

STANDARDIZATION OF RATES

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Background and Acknowledgements

This document stems from discussions held by the Core Indicators Work Group in the Core Indicators for Public Health in Ontario project. The workgroup identified the need for a document that would review existing literature on the standardization of rates in order to make recommendations for best practices for the calculation of adjusted rates by public health epidemiologists in Ontario. The Core Indicators for Public Health in Ontario is a project of the Association of Public Health Epidemiologists in Ontario (APHEO).

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I. INTRODUCTION

In epidemiologic research, population data are used to examine and compare statistics on disease incidence, prevalence and mortality. **Crude rates** can be calculated from these data by dividing the total number of events (e.g. deaths, incident cases, hospitalizations etc.) in a population by the sum of a population in a specified year – typically expressed per 1000 or 100,000 population. This rate reflects the *actual experience* of a population and should always be examined when assessing the morbidity or mortality of a population.

However, crude rates can be misleading if comparisons are being made across groups or over time. When comparing crude rates for two population groups, the groups may differ with respect to certain underlying characteristics such as age. For example, a population with a higher proportion of elderly people will have a higher overall crude death rate as well as higher mortality for most chronic conditions because the risk of dying is greater with increasing age. That is, increasing age is a risk factor for death. Similarly, areas with a younger population may have higher crude mortality rates for injury-related deaths. Comparing areas based on a crude rate alone could lead to erroneous conclusions when the populations being compared have different age compositions or other underlying characteristics. Crude rates, therefore, should not be used to make comparisons across population groups or over time.

One method used to account for differences in the distribution of a risk factor across populations is stratification followed by analysis of the stratum-specific rates. The commonest and most important stratum-specific rate is the **age-specific** rate. Age-specific rates are calculated as the number of events over a given time period in a specific age group divided by the population in that age group over the same time period, typically expressed as per 1000 or 100,000 population per year. These rates allow for direct comparison of each age group across populations or time. The comparison of age-specific rates is the most comprehensive and reliable method of comparing rates over time or between population groups. However, calculating, presenting and interpreting stratum-specific rates for each age group results in a large number of comparisons, which is cumbersome. Having a single summary rate that is independent of the underlying age or age-sex structure of the population can serve as a useful measure.

Standardization adjusts or controls for differences in population structure and provides a single summary measure for the comparison of populations. The resulting **adjusted rate** is an artificial rate that allows for comparisons over time and place. Standardization can be used to adjust for any one underlying factor (e.g., age, sex, race, SES level), or simultaneously for two or more factors. Although multiple-adjustment is possible, age is the one factor that is most commonly adjusted for because it is strongly related to illness and death, is likely to vary across time and place, and, unlike some other factors that are strongly associated with health, it is consistently available for analysis. Therefore, this

report focuses on age standardization, but the methods are equally applicable to producing rates adjusted for other population characteristics.

There are two different approaches to standardization: the **direct** method and the **indirect** method. Both methods yield a single summary rate that can be useful for comparison purposes but the rate produced by either direct or indirect standardization is hypothetical (artificial) and describes a rate that would have been obtained had the underlying structure been the same as that of the standard population. Consequently, adjusted rates or ratios do not represent the actual morbidity or mortality experience of the population and use of these rates should not act as a substitute for the examination of crude and stratum-specific rates.

Indirect standardization results in the calculation of Standardized Mortality/Morbidity Ratios (SMRs). It uses age-specific rates from a standard population (e.g., Ontario, Canada) to derive the expected number of events in a study population (e.g., public health unit). The ratio of actual to expected events provides the SMR. This method is useful when age-specific data for the study population are not available.

With the **direct method** of standardization age-specific rates from a study population are applied to the population distribution of a standard population to yield the number of events that would have been expected if the study population had the same age distribution as the standard.

II. DIRECT STANDARDIZATION

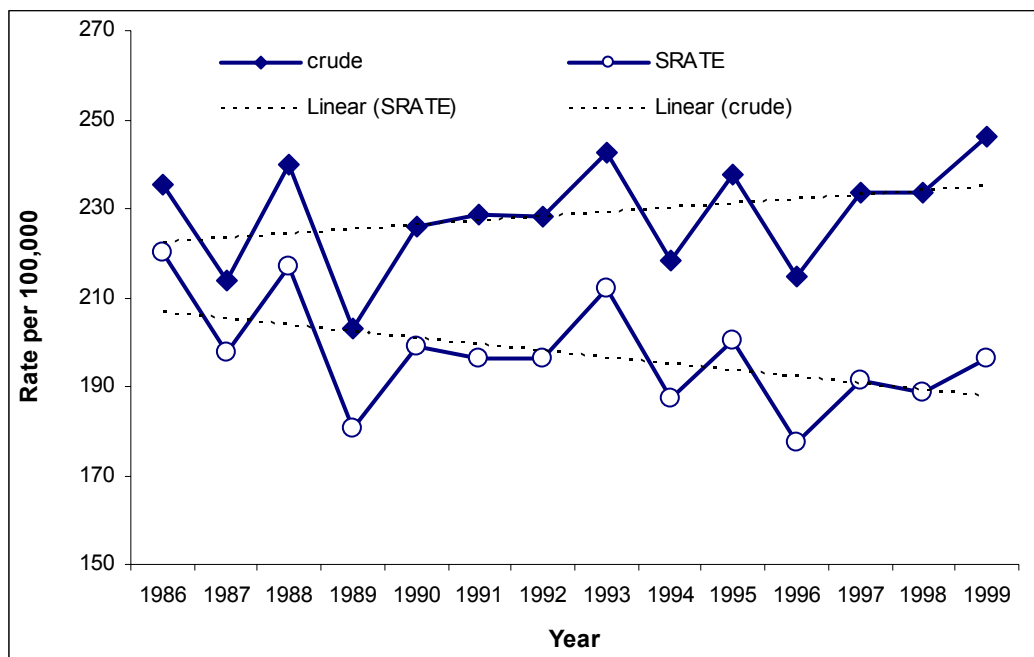
What is it?

The **direct method** of standardization involves the application of age-specific rates in a population of interest to a standard age distribution in order to eliminate differences in observed rates that result from differences in population composition. The resulting age-standardized rate may be labeled differently depending on the application, but common forms include the ASIR' (Age-Standardized Incidence Rate), the 'ADR' (Adjusted Death Rate), the AAR (Age Adjusted Rate), and the 'ASMR' (Age-Standardized Mortality Rate). The term 'SRATE' (standardized rate) was commonly used by the Ontario Ministry of Health in the 1990s and is sometimes used by APHEO members.

An **age-adjusted rate** adjusted by the direct method produces a rate that *would* occur if the observed age-specific rates in the study population were present in a population with an age distribution equal to that of the standard population. Similarly, the **age/sex-adjusted rate** is the rate that would occur if the observed age/sex specific rates in the study population were present in a population with the age/sex distribution of the standard.

Figure 1 shows the crude and age-adjusted (using the direct method) rates for cancer mortality in an Ontario public health unit (PHU) area. The crude rates suggest that the cancer mortality has increased steadily from 1986-1999 whereas the directly adjusted SRATE shows that cancer mortality has been decreasing.

Figure 1: Crude and adjusted cancer mortality rates, Renfrew County (1988-1999)



How to calculate an age-adjusted rate

In the direct method, age-specific rates of the study population (i.e, the population of interest) are applied to an arbitrarily chosen standard population. This produces the expected number of events, which represents the number of events that would be expected in the standard population if it had experienced the same age-specific event rate as the study population. The directly standardized rate is obtained by dividing the expected number of events by the total standard population. The choice of an appropriate standard population is important and is discussed in the next section.

The requirements for this calculation are:

- Number of events (e.g., deaths, incident cases) for each age group in the study population
- Population estimates for each age group in the study population
- Population for each age group in the standard population

Two methods for obtaining age-adjusted rates are shown. Both examples use Ontario as the study population, and the total 1991 population of Canada (males & females combined) as the standard.

Formulae

e_i is the observed number of events in age group i in the study population

p_i is the number of persons in age group i in the study population

r_i is the event rate in study population for the persons in age group i

P_i is the number of persons in age group i in the standard population

E_i is the expected number of events in age group i in the standard population

For each age category, the age-specific (crude) rate is calculated by dividing the number of events by the study population for that age category.

$$\text{Age-specific crude rate} = r_i = e_i / p_i$$

For each age category, the age-specific crude rate is multiplied by the age-specific standard population to obtain the expected number of events.

$$\text{Age-specific expected events} = E_i = r_i * P_i$$

The total Crude Rate (per 100 000) is the sum of deaths in the study population divided by the total study population	$= \frac{\sum e_i}{\sum p_i} * 100,000$
The Standardized Rate (per 100 000) is the sum of all expected events divided by the total standard population	$= \frac{\sum E_i}{\sum P_i} * 100,000$

Table 1: Direct standardization, age-adjusted rates (Method I)

Age Groups	Study Population		Standard Population (Canada 1991)	Crude Rate	Expected deaths
	events	population			
	e_i	p_i	P_i	$r_i = e_i/p_i$	$E_i = r_i * P_i$
<1 year	7	147,787	403,061	0.0000474	19.09
1 - 4	30	608,268	1,550,285	0.0000493	76.46
5 - 9	25	760,339	1,953,045	0.0000329	64.22
10 - 14	23	740,079	1,913,115	0.0000311	59.46
15 - 19	27	721,396	1,926,090	0.0000374	72.09
20 - 24	47	747,171	2,109,452	0.0000629	132.69
25 - 29	66	826,426	2,529,239	0.0000799	201.99
30 - 34	122	994,837	2,598,289	0.0001226	318.64
35 - 39	264	973,239	2,344,872	0.0002713	636.07
40 - 44	443	865,317	2,138,891	0.0005120	1095.01
45 - 49	731	790,269	1,674,153	0.0009250	1548.59
50 - 54	1,022	608,638	1,339,902	0.0016792	2249.91
55 - 59	1,523	501,218	1,238,441	0.0030386	3763.12
60 - 64	2,223	459,365	1,190,217	0.0048393	5759.80
65 - 69	3,108	431,223	1,084,588	0.0072074	7817.07
70 - 74	3,866	374,246	834,024	0.0103301	8615.55
75 - 79	3,345	255,754	622,221	0.0130790	8138.01
80 - 84	2,719	167,495	382,303	0.0162333	6206.05
85 - 89	1,692	85,585	192,410	0.0197698	3803.91
90 +	906	42,224	95,467	0.0214570	2048.43
Total	22,189	11,100,876	28,120,065	.00199885	52,626.16
Crude Rate per 100,000				199.89	
Standardized Rate per 100,000					187.15

An alternate calculation approach uses *population weights* derived from the standard population. **Algebraically, these two methods are identical.** A sample calculation is provided.

To obtain W_i (the weight of each age group in the standard population), the population in each age group is divided by the total population to give the proportion of population in each stratum ($403,061 / 28,120,065 = 0.014334$).

For each age category the study population's age-specific crude rate is multiplied by the age-specific standard population weight to obtain the expected number of deaths.

$$\text{Age-specific expected events} = r_i * W_i = E_i$$

The **Standardized Rate (per 100 000)** is the sum of all expected events $= \sum E_i * 100,000$

Table 2: Direct standardization - age adjusted rates (Method II)

Age Groups	Study Population		Standard Population (Canada 1991)	Weight $W_i = (P_i) / \sum(P_i)$	Crude Rate $r_i = e_i / p_i$	Expected deaths $E_i = r_i * W_i$
	deaths e_i	population p_i				
<1 year	7	147,787	403,061	0.014334	0.0000474	0.0000006789
1 - 4	30	608,268	1,550,285	0.055131	0.0000493	0.0000027191
5 - 9	25	760,339	1,953,045	0.069454	0.0000329	0.0000022836
10 - 14	23	740,079	1,913,115	0.068034	0.0000311	0.0000021143
15 - 19	27	721,396	1,926,090	0.068495	0.0000374	0.0000025636
20 - 24	47	747,171	2,109,452	0.075016	0.0000629	0.0000047188
25 - 29	66	826,426	2,529,239	0.089944	0.0000799	0.0000071831
30 - 34	122	994,837	2,598,289	0.092400	0.0001226	0.0000113313
35 - 39	264	973,239	2,344,872	0.083388	0.0002713	0.0000226197
40 - 44	443	865,317	2,138,891	0.076063	0.0005120	0.0000389404
45 - 49	731	790,269	1,674,153	0.059536	0.0009250	0.0000550708
50 - 54	1,022	608,638	1,339,902	0.047649	0.0016792	0.0000800108
55 - 59	1,523	501,218	1,238,441	0.044041	0.0030386	0.0001338235
60 - 64	2,223	459,365	1,190,217	0.042326	0.0048393	0.0002048290
65 - 69	3,108	431,223	1,084,588	0.038570	0.0072074	0.0002779890
70 - 74	3,866	374,246	834,024	0.029659	0.0103301	0.0003063846
75 - 79	3,345	255,754	622,221	0.022127	0.0130790	0.0002894023
80 - 84	2,719	167,495	382,303	0.013595	0.0162333	0.0002206982
85 - 89	1,692	85,585	192,410	0.006842	0.0197698	0.0001352739
90 +	906	42,224	95,467	0.003395	0.0214570	0.0000728460
Total	22,189	11,100,876	28,120,065	1.0	.0019988	0.0018175
Rate per 100,000					199.89	187.15

With this method it becomes more obvious that the adjusted rate is simply a *weighted average* of the age-specific deaths rates where the weights represent the proportion of the standard population in each age strata.

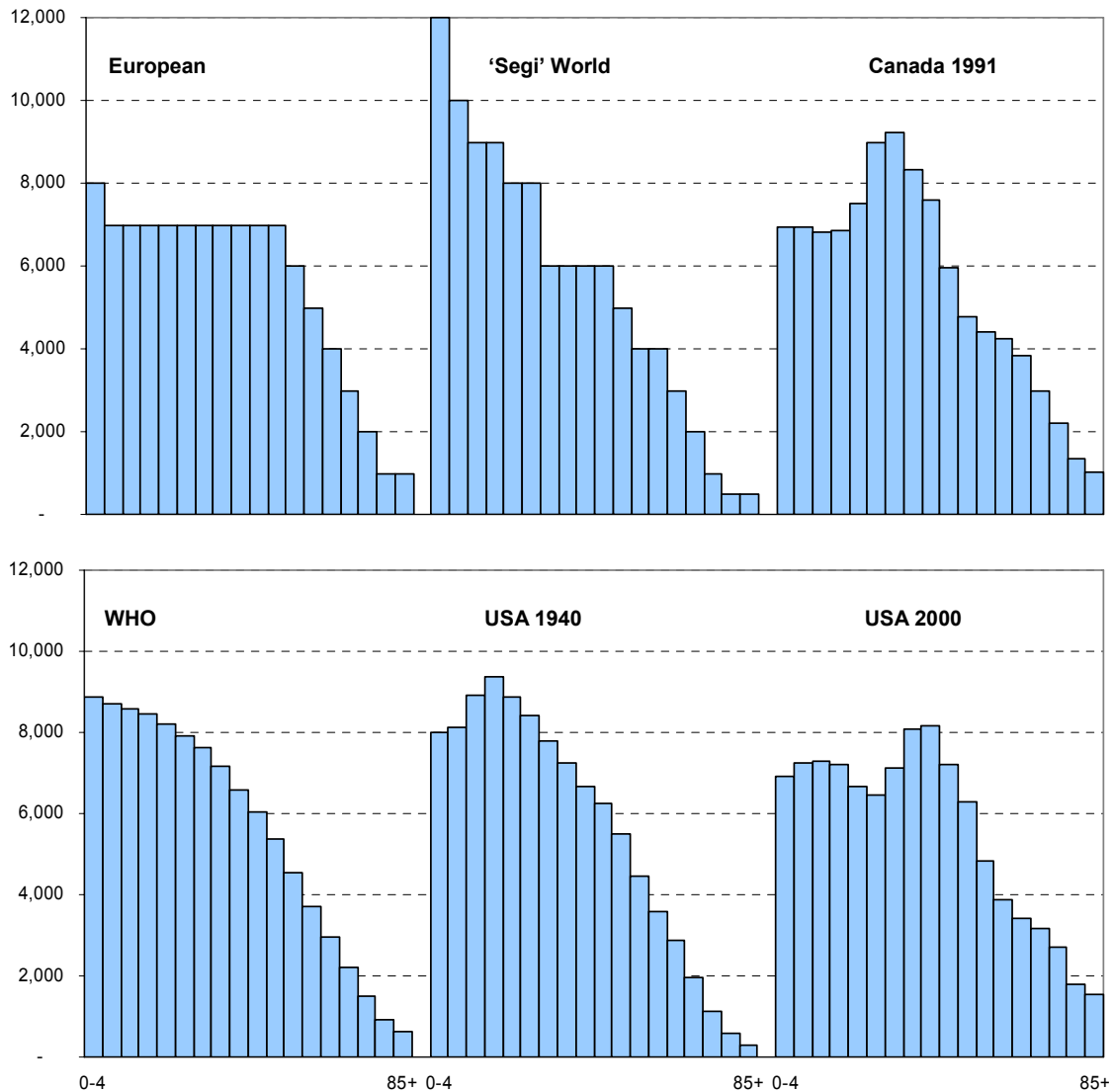
Choice of a standard population

The standard population can be any population and the selection of a standard is somewhat arbitrary. In general, the greater the difference between the age distributions of the standard population and the study population, the greater the difference in the crude and adjusted rates for the study population. The standard population one chooses can affect the magnitude of the adjusted rate, the perceived trends in rates, and ranking of priorities (e.g., ranking of leading causes of death). Thus the standard population should be chosen carefully since it can have a significant influence on the results and the conclusions drawn (Choi, deGuia & Walsh, 1999; Kitagawa, 1964).

For example, a standard population chosen from the past (e.g., 1971) will give slightly more weight to the younger population. The current Canadian Standard (1991) gives more weight to older ages and therefore greater emphasis to conditions that occur late in life. Cancer statistics are often standardized to the World Standard (the 'Segi' world standard) population to facilitate international comparisons. The World Standard has a relatively young distribution. Some international statistics such as those produced by the Organization for Economic Co-operation and Development (OECD) are standardized to

the European standard population which gives equal weight to all age groups from ages 5 through 54. The World Health Organization (WHO) bases their standard on an 'average world population' which, compared to the Canada 1991 population, gives more weight to younger age groups. Figure 2 shows the age distributions, by 5 year age groups (0-4, 5-9...80-84, 85+) of six different standard populations. The populations are scaled to a total population of 100,000 to facilitate comparison. The figure shows that the Canada 1991 population distribution is quite different from the WHO and world standards, but similar to the USA 2000 standard.

Figure 2: Age distributions of six different standard populations



The United States appears to be the only jurisdiction where the advantages and disadvantages of various standards have been extensively debated. After much consideration their National Centre for Health Statistics made a decision, in 1998, to

move from a 1940 standard population (a relatively young population thought to be incompatible with the current age structure of the U.S population) to the 2000 population (an older population which, therefore, gives more weight to diseases that affect the elderly) (Curtin & Klein, 1995; Anderson & Rosenberg, 1998; Spiegelman & Marks, 1966; Hoyert & Anderson, 2001; Feinleib & Zarate, 1995). The use of the 2000 standard produced adjusted rates that were greater in magnitude than those that had been calculated using the 1940 standard. This in itself is not important because adjusted rates are hypothetical. However, researchers also demonstrated that a change in the standard affected mortality *trends* for certain causes and made a difference in the perceived burden of disease (Anderson & Rosenberg, 1998; Feinleib & Zarate, 1995).

The use of an 'older' standard (1990) also resulted in a different ranking of the leading causes of death compared with a younger (1940) standard. Figure 3 illustrates this point using Ontario cancer mortality data for five sites standardized to different populations. The choice of standard affected the magnitude of the adjusted rate (lung cancer rates were highest with the USA 2000 population which gave greatest weight to the elderly) but also affected the 'ranking' with respect to these five cancers. Female breast cancer ranked behind colon cancer, for example, when the Canadian, European or USA 2000 standards were used.

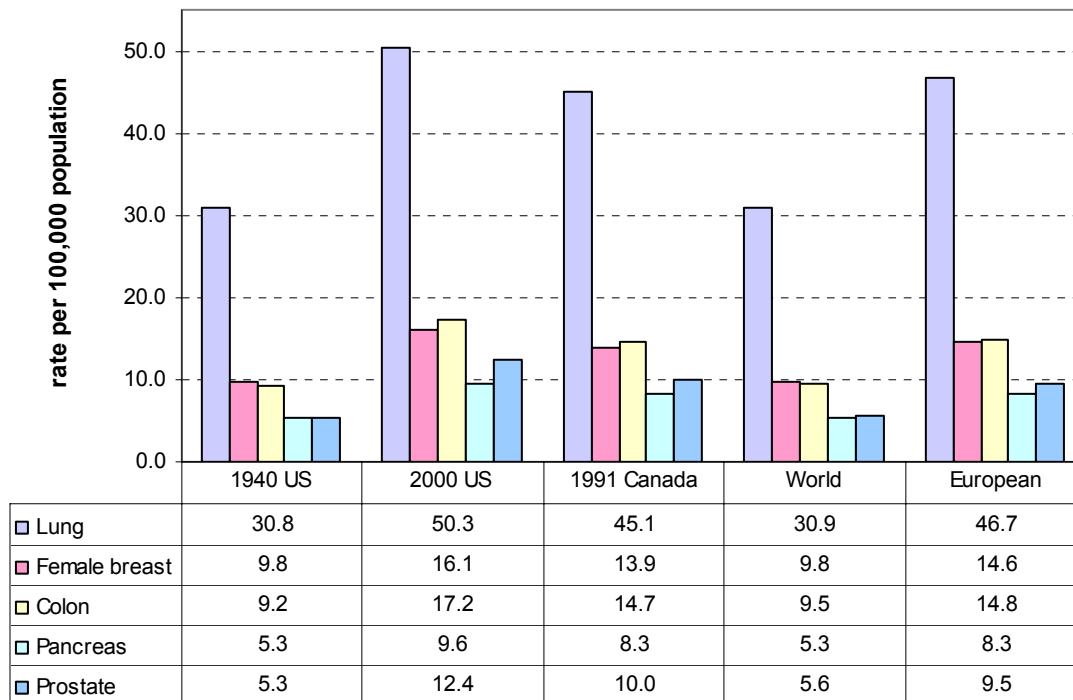
For specific conditions which overwhelmingly affect the elderly (e.g., Alzheimer's disease), the use of an older standard population produced a trend that showed a dramatic increase whereas the trend line produced by using a younger standard was perceived to be a more modest increase. The examination of trends over time in some cases, such as for cancer deaths, was affected because age-specific mortality rates for older age groups have been increasing whereas those for younger groups have been decreasing. Using Canadian data, Choi et al. (1999) demonstrated that different standards could produce different results. They examined standardized rates for chronic respiratory disease for Canada using the 1971 and 1991 standard population and found that they obtained similar trends, even though the underlying age-specific hospitalization rates were very different.

It is important to note that *these differences came about mostly for conditions where it was inappropriate to adjust in the first place*. Although the choice of a standard will affect the magnitude of the standardized rate, it should not substantially affect comparisons over time or place *if* the age-specific rates in the populations being compared have a consistent relationship (i.e., they are increasing or decreasing in the same direction). For example, if age-specific rates for asthma increase with age for 'area A' but decrease with age for 'area B,' then the choice of a standard population to calculate an age-adjusted rate will affect the comparison. A standard population with a 'younger' distribution will produce a higher adjusted rate for 'area B' and vice-versa. Thus, if the age-specific rates in the population being compared are not consistent then the choice of a standard population can affect comparisons (Anderson & Rosenberg, 1998; Rosenberg, Curtin, Maurer & Offutt, 1992). Curtin and Klein (1995) state that:

"The general consensus of the scientific literature is that, if it is appropriate to standardize then the selection of the standard population

should not affect relative comparisons. However, standardization is not appropriate when age-specific death rates in the populations being compared do not have a consistent relationship.....It can be noted that when age-adjusted rates are computed using two distinct standards and the comparisons are different, then it is not appropriate to standardize in the first place. [And] only age-specific comparisons may be valid.”

Figure 3: Ontario cancer mortality rates calculated with different standard populations



Ultimately however, the choice of a standard population must take into account both statistical and non-statistical considerations. These are described by Choi et al. (1999) and Rosenberg et al. (1992).

Statistical Considerations

- 1) When several different populations are being compared, a ‘pooled’ standard population (i.e., a standard population that is created by adding together the populations of the areas being compared) would minimize the variance of the standardized rates.
- 2) In examining trends over time, using the base-year population as a standard can be useful because statistically the difference between the crude rates for the base and subsequent years can be broken down into a difference of age-specific rates weighted by the base-year population, a difference between the populations in the two years being compared, and a rate-population interaction term.

Non Statistical Considerations

- 1) The standard should be similar to the population of interest¹.
- 2) Standards should not be changed frequently because all historical data would need to be recomputed to the new standard.
- 3) A change in standard can change the perception in the burden of disease and the ranking of disease.
- 4) A change in the standard can lead to perceived change in disease trends.
- 5) The importance of promoting uniformity, continuity and comparability of major health indicators should be considered.
- 6) A single standard is less likely to cause confusion than multiple, or changing standards.

In general, the standard population should only be changed if there are compelling reasons. A change in standard will give rise to technical, administrative and interpretive challenges. Furthermore, directly standardized rates can be compared with each other only if they have been calculated using the same standard population.

In the United States the Centre for Disease Control (CDC) and National Centre for Health Statistics (NCHS), following their second workshop on age adjustment, made and approved a number of recommendations relating to the use of the population standard including the following:

- That a single standard should be used by all agencies for official presentation of data but that alternative standards may be used for special analyses as appropriate to the research;
- That agencies should continue to use 11 age groups for calculating age-adjusted rates; and
- That the NCHS convene a workgroup to evaluate the age-adjustment standard at least every 10 years. With this last point they acknowledged that a future change in the standard population should only be made if differences between the standard and actual population become problematic (Anderson & Rosenberg, 1998).

Unlike the United States, there are no formal recommendations in Canada on which population should be used as the standard. National statistics, however, such as those produced by Statistics Canada and the Canadian Institute for Health Information (CIHI), are standardized to the **1991 Total Population of Canada**. The population of Canada reflects the population structure of most provinces within Canada over the 1981-2001 time period and therefore the 1991 population of Canada meets many of the considerations outlined by Choi et al. (1999) and the WHO.

The standard population given in recent Statistics Canada documents (e.g., Vital Statistics, Health Indicators, 2008) differs slightly from that published in earlier reports

¹ The WHO standard population for example reflects the average structure of all populations to be compared over the period of use, not just the current age-structure of some population(s). The WHO's world standard population is based on the 'average' composition of the world population structure over the 2000-2025 time period based on known and projected population estimates (Ahmad, Boschi-Pinto, Lopez, Murray, Lozano & Inoue, 2001).

and documents (Statistics Canada, 1997). This has led to some confusion. Table 3, however, shows that the relative age distribution in both versions is identical and age-standardized rates calculated with either of these standards will give the same result. Version 2 (where total population= 28,120,065) is currently used by Statistics Canada (2008), the Public Health Agency of Canada (2008) and is provided on the APHEO website. **To ensure consistency and comparability of age-adjusted rates it is suggested that the 1991 Total Canadian Population (Version 2) be used as the standard.**

When producing age-adjusted rates for the Canadian Community Health Survey the standard population is needed for additional age groups (e.g., 12-14). The standard population for these age groups is provided below in Table 4 (Greenburg, personal communication, April 2008).

Table 3: Comparing two versions of Canada 1991 population

Age (years)	Standard population, Canada 1991			
	Population Numbers		% of Total	
	Version 1	Version 2	Version 1	Version 2
<1 year	401,731	403,061	1.43%	1.43%
1 - 4	1,551,438	1,550,285	5.52%	5.51%
5 - 9	1,952,910	1,953,045	6.95%	6.95%
10 - 14	1,912,988	1,913,115	6.80%	6.80%
15 - 19	1,925,926	1,926,090	6.85%	6.85%
20 - 24	2,108,995	2,109,452	7.50%	7.50%
25 - 29	2,528,685	2,529,239	8.99%	8.99%
30 - 34	2,597,980	2,598,289	9.24%	9.24%
35 - 39	2,344,684	2,344,872	8.34%	8.34%
40 - 44	2,138,771	2,138,891	7.61%	7.61%
45 - 49	1,674,125	1,674,153	5.95%	5.95%
50 - 54	1,339,856	1,339,902	4.77%	4.76%
55 - 59	1,238,381	1,238,441	4.40%	4.40%
60 - 64	1,190,172	1,190,217	4.23%	4.23%
65 - 69	1,084,556	1,084,588	3.86%	3.86%
70 - 74	834,014	834,024	2.97%	2.97%
75 - 79	622,230	622,221	2.21%	2.21%
80 - 84	382,310	382,303	1.36%	1.36%
85 - 89	192,414	192,410	0.68%	0.68%
90 +	95,466	95,467	0.34%	0.34%
Total	28,117,632	28,120,065	1	1

Version 1: Used in some materials distributed by Ontario Ministry of Health.

Version 2: Currently used by Statistics Canada, CIHI, and provided on APHEO website.

Table 4: Age groups for standardizing data from Canadian Community Health Survey

Age (years)	Total
10-11	777,691
12-14	1,135,424
10-14	1,913,115
15-17	1,149,377
18-19	776,713
15-19	1,926,090

Sex-specific age-standardized rates

Regardless of the method of calculation, comparisons of adjusted rates will be valid only if they are derived from the same standard population. For example, if one wants to compare age-adjusted rates for ischemic heart disease for males and females, then both the male and female rates must be standardized to the total (combined male and female) standard population. If the female rates were standardized to the female standard population and the male rates standardized with the male standard population, then the resulting standardized rates could not be compared across the male and female groups because the standard populations of each group are different.

The population distribution of males (by age) *is* different from the population distribution of females for the 1991 Canadian Population. Up to the age of 59, males outnumber females in each age group. After age 60, the reverse is true. By generating a single summary standardized rate, these sex-related differences cannot be analyzed. To avoid this, it may be appealing to generate **sex-specific age-standardized rates**: in other words, male or female rates standardized to the 1991 Canadian male or female standard population, respectively. Sex-specific age-standardized rates are useful when conducting analyses on conditions which affect one sex either exclusively or more dramatically than the other or when conducting analyses on one sex only. These sex-specific adjusted rates are more appropriate for examining trends within male or female populations, but cannot be used for cross-gender comparisons because these rates will have been calculated using different standard populations.

As with all standardized rates, if sex-specific age-standardized rates are being presented, one should state explicitly which standard population was used. Figure 4 shows ASMRs for Ontario males and females for ischemic heart disease mortality calculated using either the total population or the sex-specific population as the standard. It illustrates the difference between rates that are standardized to the male- or female-only standard population versus those standardized to the total population. Standardizing to the male-only standard population produces rates that are lower than rates standardized to the total population. This is because the male standard population gives more weight to younger years and thus the adjusted rate is weighted down (since most heart disease events occur in older years). The opposite is true for rates standardized to the female standard population. Here the adjusted rates are higher when the female population is used (as opposed to the total population). The female population distribution gives more weight to events that happen in later years and this, in combination with a higher incidence of ischemic heart disease in later years, results in a higher adjusted rate.

Figure 4: Sex-specific age-standardized rates versus age-standardized rates (ischemic heart disease mortality for Ontario)

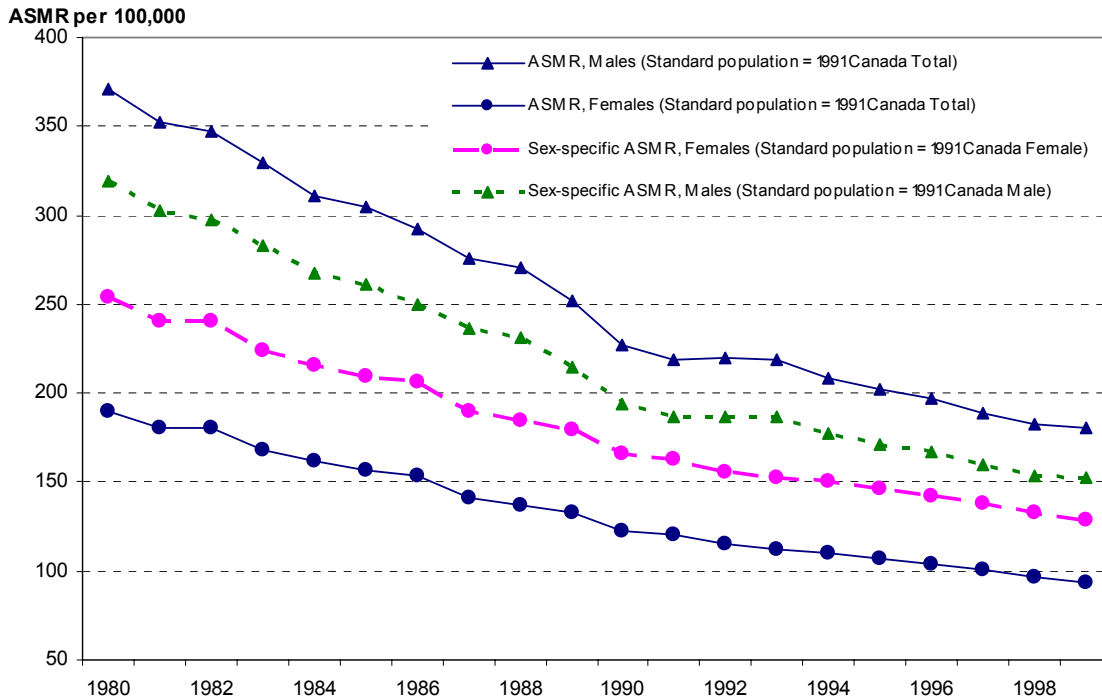


Figure 4 was created using data from the Public Health Agency of Canada's 'Cardiovascular Disease Surveillance Ontario' website (PHAC, 2008) which allows users to generate both ASMRs and sex-specific ASMRs. Within Figure 4, it is appropriate to compare the two solid lines (which show rates that have been adjusted to same population standard) but inappropriate to compare the sex-specific ASMRs (shown by dashed lines) with each other.

Age/sex standardization

Whereas age-standardization adjusts for underlying differences in the age distribution of the combined male-female population, age/sex-standardized rates adjust for differences in the population distribution by both age and sex simultaneously. **Age/sex-standardized rates are NOT the same as sex-specific age-adjusted rates discussed in the previous section.**

Like age, sex has a powerful influence on disease rates. Males and females have markedly different incidence, prevalence, and mortality rates for certain diseases and males have a shorter life expectancy than females. Therefore, in order to fully account for these differences, researchers may want to adjust for both age and sex when making comparisons for some conditions. Atlas reports from the Institute from Clinical Evaluation Sciences (ICES) often present rates that are age/sex standardized (Hux & Tang, 2003; Perruccio, Badley & Guan, 2004).

The calculation for age/sex adjustment differs from age-standardization in that the individual age-specific rates are stratified by sex and are applied to the standard population stratified by sex. A sample calculation is provided in Table 4.

The requirements for the calculation of age/sex standardized rates are:

- Study population by age and sex
- Standard population by age and sex
- Number of events for males and females in the study population

Formula

$e_{i(f)}$ is the number of events for females in age group i

$e_{i(m)}$ is the number of events for males in age group i

$p_{i(f)}$ is the number of females in age group i the study population

$p_{i(m)}$ is the number of males in age group i the study population

$P_{i(f)}$ is the number of females in age group i in the Standard population

$P_{i(m)}$ is the number of males in age group i in the Standard population

For each age stratum the expected number of events is the sum of the expected number of events for males plus the expected number of events for females in that stratum.

<p>Age-specific expected events</p>	$= E_i = \left(\frac{e_{i(m)}}{p_{i(m)}} * P_{i(m)} \right) + \left(\frac{e_{i(f)}}{p_{i(f)}} * P_{i(f)} \right)$
<p>The age/sex Standardized Rate (per 100 000) is the sum of all expected events divided by the total standard population</p>	$= \frac{\sum E_i}{\sum P_i} * 100,000$

Table 4: Direct standardization – Age/sex-adjusted rates (Method I)

Age groups	Study Population				Standard Population		Expected events $E_i = [e_{i(m)} / p_{i(m)} * P_{i(m)}] + [e_{i(f)} / p_{i(f)} * P_{i(f)}]$
	Events		Population		1991 Canadian Population		
	male	female	male	female	male	female	
	$e_{i(m)}$	$e_{i(f)}$	$P_{i(m)}$	$P_{i(f)}$	$P_{i(m)}$	$P_{i(f)}$	
<1 year	2	5	75,676	72,111	206,370	195,361	19.00
1-4	17	13	311,955	296,313	793,902	757,536	76.50
5-9	12	13	390,096	370,243	998,205	954,705	64.23
10-14	14	9	379,922	360,157	980,454	932,534	59.43
15 - 19	17	10	371,156	350,240	985,072	940,854	71.98
20 - 24	32	15	378,228	368,943	1,067,654	1,041,341	132.67
25 - 29	32	34	412,042	414,384	1,282,185	1,246,500	201.85
30 - 34	60	62	500,645	494,192	1,312,036	1,285,944	318.57
35 - 39	122	142	484,808	488,431	1,173,504	1,171,180	635.80
40 - 44	174	269	425,652	439,665	1,077,008	1,061,763	1089.88
45 - 49	307	424	391,670	398,599	844,091	830,034	1544.55
50 - 54	494	528	301,936	306,702	673,195	666,661	2249.10
55 - 59	787	736	247,139	254,079	618,181	620,200	3765.12
60 - 64	1,252	971	225,081	234,284	578,610	611,562	5753.13
65 - 69	1,799	1,309	205,114	226,109	497,864	586,692	7763.13
70 - 74	2,161	1,705	164,342	209,904	364,284	469,730	8605.62
75 - 79	1,813	1,532	105,385	150,369	255,603	366,627	8132.58
80 - 84	1,455	1,264	62,541	104,954	142,234	240,076	6200.36
85 - 89	777	915	26,909	58,676	62,193	130,221	3826.51
90 +	347	559	9,976	32,248	25,490	69,976	2099.62
Total	11,674	10,515	5,470,273	5,630,603	13,938,135	14,179,497	52609.65
Adjusted rate = $\sum E_i / \sum P_i = 52609.65 / 28,117,632 * 100000 =$							187.11

Method II (using population weights) is shown in Table 5. In this case, the weight (W_i) is calculated as the proportion of the total population in each age-sex specific stratum.

$$\text{Weight (males)} = W_{i(m)} = P_{i(m)} / \sum P_i$$

$$\text{Weight (females)} = W_{i(f)} = P_{i(f)} / \sum P_i$$

As seen with the sample calculations for age-adjusted rates, these two methods produce identical results. The resulting age/sex adjusted rate is 187.11.

As already mentioned, the main advantage of age/sex-adjusted rates is that it allows one to simultaneously adjust for two factors. The main disadvantage of this approach is that, with so many strata, a large number of events/deaths are required so that data are not spread too thin. This approach produces rates that cannot be compared with rates that have been age-adjusted (i.e. where the standard population=total population).

Table 5: Direct standardization – Age/sex-adjusted rates (Method II)

Age Groups	Study Population				Standard Population (1991 Canada)				Crude Rates		Expected deaths $E_i = [r_{i(m)} * W_{i(m)}] + [r_{i(f)} * W_{i(f)}]$
	Events		Population		Population numbers		Stratum specific weights		rate male	rate female	
	male	female	male	female	male	female	Weight male	Weight female			
	$e_{i(m)}$	$e_{i(f)}$	$p_{i(m)}$	$p_{i(f)}$	$P_{i(m)}$	$P_{i(f)}$	$= P_{i(m)} / \sum P_i$	$= P_{i(f)} / \sum P_i$	$r_{i(m)}$ $= e_{i(m)} / p_{i(m)}$	$r_{i(f)}$ $= e_{i(f)} / p_{i(f)}$	
<1 year	2	5	75,676	72,111	206,370	195,361	0.00734	0.006948	0.000026	0.000069	0.0000007
1-4	17	13	311,955	296,313	793,902	757,536	0.028235	0.026942	0.000054	0.000044	0.0000027
5-9	12	13	390,096	370,243	998,205	954,705	0.035501	0.033954	0.000031	0.000035	0.0000023
10-14	14	9	379,922	360,157	980,454	932,534	0.03487	0.033165	0.000037	0.000025	0.0000021
15 – 19	17	10	371,156	350,240	985,072	940,854	0.035034	0.033461	0.000046	0.000029	0.0000026
20 – 24	32	15	378,228	368,943	1,067,654	1,041,341	0.037971	0.037035	0.000085	0.000041	0.0000047
25 – 29	32	34	412,042	414,384	1,282,185	1,246,500	0.045601	0.044332	0.000078	0.000082	0.0000072
30 – 34	60	62	500,645	494,192	1,312,036	1,285,944	0.046662	0.045734	0.000120	0.000125	0.0000113
35 – 39	122	142	484,808	488,431	1,173,504	1,171,180	0.041736	0.041653	0.000252	0.000291	0.0000226
40 – 44	174	269	425,652	439,665	1,077,008	1,061,763	0.038304	0.037761	0.000409	0.000612	0.0000388
45 – 49	307	424	391,670	398,599	844,091	830,034	0.03002	0.02952	0.000784	0.001064	0.0000549
50 – 54	494	528	301,936	306,702	673,195	666,661	0.023942	0.02371	0.001636	0.001722	0.0000800
55 – 59	787	736	247,139	254,079	618,181	620,200	0.021986	0.022057	0.003184	0.002897	0.0001339
60 – 64	1,252	971	225,081	234,284	578,610	611,562	0.020578	0.02175	0.005562	0.004145	0.0002046
65 – 69	1,799	1,309	205,114	226,109	497,864	586,692	0.017706	0.020866	0.008771	0.005789	0.0002761
70 – 74	2,161	1,705	164,342	209,904	364,284	469,730	0.012956	0.016706	0.013149	0.008123	0.0003061
75 – 79	1,813	1,532	105,385	150,369	255,603	366,627	0.00909	0.013039	0.017204	0.010188	0.0002892
80 – 84	1,455	1,264	62,541	104,954	142,234	240,076	0.005059	0.008538	0.023265	0.012043	0.0002205
85 – 89	777	915	26,909	58,676	62,193	130,221	0.002212	0.004631	0.028875	0.015594	0.0001361
90 +	347	559	9,976	32,248	25,490	69,976	0.000907	0.002489	0.034783	0.017334	0.0000747
Total	11,674	10,515	5,470,273	5,630,603	13,938,135	14,179,497	0.495708	0.504292	0.00213	0.001867	0.0018711
Rate per 100,000									213.41	186.75	187.11

How many age categories?

Five-year or ten-year age groups are most commonly employed because of ease of use, but age-standardization can be performed over a limited age range. Most text books caution that using broad age groups will produce a less precise adjustment and affect the comparability of age-specific death rates to other populations. A broad age group (e.g., 15-44) will not be sensitive to any changes in age-specific rates within this category. With the exception of the U.S. NCHS and National Cancer Institute (NCI), the documents reviewed for this paper provided no specific advice on which age groups or how many age groups to use. The U.S. NCHS recommend the use of 11 age groups for standardizing mortality statistics. These are: <1, 1-4, 5-14, 15-24, 25-34, 35-44, 45-54, 55-64, 65-74, 75-85, 85+ whereas the NCI uses nineteen age groups (5 year groups with <1 years of age separated). Note that the U.S. NCHS breakdown of age groups does not correspond directly to any of the pre-defined age groups available in Ontario's Provincial Health Planning Database (PHPDB), but can easily be constructed from age group 2 ('Morbidity and Mortality' 13 age groups).

Table 6: Age categories

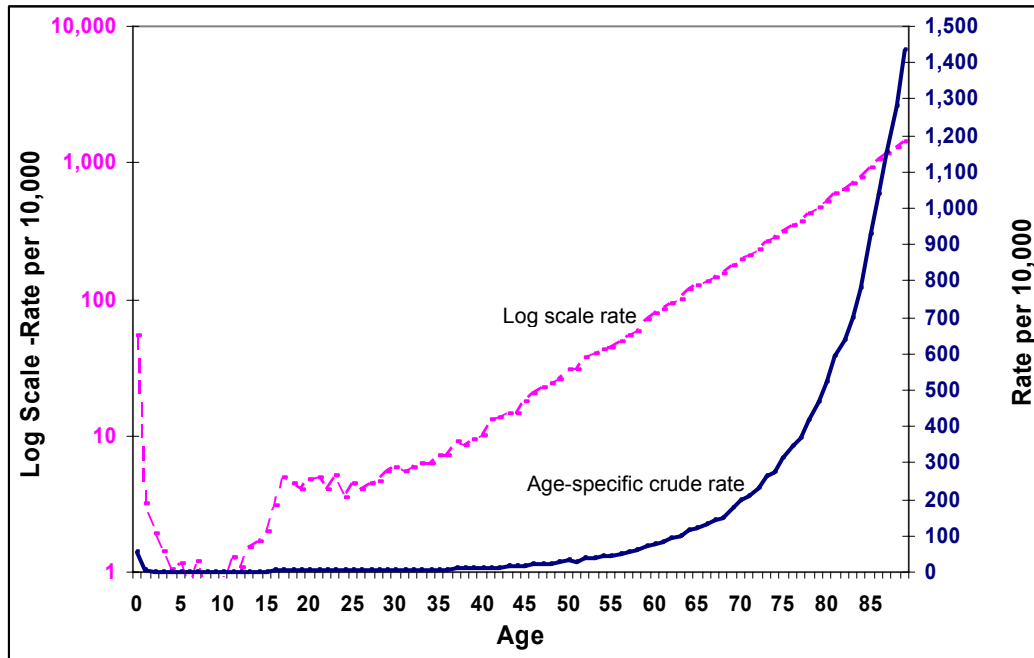
U.S. NCI (19 age groups)	M & M¹ (13 age groups)	U.S. NCHS (11 age groups)
<1	<1	<1
1 - 4	1 - 4	1 - 4
5 - 9	5 - 9	5 - 14
10 - 14	10 - 14	
15 - 19	15 - 19	15 - 24
20 - 24	20 - 24	
25 - 29	25 - 34	25 - 34
30 - 34		
35 - 39	35 - 44	35 - 44
40 - 44		
45 - 49	45 - 54	45 - 54
50 - 54		
55 - 59	55 - 64	55 - 64
60 - 64		
65 - 69	65 - 74	65 - 74
70 - 74		
75 - 79	75 - 84	75 - 84
80 - 84		
85+	85+	85+

1. 'Morbidity and Mortality' age group type available in the PHPDB.

Figure 5 presents all cause age-specific mortality rates (by single year of age) for Ontario in 2003. The solid line shows that, between the ages of 1-45, mortality rates are fairly low. The mortality experience of the <1 age group is notably higher. After the age of 45, mortality rates increase steadily with age. The dashed line shows these same age-specific mortality rates on a log-scale makes it easier to see the variation in the younger

age groups. For example, mortality rates in the 5-13 ages are similar, as are those for ages 20 through 34 which show little variability.

Figure 5: Age-specific all-cause mortality rates per 10,000 population, Ontario 2003

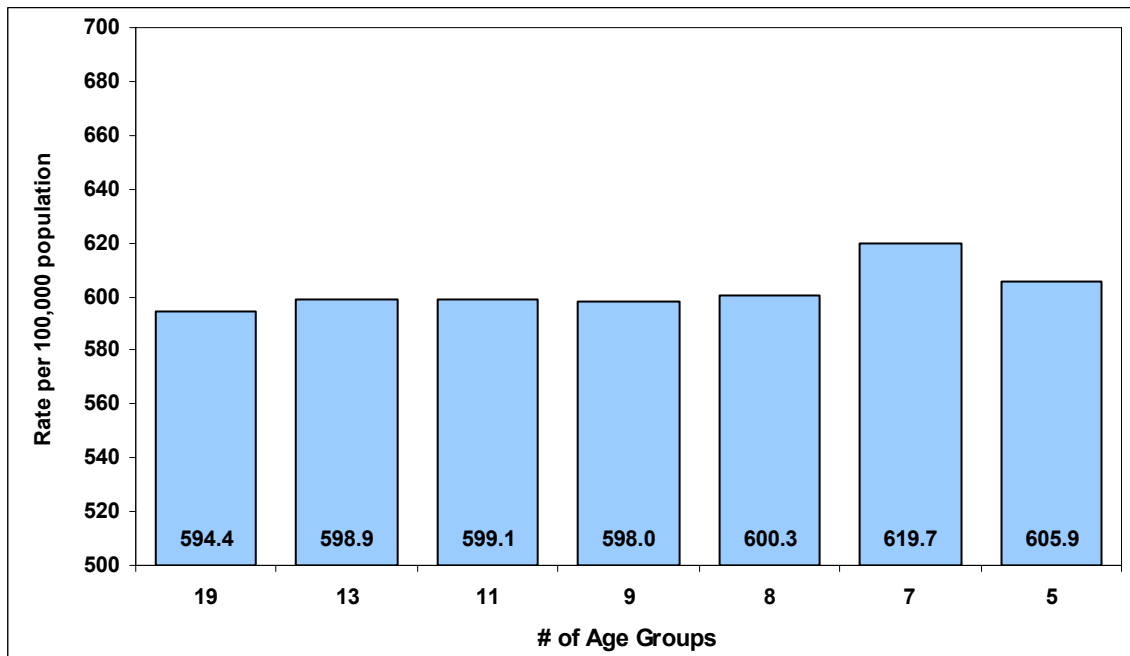


In some instances the age groups used will be dictated by the availability of data. Klein & Schoenborn (2001) note that in choosing the number of age groups, two competing interests must be addressed:

- 1) a greater number of age groups means better control of the effect of any differences in the age distribution among the groups or time periods being compared but,
- 2) with more age groups the data become sparse and there may not be enough events to populate all the strata, resulting in standardized rates with large variances.

The grouping together of age groups with very different rates will result in a single rate that is insensitive to any changes in the age-specific rates within the group. The age groups chosen for standardization should take this into account. Furthermore, two people using identical data (i.e., same events in study population and same standard population) can end up producing different age-standardized rates if they have used different age groupings in the adjustment calculations. Figure 6 illustrates this.

Figure 6: Age standardized rates calculated using different age groupings



Rates shown are for all cause mortality, Oxford County PHU (2001)

Small numbers of events

Most text books warn that age-adjusted rates based on a small number of events will be unstable and exhibit a large amount of random variation. When the number of cases is small it can be difficult to distinguish true changes from random fluctuation. The NCHS (Curtin & Klein, 1995) suggests that there be at least 20-25 deaths over all age groups before even attempting to standardize using the direct method. The Relative Standard Error (RSE) relates the stability of estimates to the number of cases.

The RSE is a measure of an estimate's reliability (similar to a coefficient of variation). Estimates with a large RSE are considered unreliable. The RSE is a function of the number of cases – the variation is inversely related to the number of events used in calculating the rate. For crude and adjusted rates the RSE is obtained by dividing the standard error of the estimate by the estimate itself and multiplying by 100 to express it as a percent (New York State Dept of Health, 1999).

$$\mathbf{RSE} = \frac{SE}{rate} * 100 = \frac{1}{\sqrt{cases}} * 100$$

Where

$$\mathbf{SE} = \frac{rate}{\sqrt{cases}}$$

An RSE of 50% means that the standard error is half the size of the estimate. In the U.S. the NCHS has started reporting the RSE along with estimates and they now regularly suppress age-adjusted rates with an RSE greater than 23% (fewer than 20 events) (New York State Dept. of Health, 2008; Klein, Proctor, Boudreault & Turczyn, 2002). In some publications these are marked with the notation 'DSU' (Data Statistically Unreliable).

Where there are fewer than 20 events, data should be grouped by combining multiple years or data or geographies. Alternatively, an indirectly standardized rate can be calculated.

Cells with zero counts

A problem occurs when there are small numbers or zero events in one or more strata of the study population resulting in a stratum-specific rate of zero. Zero cell counts may occur when the total number of events in the study population is small (i.e., cells are very sparsely populated and some cells have no events), or when dealing with events that occur rarely in some age groups (e.g., lung cancer in younger age groups). As discussed in the previous section, having a small number of events produces unstable rates. Similarly, having no events in a strata can produce misleading results, since cells with zero events will have no variance associated with them, resulting in an underestimate the true variance. Some options for treating cells with a zero count include:

- combine multiple years or geographies
- collapse strata to avoid zero values, thereby giving stability to the direct standardization
- enter a small value in place of the zero
- leave the zero values as-is

Some preliminary sample calculations using Ontario mortality data (not shown) revealed that three of these approaches (leave zero count cells as is, add a small value such as 0.1 and collapse age groups) resulted in slightly different standardized rates and confidence intervals. The difference was more notable when the overall number of events in the study population was small. Furthermore, when the overall number of events is small, and where there is more than one strata with a zero count, substituting a value such as 0.5 can distort the overall SRATE calculation. Collapsing strata to avoid cells with a zero count gives stability to the direct standardization calculations but requires reviewing each calculation. This can be time consuming, especially when large numbers of age-standardized rates are being computed. Also, the SRATE can differ substantially depending on how the age groups are collapsed together (Chan, Feinstein, Jekel & Wells, 1988).

Standardizing rates for sub-set of the population

Sometimes an analysis will focus on a subset of the population (e.g., a child or seniors health report). To produce standardized rates, the weights will have to be recalculated to

sum up to 1.0. The example below shows the calculation of an age-adjusted rate for children and young adults (0-24) using the 'population weights' methods.

Table 6: Age standardized rate for population sub-set age 0-24

Age Groups	Study Population		Standard Population (Canada 1991)	Weight	Crude Rate	Expected deaths
	events	population		$W_i = (P_i) / \sum (P_i)$	$r_i = e_i / p_i$	$E_i = r_i * W_i$
<1 year	7	147,787	403,061	0.040899	0.0000474	0.00000194
1 - 4	30	608,268	1,550,285	0.157309	0.0000493	0.00000776
5 - 9	25	760,339	1,953,045	0.198177	0.0000329	0.00000652
10 - 14	23	740,079	1,913,115	0.194125	0.0000311	0.00000603
15 - 19	27	721,396	1,926,090	0.195442	0.0000374	0.00000731
20 - 24	47	747,171	2,109,452	0.214048	0.0000629	0.00001346
Total	159	3,725,040	9,855,048	1.0	.00004268	0.00004302
Rate per 100,000					4.2684	4.3024

Calculating variance estimates and confidence intervals

“There are a few in public health who believe that confidence intervals should not be used around estimates derived from 'population' statistics such as the death rate in a given population, because they believe there is no statistical uncertainty in such estimates. This belief is contrary to the statistical theory underlying confidence intervals, and the biological and random processes governing the occurrence of events such as deaths and illnesses.”

Washington State Department of Health, 2002

With vital events or administrative data the number of events should represent complete counts and these data are not subject to sampling error. However these data can be affected by errors in the registration process or due to incomplete registration. Furthermore, for the purposes of analytic work (such as examining trends over time or comparing across areas) the events that occur can be thought of as one of a series of possible results that could have arisen under the same circumstances (i.e., they are still subject to errors resulting from random fluctuations) (Curtin & Klein, 1995; Anderson & Rosenberg, 1998). If there is any uncertainty around the point estimate then confidence intervals should be used with the understanding that confidence intervals only account for random fluctuation and not bias (biases are systematic errors).

The variance for a standardized rate can be thought of as a weighted average of the variances for each of the age groups with the weights reflecting the square of the proportion of the standard population at each age. Vital events can be assumed to follow a binomial distribution but rarer events (fewer than 100) may be assumed to follow a Poisson distribution (Rosenberg et al., 1992).

The U.S. NCHS assumes a binomial variance for vital events (Curtin & Klein, 1995). Statistics Canada also uses this formula for calculating confidence intervals (CIs) in the

'Health Indicators' publication for indicators based on vital statistics. This same formula is sometimes referred to as the 'Spiegelman method' or the 'Lilienfeld formula'. It is also given by Armitage and Berry (1987). A disadvantage of this approach is that variance estimates based on the binomial distribution tend to underestimate the variance associated with the death rate.

Variance formula based on binomial

- p_i is the number of persons in age group i in the Study population
- r_i is the death rate in the Study population for the persons in age group i
- P_i is the number of persons in age group i in the standard population

The Variance for the SRATE is given by: $\sum \left(\frac{P_i}{\sum P_i} \right)^2 * \frac{r_i(1-r_i)}{p_i}$
And the 95% confidence interval is given by: $SRATE \pm 1.96 * \sqrt{\text{var}}$

When the number of events is small (e.g., <100) formulas based on a discrete distribution (e.g., chi square), or a variance formula based on a Poisson distribution (Curtin & Klein, 1995) are preferable. Calculating an exact Poisson confidence interval requires the use of a look-up table to obtain confidence limit factors. The approach is described by Wagg and Gutmanis (2003) and the Poisson tables with the confidence limit factors are provided in technical appendix from the US NCHS (1999). The Poisson based formula will provide a more conservative estimate of the variance of age-adjusted rates. Another approach that produces valid confidence intervals when the number of events is small is based on the 'Gamma' distribution (Fay & Feuer, 1997). A brief description of the method and a sample SAS code is available online (Washington State Dept. of Health, 2002).

An alternative, when dealing with small numbers of events, is to use a *Poisson approximation*. The Poisson approximation based formula is also referred to as the 'Chiang' formula.

Variance formula based on Poisson approximation

- d_i is the number of events in age group i the study population
- r_i is the death rate in the study population for the persons in age group i
- P_i is the number of persons in age group i in the standard population

The Variance for the SRATE is given by: $\sum \left(\frac{P_i}{\sum P_i} \right)^2 * \frac{r_i^2}{d_i}$
Note that this formula is sometimes written in this alternate format (where p_i is the study population in strata i), but they are algebraically identical: $\sum \left(\frac{P_i}{\sum P_i} \right)^2 * \frac{d_i}{p_i^2}$
As before, the 95% confidence interval is given by: $SRATE \pm 1.96 * \sqrt{\text{var}}$

The main advantage of the binomial and Poisson approximation formulas is that they are easy to use in spreadsheets whereas CIs based on the gamma or chi-square distribution will require the use of a statistical software package. The disadvantage is that when the number of events is small (fewer than 100), these formulae can result in a lower confidence which is less than 0 (a statistical impossibility when reporting mortality data). This can be dealt with by applying a log-transformation to the rates or clipping the results at a lower bound of 0. Anderson and Rosenberg (1998) state that variance estimates based on the binomial tend to underestimate the variance associated with mortality rates and the Poisson is conceptually and computationally just as simple to use.

Using confidence intervals to approximate a statistical test

Guidelines from the Washington State Department of Health (2002) provide sound advice on the use of confidence intervals for comparing age-standardized rates. They state that it is acceptable to use confidence intervals as a statistical test in a 'one sample' case (for instance where an adjusted rate for a study population is compared to a standard value) but not acceptable in a two sample case (to compare confidence intervals around adjusted rates for two neighbouring health units and conclude that the rates are or are not significantly different). This comparison may approximate a statistical test but is not equivalent to one because a proper statistical test for the difference between the two rates will need to take into account the pooled sample size of the two areas and will therefore produce a different result.

In reality however, comparisons of confidence intervals around age-adjusted rates serve as a quick, useful, conservative approximation of statistical significance. In general:

- ◆ if two confidence intervals DO NOT overlap, a proper statistical test will (also) indicate a statistically significant difference, but
- ◆ if two confidence intervals DO overlap (suggesting no difference), a proper statistical test in some instances may still show a statistically significant difference.

If multiple comparisons are being made, or when age-standardized rates are being computed for recurrent events (e.g., hospital separations), other variance formulae may need to be considered. Carriere and Roos (1994) describe an approach for variance estimation that is non-parametric and can be used with recurrent and non-recurrent events. Access to person-based data is required to apply the method. A subsequent paper builds on their approach and describes a method for calculating variance estimates that is appropriate when comparisons are being made across several areas, does not require person-based data, and is 'approximately correct' when used for recurrent events if the repeated events are rare (i.e., less than 100 per 100,000 population) (Carriere & Roos, 1997).

When multiple comparisons are being made, 5% of the comparisons may be statistically significantly different because of chance alone. Wagg and Gutmanis (2001) explain that this latter approach, when used for making simultaneous comparisons across several adjusted-rates, "adjusts the width of the confidence intervals in order to maintain an

overall specified probability of Type 1 error....allow[ing] one to make simultaneous comparisons between rates while maintaining an overall 5% probability of finding a difference due to chance alone”.

When not to use standardized rates

Curtin and Klein (1995) and Choi et al. (1999) show that when *stratum-specific rates are constant over time*, then the comparison of standardized rates over that same time period is valid. Standardization is not appropriate when age-specific rates in the populations being compared do not have a consistent relationship (i.e., age is essentially acting as an effect modifier). Similarly, if two populations being compared have different patterns of age-specific mortality/disease, the summary adjusted rate may suggest they have similar mortality/disease rates. In these cases, the standardized rate will conceal important age-specific trends or differences and the analyst should consider presenting age-specific rates.

III. INDIRECT STANDARDIZATION

Indirect standardization is typically used in two circumstances; *when stratum-specific rates are unavailable for the population of interest* (i.e., the age-specific distribution of events in the study population is unknown) *and/or when there are a small number of events in the study population* (resulting in unstable age-specific rates). In the former situation, direct standardization is not possible, and in the latter situation indirect standardization provides a more precise estimate since it uses more 'stable' rates from a larger population.

What is it?

The indirect method is a mirror image of direct standardization. With the indirect method age-specific rates are calculated for the standard population and applied to the study population to yield the expected deaths. Once these rates are obtained, the observed number of events in the study population is divided by the expected number of events to produce the **standardized mortality/morbidity ratio (SMR)**. The standardized ratio allows one to see the magnitude of the difference between what an area actually experienced, and what it would have experienced if it had the same age distribution as the standard population.

As with directly standardized rates, the SMR is a *hypothetical value and is used for comparison purposes only*. The main disadvantage of indirectly standardized ratios is that they cannot be used for multiple comparisons; the SMR for PHU A cannot be compared directly to the SMR for PHU B. An SMR can only be used to compare each area to a single standard.

How to calculate an indirectly age-adjusted rate

The requirements for this calculation are:

- Age-specific rates in a standard population
- Size of the study population in each age group
- Observed number of events (total) in the study population

Formula

e is the total observed number of events in the study population

p_i is the number of persons in age group *i* in the study population

R_i is the event rate in the standard population for the persons in age group *i*

For each age category, the age-specific crude rate in the standard population is multiplied by the population in the study population to obtain the expected number of events for that age category.

$$\text{The SMR} = \frac{\sum e}{\sum p_i * R_i}$$

Table 7: Indirect standardization - SMRs

Age Groups	Standard Population (Ontario, 2001)			Study Population, PHU A, 2001		
	Events	Population	Rate	Population	Events, Observed	Events, Expected
	E_i	P_i	$R_i = E_i / P_i$	p_i	e	$F_i = R_i * p_i$
<1 year	7	147,787	0.00004737	951	-	0.045
1-4	30	608,268	0.00004932	4,433	-	0.219
5-9	25	760,339	0.00003288	6,141	-	0.202
10-14	23	740,079	0.00003108	6,369	-	0.198
15 – 19	27	721,396	0.00003743	6,241	-	0.234
20 – 24	47	747,171	0.00006290	5,088	-	0.320
25 – 29	66	826,426	0.00007986	5,128	-	0.410
30 – 34	122	994,837	0.00012263	5,705	-	0.700
35 – 39	264	973,239	0.00027126	6,934	-	1.881
40 – 44	443	865,317	0.00051195	6,776	-	3.469
45 – 49	731	790,269	0.00092500	5,940	-	5.495
50 – 54	1,022	608,638	0.00167916	5,541	-	9.304
55 – 59	1,523	501,218	0.00303860	4,526	-	13.753
60 – 64	2,223	459,365	0.00483929	3,666	-	17.741
65 – 69	3,108	431,223	0.00720741	3,009	-	21.687
70 – 74	3,866	374,246	0.01033010	2,837	-	29.307
75 – 79	3,345	255,754	0.01307897	2,431	-	31.795
80 – 84	2,719	167,495	0.01623332	1,658	-	26.915
85 – 89	1,692	85,585	0.01976982	983	-	19.434
90 +	906	42,224	0.02145699	381	-	8.175
Sum	22,189	11,100,876	0.00199885	84,738	203	191
SMR = Observed events / Expected events = 203 / 191						1.06

- ◆ An SMR of 1.0 indicates that study population had the same mortality/disease risk as the standard population.
- ◆ An SMR which is greater than 1.0 means that the study population had an increased mortality/disease risk since the number of events observed in the study population was higher than would be expected on the basis of the rates observed for the standard population.
- ◆ If the ratio is less than 1.0, the study population had a lower risk than the standard population; fewer events than expected were observed.
- ◆ The SMR for the standard population is always 1.0.

As with direct standardization, an age and sex adjusted SMR can be produced if the age/sex specific rates for the standard and the age/sex population distribution for the study population are known. As a rule of thumb, one state department of health suggests that SMRs should not be calculated if there are fewer than 10 events (Commonwealth of Pennsylvania, 2001).

Choosing a standard population

For indirect standardization the standard population for calculating an SMR should be chosen depending on the study population being examined. It is best to use a standard that is similar to the years of data available for the study population. For example, to calculate a SMR for a public health unit area in 1997, the standard population could be the 1997 deaths and population of Ontario. If the study population includes three years of

data (e.g., cancer deaths for 2000-2002) an appropriate standard would be Ontario cancer 2001 (age-specific cancer deaths and population for Ontario 2001).

Confidence intervals for SMRs

An exact confidence interval, based on Poisson distribution, can be calculated for SMRs using a formula that relates the chi-square and Poisson distributions. The formula is given in Breslow and Day (1989). However, Buchan (2004) found that translating the equation into function expressions in Microsoft Excel spreadsheets resulted in calculation errors for a substantial number of typical data.

An alternative version, suggested by Byar and presented by Breslow and Day (1989) presents an extremely accurate approximation of the exact Poisson test. The formula is as follows:

$M_L = \left\{ 1 - \frac{1}{9d} - \frac{Z_{\alpha/2}}{3\sqrt{d}} \right\}^3 * 100$
$M_U = \frac{d+1}{E} * \left\{ 1 - \frac{1}{9(d+1)} + \frac{Z_{\alpha/2}}{3\sqrt{(d+1)}} \right\}^3 * 100$

Where $Z_{\alpha/2}$ refers to the 100(1- $\alpha/2$) percentile of the standard normal distribution. For 95% confidence limits $Z_{\alpha/2} = 1.96$.

The lower and upper confidence limits of the SMR are then calculated as:

Upper limit = $SMR_U = M_U * SMR$
 Lower limit = $SMR_L = M_L * SMR$

Guidelines from the Washington State Dept. of Health (2002) suggest that the above formula should only be used when there are large number of events (i.e., greater than 100 observed cases in the study population). However, Breslow and Day (1989) show that even with a relatively small number of events (25 observed events in the study population), Byar's approximation produces results that are the same as the exact limits to the third decimal place.

Armitage and Berry (1987) provide a simple formula for calculating confidence intervals for SMRs. This formula has been used in the past by the Ontario Ministry of Health, and it is more conservative than the Byar approximation when there are small numbers.

$\text{SMR Variance} = \frac{\sum d}{(\sum R_i * p_i)^2} = \frac{\sum d}{(\sum E_i)^2}$
<p>The 95% confidence interval is then given by: $SMR \pm 1.96 * \sqrt{\text{var}}$</p>

SUMMARY

The examination of overall crude and age-specific rates should always precede any calculation of standardized rates. They provide a 'true' picture of disease or mortality events. To facilitate comparisons over time and place standardized rates, which can control for differences in population structure, are a useful summary measure.

Both direct and indirect methods of standardization have their own merits and are appropriate to use depending on the situation. Indirect standardization is more stable when studying rates based on small numbers. The ratio of observed to expected cases is also intuitively easy to understand. However, because the age-distribution of the study population is used to calculate SMRs it is incorrect to compare indirectly adjusted rates for different areas. The same age-specific rates (from a standard) applied to study populations with different age distributions will result in very different SMRs.

Direct standardization preserves the consistency between different study populations; since many study populations can be adjusted to the same standard, the resulting rates can be compared against each other. This is important when many study populations are being compared across place or time. Careful consideration should be given to the choice of the standard population; the use of a common standard will help maintain comparability of rates. Other factors, such as the number of age strata used and the treatment of null cells can also affect the rate that is obtained.

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