WP 5.4
16 October 2013

UNITED NATIONS STATISTICAL COMMISSION and ECONOMIC COMMISSION FOR EUROPE

STATISTICAL OFFICE OF THE EUROPEAN UNION (EUROSTAT)

Joint Eurostat/UNECE Work Session on Demographic Projections
organised in cooperation with Istat
(29-31 October 2013, Rome, Italy)

Item 5 – Assumptions on Future Mortality

Changing mortality trends by age and sex are challenges for assumptions on future mortality

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Changing mortality trends by age and sex are challenges for assumptions on future mortality

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Paper presented at the Joint Eurostat/UNECE-meeting in Rome 29–30 October 2013.

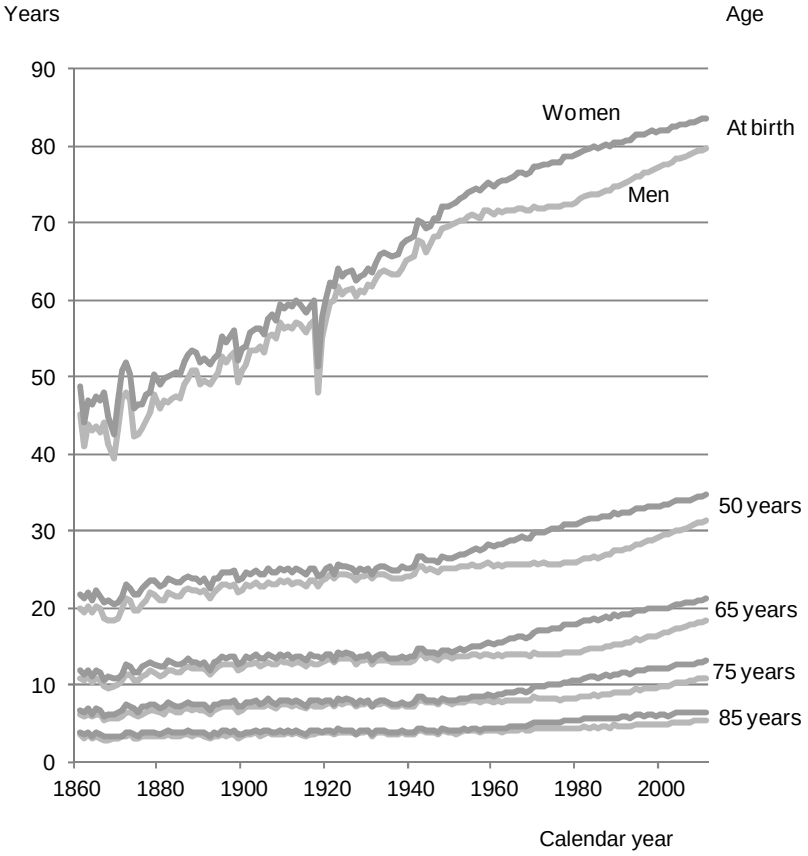
Introduction

This paper summarizes some of the analyses that was performed regarding mortality prior to the population projection for Sweden in 2012 (Statistics Sweden, 2012).

Long term trends for life expectancy in Sweden

Life expectancy in Sweden has increased by about 35 years during the period 1861–2011, from 49 to nearly 84 years for women and from 45 to nearly 80 years for men, as shown in figure 1. The length of life expectancy has increased on average by about 2.5 years per decade since 1900. However, the increase was larger up until the mid-20th century than it was afterwards. The changes are not unique for Sweden and has been observed in a number of other countries (Ahlbom, Drehfahl, & Lundström, 2010).

Figure 1. Sex-specific life expectancy at birth, 50, 65, 75 and 85 years 1861–2011.



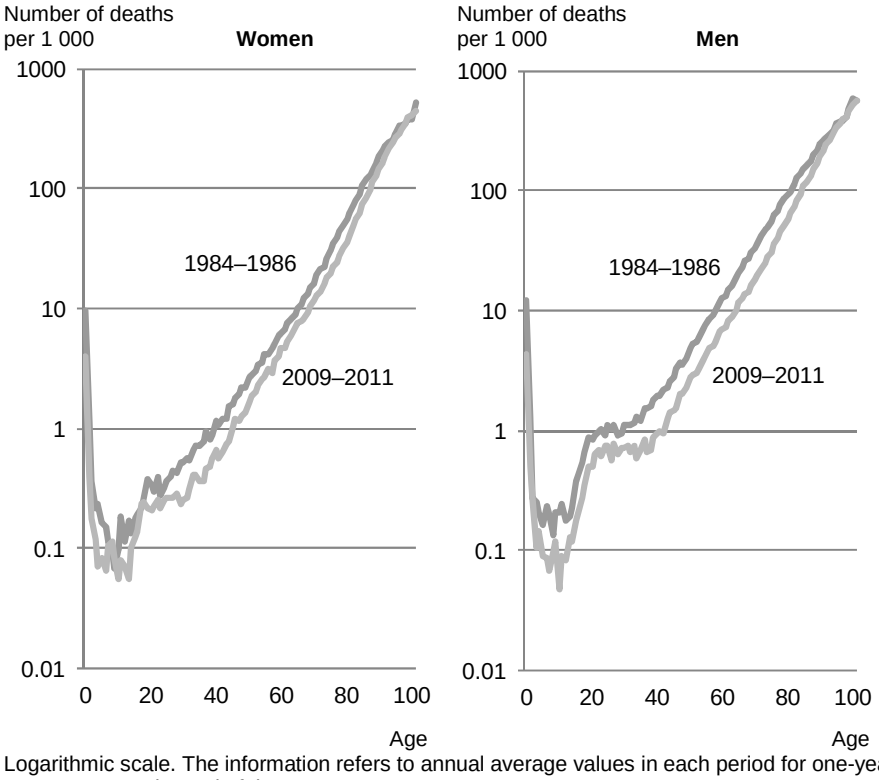
Women have had a more unbroken increase of life expectancy than men. Life expectancy at age 65 increased for instance about as much for women and men during the entire period 1861–1950. From the 1950s onwards, life expectancy of women from age 65 began to increase at a faster rate than earlier. The same clear increase from age 65 for men was not observed until 1980s, that is, three decades later than for women.

Since the end of the 1970s life expectancy has increased more for men than for women. However, this does not mean that the life expectancy for women has stagnated in the same way as it did for men during the period 1950–1980. Since the 1950s life expectancy for women has increased by between 0.6 and 1.2 years per five-year period. Between the most recent two five-year periods, 2001–2005 to 2006–2010, the increase for women was 0.8 years. This was near the average increase of 0.9 years per five-year period for the entire period 1951–2010 (Statistics Sweden, 2011). The corresponding increase on average for men was 0.8 years per five-year period.

Mortality change in recent decades

As seen in Figure 2, mortality have declined for women and men for all ages during recent decades. Changes have occurred in the age pattern of mortality for certain ages, such as for men where the mortality rates are in principle the same for an age interval of about 20–40 years of age. Previously mortality was clearly higher among men in their 40s than men in their 20s.

Figure 2. Mortality rate by sex and age for the periods 1984–1986 and 2009–2011



Logarithmic scale. The information refers to annual average values in each period for one-year age groups. Age at the end of the year.

When projecting future mortality it is important to consider the changing ages at death. Assumptions of future mortality is most important for those ages where the largest number of deaths occur. In the period 2006–2010 only 1.5 percent of

the deaths among women, and 2.6 percent of the deaths among men, occurred in the age interval 0–44 years.

Analysis of the mortality trends by age and sex

There are a number of different ways to forecast mortality. Extrapolative methods, such as the one suggested by Lee and Carter (LC), has been widely used in recent years (Lee & Carter, 1992). Evaluations of the mortality development during the 20th century suggest that the LC-model satisfactorily predicts future gains in life expectancy. Key assumptions of the LC-model are constant age dependency to the predicted general mortality change. The LC-model is therefore conditioned upon rather smooth mortality changes and relatively homogenous time trends across age groups.

From 2003 onwards Statistics Sweden has partly used outcomes from the LC-model in the population projections. In the forecasts of 2003 (Statistics Sweden, 2003), 2006 (Statistics Sweden, 2006) and 2009 (Statistics Sweden, 2009a) however, the results of the estimations of the model have not been allowed to be used during the entire forecast period.

Problems and questions

A critical viewpoint of the LC-model, as well as other extrapolative methods, is that if a break in the trend occurs over time, the result of the model could be misleading for the ages that have had such a break in the trend. It is particularly important to consider any changes in the speed of the mortality changes in different ages. Such changes have occurred since the beginning of the 20th century and mortality reduction has been about the same, about 2 percent per year, for an extended age interval, about 15–80 years, in several countries (Lee & Miller, 2000). If for instance mortality decreases more among older people than among younger people at the end of a base period, the mortality decline of the future can be underestimated. This may be a reason that mortality forecasts based on the Lee-Carter model with long base periods tend to somewhat underestimate the mortality decline in the long term. A smaller underestimation of the mortality decline has been evaluated (Lee & Miller, 2000).

When men and women have had different trends in mortality in recent years, it has been observed that the model has led to increased sex differences in mortality and not decreases (Lee, 2000). Such a result would also be the effect of using a long historical base period for Sweden. The last 25 years has been

proposed as a suitably long base period to capture the different trends of a mortality decline for women and men (Lundström & Qvist, 2004).

Data and method

In the analyses in relation to the population forecast for Sweden in 2012, the development of Swedish mortality in the period 1975–2011 was analyzed by means of various sex-specific LC-models using base-periods of varying length, but also compared with simple trend calculations separate by age and sex (Statistics Sweden 2012).

The parameters of the Lee-Carter model are estimated with an original matrix of mortality rates per age, sex and time. The model uses a logarithm of mortality rates per sex, age and time. The following expression describes the model according to Lee and Carter:

$$\ln(m_{x,t}) = a_x + b_x k_t + \varepsilon_{x,t} ,$$

a_x = age-specific average level of mortality

b_x = age-specific weight for trends over time

k_t = trends over time in the mortality rate

$\varepsilon_{x,t}$ = random terms

The effects of age and time, b_x and k_t, are estimated using ”singular value decomposition” (SVD) for men and women.

To compare the different results of the Lee-Carter models, a simplified method was also used to estimate mortality trends at different ages. This if often called trend estimation with the empirical intensity of mortality (Olsén, J, 2005). The mortality rate for an age category is then compared with a starting year *i* and a finishing year *j*. The average annual change c_x, was calculated as follows:

$$c_x = \left(\frac{\mu_x^j}{\mu_x^i} \right)^{1/(j-i)} - 1$$

The annual average values are used in the calculation for a period of three years to avoid the random error that can easy be the result of only using one starting and one finishing year. The notation *i* and *j* in the above expression thus stand for an annual average for a short period. The difference between *j* and *i* is the number of years between the starting period and the finishing period. The rate of

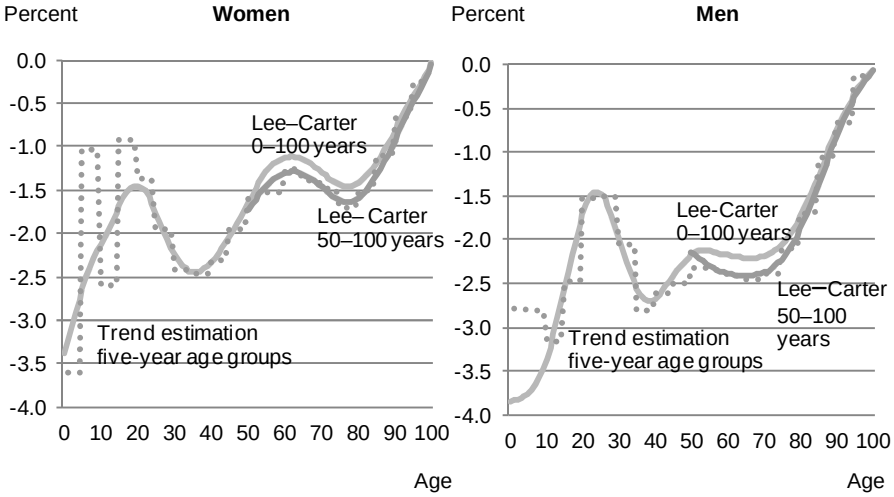
change c_x gives the relative change in mortality per year for each age category for 1–99 years. The age categories that are used are 1–4 years and five-year age groups starting with 5–9 years up until 95–99 years.

Results

The assumptions about future changes in mortality are mainly based on mortality trends from the 1970s up until 2011. The period that comprises the main observation period (base period) is 1985–2011, that is, about that which was previously proposed as a suitably long period to estimate the partially different mortality trends for men and women since the beginning of the 1980s.

Different estimations of annual mortality rates based on trend analyses for the period 1985–2011 consistently show negative values (Figure 3). The rates of change can therefore be seen as reduction rates.

Figure 3. Percentage annual change in mortality rates by sex and age with three different estimations 1985–2011



For trend estimation with five-year age groups, the annual average values for mortality rates 1984–1986 and 2009–2011 have been used as start and end points.

Figure 3 shows the smoothing reduction rates over the ages that are the result of the Lee-Carter calculation, but significant swings in ages less than 50 years. For men up to age 50, the simple trend estimation gives nearly identical reduction rates as a Lee-Carter model for ages 0–100 years. At older ages the simple trend estimation is instead completely in line with the result of a Lee-Carter model for ages 50–100 years. For women the age specific trend estimation gives greater fluctuations than the Lee-Carter model for younger women. For older women the reduction rates from the simple trend estimations follow the outcome of the Lee-Carter model for ages 50–100 years.

The Lee-Carter model for all ages (0–100 years) seems to underestimate the mortality reduction among older persons compared to the simple trend estimation. The results therefore speak for choosing the results of the Lee-Carter model for ages 50–100 years as the main alternative[1]. Up until about age 50 the trends in mortality are not stable. The results from the Lee-Carter method have therefore been concentrated to ages 50 and older, which is about the same as in the previous forecasts for Sweden of most recent years.

The number of deaths below age 50 comprise a small part of mortality and have little significance in the context of forecasts. Further, the weights for age have not been especially stable at younger ages (Lundström & Qvist, 2004). For younger ages, 0–44 years, the annual average change in mortality is used between the life tables 1996–2000 and 2006–2010. The change (mortality decline) is calculated as a total for women and men at 2 percent annually.

For women the choice of a base period 1975–2001, 1985–2011 or 1995–2011 has little significance on the mortality reduction that will be assumed in the future. For men the mortality decline at certain ages has been quicker at the end of the period 1975–2011 than at the beginning. This means that there is greater uncertainty in the mortality assumption for men than for women, especially for those aged 65 and older. The results from the base period 1985–2011 are mainly used for both sexes.

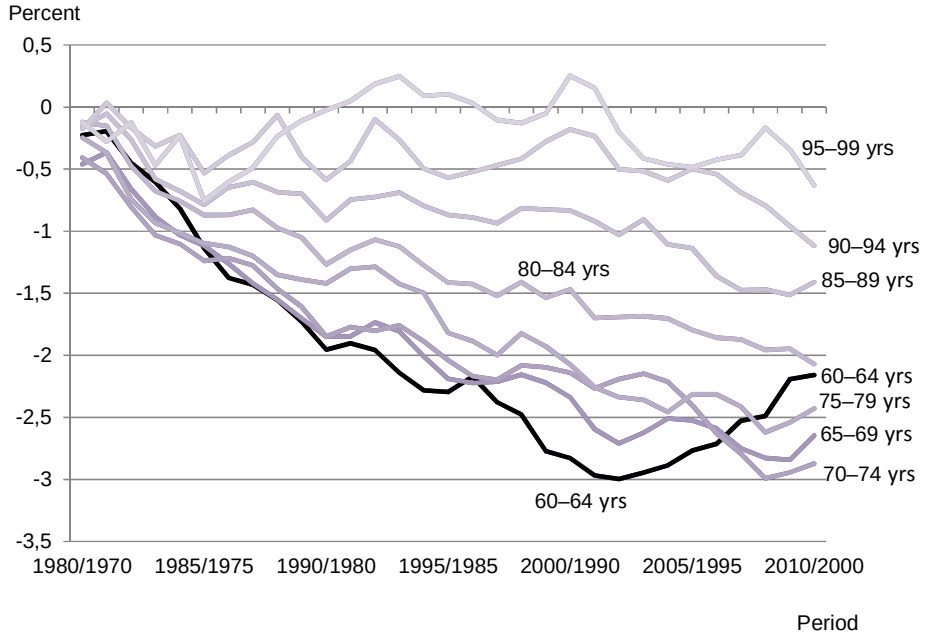
Changing mortality trends in older men

Mortality changes in the period 1970 (mean from 1969 to 1971) to 2010 (2009 to 2011) were analyzed by means of moving averages, and mortality changes between all 10-year periods were measured. This indicate that men's mortality reduction has changed almost constantly, from small reductions to larger reductions (Figure 4). This is probably one reason why LC-models are not so suitable for extrapolating men's mortality for the future. In certain age groups, such as 80 to 84 years, there has been a constant increase in the mortality decline over time, whereas in other age groups this development has been halted and even reversed.

[1]It is most common to use all ages. But the results may be because the evaluations of the results of the Lee-Carter model showed a certain underestimation of mortality reduction in the long term (Lee & Miller, 2000).

There are no such changes in mortality reductions for women, not shown in a figure. Therefore, the LC-model is probably more accurate in projecting women's mortality.

Figure 4. Annual mortality change between 10 years by age group 1970−2010. Changes are estimated from 3-year moving averages. Swedish men in the age interval 60−99 years.



Changes are estimated from 3-year moving averages. The first observation is based on the mortality change between 1969−1971 (1970 in the figure) and 1979−1981 (1980), and the last observation is based on changes between 1999−2001 (2000) and 2009−2011 (2010).The figure displays all the moving values between 10 years. This is one way to detect the moving trend in older Swedish men.

Epidemiologic analysis

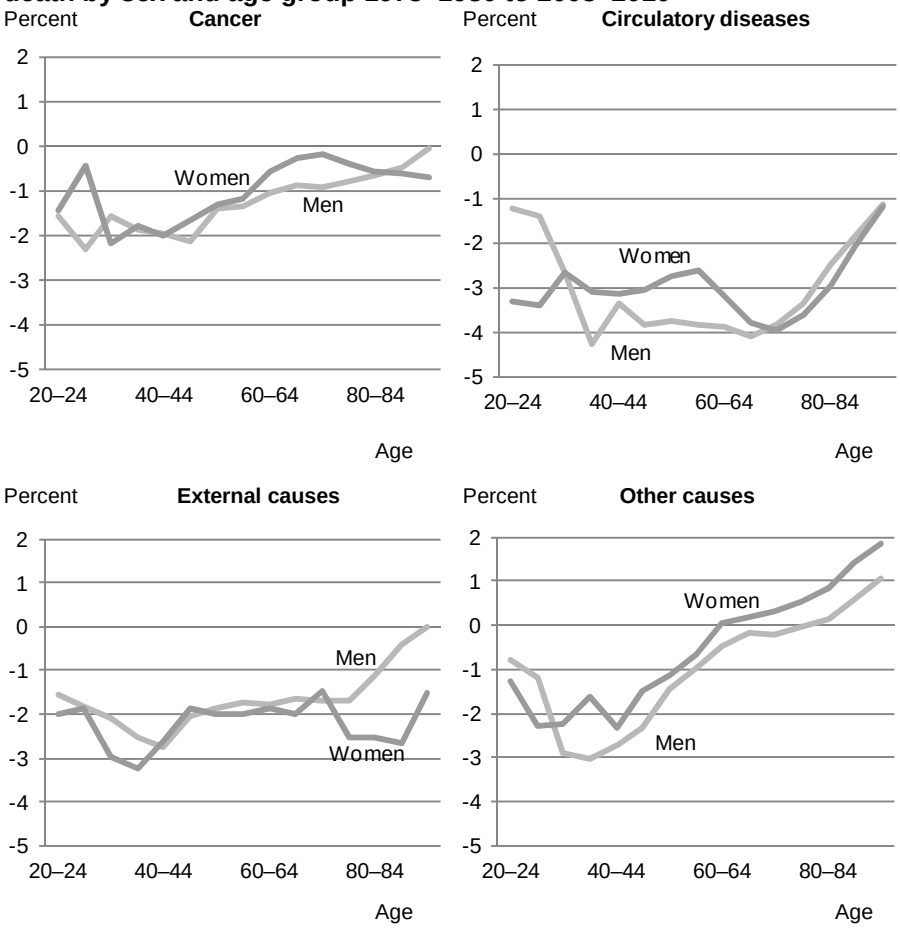
It is necessary to understand the reasons behind the trends for mortality in order to predict the trends for the future. One way to come closer to this understanding is to describe the trends for different causes of death, an epidemiologic analysis. There are interesting attempts to include historical trends in well-known epidemics that produces shifts and changes in population mortality rends. This has been done for instance with the smoking epidemic (Wang & Preston, 2009; Janssen, van Wissen, & Kunst, 2013).

During the last three decades death among younger and middle aged persons has decreased significantly for both men and women in the four larger groups of causes of death that are presented here, i.e. cancer, circulatory diseases, external causes of death and other causes, see Figure 5.

A more varied picture is seen for the older part of the population (age 65 and older). There is a decline in cancer mortality for most ages, with the exception of

women in their 70s and men 90 and older. For other causes of death, among them respiratory diseases and diseases of the digestive system, mortality has increased among the old.

Figure 5. Average annual change in mortality rates for four main causes of death by sex and age group 1978–1980 to 2008–2010



Source: Processed statistics from the National Board of Health and Welfare and Statistics Sweden. The change is calculated on the annual average values 2008–2010 compared to 1978–1980 per cause of death, sex and five-year age group (starting with age group 20–24 years until age group 85–89 years) and an age group 90 years and older.

The somewhat different development for causes of death indicates several processes that have varying degrees of significance for different causes of death. Different changes in risk factors have probably caused the difference in the trends of causes of death. Mortality from circulatory diseases have decreased the most during the last three decades, 3–4 percent per year for women and men alike at the entire age interval of 30–79 years. In ages 35–64, the decline was larger for men than for women, 4 and 3 percent respectively.

Deaths of women from external causes of death have declined by 1.5–3 percent per year for all age groups. This also applies to men aged 20–74. However, mortality from external causes for men of older ages has had a smaller decline than that for women.

Other causes of death have decreased more for men than for women who are middle aged, while they have increased for women aged 60–79 and decreased for men. At age 80 and older, women have had a larger increase in mortality than men.

The somewhat varying trends of causes of death over time, especially among older persons, make the assumption on the future mortality trends more difficult since the distribution of the causes of death gradually change. During the last three decades the proportion of deaths from circulatory diseases has decreased. Instead the proportion of deaths caused by cancers and other causes of death has increased (Statistics Sweden, 2011). It is possible that mortality from certain chronic diseases, such as deaths from cancers, change according to a cohort pattern[2]. Then a mortality decline from cancers in recent decades for middle-aged persons could indicate an expected decline among older persons in the future.

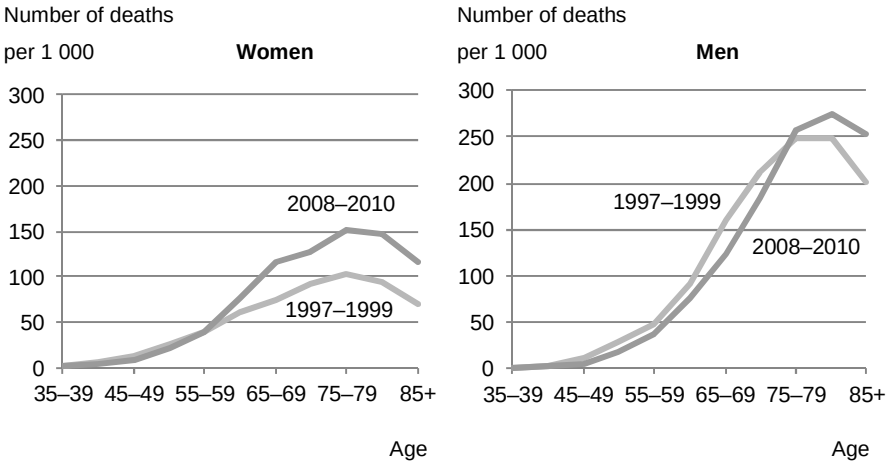
Certain lifestyle-related causes of death

Are there trends for known risk factors that have contributed to the different trends in causes of death? Causes of death that have a well-documented connection with smoking, such as lung cancer and chronic diseases in the lower respiratory passages (such as chronic obstructive pulmonary disease COPD), have in recent years had a development that to a certain extent is similar to other causes of death presented in Figure 5. Mortality from lung cancer has increased in recent years, especially among older women. This is shown in Figure 6. In contrast, mortality from lung cancer has decreased among men in the 35–74 year age interval. Despite several decades of reduced smoking among men, mortality from lung cancer has still not begun to decline among the oldest men. Even though lung cancer mortality is low for persons under age 60, it is important to note a decline from lung cancer mortality among women and men in these ages. Mortality from chronic diseases in the lower respiratory passages such as COPD has developed in about the same way as lung cancer since the end of the 1990s. However, mortality from this cause of death group has also decreased somewhat

[2]If a certain birth cohort has been exposed to particular health risks more than others, which have remaining health effects during the rest of their lives, mortality will increase for younger ages first. The increase will then gradually spread to older ages. When the birth cohorts with special risk factors are replaced by birth cohorts without risk factors, the mortality decline will begin for younger ages and gradually spread with time to older ages. Such proposals for mortality changes per cohort are among other things found for smoking (Wang & Preston, 2009).

even for men in the oldest age groups since the end of the 1990s. For women age 70 and older, mortality from chronic diseases in the lower respiratory passages has increased during the same period. Figure 5 includes this specific cause of death group in other causes of death.

Figure 6. Lung cancer mortality by sex and age group 1997–1999 and 2008–2010



Source: Calculations from the information that was collected from the statistical database of the National Board of Health and Welfare in January 2012. The information is from annual average values for each period.

The difference in lung cancer mortality between the sexes has changed in a short time, as seen in Figure 7. At the end of the 1990s men had higher lung cancer mortality than women. Those differences changed one decade later. In the younger ages (35–54 years), women's lung cancer mortality was as high or higher than men's as early at the end of the 1990s. In the older ages the difference between the sexes has decreased, but men still have twice as high lung cancer mortality as women in ages 80 and older. The change between 1997–99 and 2008–10 shows the trend that is probable in the near future. The percentage of daily smokers has been somewhat higher among women than men since the middle of the 1990s. (The National Board of Health and Welfare & Swedish National Institute of Public Health, 2012)[3]. At the same time, since the end of the 1980s a higher percentage of men than women report occasional smoking (The Swedish National Institute of Public Health, 2011). In a few decades the trends of smoking habits should also show a little or no difference between the sexes in lung cancer mortality even in the oldest age groups.

[3]National information about smoking in a longer historical perspective come from Statistics Sweden's Living Conditions Surveys and are limited to ages 16–84.

Figure 7. Difference in lung cancer mortality between women and men in various age groups 1997–1999 and 2008–2010. The difference is calculated as a ratio between the mortality rate for men compared to the mortality rate for women

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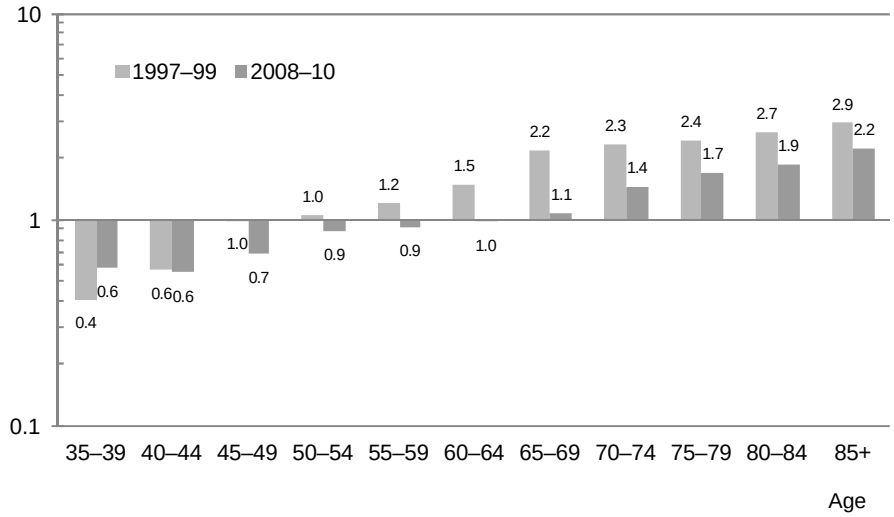


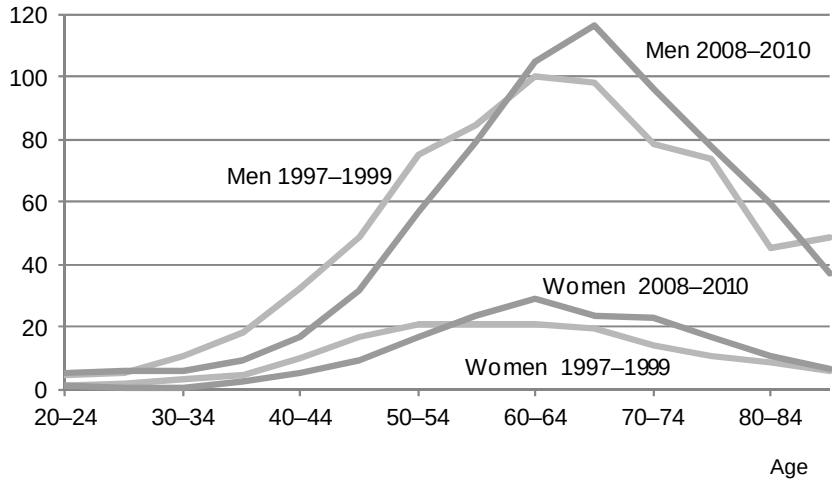
A logarithmic scale has been used so the bars in the figure will be comparable in terms of size, regardless if the index value is smaller or larger than 1. An index value greater than 1 means that men have a higher mortality than women and a value of less than 1 that women have a higher mortality than men.

Source: Calculations from the information that was collected from the statistical database of the National Board of Health and Welfare in January 2012. The information is based on annual average values for each period.

Just like lung cancer, alcohol-related causes of death have contributed to reduced mortality in certain ages but increased mortality in others. During the last decade mortality from these causes of death have increased somewhat for ages 60–84, but decreased or remained unchanged for other ages, see Figure 8. Mortality from alcohol-related deaths is several times higher among men than among women. In contrast to lung cancer, the difference between the sexes has not changed particularly for these causes of death. During the years 1997−1999 as well as 2008−2010, men had at least three times higher mortality than women in various age groups.

Figure 8. Mortality from alcohol-related causes of death by sex and age group 1997–1999 and 2008–2010

Number of deaths per 100 000



Source: Calculations from the information that was collected from the statistical database of the National Board of Health and Welfare in January 2012. The information is based on annual average values for each period. Alcohol-related deaths are defined as either from underlying or contributory causes of death according to the index from the National Board of Health and Welfare (2011).

Discussion

A number of factors may have caused the different mortality trends for men and women. But an important contributing factor has been the historical trends of smoking among men and women (Hemström, 1999). The shrinking difference in mortality between women and men that has been seen in several countries in recent years is largely centred on causes of death that have a clear connection to smoking, among other things heart and circulatory diseases, cancer and respiratory diseases (Pampel, 2002).

Sweden has had a small difference in smoking behaviour between the sexes for several years. From birth cohorts born from the 1940s and later, sex differences has been small for several decades, and the proportion of daily smokers have decreased among both sexes in all cohorts born after 1920 from the end of the 1980s until 2004–05 (Danielsson, Gilljam, & Hemström, 2012). The effects of this smoothing out have already been seen in ages up to 69 years where women and men have largely the same mortality from lung cancer, see Figure 7. In the theory about the global spreading of the smoking epidemic, the percentage of smoking-related

deaths in the population will decrease for men before they decrease among women (Lopez, Collishaw, & Piha, 1994).

Other causes of death with considerable differences between women and men, which are largely directly related to lifestyle, have not shown any clearly narrowing sex differences in mortality. Among other things, this applies to external causes of death, such as suicides, as well as alcohol and drug-related mortality. However, these causes of death have developed about the same for women and men in recent decades. This means that in the long term we assess that women and men will have about the same mortality trend. It also means that life expectancy between men and women will largely remain.

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