have IF it had the same age distribution as the standard population.**

✐ *Formula:*

$$\text{Age-adjusted death rate} = \frac{\text{total expected deaths}}{\text{standard population}} \times 1{,}000$$

Age-adjusted death rates for different geographic areas or population groups are comparable when they are adjusted to the same standard population. The 2000 U.S. population by age has been used as the standard population for all recent publications of the State Center for Health Statistics, following the practice of the National Center for Health Statistics (reference #2). Most often, a "standard million" is used for the standard population (population total is 1,000,000) rather than the actual 2000 population of the U.S. For the age-adjustment calculations, it is only important that the proportions by age for the year 2000 be maintained. A standard population is in effect just an arbitrary set of proportions by age, though it is the current convention to use the proportions from the 2000 U.S. population.

Table 2 provides an example. The age-specific death rates for all causes of death for Hertford County are applied to the 1980 North Carolina population by age, which is used as the standard population only for this illustration of the calculations. To generate the expected deaths in column 4, the rates shown in column 1 are converted to a proportion by moving the decimal point three places to the left and then multiplying by the standard population groups by age in column 2. The total expected deaths are then divided by the total standard population and the result multiplied by 1,000 to yield an age-adjusted death rate for Hertford County of 8.7. Usually it would not be necessary to show the age-specific death rates to two decimal places, but in this case the extra digits are needed to get a more accurate estimate of the number of expected deaths.

This age-adjusted death rate of 8.7 is considerably lower than the crude death rate of 11.9. This is mainly because the percentages in the age groups 65 and older are substantially lower in the 1980 North Carolina standard population (Table 2, column 3) than the same percentages in the 1991–95 Hertford County population (Table 1, column 3). When the Hertford County age-specific death rates are adjusted to a younger standard population, the overall adjusted rate is lower.

Ten age groups are often used for age adjustment of death rates. This provides enough detail to capture differences in the age distributions of the populations that are being compared, but not so many age categories that the data are "spread too thin."

An alternate way to compute the age-adjusted death rate by the direct method is simply to multiply the age-specific death rates by the corresponding proportion of the standard population in that age group and then sum these products across all 10 age groups. This weighted sum is represented by the following formula.

✐ *Formula:*

$$\text{Directly age-adjusted death rate} = \sum_{i=1}^{10} (w_i \, p_i)$$

where p_i is the age-specific mortality rate for age group i and w_i (or the weight) is the proportion of the standard population in age group i. (Tip: Move the decimal point of the percentages in column 3 of Table 2 two places to the left to get the proportion.) The crude death rate can also be expressed as a weighted sum of the age-specific death rates and the proportions of the population by age, but in this case the proportions are simply the proportions of the study population (instead of the standard population) in each age group. Try to reproduce the crude and age-adjusted death rates in Tables 1 and 2 using this weighted sum method! Any minor differences are due to rounding.

An age-adjusted death rate is a summary measure that condenses a lot of information into one figure. Where feasible, it is always desirable to inspect the age-specific death rates of the populations being compared. This extra attention to detail often provides further insights into the nature of the mortality differences between the populations.

Table 2. Age Adjustment of the All-Cause Death Rate Using the Direct Method: Hertford County, North Carolina Residents (1991–95 Combined)

Age Group	1 Age-Specific Death Rates per 1,000 Population	2 1980 N.C. Population (Standard)	3 Percentage of Standard Population by Age	4 Expected Deaths in Hertford County
0–4	3.68	404,560	6.9	1,489
5–14	0.12	927,836	15.7	111
15–24	1.45	1,144,204	19.4	1,659
25–34	2.29	968,215	16.4	2,217
35–44	3.64	689,838	11.7	2,511
45–54	6.87	601,866	10.2	4,135
55–64	14.30	552,494	9.4	7,901
65–74	32.55	389,244	6.6	12,670
75–84	72.10	172,408	2.9	12,431
85+	133.41	45,956	0.8	6,131
Total	11.9 (Crude death rate)	5,896,621	100.0	51,255

Age-Adjusted Death Rate = (51,255 ÷ 5,896,621) x 1,000 = 8.7

Table 3. Age Adjustment of the All-Cause Death Rate Using the Indirect Method: Hertford County, North Carolina Residents (1991–95 Combined)

Age Group	1 Total Population (1991–95)	2 Age-Specific Death Rates in 1993 North Carolina Standard Population (per 1,000)	3 Expected Deaths in Hertford County
0–4	8,150	2.44	20
5–14	17,109	0.25	4
15–24	16,601	0.98	16
25–34	14,872	1.53	23
35–44	16,199	2.55	41
45–54	12,381	5.03	62
55–64	10,277	12.41	128
65–74	9,370	28.48	267
75–84	5,631	63.19	356
85+	1,829	147.85	270
Total	112,419	9.0 (Crude Rate in Standard)	1,187

Indirect Method

When to Use:

- When the numbers of deaths in each age group in the study population are too small to calculate stable age-specific rates.
- In developing countries or other areas where no information is available on age-specific deaths for the study population, only for a national or standard population.

The indirect method of age-adjustment applies the age-specific death rates of the standard population to the age distribution of the study population in order to generate expected deaths in the study population. **These are the deaths that would occur in the study population IF the age-specific death rates in the standard population were in operation.** The expected deaths are then summed across the age groups and compared to the actual or observed number of deaths for the study population. This ratio of observed/expected deaths is often referred to as the **standardized mortality ratio**, or SMR. A ratio greater than 1.0 indicates higher mortality in the study population compared to the standard population (controlling for age distribution), while a ratio less than 1.0 indicates lower mortality in the study population. The SMR controls for age distribution since both the observed and expected deaths are based on the age distribution of the study population. Multiplying the SMR times the crude death rate in the standard population produces the **indirectly standardized death rate** for the study population.

Table 3 presents an example of indirectly standardized death rates. After moving the decimals three places to the left, age-specific death rates in the 1993 North Carolina standard population (column 2) are multiplied by the 1991–95 Hertford County population in column 1 to produce the expected deaths in column 3. These expected deaths by age group may be compared to the actual 1991–95 deaths by age group in Hertford County (Table 1, column 1). Dividing the 1,336 total deaths observed in Hertford County during 1991–95 by the 1,187 total expected deaths gives us an SMR of 1.13. This indicates that the overall 1991–95 death rate in Hertford County was higher than the rate in the 1993 North Carolina standard population, controlling for age. Multiplying the crude death rate in the standard population of 9.0 by 1.13 gives an indirectly standardized death rate for Hertford County of 10.2. To avoid differences between the observed and expected deaths due to changing (often declining) age-specific death rates over time, it is usually desirable to use a standard population that is close to the same year(s) as the data for the study population. Therefore, the 1993 (midpoint) North Carolina standard was used in this example.

✐ *Formula:*

Standardized mortality ratio (SMR) =
observed deaths ÷ expected deaths

Ex: SMR for Hertford County using information above =
1,336 ÷ 1,187 = 1.13

✐ *Formula:*

Indirectly standardized mortality rate =
crude death rate X SMR

Ex: Indirectly standardized mortality rate
for Hertford County =
9.0 X 1.13 = 10.2

Issues in Using Different Standard Populations

An age-adjusted death rate is a hypothetical index, designed to facilitate comparisons among populations, rather than a true measure of risk. An age-adjusted death rate (by the direct method) answers the question: What would the death rate in a study population be IF that population had the same age distribution as the standard population? So in theory any population distribution can be used as the standard; it is only a set of weights applied to the age-specific death rates. The choice of the standard population will not usually have a great effect on the **relative** levels of the age-adjusted rates that are being compared. But it is important to remember that age-adjusted death rates can be compared to each other only if they are adjusted to the same standard.

For many years the National Center for Health Statistics used the 1940 United States population as the standard for age-adjusting death rates. Converted to a population of one million with the same proportions at each age as in the 1940 population, this standard was presented as a "standard million." An advantage of consistently using this same standard population is that it promotes comparisons of age-adjusted death rates, especially in looking at trends over time from 1940 to later years. A disadvantage of using this standard is that the size of the adjusted rate is often much different from the size of the crude rate in the study population. This is

Comparison of the Direct and Indirect Methods of Adjustment

Direct Method	Indirect Method
• Use when the number of deaths in the study population is large enough to produce stable age-specific death rates.	• Use when the number of deaths in the study population is too small to calculate stable age specific death rates.
• Assumes a constant age distribution across all study populations.	• Maintains differences in age distributions between study populations.
• Rates from different study populations (e.g., counties in North Carolina) *can* all be directly compared to each other if adjusted using the same standard population.	• Rates from different study populations *cannot* be compared to each other since they are not based on a common age distribution.
	• Should compare the adjusted rate only with the rate of the standard population.

mainly because: a) the 1940 United States population was much younger than more recent North Carolina and U.S. populations, and b) death rates are much higher in the older age groups. Therefore, standardizing to a much younger population results in a much lower age-adjusted death rate. In recognition of this problem, the National Center for Health Statistics and the State Center for Health Statistics now use the year 2000 United States population as the standard population (reference #2). This means that the age-adjusted death rates are generally much more similar in size to contemporary crude death rates.

One should be especially careful when assessing trends over time using age-adjusted death rates. **It is essential that rates for different years be adjusted to the same standard population before making comparisons.** Also, if the standard population is very different from the populations of the years being compared (as is often the case when using the 1940 U.S. standard), changes in the adjusted rates over time may not be an accurate reflection of the actual changes in the risk of death. In an attempt to promote comparability of age-adjusted death rates over time, the State Center for Health Statistics recomputed age-adjusted death rates for the period 1979 through 1998 (years in which the 9th revision of the International Classification of Diseases was used for death coding) using the 2000 U.S. standard population. This time series of rates can be accessed at www.schs.state.nc.us/SCHS/deaths/lcd/1998. All adjusted death rates in State Center for Health Statistics publications for the years 1999 and forward use the 2000 U.S. standard population for age adjustment, though for some causes of death there are problems of comparability with previous years due to the use of the 10th revision of the International Classification of Diseases for death coding beginning in 1999.

Errors of Adjusted Rates

A detailed discussion of random errors in age-adjusted death rates is beyond the scope of this paper. The reader should refer to the *Statistical Primer* cited in reference #1 for information on the general concepts of random errors in rates, confidence intervals, and determining if the difference between two rates is statistically significant. Using the terminology in that paper, a 95% confidence interval around a proportion can be computed.

✐ *Formula:*

95% confidence interval around a proportion =

$$p \pm 1.96 \sqrt{\frac{pq}{n}}$$

The $\sqrt{pq/n}$ is commonly known as the **standard error of the proportion.** In this case a death rate is treated as the proportion (p) of people who died during the time period of interest. If the proportion who died is small, then q (which is 1-p or the proportion who did not die) will be very close to 1.0 and the formula becomes $\sqrt{p/n}$, where n is the total population.

We saw from the discussion above that a directly age-adjusted death rate is a weighted sum of the age-specific death rates. To get the standard error of the age adjusted death rate, sum up all the products of the square of the weight (w) for each age group and the standard error (squared) of the age-specific death rate. Then take the square root of the sum.

✐ *Formula:*

Standard error of the age-adjusted death rate =

$$\sqrt{\sum_{i=1}^{10} w_i^2 \, (p_i/n_i)}$$

Remember that the weight is simply the proportion of the standard population in age group i. To get the 95% confidence interval around the age-adjusted death rate, multiple the standard error of the age-adjusted death rate by 1.96.

This is a very brief discussion of a lengthy topic. For questions or assistance, please contact the author.

Issues in Adjusting for Race and Gender

For many years, the death rates in the *Leading Causes of Death* publication of the State Center for Health Statistics were adjusted simultaneously for age, race, and gender. This was done for five-year death rates for specific causes of death, by county of residence. With 40 age-race-gender-specific rates being computed (10 age groups x 2 race groups: white/minority x 2 gender groups), the data were being spread too thin. A particular problem was in the western North Carolina counties, which generally have very small minority populations. There were also problems in other counties with small populations overall. Since some causes of deaths are statistically rare, just one or two deaths in a small population group could result in a very high age-race-gender-specific rate, which would severely inflate the adjusted death rate. If this rate were applied to the appropriate age-race-gender group of the standard population, a very large number of expected deaths could result and the adjusted rate would be extremely high. On the other hand, zero deaths in several population groups may result in a very low age-race-gender-adjusted rate. Adjusting only for age reduces the bias due to small numbers.

Age generally has a much stronger impact on mortality than race or gender, and therefore is the most important factor to adjust for. Also, there are other questions about adjusting for race. Age differences in mortality are not easily modified. Racial differences in mortality, on the other hand, are often due to factors that can be changed through public health, medical care, or socioeconomic interventions. Adjusting for race may cover up the fact that certain geographic areas, for example, have higher mortality because they have a larger percentage of minority populations (who often have higher death rates). For example, minorities in Hertford County (primarily African Americans) are approximately 63 percent of the total population. In many cases we would want to target these areas for public health interventions and not produce statistics that adjust a higher level of mortality that is potentially modifiable to make it look lower.

Rather than adjusting for race, a better approach would be to examine racial differences in mortality by calculating race-specific death rates, perhaps adjusted for age. Minority populations often have a younger age distribution than whites. Adjusting for age usually results in relatively higher death rates for minorities, and larger differences between whites and minorities than when comparing crude death rates. In adjusting the death rates of different race (or race-gender) groups for age, it is important to use the same standard population (or set of age-specific weights) in all cases so that the adjusted rates will be directly comparable. At the county level in North Carolina, small numbers of deaths generally preclude calculating statistically reliable death rates for minority populations other than African Americans. For this reason, we sometimes calculate death rates for two broad racial groups: white and all minorities combined. In North Carolina as a whole, African Americans comprise more than 85% of the minority population. (Hispanics are considered an ethnic rather than a racial group. Most Hispanics are counted within the white racial group for vital statistics.) Another problem with calculating death rates for specific minority sub-groups is the lack of accurate population estimates to use in the denominators of the death rates.

Readers with questions or comments about this *Statistical Primer* may contact Paul Buescher at (919) 715-4478 or by e-mail at Paul.Buescher@ncmail.net.

Further reading on the topic of adjusted rates may be found in references 2, 3, and 4.

Reference

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