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**AGE STANDARDIZATION OF RATES:
A NEW WHO STANDARD**

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Summary

A recent WHO analysis has revealed the need for a new world standard population (see attached table). This has become particularly pertinent given the rapid and continued declines in age-specific mortality rates among the oldest old, and the increasing availability of epidemiological data for higher age groups. There is clearly no conceptual justification for choosing one standard over another, hence the choice is arbitrary. However, choosing a standard population with higher proportions in the younger age groups tends to weight events at these ages disproportionately. Similarly, choosing an older standard does the opposite. Hence, rather than selecting a standard to match the current age-structure of some population(s), the WHO adopted a standard based on the average age-structure of those populations to be compared (the world) over the likely period of time that a new standard will be used (some 25-30 years), using the latest UN assessment for 1998 (UN Population Division, 1998). From these estimates, an average world population age-structure was constructed for the period 2000-2025. The use of an average world population, as well as a time series of observations, removes the effects of historical events such as wars and famine on population age composition. The terminal age group in the new WHO standard population has been extended out to 100 years and over, rather than the 85 and over as is the current practice. The WHO World Standard population has fewer children and notably more adults aged 70 and above than the world standard. It is also notably younger than the European standard.

It is important to note, however, that the age standardized death rates based on the new standard are not comparable to previous estimates that are based on some earlier standard(s). However, to facilitate comparative analyses, WHO will disseminate trend analyses of the “complete” historical mortality data using on the new WHO World Standard Population in future editions of the World Health Statistics Annual.

Introduction

In epidemiology and demography, most rates, such as incidence, prevalence, mortality, are strongly age-dependent, with risks rising (e.g. chronic diseases) or declining (e.g. measles) with age. In part this is biological (e.g. immunity acquisition), and in part it reflects the hazards of cumulative exposure, as is the case for many forms of cancer. For many purposes, age-specific comparisons may be the most useful. However, comparisons of crude age-specific rates over time and between populations may be very misleading if the underlying age composition differs in the populations being compared. Hence, for a variety of purposes, a single age-independent index, representing a set of age-specific rates, may be more appropriate. This is achieved by a process of *age standardization* or *age adjustment*.

There are several techniques for adjusting age-specific rates. Among them are direct and indirect standardization (Wolfenden, 1923), the geometric mean (Schoen, 1970), equivalent average death rates (Hill, 1977), life table rates, Yerushalmy's index (Yerushalmy, 1951), cumulative death rates (Breslow and Day, 1981), absolute probabilities of death and the comparative mortality index ((Peto *et al*, 1994, Breslow & Day, 1980, 1981; 1987; Esteve *et al*, 1994). However, with the increasing availability of age-specific rates, the use of direct age standardization has become the predominant technique in most applications of demography and epidemiology.

Direct standardization yields a standardized or age-adjusted death rate, which is a weighted average of the age-specific rates, for each of the populations to be compared. The weights applied represent the relative age distribution of the arbitrary external population (the standard). This provides, for each population, a single summary rate that reflects the number of events that would have been expected if the populations being compared had had identical age distribution. Symbolically, the directly standardized mortality rate for populations *A* and *B* are given by the following equations:

$$DSR_a = \sum r_{ia} \left(\frac{n_{is}}{\sum_i n_{is}} \right)$$

$$DSR_b = \sum r_{ib} \left(\frac{n_{is}}{\sum_i n_{is}} \right)$$

where n_{is} is the mid-year population in the i th age group of the *standard* population, r_{ia} and r_{ib} are the death rates in age group i in populations *A* and *B*, respectively. The ratio of two such standardized rates is referred to as the *Comparative Mortality Ratio (CMR)*, a very useful measure. If the age-specific rates in the populations being compared have a roughly consistent relationship from one age group to the next, the selection of a standard population will not substantially affect comparisons among groups or time periods. In reality, however, the relative differences are usually not constant from one age group to another. As such, both the comparison as well as the conclusions drawn are influenced by the chosen standard.

In this paper, we review the existing standard populations currently in use for international comparison, the Segi (“world”) and the Scandinavian (“European”) standard populations. Based on this review, a new WHO World Standard age-structure is presented for epidemiological comparisons using the direct approach. The age composition of the new standard has been chosen to better reflect the future age structure of the world’s population for which comparative rates will be needed.

History of Direct standardization

By the middle of the nineteenth century, public health practitioners in England had begun to recognize that simple crude rates were inappropriate summary measures for comparing population health when the age distribution of the geographic areas were markedly different. Discussions centered around the development of a summary mortality index free from the effect of age differences. In a paper he read to the Statistical Society of London, Sir Edwin Chadwick, one of the early public health reformers in England, proposed the use of “the mean age at death” as a summary measure for comparing the health condition of the various “sanitary districts” around London (Finer, 1952; Lewis, 1991). This index, he argued, represented a true summary of the age-specific risks of dying. In response, Neison, a practicing actuary, disagreed with Chadwick’s underlying logic. He argued that since mortality increased with age, Chadwick’s mean age at death for geographic areas with a relatively older population would tend to overstate excess mortality. In a subsequent article, Neison demonstrated the fallacy in Chadwick’s argument by comparing the crude mean age at death with the mean age computed by a method of *direct standardization* (Neison 1844). Neison was, thus, the first to introduced both the concepts of direct and indirect standardization, as well as the term standard population.

The Registrar General’s report of 1883 was the first reported use of Neison’s direct standardization method, using the 1881 population census of England and Wales as the standard (most current at the time). In subsequent reports, the standard was changed each time there was a new census, i.e., every ten years (Woolsey, et al., 1959; Benjamin, et al., 1980). These frequent changes of the standard were cumbersome since historical rates had to be recalculated each time in order to assess current trends. As a solution, the 1901 population census was eventually adopted as a general standard in England and Wales, and remained unchanged even when a new census became available.

In order to facilitate comparison with mortality rates in England and Wales, the United States adopted the 1901 British standard. This practice continued until the early 1940s when it was decided that the difference between the US population at the time and the 1901 English population was significant enough to warrant a change in standard. As a result, the US adopted its 1940 census population (the most current at the time) as the new standard. Recently, however, there has been growing concern that the 1940 standard no longer reflects the increasingly older US age structure. In response, the National Center for Health Statistics sponsored two national workshops in 1991 and 1997 on the issue of a new US standard. The final report of these workshops recommended the adoption of a new standard based on the projected 2000 population age distribution (NCHS, 1998).

An International Standard Population

The idea of a truly international standard was first suggested by Ogle in 1892. His proposed standard was an amalgam based on the experience of seven European countries (Ogle, 1892). There is, however, no evidence of its subsequent adoption for international comparison by any country. Various standards have been proposed since then but none adopted widely. The debate has centered largely around the question of whether any one standard is more suitable than others. This question was discussed at a May 1965 subcommittee meeting of the International Union Against Cancer (IUAC) Conference in London. Three standard populations were suggested. Each was deemed appropriate for particular population types. One standard had a high proportion of young people and was considered appropriate for making comparisons with populations in Africa (Knowelden and Oetl  , 1962). The second (“European”) standard was based on the experience of Scandinavian populations, which contained a relatively high proportion of old people and was judged particularly suitable for comparison within Western Europe (Doll and Cook, 1967). The third was proposed by Segi (1960) as an intermediate “world” standard based on the experience of 46 countries. The “European” and “world” standards were subsequently adopted by WHO for use in calculating age-standardized death rates. These standards are shown in Table 1 together with the new WHO World Standard (shown in abbreviated form for purposes of comparison).

As discussed earlier, the choice of a standard can markedly alter comparisons between populations. Table 2 shows a time series of circulatory disease mortality among US males for the period 1970-1995 using the three standards (Segi, Scandinavian and the WHO World Standard). Even though the overall percentage decline from 1970 to 1995 is almost the same for all three standards (48-49%), the relative differences in the standardized rates, using the WHO standard as baseline, varies from –20% in one standard to +24% in the other. Table 3 compares twenty countries on the standardized death rates for respiratory infections as well as the ranking of countries according to rates. In general, the Scandinavian standard tends to yield rankings that are closer to those obtained with the WHO World Standard. In about half the cases, there are only minor differences in ranking between the three standards. In other cases, however, substantial shifts in ranking occur when the standard is changed. For instance, the Russian Federation ranks 9th on the Segi but 13th on the Scandinavian and WHO standards. Similarly, Cuba ranks 10th on the Scandinavian, 11th on the WHO and 14th on the Segi. The differences in the actual rates are even more dramatic. The age-standardized mortality rate for respiratory infections for Hong Kong ranges from 44.9 using the Segi standard to 76.9 using the Scandinavian (“European”). Much larger differences are evident in some of the other countries. If the choice of a population standard for direct age-standardization can have such marked influence on comparisons over time and between populations, how should a world standard be selected?

A New WHO World Standard Population

Age-structure varies tremendously across populations of the world at different levels of the demographic transition. Should one, therefore, choose a standard population with higher proportions in the younger age groups (thereby weighting events at these ages disproportionately), or choose an older standard, or rather something in-between? There

is clearly no conceptual justification for choosing one standard over another, hence the choice will eventually be arbitrary. Whatever standard is chosen should ideally be maintained for a number of years, during which time the age-structure of populations will alter. For this reason, attempting to match a particular standard to current population age structures is insufficient justification for choosing one standard over another. Hence, rather than selecting a standard to match the current age-structure of some population(s), the standard must be chosen to reflect the average age-structure of all populations to be compared over the period of use.

The approach proposed by WHO is to base the standard on the average age-structure of those populations to be compared (the world) over the likely period of time that a new standard will be used (some 25-30 years). The United Nations Population Division carries out two-yearly comprehensive assessment of population age-structure for each country by age and sex (the latest assessment is for 1998 - UN Population Division, 1998). Estimates are prepared for countries for each quinquennial year from 1950 and projected to 2025, based on population censuses and other demographic sources, adjusted for enumeration errors. From these estimates, an average world population age-structure is constructed for the period 2000-2025. Figure 1 shows the expected evolution of the world's population age-structure over the first quarter of the 21st century, and the average composition which defines the new WHO World Standard.

The use of an average world population, as well as a time series of observations removes the effects of historical events such as wars and famine on population age composition. Table 4 gives the percentage of the population in each 5-year age group in the new WHO World Standard population. Given the rapid and continued declines in age-specific mortality rates among the oldest old, and the increasing availability of epidemiological data for higher age groups, the terminal age group in the new standard population has been extended out to 100 years and over, rather than the 85 and over as is the current practice. The difference with respect to the Segi and Scandinavian standards can be seen in Figure 2. The WHO World Standard population has fewer children and notably more adults aged 70 and above than the Segi standard. It is also notably younger than the Scandinavian standard. Implementation of this new standard will facilitate international comparative analysis and reduce confusion among data users.

Discussion

To facilitate comparisons of sets of age-specific epidemiological and demographic rates across populations with different age composition, it is useful to calculate summary health statistics which remove the effects of variation in age structure. The dominant method currently in use is the direct age-standardization of rates using an arbitrary standard population. National (as exemplified by the United Kingdom and the United States) and international experience suggest that population standards have been adopted for arbitrary reasons and once adopted have been used for many decades. Given current WHO initiatives, which involve comparisons of vastly different populations, existing standards appear too extreme. We present a new WHO World Population Standard which is especially defined to reflect the average age structure of the world's population expected over the next generation, from the year 2000 to 2025. Comparisons across populations of the world should preferably be based on an average world population age

structure and that average age structure should correspond to the period of likely use of a standard (20-30 years).

To facilitate comparisons globally, all age-standardized rates produced by WHO will be made according to the new WHO World Standard Population. Hopefully, this single standard will be widely adopted for global comparisons.

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| Table 1. Standard Population Distribution (percent) | | | |
|--|-------------------------|------------------------------------|---------------------|
| Age group | Segi ("world") standard | Scandinavian ("European") standard | WHO World Standard* |
| 0-4 | 12.00 | 8.00 | 8.86 |
| 5-9 | 10.00 | 7.00 | 8.69 |
| 10-14 | 9.00 | 7.00 | 8.60 |
| 15-19 | 9.00 | 7.00 | 8.47 |
| 20-24 | 8.00 | 7.00 | 8.22 |
| 25-29 | 8.00 | 7.00 | 7.93 |
| 30-34 | 6.00 | 7.00 | 7.61 |
| 35-39 | 6.00 | 7.00 | 7.15 |
| 40-44 | 6.00 | 7.00 | 6.59 |
| 45-49 | 6.00 | 7.00 | 6.04 |
| 50-54 | 5.00 | 7.00 | 5.37 |
| 55-59 | 4.00 | 6.00 | 4.55 |
| 60-64 | 4.00 | 5.00 | 3.72 |
| 65-69 | 3.00 | 4.00 | 2.96 |
| 70-74 | 2.00 | 3.00 | 2.21 |
| 75-79 | 1.00 | 2.00 | 1.52 |
| 80-84 | 0.50 | 1.00 | 0.91 |
| 85+ | 0.50 | 1.00 | 0.63 |
| Total | 100.00 | 100.00 | 100.00 |
| * For purposes of comparison, the WHO Standard age group 85+ is an aggregate of the age groups 85-89, 90-94, 95-99 and 100+. | | | |

| Table 2. Trend in Age-adjusted Circulatory Disease Mortality Rates Based on the Segi, Scandinavian and WHO World Standard Populations and the Cumulative Death Rates - US Males (1970-1995) | | | | | | | |
|--|-------|-------|-------|-------|-------|-------|--------------------|
| Rates per 100,000 | | | | | | | |
| Standard | 1970 | 1975 | 1980 | 1985 | 1990 | 1995 | % Change 1970-1995 |
| Segi | 459.5 | 399.0 | 350.3 | 305.8 | 256.8 | 232.3 | -49.4 |
| WHO World | 550.9 | 482.2 | 426.7 | 373.7 | 315.0 | 285.4 | -48.2 |
| Scandinavian | 720.1 | 630.4 | 557.8 | 488.4 | 411.6 | 372.4 | -48.3 |
| Percent Difference in Rates Relative to WHO World Standard | | | | | | | |
| Segi | -20% | -21% | -22% | -22% | -23% | -23% | |
| Scandinavian | 23% | 24% | 24% | 23% | 23% | 23% | |

**Table 3. Directly standardized male death rates from respiratory infections
and ranking of twenty countries using three different standard populations - (Around 1995)**

| | Rates Per 100,000 | | | Ranking of Countries (by age-adjusted death rates) | | |
|---------------------|-------------------|--------------|-----------|---|--------------|-----------|
| | Segi | Scandinavian | WHO World | Segi | Scandinavian | WHO world |
| Australia | 6.3 | 10.1 | 7.9 | 23 | 23 | 23 |
| Barbados | 28.8 | 41.9 | 33.8 | 12 | 12 | 12 |
| Bulgaria | 34.2 | 43.5 | 36.7 | 8 | 11 | 10 |
| Canada | 14.5 | 25.6 | 19.7 | 18 | 18 | 18 |
| Cuba | 27.2 | 44.2 | 34.6 | 14 | 10 | 11 |
| Estonia | 27.5 | 36.2 | 29.6 | 13 | 15 | 15 |
| Germany | 11.0 | 19.0 | 14.7 | 19 | 19 | 19 |
| Hong Kong | 44.9 | 76.9 | 59.1 | 5 | 3 | 4 |
| Hungary | 9.6 | 13.1 | 10.7 | 21 | 22 | 22 |
| Iceland | 26.9 | 49.1 | 37.9 | 15 | 8 | 8 |
| Ireland | 37.0 | 65.6 | 50.4 | 7 | 6 | 7 |
| Japan | 37.8 | 67.5 | 51.8 | 6 | 5 | 6 |
| Latvia | 29.5 | 38.1 | 31.7 | 11 | 14 | 14 |
| Luxembourg | 8.4 | 15.1 | 11.7 | 22 | 21 | 21 |
| Mauritius | 45.2 | 72.6 | 56.6 | 4 | 4 | 5 |
| New Zealand | 15.3 | 27.7 | 21.5 | 17 | 17 | 17 |
| Portugal | 21.0 | 35.1 | 27.4 | 16 | 16 | 16 |
| Russian Federation | 32.7 | 38.3 | 33.1 | 9 | 13 | 13 |
| Singapore | 71.9 | 120.8 | 93.3 | 3 | 1 | 1 |
| Spain | 10.9 | 18.6 | 14.5 | 20 | 20 | 20 |
| Trinidad and Tobago | 30.2 | 46.7 | 37.2 | 10 | 9 | 9 |
| Turkmenistan | 114.2 | 87.9 | 91.2 | 1 | 2 | 2 |
| Uzbekistan | 80.6 | 63.6 | 65.1 | 2 | 7 | 3 |

| Table 4. WHO World Standard Population Distribution (%), based on world average population between 2000-2025 | |
|---|-------------------------|
| Age group | World Average 2000-2025 |
| 0-4 | 8.86 |
| 5-9 | 8.69 |
| 10-14 | 8.60 |
| 15-19 | 8.47 |
| 20-24 | 8.22 |
| 25-29 | 7.93 |
| 30-34 | 7.61 |
| 35-39 | 7.15 |
| 40-44 | 6.59 |
| 45-49 | 6.04 |
| 50-54 | 5.37 |
| 55-59 | 4.55 |
| 60-64 | 3.72 |
| 65-69 | 2.96 |
| 70-74 | 2.21 |
| 75-79 | 1.52 |
| 80-84 | 0.91 |
| 85-89 | 0.44 |
| 90-94 | 0.15 |
| 95-99 | 0.04 |
| 100+ | 0.005 |
| Total | 100 |

Figure 1. World population by age group in percent of total population 2000 to 2025 and average of 2000 to 2025

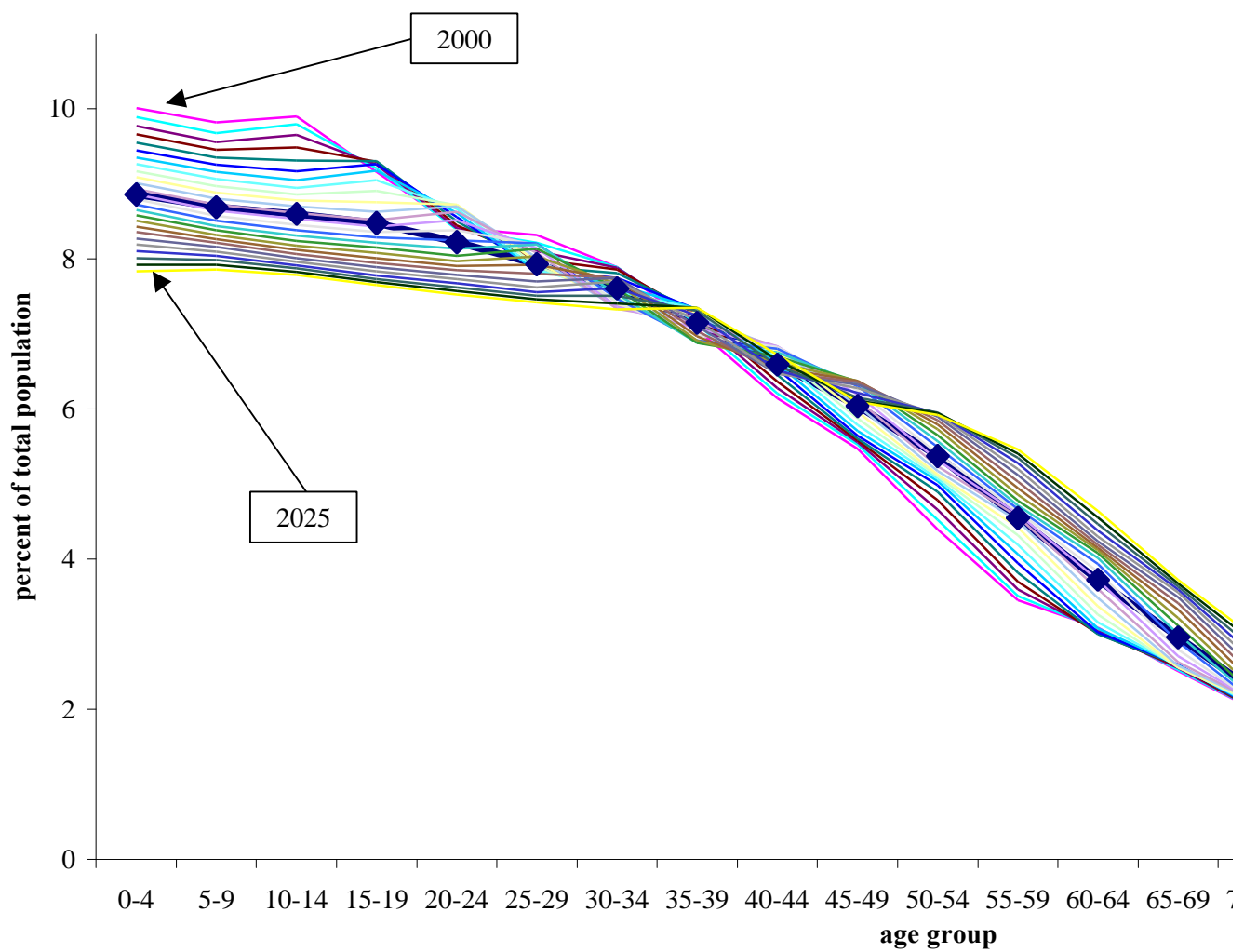


Figure 2. Comparison of "Segi" and "Scandinavian" standards with world population

