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Measures of Mortality

Crude and Standardized Death Rates

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Death spectrum

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Different types of death rates are computed depending upon the specific groups, such as age and gender, they address. Described below are the rates based on overall deaths in a population and later in this section are more specific death rates for various groups.

Crude Death Rate (CDR)

This is the number of deaths in an area in a year per 1000 population counted at midyear, i.e.,

$$\text{Crude death rate} = \frac{\text{number of deaths in one year}}{\text{midyear population}} * 1000 \qquad (1)$$

it ranged from a low of 1 per 1000 population in United Arab Emirates, to a high of 29 in Swaziland in the year 2004. Thus, this rate varies widely from country to country.

A problem with CDR is that it disregards the age structure of the population. For this reason, it is called *crude*. If people in an area are predominantly old, a high CDR is not as bad as in an area where the population is predominantly young. Thus, a CDR of 7 per 1000 population in the year 20010 in Sweden should not be construed to mean that the health status is nearly the same as in India, where also the CDR was nearly seven. The crude rate can be misleading. India had only 8 percent of the population of age 60 years or more whereas Sweden had 23 percent. Old people die anyway, and the CDR naturally becomes high. A valid comparison is obtained when the rate is recomputed by assuming same age structure in the two countries. This is one form or standardization. The other brings the agewise mortality pattern to a common base. Both require age-specific death rates.

Age-specific Death Rate (ASDR)

When the numerator and the denominator in Eq. (1) are restricted to a particular age group, we get the specific death rate for that age group. For example, the ASDR for age group 65-74 years is the deaths in this age group per 1000 persons aged 65-74 years. Such a rate provides an adequate comparison of the health status in two areas or at two times for that particular age group. In the year 2006, the ASDR in the age group (5-14) years was 1.0 in Peru but only 0.08 in Sweden per 1000 population of that age. The rate in Peru was more than 10 times. That shows the qualitative difference in deaths in these two countries.

Standardized Death Rate

Standardization is a method of adjustment. This is generally done for age differentials but can also be done for other factors. The objective is to remove the effect of differential mortality or differential structure of the subgroups in the two populations under comparison. The rates are then brought to a common base and thus made comparable. Two methods of standardization are in use. Both require assumption of a **standard** or a reference population. This could be real or hypothetical, but in both cases the standard is arbitrary. In case of age standardization, the standard may have a predefined age structure or a predefined ASDR. These two methods of standardization can give entirely different results.

In the direct method, actual ASDRs in the study population are used on the standard population that has a predefined age structure. Thus,

$$\text{Directly standardized death rate} = \Sigma_k P_{ks} d_k / \Sigma_k P_{ks}; \quad k = 1, 2, \ldots, K; \tag{2}$$

where

the population is divided into K age groups,

P_{ks} is the predefined standard population (in percent or count) in the kth age group, and

d_k is the ASDR in the kth age group of the study population.

Thus the age structure is standardized. When **direct standardization** is done for two populations, any difference between the two can be ascribed to the difference in their ASDRs.

If they are not known, the **indirect method** is used. In this method, predefined values of ASDRs in the standard population are used on the actual age structure of the study population. Thus,

$$\text{Indirectly standardized death rate} = \Sigma_k p_k D_{ks} / \Sigma_k p_k; \quad k = 1, 2, \ldots, K; \tag{3}$$

where

p_k is the actual *study* population (in percent or count) in the kth age group and

D_{ks} is the predefined ASDR in the kth age group of the standard population.

When this is done for two populations, both are then based on the same ASDRs and any difference between the two would be due to their differential age structure.

Table 1 Population and death rates in different age groups in the U.S. and Venezuela, and the

WHO World Standard

Age group (years)	U.S. 2002		Venezuela 2002		Standard	
	Population (%)	ASDR per 1000	Population (%)	ASDR Per 1000	Population (%)	ASDR Per 1000
A	B	C	D	E	F	G
0-4	6.8	1.7	11.1	3.5	8.9	10.0
5-14	14.2	0.2	21.6	0.3	17.3	1.0
15-24	14.1	0.8	19.4	1.8	16.7	0.5
25-34	13.8	1.0	15.6	2.1	15.5	0.5
35-44	15.6	2.0	12.9	2.4	13.7	1.0
45-54	13.9	4.3	9.2	4.5	11.4	5.0
55-64	9.2	9.5	5.5	8.8	8.3	10.0
65-74	6.3	23.1	3.2	21.5	5.2	15.0
75-84	4.4	55.6	1.3	52.4	2.4	35.0
85+	1.6	148.3	0.3	140.0	0.6	100.0
Total	100.0	8.5 CDR	100.0	4.2 CDR	100.0	5.0 CDR

Source for Venezuela: United Nations Statistics Database

Example 1 Standardized death rate for the U.S. and Venezuela

Shown in Table 1 are the age structures of the populations in the U.S. and Venezuela, and their ASDRs. The standard population given is as suggested by the World Health Organization (WHO). The standard ASDRs in the last column are my own proposal. No widely acceptable standard is available for ASDRs.

Note that CDR in the U.S. is nearly twice of Venezuela rate. But also note that the U.S. has more people of old age group. From formula (2),

Directly standardized death rate for the U.S.

$$= \frac{1.7\times8.9 + 0.2\times17.3 + ... + 148.3\times0.6}{8.9 + 17.3 + ... +0.6}$$

= 5.5 per 1000 population,

and for Venezuela

$$= \frac{3.5\times8.9 + 0.3\times17.3 + ... +140.0\times0.6}{8.9 + 17.3 + ... + 0.6}$$

= 5.8 per 1000 population.

The difference now almost vanished after standardization.

From formula (3), indirectly standardized death rate for the U.S.

$$= \frac{10.0\times6.8 + 1.0\times14.2 + ... +100.0\times1.6}{6.8 + 14.2 + ... + 1.6}$$

= 6.8 per 1000 population,

and for Venezuela

$$= \frac{10.0\times11.1 + 1.0\times21.6 + ... + 100.0\times0.3}{11.1 + 21.6 + ... + 0.3}$$

= 3.9 per 1000 population,

The death rate for Venezuela is again lower.

Note the following for Example 1.

1. Venezuela has higher population in younger age groups and the ASDRs are also higher in younger age groups.

2. For direct standardization of death rate in the U.S., ASDRs in column C are multiplied by the standard population in column F, added, and divided by the total of standard population in column F. The numerator so obtained is the expected number of deaths that would have occurred if the age structure were standard. For direct standardization of death rate in Venezuela, its ASDRs in column E are multiplied by the standard population in column F.
3. For indirect standardization, the population (column B for the U.S. and column D for Venezuela) is multiplied by the ASDRs in the standard population (column G), added, and divided by the total population in the country, i.e., the total of column B for the U.S. and of column D for Venezuela. The numerator in this case is the expected number of deaths that would have occurred if the ASDRs were the same as in the standard population.
4. Directly standardized DR is less than CDR in the U.S. because the standard population is less in the age groups where the U.S. ASDR is high. When the standard population is more in higher mortality groups as in Venezuela, the directly standardized DR is more than the CDR.
5. Directly standardized rate brings the age structure of the two populations to the same pattern. When this is done, the U.S. rate becomes nearly same as that in Venezuela.
6. Indirect standardization has a different effect in this case. The indirectly standardized DR is higher in the U.S. The difference between the indirectly standardized rates in U.S. and Venezuela is mostly due to the difference in age structure in the two countries.
7. In Example 11.1, the age structure is given in terms of percentages but the actual population can also be used in formulas (2) and (3).
8. As in this example, the two methods of standardization can give entirely opposite results. Thus, it is important that the method of standardization is correctly chosen in accordance with your objective of doing the standardization. In addition, the interpretation of the standardized rate should be proper for the method used.

The standardized rate depends heavily on the standard chosen. No universal standard is available, and this is arbitrarily chosen. If a desirable structure exists or can be constructed, then that can be chosen as the standard. If not, a structure that is of middling type or commonly seen or easy to implement can be chosen as the standard. In column F of Table 1 is the WHO World Standard population. This actually extends to age 100 years and over, and is in 5-year intervals but in Table 1 is an abridged version with 85 and over as the last interval and age intervals 10 years.

Since standard is arbitrary anyway, it should be simple. This is not the case with WHO World Standard population. The ASDRs in column G are my own standard, and are simple. For interregional comparison within a country, the age structure of the total country or its ASDRs can be used as standard.

The direct method seems more appropriate in most cases because this gives the death rate expected for standard age structure. But this method cannot be used when the ASDRs are not known. Also, this method should not be used when ASDRs are unstable and based on a small number of subjects. Indirect standardization is generally used for disease mortality because of unstable ASDRs. This, when used for small groups instead of the general population, is called the standardized or adjusted mortality rate and leads to a popular measure known as the **standardized mortality ratio**. This is discussed later in this note. Such an adjustment can be done not only for age but also for any other factor that might influence the mortality pattern.

The illustration in Example 1 is for population mortality as that is the most common application of standardized death rate. But this can be used, e.g., for disease specific mortality. For example, if age-specific death rates for circulatory diseases are known and if the purpose is to compare two age-wise diverse populations, the comparison should be based on standardized rates. For emphasizing the importance of the choice of the standard in this context, it was shown [2] for the year 1995 that standardized death rate by circulatory disease in U.S. males using WHO World Standard is 285 per 100,000 population but is 372 when Scandinavian standard is used. This reflects a large difference of 23 percent and underscores the heavy dependence of standardized death rate on the standard chosen for this purpose.

Comparative Mortality Ratio

The term comparative modality ratio has not achieved yet the globally accepted meaning. This can be used to express one mortality rate compared to the other when both have same base.

$$\text{Comparative mortality ratio} = \frac{\text{death rate-1}}{\text{death rate-2}} \times 100, \tag{4}$$

where the two death rates have common base.

One popular meaning of comparative mortality ratio is the ratio of expected number of deaths arrived by direct standardization to the actual deaths. In Example 1, this comparative mortality ratio for the U.S. is 100×5.5/8.5 = 65 percent, and for Venezuela is 100×5.8/4.2 = 138 percent. This again is heavily dependent on the age structure chosen as standard.

The utility of comparative mortality ratio increases when calculated for standardized rates. This ratio for the U.S. compared to Venezuela in Example 1 is 100×5.5/5.8 = 95 percent. Since both rates refer to the same standard population, this can be interpreted as saying that the death rate in the U.S. is 95 percent of that in Venezuela. Although both rates under comparison are standardized for the same age structure yet the effect of the chosen standard is not eliminated. If another standard age structure is chosen, the ratio can become very different.

The utility of comparative mortality ratio increases further when several populations are compared. For example, if U.S. age-standardized heart disease death rate in white males is considered 100, the comparative mortality ratio for age-standardized death rate is more than 120 for many Health Service Areas (HSAs) in the mid-south-east and less than 80 for many HSAs in the west. Thus, comparative mortality ratio is one more method to know which segment of population has relatively higher or lower mortality. Strategies for controlling mortality can be accordingly devised.

Standardized Mortality Ratio (SMR)

This is the ratio of the number of observed deaths in a study group to the number that would be expected if the study group had the same specific rates as in a standard group. This procedure is the same as indirect method of standardization. The ratio is sometimes multiplied by 100 to express it in terms of percentage.

$$\text{SMR} = \frac{\text{observed number of deaths}}{\text{expected number of deaths}} * 100, \tag{5}$$

where the denominator is based on the specific rates in the chosen standard population. These are not necessarily age specific but could be gender specific, exposure specific, or specific for any other categorization. An SMR greater than 100 is interpreted as indicating that the study group has excess mortality relative to the standard. The study and the standard group can be disease and control groups in a case-control study or general populations of two types or any other groups of interest. In this method, more stable rates of the larger population are applied to the smaller study group to obtain the expected number of deaths. SMR gives a measure of the likely excess or reduction in mortality in the study group.

Table 2 Calculation of SMR in textile workers

Age group (years)	ASDR* in the national population per 1000	Textile workers	
		Number	Expected deaths
25-34	3.0	400	1.2
35-44	5.0	300	1.5
45-54	8.0	200	1.6
55-64	25.0	100	2.5
Total		1000	6.8

* Age specific death rate

Example 2 SMR for textile workers

Stress of work, exposure to fiber dust, and other factory environmental factors are known to cause excess mortality in the staff of a textile mill. Their age distribution and calculation of SMR are shown in Table 20-6.

Expected deaths are obtained by applying the national ASDRs to the number of textile workers in different age groups. Since the national rate for the age group 25-34 years is 3.0 per 1000 population, the expected deaths in 400 workers of this age group are $3.0 \times 400/1000 = 1.2$. Similarly for other age groups. If the total number of observed deaths is 10 and the expected based on the national rates is 6.8, from formula (5),

$$\text{SMR} = (10/6.8) \times 100 = 147.$$

This shows that the mortality level of textile workers (in this mill) was 147 percent of the national average. This is 47 percent higher than that experienced by the national population.

Side note: Excess mortality in textile workers was never in doubt, but SMR delineates the exact magnitude of this excess.

For a similar but more extensive application of SMR, see Johansen and Olsen. They investigated mortality from amyotrophic lateral sclerosis (ALS) and other chronic disorders among male employees of electric supply companies in Denmark. The 21,236 men included in the study accrued nearly 303,000 person-years of follow-up. They observed 14 deaths from ALS when only 6.9 deaths were expected on the basis of the national ASDRs. This yielded an SMR of nearly 200. This means that these employees are dying from ALS nearly twice as much as the general population.

Other Measures of Mortality

It is useful for health authorities to know the extent of deaths occurring due to various causes. The number one killer in the U.S. is vehicular accidents, whereas in Indian rural areas it is respiratory diseases. Similar statements can also be made for the age groups contributing to deaths. Such proportional mortality can be measured in several different ways.

Proportional deaths due to cause A

$$= \frac{\text{deaths due to cause A}}{\text{total deaths}} * 100$$

For age group 60+ years, proportional deaths

$$= \frac{\text{deaths in the age group 60 years and above}}{\text{total deaths}} * 100 .$$

This can be computed for any cause or any age group. In both these the denominator is total deaths. The proportional deaths for any cause is different from the cause-specific death rate.

Cause-specific death rate (due to cause A)

$$= \frac{\text{deaths due to cause A}}{\text{population}} * 100{,}000$$

This basically is the same as the CDR but is restricted to a particular cause of death. The sum of specific death rates for all causes would be the same as the CDR. If the rates in two areas are to be compared, then a standardized proportional death rate is compared using the direct or the indirect method described earlier.

$$\text{Case-fatality rate (CFR)} = \frac{\text{deaths among those affected}}{\text{number of individuals affected}} * 100$$

Case-fatality rate represents the lethal power of a disease. This rate is typically used in acute conditions. CFR is high for diseases such as a rabies and tetanus, and low for diseases such as typhoid and influenza. Case-fatality can be considered to measure the virulence of a disease. This is related to duration. One-year case-fatality of leukemia is very different from five-year case-fatality. For this reason, this term is customarily used for short duration diseases such as peritonitis.