The Sex Gap in Mortality:
Historical Patterns Across Twenty-Four Countries

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Paper to be presented at
Section 203: Gender, Health, and Mortality,
IUSSP 2005, Tours, France

Last revised: June 13, 2005

ABSTRACT

This paper uses data from the Human Mortality Database to examine sex differences in e_0 and age patterns in sex ratios of $_nM_x$ over time for 24 countries. From 1751 to 1900, the female advantage in e_0 was relatively small, sex ratios were close to 1.0, and infant mortality accounted for 30-65% of the sex difference. In the early 1900s, the sex gap began to widen primarily due to increasing sex ratios in mortality. By the late 1940s, ages 40-79 accounted for 60-75% of the sex gap, which was growing rapidly in virtually all countries. Since the 1980s, the sex gap has begun to narrow in most countries, but only in part due to declining sex ratios. Simulations suggest that even if sex ratios had remained at 1970s levels, the sex difference would still have narrowed considerably due to declining mortality—in many cases much more than it actually did.

INTRODUCTION

Over the last 200 years, women in Europe and North America have enjoyed higher life expectancy at birth (e_0) than men (Tabutin and Willems, 1998). Indeed, sex differences in mortality are often wider than those between other subgroups (e.g., race/ethnicity) (United Nations, 1988). Yet, available data suggest that the sex gap in e_0 was relatively small in the late 1800s, but grew rapidly through most of the 20th century (United Nations, 1988). Around the 1980s and 1990s, this trend appears to have reversed and the sex differential in e_0 has begun to narrow in many developed countries (Meslé, 2004; Trovato and Lalu, 1996).

Projections of future mortality depend on assumptions about relative levels of mortality decline by sex and the age pattern of those declines. Thus, a better understanding of the historical patterns in these sex differences (both relative and absolute) may provide important clues for predicting future trends. Although demographers often rely on recent trends to predict future trends, it is useful to consider the historical context because recent trends may represent an anomaly within long-term trends. Moreover, overall trends in mortality may result from different patterns of mortality decline for men and women. For example, after a period of rapid mortality decline in the 1970s, the pace of mortality decline in the United States slowed over the last 20 years, but this slowdown was especially pronounced among women. Between 1980 and 1999, life expectancy at birth for U.S. males increased by 4.0 years, while their female counterparts gained only 1.9 years (HMD, 2005).

While some studies focus on absolute sex differences in mortality, others examine relative sex ratios. These two approaches serve different purposes and may, in fact, tell a different story. Preston (1976) noted that as mortality declines, sex differences in mortality rates tend to shrink whereas sex ratios tend to increase. On the one hand, sex ratios in mortality provide information about the relative excess of mortality suffered by one sex compared to the other. Yet, when mortality is low, large sex ratios can result from very small absolute differences in mortality rates. Thus, large sex ratios may not necessarily translate into big differences in life expectancy.

Using data from the Human Mortality Database (HMD, www.mortality.org) for 24 national populations with high quality mortality statistics, this paper explores age patterns in sex ratios of mortality rates and the trajectory of sex differences in life expectancy over time and place. The HMD makes it possible to investigate sex differentials and sex ratios in mortality over a longer time series and for a wider range of countries than has been previously possible. These data cover a period starting as early as 1751 and extending into the early 21st century. Moreover, HMD estimates are calculated using a uniform method across countries, which allows for better cross-national comparisons by reducing the possibility that differences across countries are due to differences in the estimation methods.

The first section of the analysis investigates whether the age pattern of relative sex ratios is similar across time and place. We address the following questions: 1) Are there groups of countries that follow similar age patterns? 2) Do those age patterns vary over time? 3) Are there groups of countries that tend to have larger sex ratios throughout time, or alternatively, is there a crossover effect such that countries with a larger sex gap in one time period tend to have a smaller gap at a later time period? The second section examines how *absolute* sex differences vary across time and place. When the level of mortality is low, high sex ratios may have little impact on the sex gap because the latter is determined by absolute differences in mortality rates and the distribution of deaths across age. Therefore, we explore whether trends in the sex gap mirror changes in sex ratios. We perform age decomposition of the sex difference in e_0 in order to determine whether age groups with the largest sex ratios are also the biggest contributor to the sex gap. Finally, we run simulations to evaluate the degree to which changes in the absolute sex difference in e_0 are accounted for by changes in relative sex ratios.

BACKGROUND

During the late 1800s, the female advantage in life expectancy was typically two to three years in most high income countries (United Nations, 1988). Yet, evidence suggests that during the 17th to the 19th century excess female mortality may have been common during later childhood and adolescence (Stolnitz, 1956; Tabutin and Willems, 1998). In England and Wales, infant mortality accounted for more than one-third of all deaths in 1901 and thus, was the biggest contributor to the sex differences in life expectancy throughout the late 1800s and early 1900s (United Nations, 1988). Although the sex gap in life expectancy was much smaller in Italy (0.5 years in 1881-82) than in England and Wales (3.3 years in 1871-80), infant mortality was also the biggest contributor to the sex gap in life expectancy in Italy (United Nations, 1988).

In the early part of the 20th century, the sex gap in e_0 began to increase in many countries. By the 1940s, lower female mortality at all ages became typical in Western countries (Stolnitz, 1956; Tabutin and Willems, 1998). By the 1950s, the sex differential in life expectancy was typically between three and five years among 30 developed countries, and continued to increase until the early 1980s reaching an average of 6.7 years, but ranging from 4.6 years in Greece to 9 years in the USSR (United Nations, 1988). This historic widening of the sex gap through most of the 20th century occurred within the context of other important demographic changes: substantial increases in life expectancy and the resulting shift in the ages at which most people die from very young to very old ages (United Nations, 1988). Large declines in mortality due to infectious and parasitic diseases during the first half of the 20th century disproportionately affected death rates at young ages. In fact, among 14 high income countries with data for the 1900s to 1980s, declines in infant mortality actually had a narrowing effect on the sex gap, whereas the vast majority of the increase in the sex gap resulted from sex differences in mortality at ages 55 and older (United Nations, 1988).

By the early 1980s, sex ratios (male/female) in mortality rates were greater than 1.0 at all ages, but were especially large at ages 15-24 and smallest in infancy and early childhood (United Nations, 1988). Available data reveal two major age patterns in sex ratios of mortality during this period: 1) a "Western" pattern (comprising 22 countries), characterized by a relatively low sex ratio in infancy (≈1.3), rising to a peak at ages 20-24 (≈3.0) followed by a sharp decline to around 1.8 at ages 35-39, increasing gradually again to a sub peak (≈2.1) around age 60 and declining thereafter; and 2) an "Eastern" pattern, evidenced by the USSR and five Eastern European countries, which demonstrates a similar increase during childhood and adolescence, but above age 30 declines much more gradually with no subsequent rise at older ages (United Nations, 1988). To our knowledge, no one has explored whether these age patterns and country groupings vary over time. Despite peak sex ratios at younger ages, ages less than 25 accounted for only about one-tenth of the sex gap in e_0 during the early 1980s, whereas ages 55 and older contributed nearly two-thirds of the sex gap (United Nations, 1988). Because of declines in mortality and the resulting shift in distribution of deaths to older ages, absolute sex differences in mortality were much larger at older ages than at younger ages and thus, had a greater impact on the sex gap.

The widening of the sex differential in e_0 during most of the 20th century resulted from a faster pace of mortality decline among women than men. If both sexes had experienced the same rate of mortality decline (i.e., sex ratios remained unchanged), males would have enjoyed a greater *absolute* decrease in mortality rates (because they started with higher rates), and thus, the sex gap in e_0 would have narrowed. Indeed, around the 1980s, the sex difference in e_0 began to decline in many Northern European and Anglo-Saxon countries (Meslé, 2004). Waldron (1993) notes that sex ratios in mortality also stopped increasing in the 1980s. Trovato and Lalu (1996) demonstrate that between the early 1970s and the late 1980s the sex gap in e_0 narrowed substantially (-1.85 in Hong Kong to -0.26 years in USSR) in nine countries, including most English-speaking countries (i.e., USA, Canada, U.K., Australia) as well as several other countries (i.e., Hong Kong, Iceland, Austria, Finland, USSR). This narrowing of the sex gap resulted from greater declines in mortality among men compared with women, especially at ages 25-

59 (Trovato and Lalu, 1996). Yet, during this period, the sex gap continued to widen among Eastern Europe countries and, to a somewhat lesser extent, Southern European countries and Ireland (Trovato and Lalu, 1996). More recently, declines in the sex gap have become apparent among other countries in Western Europe, and the sex differential appears to be leveling off among several countries in Southern Europe, although the sex gap continues to increase in Japan (Meslé, 2004).

DATA AND METHODS

Death counts and exposure estimates by country, calendar year, and age come from the Human Mortality Database (HMD, 2004). Data comprise 24 national territories (counting the former East and West Germany separately) and cover a period as long as 253 years (1751-2003: Sweden). All but six countries have data back to at least 1950, and nine countries have more than 100 years of data (see Table 1).

Because war can have a big impact on the sex ratio in mortality, we exclude the data for the periods during World War I (1914-19) and World War II (1939-45). Then, data for each country are pooled into 10-year time intervals (1751-59, 1760-79…1990-99, 2000-03). Period death rates and life expectancy at birth (e_0) are calculated using standard methods (Wilmoth, 2004).

The first part of the analysis focuses on sex ratios (${}_nM_x^m / {}_nM_x^f$) of mortality rates, where ${}_nM_x^m$ represents the period death rate for males aged x to $x+n$ for a selected time interval and ${}_nM_x^f$ is the corresponding death rate for females. Sex ratios are calculated for the following age groups: 0, 1-14, 15-24, 25-39, 40-64, 65-79, 80+. These sex ratios are graphed by age group, decade, and country in order to visually assess how the age pattern varies over time and country. As a measure of the overall level of sex ratios, we calculate the age-standardized sex ratio of mortality rates, using weights based on the distribution of total exposure by age group for all countries in the 1990s.

The second section of the analysis examines sex differences in life expectancy at birth ($e_0^f - e_0^m$). These sex differences are graphed across time and by country in order to ascertain which countries tend to have larger (or smaller) *absolute* sex differences and how the trajectory changes over time. Next, we decompose the sex gap by age group in order to determine which ages are the biggest contributors to the sex difference in e_0. We use the method of age decomposition developed by Arriaga (1984), grouping data across the following time periods: 1751-1830, 1830-99, 1900-39, 1946-79, and 1980-2003.

Finally, in order to assess the extent to which changes in the absolute sex gap result from changes in relative sex ratios, we simulate the sex difference in e_0 for a given decade assuming the sex ratios from an earlier decade. That is, we use the observed female mortality rates and apply the sex ratio from an earlier decade to simulate male mortality rates and the resulting sex gap in e_0. This simulation represents the sex gap that would have occurred if males had experienced the same proportionate changes in mortality rates as females did between these two decades.[1]

RESULTS

Sex ratios in mortality rates

Figure 1 displays the sex ratios by age group and decade for 10 countries with available data during 1751-1913. Prior to World War I (WWI), sex ratios in mortality were generally low (i.e., close to 1.0) at

[1] Alternatively, the sex gap could be simulated based on observed mortality rates for males and adjusting female rates to maintain the same sex ratios. Results using this method are generally similar to those shown and thus, are not presented.

all ages, but tended to peak around 1.25 at ages 40-64. The exception was Norway, where the highest sex ratios (1.3-1.4) occurred at ages 15-24. At other ages, the sex ratios were quite low, and in fact, several countries (Italy, England & Wales, Denmark, and the Netherlands) revealed excess female mortality during prime childbearing ages.

Between WWI and WWII, sex ratios continued to peak at ages 40-64 (1.2-1.7) in 8 out of 13 countries (Figure 2a). Yet, among Canada, Denmark, the Netherlands, Norway, and Sweden, the sex ratio was highest at age 0 (≈1.3) and relatively low at older ages (Figure 2b). Substantial excess female mortality was still evident at ages 25-39 in Canada, Denmark, and the Netherlands.

After WWII (1946-49), the age pattern began to shift with the peak sex ratio moving from ages 40-64 to ages 15-24. The first countries to initiate this transition were Denmark, the Netherlands, Norway, and Sweden (Figure 3b). Although sex ratios at ages 15-24 also increased in most other countries, they still peaked at ages 40-64 (Figure 3a). Overall, sex ratios began to increase at this time, and excess male mortality became pervasive in all countries at all ages.

By the 1950s, sex ratios in most countries followed the new age pattern, although the peak at ages 15-24 was much higher relative to age 40-64 in some countries (Figure 4a) than in other countries (Figure 4b). The only countries where sex ratios continued to peak at ages 40-64 were Bulgaria, Finland, Spain, and Japan (Figure 4c). While sex ratios at ages 15-24 were certainly increasing in magnitude (topping 2.0 in many countries), they were also increasing at ages 40-64 (>1.5 in 14 of 21 countries). Starting in 1959, we have data for three countries of the former USSR (Latvia, Lithuania, and Russia). These countries appear to follow a somewhat different age pattern: sex ratios at prime adult ages (25-39) tend to be nearly as high or higher (>2.0) than at ages 15-24 (Figure 5).

Sex ratios continued to increase in the 1960s, (Figure 6a and 6b). With the exception of countries of the former USSR, sex ratios peaked at ages 15-24 (1.8-2.9) in all countries. Nonetheless, ten countries continued to exhibit a W-shaped age pattern with a sub-peak in sex ratios at ages 40-64 that is nearly as high as the peak at ages 15-24 (Figure 6b). Finland is unusual in that the sex ratio is also high at ages 25-39, somewhat like the pattern in former Soviet countries. In Latvia, Lithuania, and Russia (Figure 5), sex ratios clearly peak at ages 25-39 (2.7-3.0).

Peak sex ratios continued to climb in the 1970s reaching ≈3.75 at ages 25-39 in countries of the former USSR (Figure 5) and between 2.2 and 3.2 at ages 15-24 among the other 21 countries (Figures 7a and 7b). Sex ratios at ages 40-64 also increased in most countries and were especially high (>2.0) in the Czech Republic, Finland, France, Italy, Latvia, Lithuania, Norway, and Russia.

In the 1980s, the magnitude of peak sex ratios started to level out in many countries. Most countries continued to reach peak sex ratios (2.3-3.4) at ages 15-24 (Figures 8a and 8b). Meanwhile, the level and age pattern of sex ratios in Latvia, Lithuania, and Russia was similar to that of the 1970s: peak (3.5-3.75) at ages 25-39, but also very high (≈3.4) at ages 15-24. Bulgaria exhibited a similar age pattern, albeit lower in magnitude (peak at ages 25-39 of 2.3).

For most countries, the level and age pattern in the 1990s remained similar to the previous decade (Figure 9a). Nonetheless, the peak sex ratio rose yet again in countries of the former USSR, reaching nearly 4.0 at ages 25-39 (Figure 5). The Eastern European countries (i.e., Bulgaria, Czech Republic, Hungary, former East Germany) as well as Finland, France, and Spain also show sex ratios at ages 25-39 (2.4-3.0) that are nearly as high or higher than at ages 15-24 (2.3-3.0) (Figure 9b). Japan and the Netherlands are unusual in that sex ratios at older ages (40-79) continue to be high relative to those of young adults.

These patterns appear to continue in the early part of the new millennium (Figure 10a and 10b). There is some evidence that the sex ratios at ages 25-39 have begun to decline in Latvia, Lithuania, and Russia—down to 3.6-3.9 from a high of 4.0 in the 1990s (Figure 5). In other countries, sex ratios at 15-24 also appear to be on the decline, ranging from 1.7-3.0 versus 2.2-3.4 in the 1990s.

In answer to the questions posed in the introduction, the age pattern of sex ratios appears to be more similar across countries than across time. In general, countries tended to follow a similar age pattern within a time period, but those patterns changed over time and some countries made those transitions earlier than others. Nonetheless, countries of the former Soviet Union revealed a somewhat different age pattern, and at least since the 1960s, have exhibited much higher sex ratios than other countries. In the next section, we explore whether sex differences in e_0 mirror changes in the sex ratios.

Sex differences in life expectancy at birth

Sex differences in e_0 across time for each country are presented in Figure 11. Countries are grouped that share a similar trajectory. In Sweden—the only country for which we have data prior to the 1830s—the sex difference in e_0 was around three years during the late 1700s, but began to increase in the early 1800s reaching 4.4 years by the 1840s.

Starting around the mid-1800s, data became available for England & Wales, Denmark, the Netherlands, and Norway. At this time, the sex gap in e_0 was around two to three years with two exceptions. First, life expectancy in England & Wales was actually lower among females than males (-1 years) during the 1830s and only 0.4 years higher than males in the 1840s, although the sex gap increased substantially in the 1850s to a level comparable with that of other countries. Second, the sex difference in Sweden in the 1850s remained the largest (4.1 years) among these five countries.

Data series for Italy, Finland, and Switzerland begin in the 1870s. The sex gap remained around two to three years for most of the eight countries observed. Italy represents an exception with a much smaller gap in life expectancy (0.7 years in the 1870s and 0.25 years in the 1880s). Through the second half of the 19th century the sex difference steadily declined in Sweden and Denmark, whereas it grew in England & Wales and Finland.

By the 1900s, data series began for two more countries: France and Spain. The sex gap remained by far the lowest in Italy (0.6 years in the 1900s). The largest sex differences were observed in England & Wales (3.8 years) and France (3.6 years). Among the other 10 countries, the sex gap remained around two to three years. From 1910, the sex gap continued to grow in England & Wales, Finland, and France and in the 1920s, began to increase in Italy and Spain as well. On the other hand, after increasing somewhat in the late 1800s, the sex gap declined through the 1920s in Denmark and the Netherlands.

Data series for Belgium, Canada, and New Zealand began in the 1920s or 1930s, bringing the total number of countries to 15. By the 1940s, the sex gap in e_0 was growing rapidly in virtually all countries. The exceptions were Finland and Spain, where there was a decrease in the sex gap in between the 1940s and the 1950s because males gained more in life expectancy than females, perhaps due to declines in male mortality after WWII and the Spanish Civil War. After the 1950s, Finland and Spain joined the other countries in demonstrating substantial widening of the sex gap.

By the 1950s, data series began for nine additional countries (Bulgaria, East and West Germany, Hungary, Japan, Latvia, Lithuania, Russia, United States). The sex difference in e_0 continued to increase in all 24 countries through the 1970s. During the 1970s, countries of the former USSR (Latvia, Lithuania, and Russia) exhibited the largest sex differences (9-11 years), whereas Bulgaria and Japan demonstrated the smallest sex gaps (≈5 years).

In the last couple decades of the 20th century, the sex gap in e_0 began a steady decline in most countries, starting with Finland and the English-speaking countries (Canada, England & Wales, New Zealand, and the US). Among these countries, the sex gap peaked in the 1970s and began to decline in the 1980s. In several other countries, including the rest of the Scandinavian countries (Denmark, Norway, Sweden) as well as the Netherlands, Austria, (former) West Germany, and Switzerland, the sex difference leveled off in the 1980s and began a substantial decline in the 1990s. Belgium, France, and Italy also showed a slight decline during the 1990s, but did not demonstrate a substantial narrowing of the sex gap until after 2000. In the beginning in 21st century, the sex gap also began to narrow in most of the Eastern European countries (Bulgaria, Czech Republic, former East Germany, Hungary, and Latvia) as well Spain. Nonetheless, the sex gap continues to widen with no evidence of narrowing in Russia, Lithuania, and Japan (data for Japan are not available ≥ 2000). At the present date, Russia, Lithuania, and Latvia continue to have the biggest sex gaps in e_0 (11-13 years) among these 24 countries. The smallest sex differences are found in Sweden and Denmark (4.5 and 4.6 years, respectively).

In general, countries with higher relative sex ratios also tend to have bigger absolute differences in e_0. For example, very small sex gaps in e_0 for England and Wales in the 1830s and 1840s and for Italy through the early 1900s correspond with low sex ratios and excess female mortality during those periods. Through the 1960s and 1970s, sex ratios grew more rapidly in former Soviet countries than in other countries, and consequently, the sex gap in e_0 also widened.

Nonetheless, changes in the sex gap do not always mirror changes in sex ratios. In some countries, sex ratios in mortality began to decline around the same time the sex gap began to narrow, but in other countries the sex gap began to decline before any noticeable decline in sex ratios. For example, the sex gap in Finland began to narrow in the 1980s despite little change in sex ratios. This phenomenon is demonstrated more clearly by comparing trends in the sex gap in e_0 with trends in the age-standardized sex ratio in mortality rates (see Figure 12a). In the Netherlands, we observe the opposite effect: the age-standardized sex ratio of mortality began to decline in the 1980s, yet the sex gap continued to widen until the 1990s (Figure 12b). To understand this paradox, we need to consider how changes in the mortality curve affect the sex gap.

Decomposition of sex difference in life expectancy by age group

Decomposition of sex differences in e_0 by age group confirms that prior to the 20th century, the first year of life made the biggest contribution to the overall sex difference. In Sweden, the only country for which we have data prior to the 1830s, age 0 accounted for 33% (1.1 years) of the total sex difference in e_0 during the period from 1751-1829 (data not shown), while ages 40-64 accounted for another 26% (0.8 years). Among the nine countries with available data during 1830-1899, we observe a similar pattern (Figure 13): the biggest contributor to the sex gap is age 0 (≈30-65%) followed by ages 40-64 (≈25-40%). So, although sex ratios in mortality tended to be higher at ages 40-64 than at age 0 (Figure 1), infant mortality had a bigger impact on the sex gap. This apparent contradiction is explained by high infant mortality, which resulted in a substantial proportion of deaths occurring in the first of life (8-23% based on ${}_1d_0$ from the life table, data not shown); those early deaths have a much greater effect on estimates of e_0 than deaths at older ages.

As noted earlier, several countries (Italy, Denmark, and the Netherlands) demonstrated substantial excess female mortality at ages 25-39 prior to 1900, which had a dampening effect on the sex gap. Although sex ratios at ages 1-14 were close to 1.0 (Figure 1), excess female mortality at these ages also reduced the sex gap in Italy and Denmark because many deaths occurred at those ages.

In the early 1900s, the first year of life remained the biggest contributor to the sex gap in most countries (8 of 13), although we begin to see a shift to older ages. Among five countries (Finland, France, New Zealand, Spain, and Switzerland), ages 40-64 accounted for the biggest part (35-45%) of the sex gap in e_0, in part due to modest increases in sex ratios at ages 40-64 (Figure 1 and Figure 2). Yet, this structural shift was also influenced by changes in the mortality curve. As infant mortality declined, a larger proportion of deaths shifted to older ages. Consequently, older ages began to have a bigger impact on life expectancy, and hence sex differences in e_0.

By 1940-1979, the age group 40-64 was the biggest contributor (36-50%) to the sex gap in all 24 countries, and infant mortality made only a small contribution (6-14%). Despite the trend toward peak sex ratios at ages 15-24, this age group accounted for only 4-9% of the sex difference in e_0 because relatively few people died at those ages (<5% based on ${}_{10}d_{15}$).

In recent decades, older ages have continued to have a bigger effect on the sex gap. During 1980-2003, ages 40 and older accounted for the vast majority of the sex gap (66-70% in countries of the former USSR and 78-89% in other countries), which is not surprising given that these ages accounted for 84-99% of all deaths (based on ${}_{\infty}d_{40}$). In fact, ages 65-79 made the greatest contribution to the sex gap (37-47%) for half of all countries. By this point, infant mortality had very little effect on the sex gap.

So, why did the sex gap in Finland begin to narrow as early as the 1980s despite little change in sex ratios? The answer lies in the structural shift of deaths to older ages. Based on age decomposition for each decade (data not shown), we find that ages 65 and older accounted for only 27% of the sex gap in the 1970s versus 36% in the 1980s. Meanwhile, ages 40-64 became less important (51% in 1970s versus 46% in the 1980s). This shift is largely due to increasing life expectancy (total e_0 increased from 71.7 in the 1970s to 74.5 in the 1980s), which resulted in a greater proportion of deaths at very old ages. Because sex ratios at these ages were *lower* than at ages 40-64, the sex gap began to narrow.

Declining mortality and the resulting shift in the distribution of deaths to older ages also explains why the sex gap in the Netherlands continued to widen between the 1970s and 1980s despite a decline in overall sex ratios. Like Finland, ages 40-64 also became less important while older ages accounted from an increasing proportion of the sex gap. Yet, in this case, it amplified the sex gap because sex ratios in the Netherlands were *higher* at ages 65-79 than at ages 40-64 (Figure 10b).

These analyses reiterate that the age group with the highest sex ratios in mortality rates does not necessarily have the greatest impact on the sex gap in e_0. In the 19th century, sex ratios generally peaked at ages 40-64, yet the first year of life was a biggest contributor to the sex gap. Similarly, in recent decades sex ratios have tended to peak at ages 15-24, but those ages account for less than eight percent of the sex gap, while older ages have a much bigger impact. To determine which ages have the greatest impact on the sex gap, one must consider not only relative sex ratios, but also the shape of the mortality curve and distribution of deaths across age.

The Effect of Changes in Relative Sex Ratios on Changes in the Absolute Sex Gap

Although changes in relative sex ratios in mortality certainly affect absolute sex differences in e_0, the sex gap is also a function of the level and shape of the mortality curve. In order to assess how much of the change in the sex gap across a selected time period results from changes in relative sex ratios, we have simulated what the sex gap would have been if sex ratios had remained unchanged. Table 1 shows the observed changes in the sex gap for selected periods as well as the simulated sex gap assuming that males had experienced the same proportionate declines in mortality at every age as females did over this period. For example, between the first decade of the 20th century and the late 1940s, the sex gap in Finland increased by 5.3 years. Yet, if sex ratios had remained at the earlier levels, the sex gap would actually have narrowed by 0.2 years. Thus, in the case of Finland and for most other countries where the sex gap widened during this period, the increase in the sex gap during the first half of the 20th century was entirely due to increasing sex ratios in mortality. Italy and Spain are the exceptions: although increasing sex ratios were responsible for most of the increase in the sex gap, changes in the mortality curve also contributed somewhat. This effect probably results from the fact that as mortality declined, a greater proportion of deaths shifted to older ages where sex ratios were higher (see Figure 3a). Denmark was the only country to exhibit a substantial decline in the sex gap during the first half of the 20th century, almost entirely due to declines in mortality.

Increasing sex ratios also account for the widening sex gap between the late 1940s and the 1970s. The simulated data shown in Table 2 demonstrates that if sex ratios had remained at the 1946-49 levels, the sex gap in e_0 would have narrowed in all countries, in most cases by more than one year.

Since the 1970s, the sex gap has continued to widen in countries of the (former) USSR as well as most Eastern European countries almost entirely because of increased sex ratios. The exception is Russia, where the sex gap widened by 2.4 years, but simulation suggests that even if sex ratios had remained at the 1970s levels, the sex gap would still have increased by 1.3 years. During this period, mortality increased in Russia, particularly at young and middle adult ages. Thus, the structural shift in the distribution of deaths to those ages where sex ratios were highest (see Figure 5) amplified the widening sex gap.

In contrast, the sex gap narrowed among 16 countries during the late 20th century, but only in part because of declining sex ratios. Declining mortality played a substantial role in the narrowing of the sex gap. In fact, changes in the mortality curve accounted entirely for the reduced sex gap in six countries: Austria, Belgium, Czech Republic, France, Italy, and Switzerland. If sex ratios had remained at 1970s levels, the sex gap would have narrowed even more that it actually did in these countries. Instead, sex ratios actually increased for some age groups, particularly at older ages, thus dampening the reduction in the sex gap. Among the other 10 countries, declining sex ratios account for only part of the narrowing sex gap: these countries would have experienced substantial declines in the sex gap even if sex ratios remained unchanged.

DISCUSSION

Among the nine countries with available data prior to 1900, the sex gap in life expectancy was relatively small (≈2-3 years) and sex ratios in mortality rates were close to 1.0. In fact, several countries exhibited substantial excess female mortality, particularly at ages 25-39. The most notable of these were England & Wales (1838-49) and Italy (1872-1913), which accounts for the small sex gap in e_0 during these periods (< 1 year). Given that most of the excess female mortality occurred at prime childbearing ages, maternal mortality probably played a major role, but females also suffered higher mortality from infectious diseases than males, perhaps because of less access to health-promoting resources (Waldron, 2005). Although sex ratios in mortality rates during this period peaked at ages 40-64 (with the exception of Norway), age 0 was the biggest contributor to sex differences in e_0 due to high infant mortality.

In first half of the 20th century, the sex gap in e_0 began to widen in many countries, primarily due to increasing sex ratios in mortality. From the end of WWII through the 1970s, the sex difference in e_0 climbed rapidly in virtually all countries, and there was no longer any evidence of excess female mortality at any age for any country. Although peak sex ratios began to shift from ages 40-64 to ages 15-24, high sex ratios at these younger ages accounted for only a small part of the sex gap because few people died at those ages. Much more important was the fact that sex ratios at ages 40-64 also increased steadily through the 1970s. Age decomposition of the sex gap shows that around the turn of the 20th century the age group making the biggest contribution to the sex gap began to shift from age 0 to ages 40-64 as mortality declined and deaths shifted to older ages. By post-WWII, the latter age group was the biggest contributor to the sex gap in all 24 countries, whereas infant mortality played a relatively small role. Many researchers have concluded that smoking played a major role in accounting for the widening sex gap during most of the 20th century (Pampel, 2002; Preston, 1970; Valkonen & Van Poppel, 1997; Waldron, 2005). Early adoption of smoking among Finnish males could explain why the sex gap began to increase so early in Finland (Valkonen and Van Poppel, 1997). Furthermore, large sex differences in smoking in Finland and Netherlands may account for higher sex ratios at older ages compared with other countries (Valkonen and Van Poppel, 1997). Other factors that may have contributed to the widening sex gap include declining fertility and maternal mortality as well as increased fat consumption, which has a more detrimental effect for men than women (Ram, 1993; Waldron, 1995, 2005).

During this period (1946-1979), former Soviet countries (Latvia, Lithuania, and Russia) had much larger sex gaps in e_0 and higher sex ratios in mortality than other countries. Like Trovato and Lalu (1996), we observe a slight decline in the sex gap in Russia between the 1970s and 1980s. Nonetheless, in the 1990s the sex gap increased dramatically in Russia as well as Latvia and Lithuania. Moreover, these countries exhibited a different age pattern: although sex ratios were high at ages 15-24, they generally peaked at ages 25-39 and this latter age group made a notable contribution (≈20%) to the sex gap in these countries. Waldron (2005) suggests that large sex ratios in these countries stem from greater sex differences in smoking habits, binge drinking, and suicide.

In the last two decades of the 20th century, the sex difference in e_0 leveled off and began to narrow in most countries. This trend started during the 1980s in Finland and English-speaking countries (Canada, England & Wales, New Zealand, USA). Most other countries followed suit in the 1990s, except for Spain and countries in Eastern Europe and the former Soviet Union, which showed no decline until after 2000 or have yet to evidence a decline (i.e., Russia, Lithuania). Widespread narrowing of the sex gap in recent years is explained only in part by declining sex ratios. In fact, among 6 of the 16 countries where the sex gap narrowed since the 1970s, sex ratios actually increased at some ages; the reduction in the sex gap was entirely due to declining mortality. Among the other 10 countries, simulations suggest that even if sex ratios had *not* declined, the sex gap would still have narrowed considerably due to declining mortality and the shift in the distribution of deaths to older ages where sex ratios were often lower.

The historical patterns demonstrated in this paper provide a better understanding of the relationship between relative and absolute sex differences in mortality and how these differentials have varied across time and place. The data suggest there were period effects experienced by virtually all countries, although they affected some countries earlier than others. Thus, attempts to explain sex differentials should look longitudinally at factors that have changed over time. Cross-sectional studies of variation in sex differentials across country may fail to reveal the causal factors involved.

The analyses also demonstrate that ages with the highest relative sex ratios do not necessarily have the biggest impact on the absolute sex gap. For example, in recent years, sex ratios tended to peak at ages 15-24 in most countries, yet these ages have relatively little effect on the sex gap because few people die at those ages. Thus, while it may be interesting to understand why there is so much excess male mortality (in relative terms) among young adults, it is important to keep in mind that such explanations may do little to account for the overall sex gap.

Furthermore, these analyses show how the absolute sex difference in e_0 may not correspond with changes in sex ratios. Finland saw little change in sex ratios between the 1970s and the 1980s, and maintained the highest sex ratio at ages 40-64 (2.6) among all 24 countries, yet the sex gap began to narrow in the 1980s because mortality declined and more deaths shifted to very old ages where sex ratios were much lower (1.9 at ages 65-79 and 1.3 at ages 80+). This structural shift had a different effect in the Netherlands because sex ratios were actually higher at ages 65-79 than at ages 40-64. Although sex ratios at ages 40-64 began to decline in the 1980s, the sex gap continued to grow until the 1990s.

The sex gap is a function not only of relative differences in mortality, but also the level of mortality and the distribution of deaths across age. Thus, factors that differ by sex (or have a differential effect by sex) can explain relative differences, but may not be sufficient to account for the absolute sex gap in e_0. For example, some of the reasons cited for recent declines in the sex gap include increased smoking among females while prevalence is declining among men, and men benefiting more from advances in medical treatments for cardiovascular disease (Pampel, 2002; Waldron, 1995, 2005). These factors may account for declining sex ratios in mortality, but the narrowing sex gap is due in large part to declines in overall mortality. Factors that affect overall mortality, even if they result in the same proportionate changes for both sexes (i.e., relative sex ratios remain unchanged), may still cause declines in the sex gap, particularly if more deaths are shifted to ages where sex ratios are lower. Thus, in order to predict future trends in the sex gap, one cannot rely solely on projecting future patterns in sex ratios, but must also predict changes in overall mortality and take into account how those changes affect the distribution of deaths across age.

ACKNOWLEDGMENTS

This project received financial support from the National Institute of Aging (grant RO1 AG11552).

REFERENCES

Arriaga, E. E. (1984). Measuring and explaining the change in life expectancies. *Demography* 21(1):83-96.

Human Mortality Database (HMD). (2005). University of California, Berkeley (USA), and Max Planck Institute for Demographic Research (Germany). Available at www.mortality.org (data downloaded on 9 June 2005).

Meslé, F. (2004). Differences in life expectancy between the sexes: Why is it reducing? Paper presented at Human Mortality over Age, Time, Sex, and Place: The 1st HMD Symposium, June 18-19, Rostock, Germany. Co-sponsored by the Max Planck Institute for Demographic Research and the Center on the Economics and Demography of Aging, University of California, Berkeley. [Published in French in *Revue d'epidemiologie et de sante publique*]

Pampel, F.C. (2002). Cigarette use and the narrowing sex differential in mortality. *Population and Development Review* 28(1):77-104.

Preston, S. H. (1970). *Older male mortality and cigarette smoking: A demographic analysis.* Berkeley: Institute of International Studies, University of California.

Preston, S. H. (1976). *Mortality patterns in national populations: with special reference to recorded causes of death.* New York: Academic Press.

Ram, B. (1993). Sex differences in mortality as a social indicator. *Social Indicators Research* 29:83-108.

Stolnitz, G. J. (1956). A century of international mortality trends: II. *Population Studies* 10(1):17-42.

Tabutin, D. and M. Willems. (1993). Differential mortality by sex from birth to adolescence: The historical experience of the West (1750-1930). Pp. 17-52 in: *Too Young to Die: Genes or Gender?* New York: United Nations.

Trovato, F. and N.M. Lalu. (1996). Narrowing sex differentials in life expectancy in the industrialized world: Early 1970's to early 1990's. *Social Biology* 43:20-37.

United Nations Secretariat. (1988). Sex differentials in life expectancy and mortality in developed countries: An analysis by age groups and causes of death from recent and historical data. *Population Bulletin of the United Nations*, No. 25-1988. New York: United Nations.

Valkonen, T. and F. Van Poppel. (1997). The contribution of smoking to sex Differences in Life Expectancy: Four Nordic Countries and the Netherlands 1970-1989. *European Journal of Public Health* 7(3):302-10.

Waldron, I. (1993). Recent trends in mortality ratios for adults in developed countries. *Social Science and Medicine* 36:451-462.

Waldron, I. (1995). Contributions of biological and behavioral factors to changing sex differences in ischaemic heart disease mortality. Pp. 161-178 in A.D. Lopez, G. Caselli, and T. Valkonen (eds.), *Adult Mortality in Developed Countries: From Description to Explanation.* Oxford: Claredon Press.

Waldron, I. (2005). Gender differences in mortality: causes and variation in different societies. Pp. 38-55 in P. Conrad (ed.), *The Sociology of Health and Illness-Critical Perspectives*. New York: Worth Publishers.

Wilmoth JR. (2004). Methods protocol for the Human Mortality Database. Available at www.mortality.org/Docs/MethodsProtocol.pdf (downloaded 17 May 2005).

Figure 1. Sex ratios in mortality rates by age group, decade, and country, 1751-1913

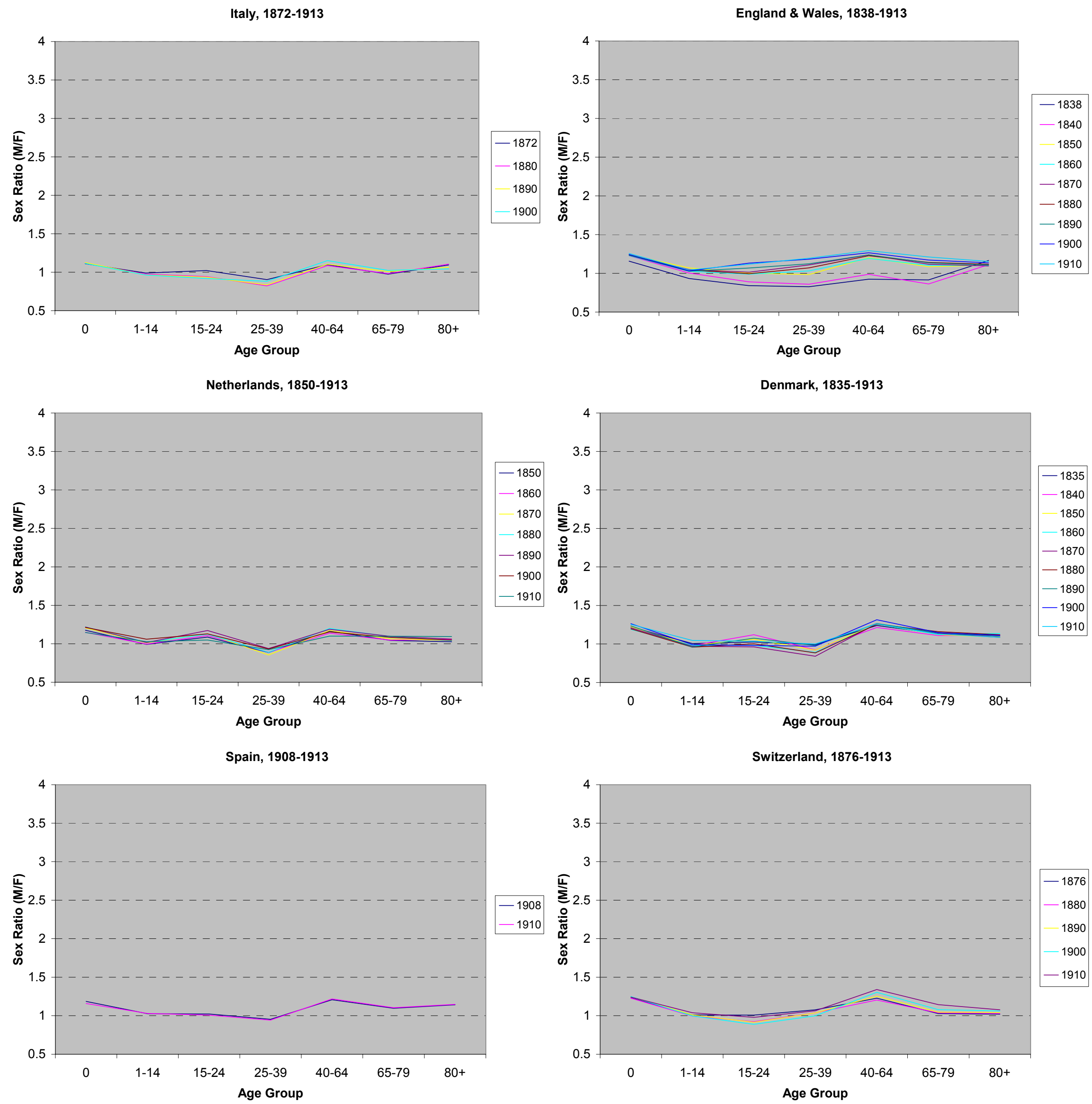


Figure 1 (continued)

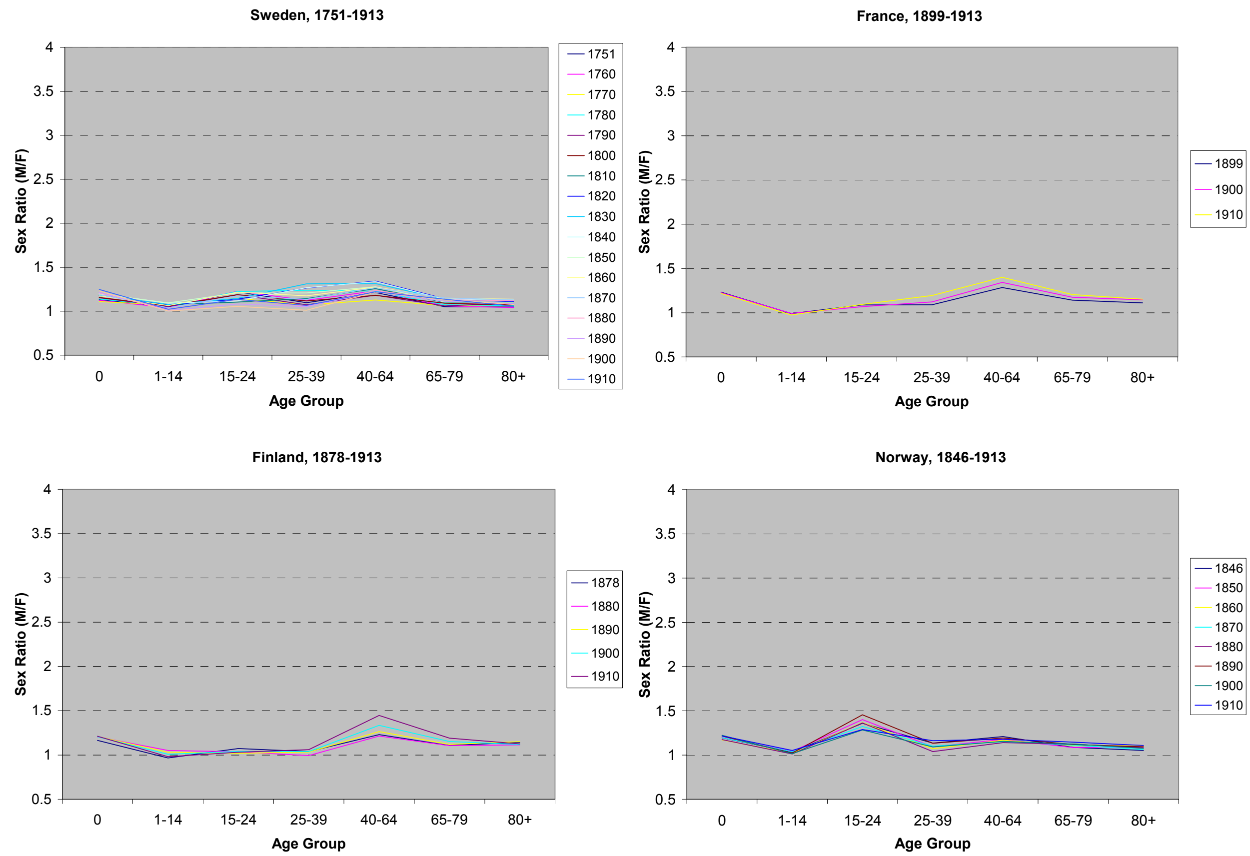
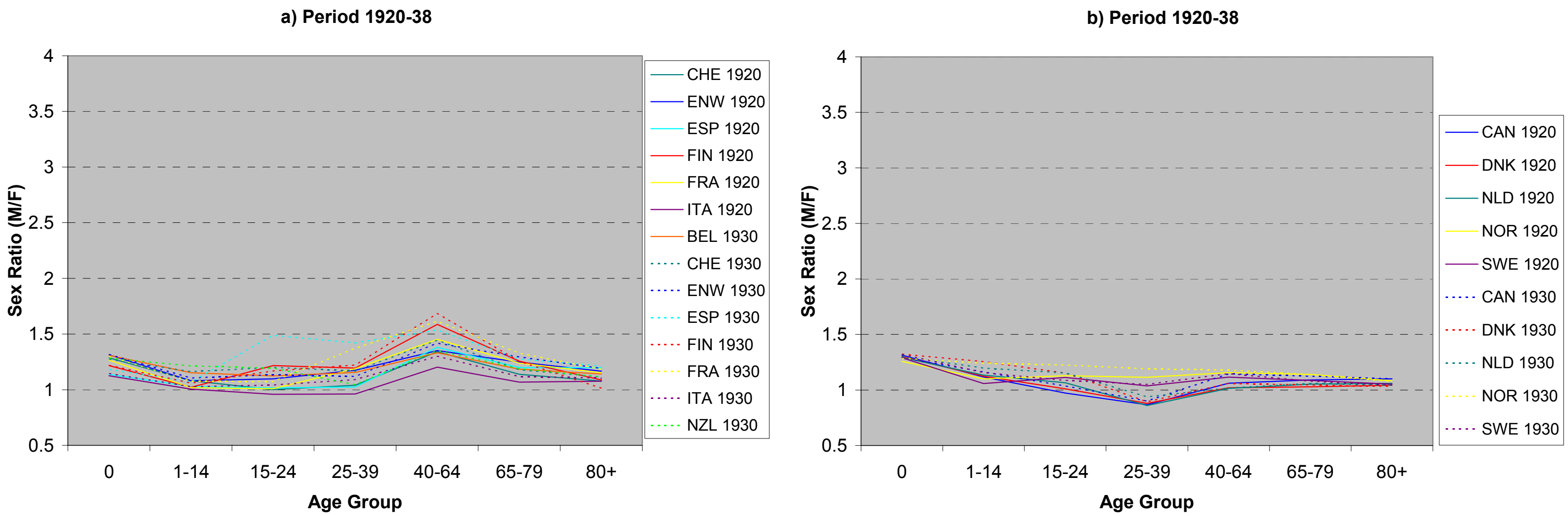


Figure 2. Sex ratios in mortality rates by age group, decade, and country, 1920-38



Note: See Table 1 for the names of countries corresponding with the 3-letter country codes.

Figure 3. Sex ratios in mortality rates by age group, decade, and country, 1946-49

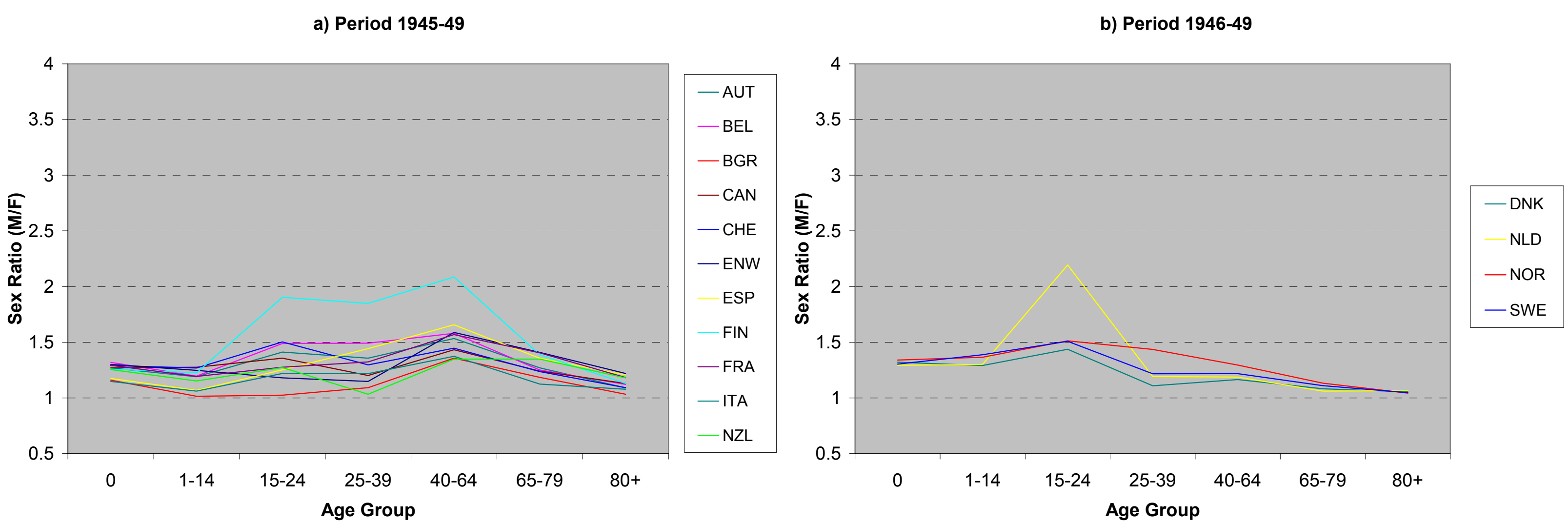


Figure 4. Sex ratios in mortality rates by age group, decade, and country, 1950-59

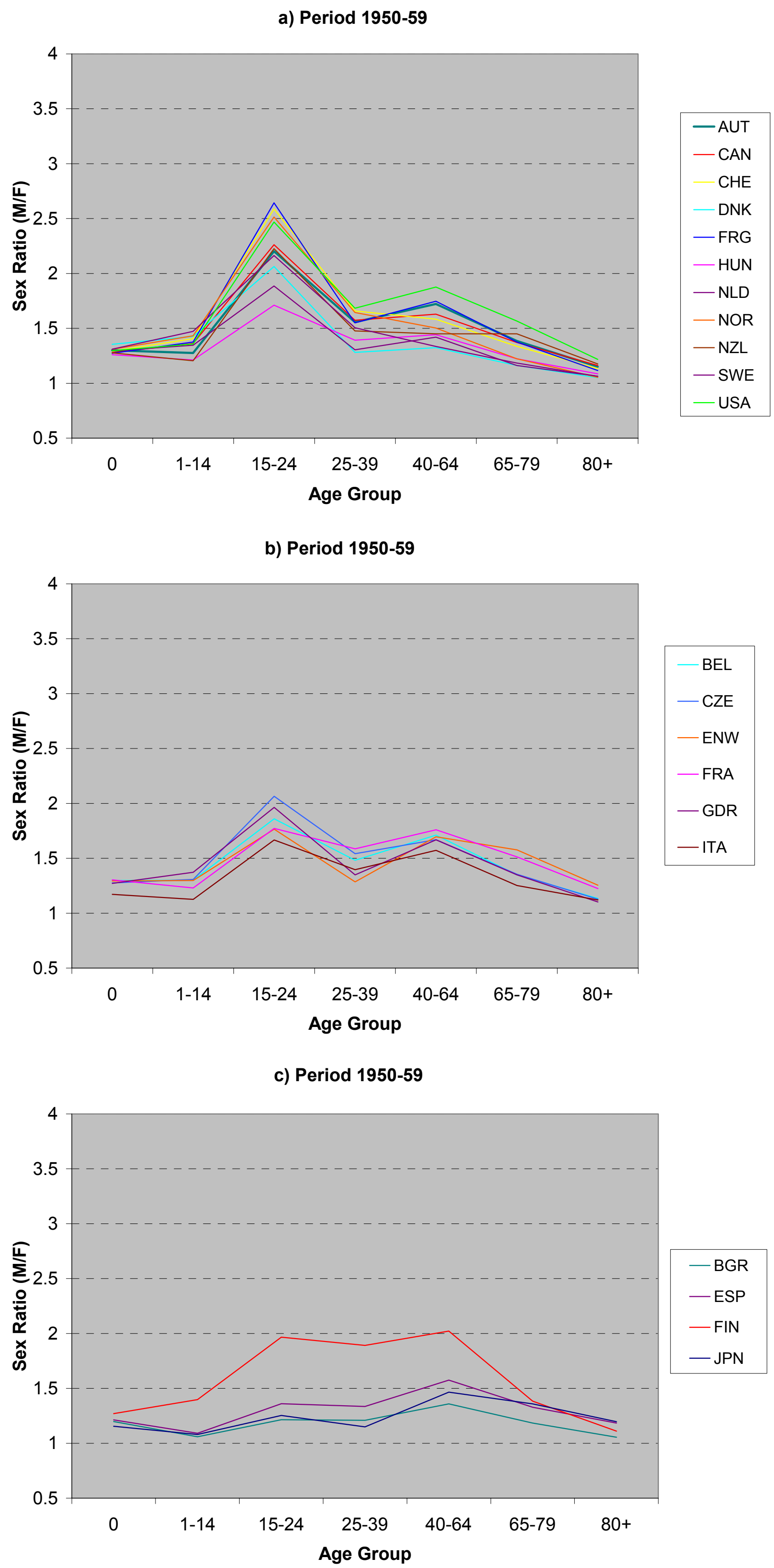


Figure 5. Sex ratios in mortality rates by age group and decade, Russia, Latvia, and Lithuania

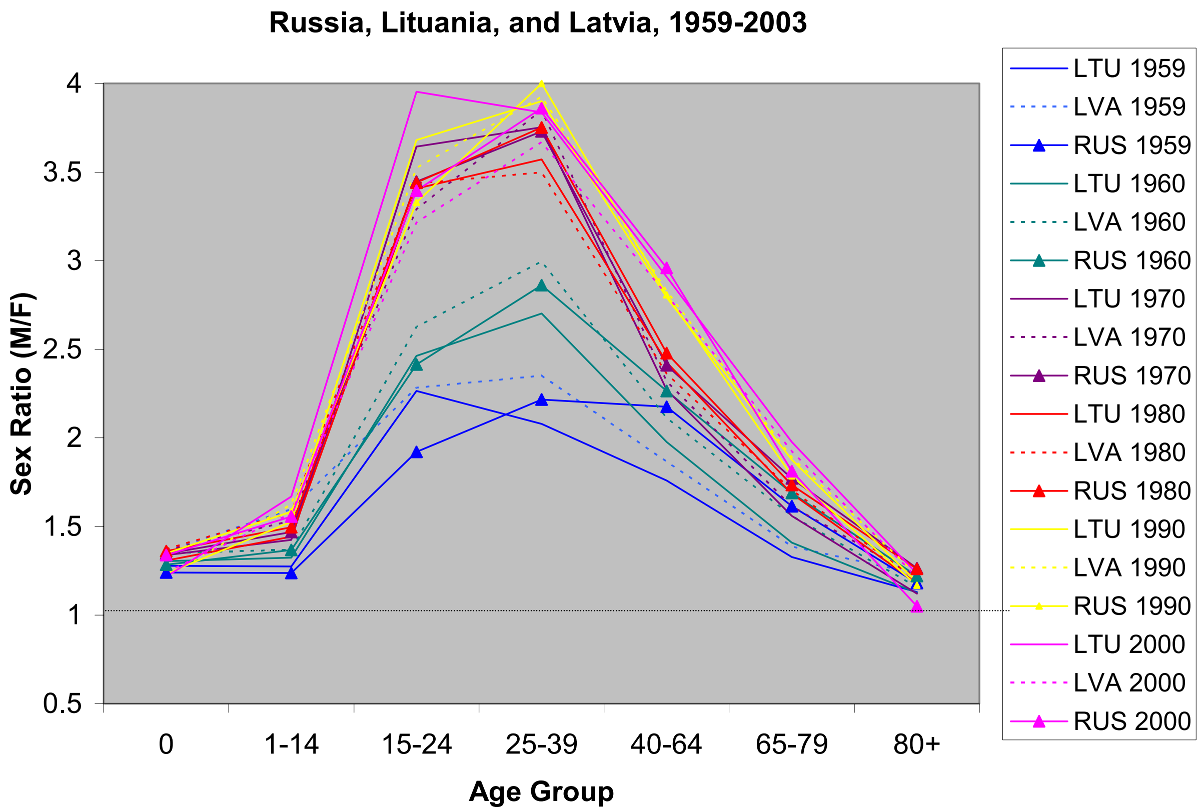


Figure 6. Sex ratios in mortality rates by age group, decade, and country, 1960-69

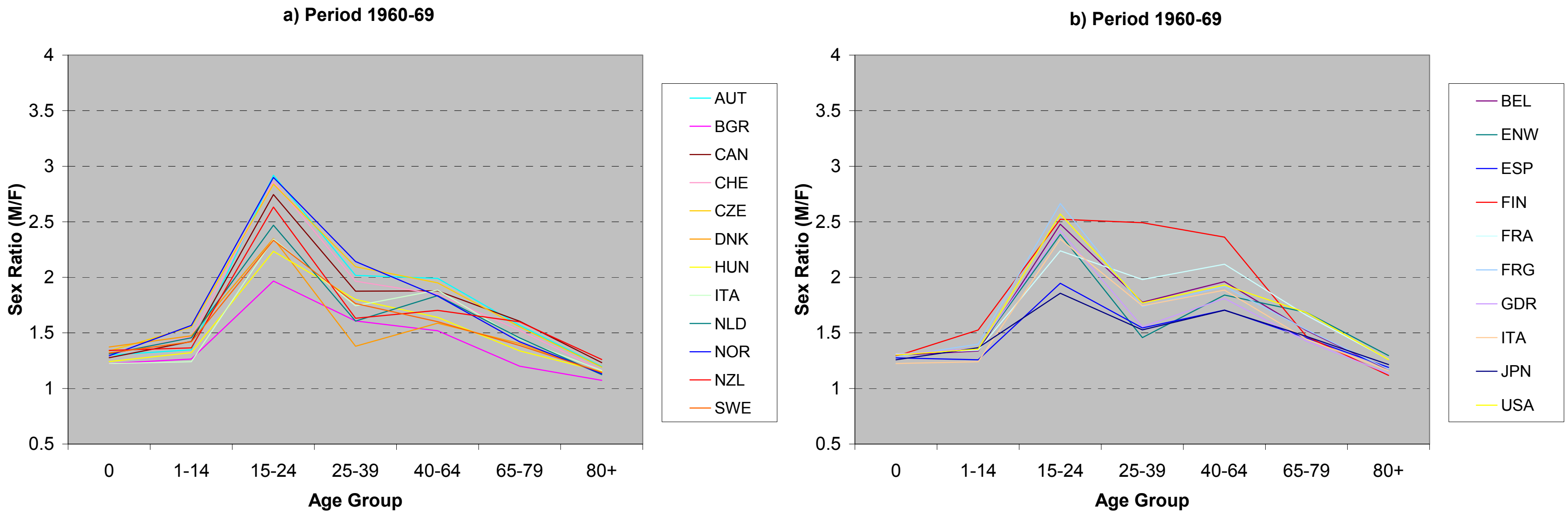


Figure 7. Sex ratios in mortality rates by age group, decade, and country, 1970-79

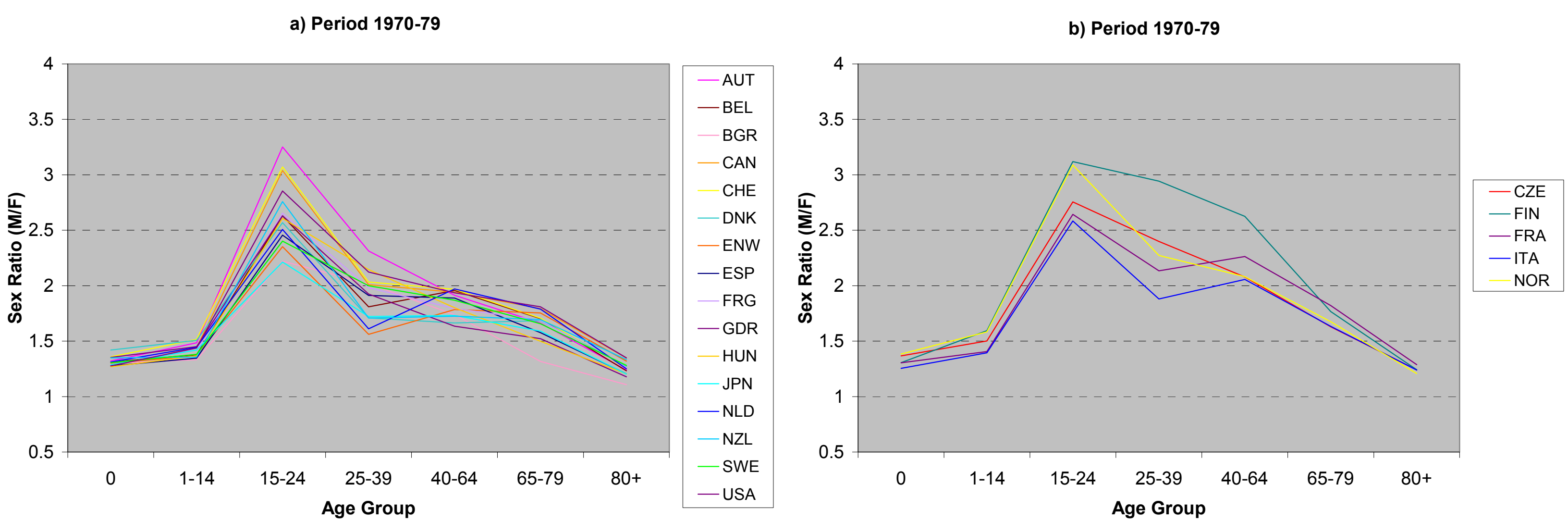


Figure 8. Sex ratios in mortality rates by age group, decade, and country, 1980-89

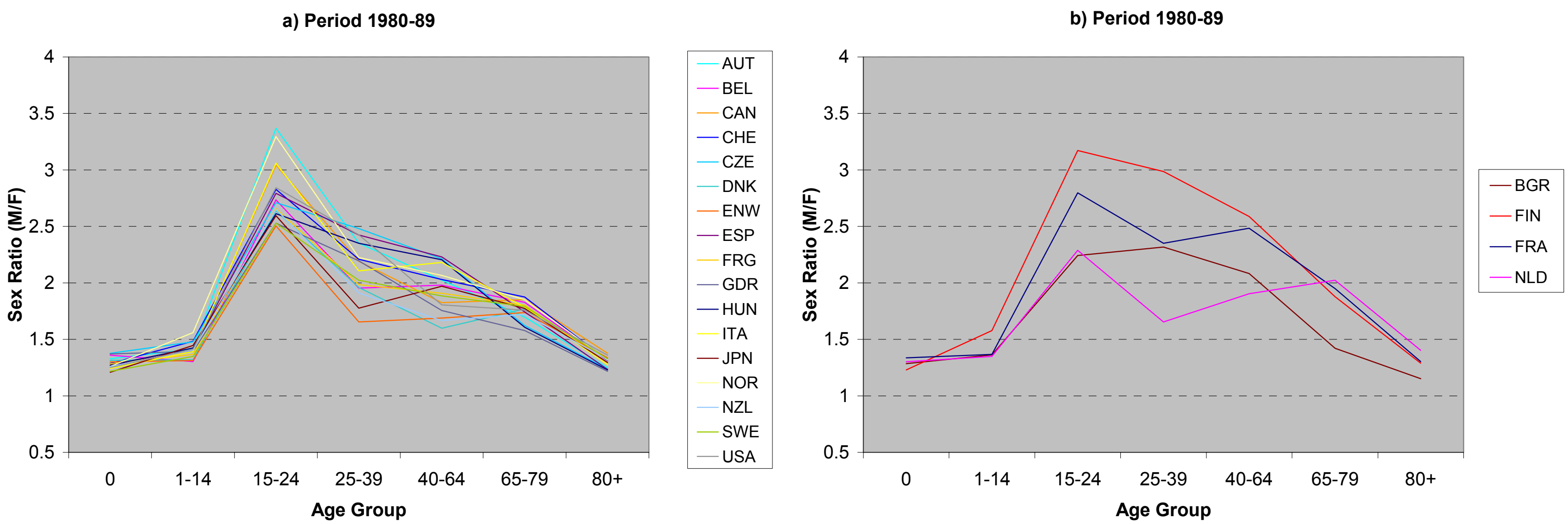


Figure 9. Sex ratios in mortality rates by age group, decade, and country, 1990-99

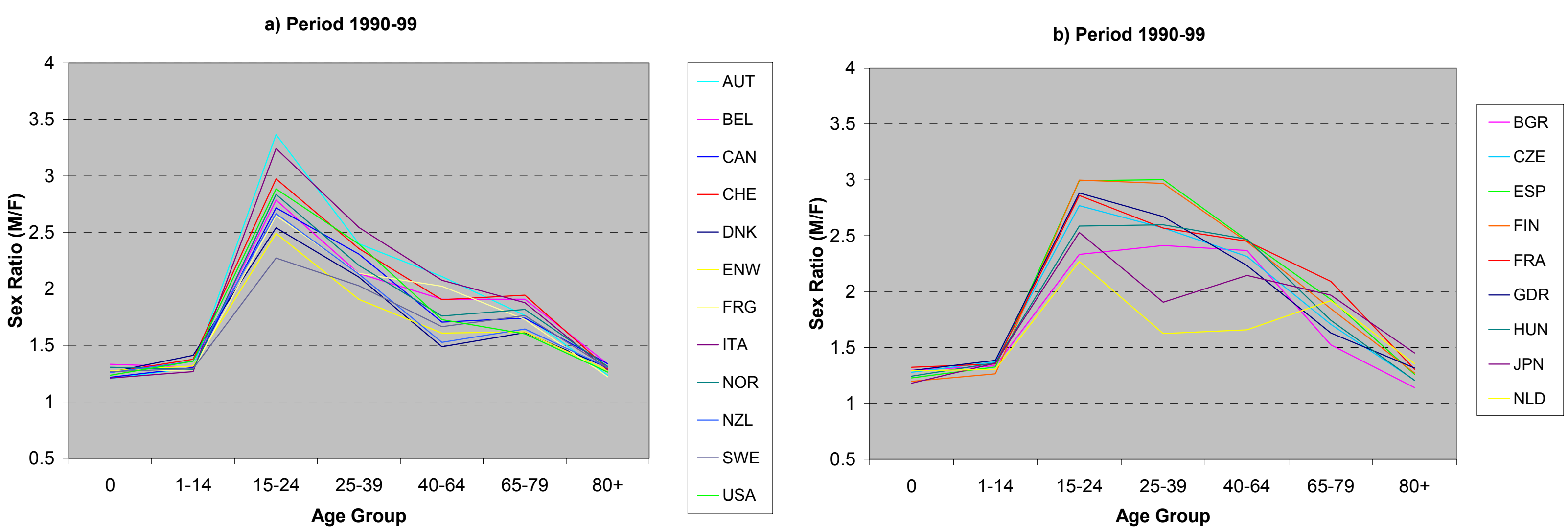
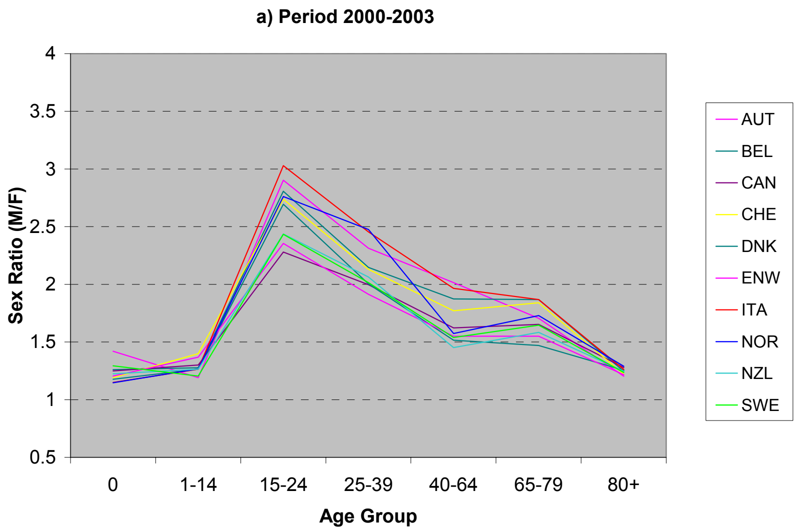


Figure 10. Sex ratios in mortality rates by age group, decade, and country, 2000-2003



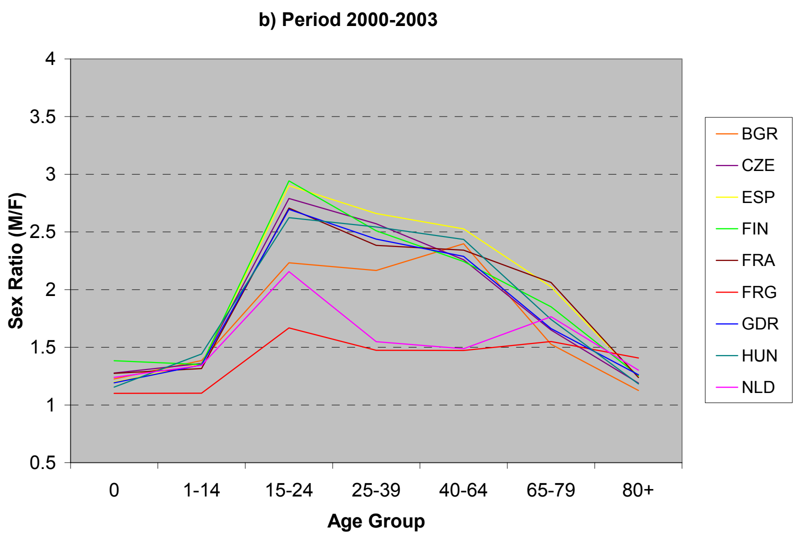


Figure 11. Sex differences in life expectancy (e0) by country and decade, 1751-2003

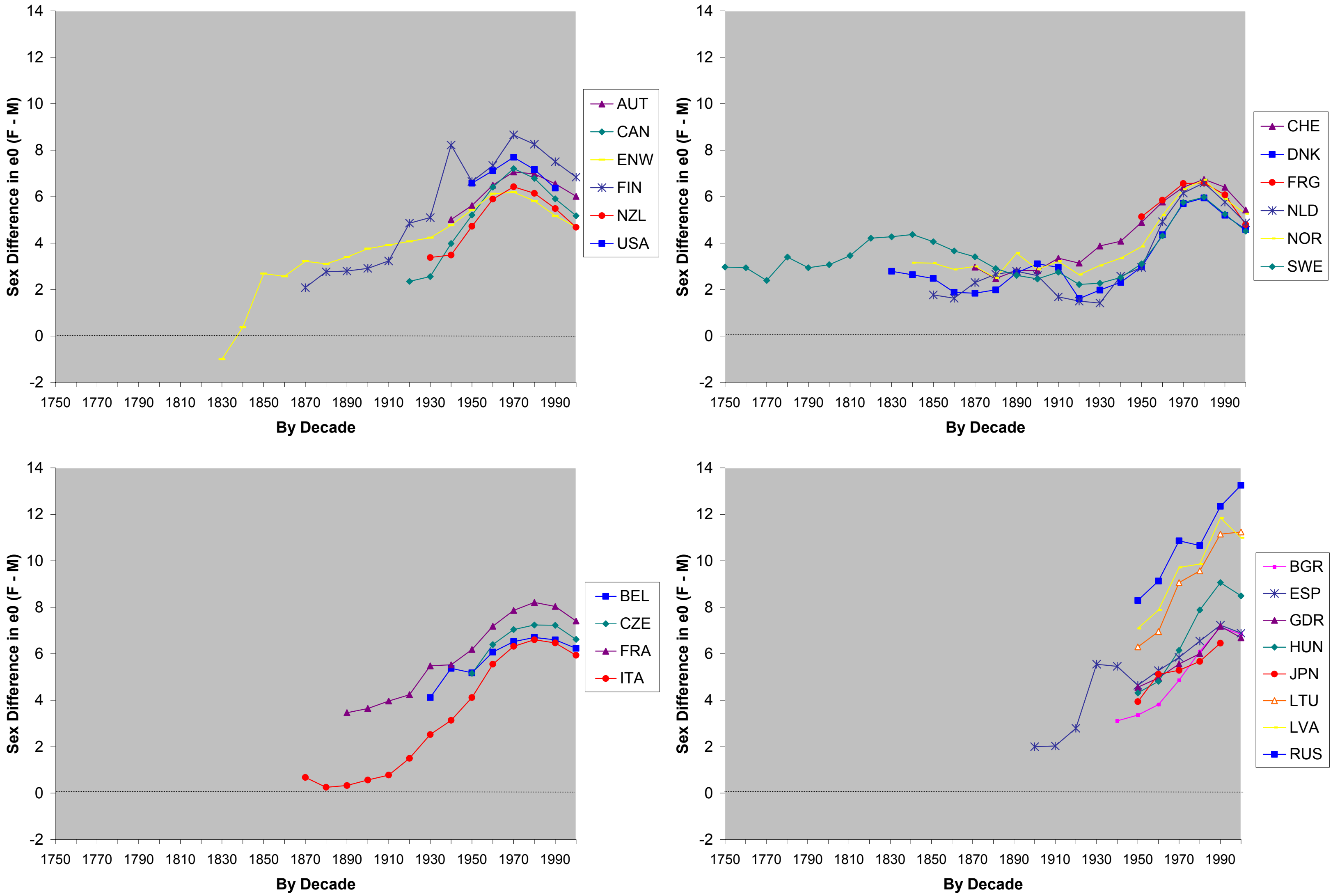
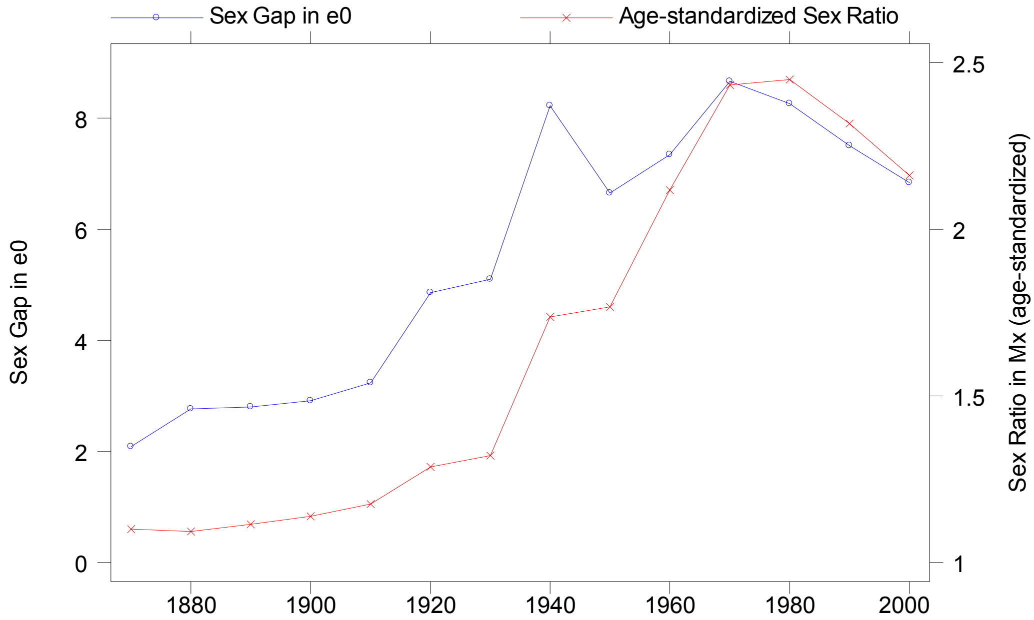
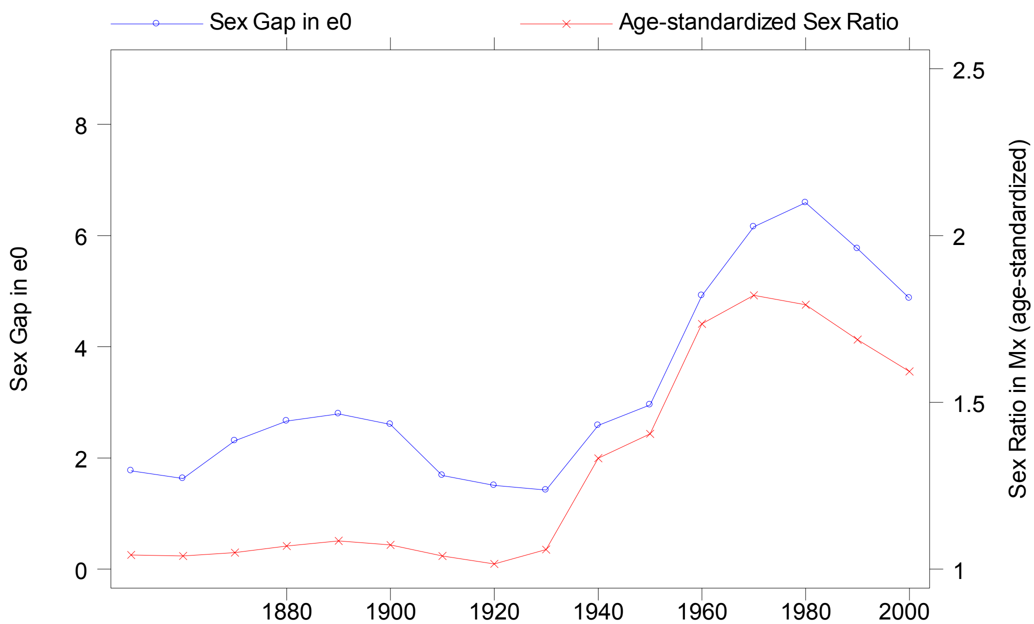


Figure 12. Sex gap in life expectancy versus age-standardized sex ratios in mortality



a) Finland, 1878-2002



b) The Netherlands, 1850-2003

Figure 13. Decomposition of sex difference in life expectancy by age group and time period

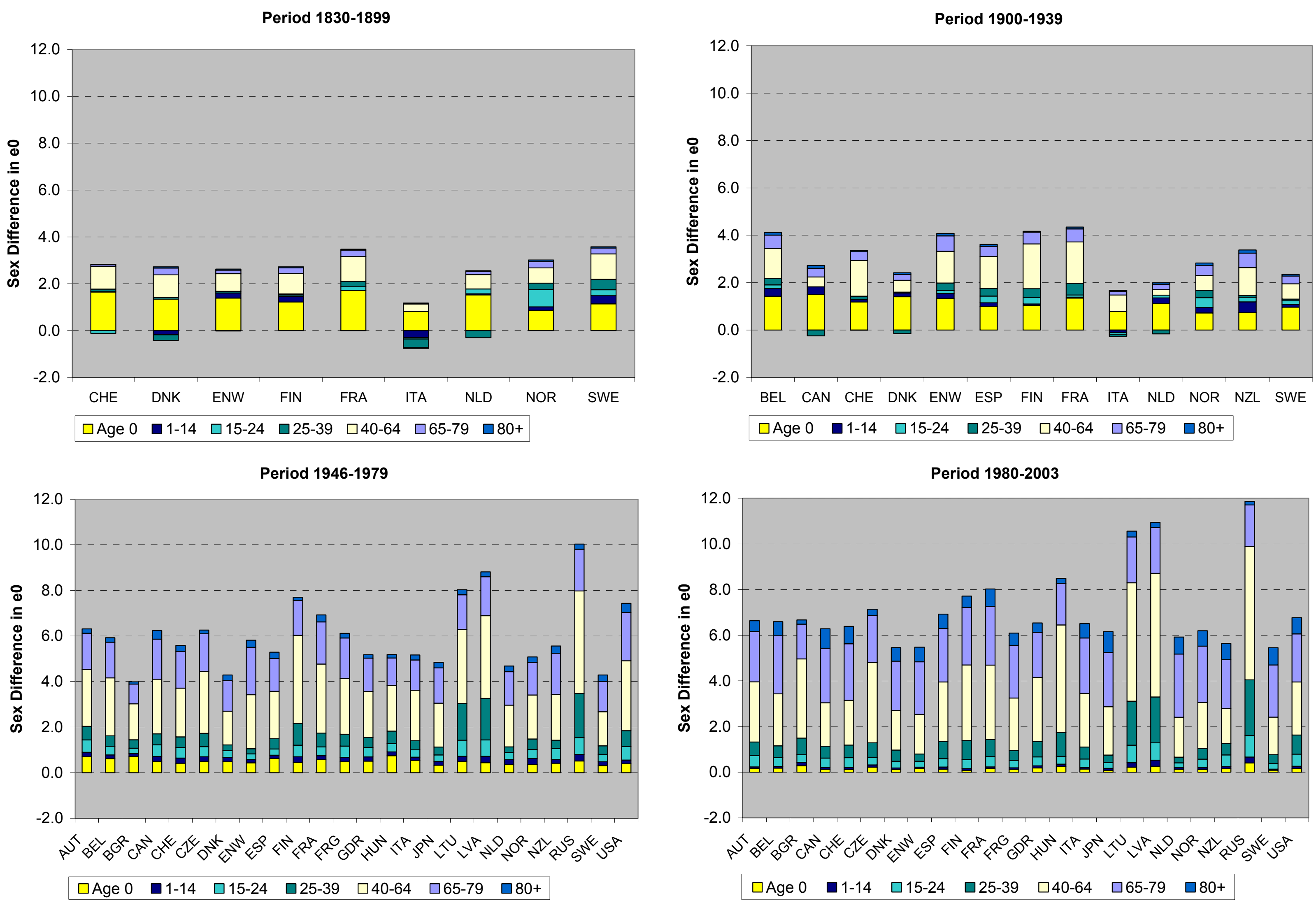


Table 1 – Countries and Range of Years Covered by the Data

Country	Country Code	Range of Years
Austria	AUT	1947-2002
Belgium	BEL	1931-2002
Bulgaria	BGR	1947-2003
Canada	CAN	1921-2000
Czech Republic	CZE	1950-2003
Denmark	DNK	1835-2002
England & Wales	ENW	1838-2000
Finland	FIN	1878-2002
France	FRA	1899-2002
Germany, East (former)	GDR	1956-2002
Germany, West (former)	FRG	1956-2002
Hungary	HUN	1950-2001
Italy	ITA	1872-2001
Japan	JPN	1950-1999
Latvia	LVA	1959-2003
Lithuania	LTU	1959-2003
Netherlands	NLD	1850-2003
New Zealand	NZL	1937-2003
Norway	NOR	1846-2002
Russia	RUS	1959-2002
Spain	ESP	1908-2002
Sweden	SWE	1751-2003
Switzerland	CHE	1876-2003
United States	USA	1959-1999

Sources: Human Mortality Database (HMD). (2005). University of California, Berkeley (USA), and Max Planck Institute for Demographic Research (Germany). Available at www.mortality.org (data downloaded on 3 March 2005).

Table 2 – Changes in Sex Gap in e_0 from 1900s to 2000s, Observed versus Simulated[†] Gap

	Observed Sex Gap (in years) in:				Change in Sex Gap between:					
					1900-09 and 1946-49		1946-49 and 1970-79		1970-79 and 2000-03	
Country	1900-09	1946-49	1970-79	2000-03	Observed	Simulated	Observed	Simulated	Observed	Simulated
Denmark	3.1	2.3	5.7	4.6	-0.8	-0.7	+3.4	-0.8	-1.1	-0.4
England & Wales	3.8	4.8	6.2	4.7	+1.0	-1.1	+1.4	-0.6	-1.5	-0.5
Finland	2.9	8.2	8.7	6.8	+5.3	-0.2	+0.4	-2.9	-1.8	-1.3
France	3.6	5.5	7.9	7.4	+1.9	-0.6	+2.3	-1.4	-0.5	-1.3
Italy	0.6	3.1	6.3	5.9	+2.6	+0.3	+3.2	-1.0	-0.4	-1.3
Netherlands	2.6	2.6	6.2	4.9	0.0	-1.1	+3.6	-1.0	-1.3	-0.6
Norway	2.9	3.4	6.3	5.3	+0.5	-1.0	+3.0	-1.3	-1.0	-0.5
Spain	2.0	5.5	5.8	6.9	+3.5	+0.3	+0.4	-1.5	+1.0	-1.3
Sweden	2.5	2.5	5.8	4.5	+0.1	-0.7	+3.2	-0.8	-1.2	-0.8
Switzerland	2.8	4.1	6.4	5.4	+1.3	-0.8	+2.3	-1.2	-1.0	-1.1
Austria	--	5.0	7.1	6.0	--	--	+2.0	-1.6	-1.0	-1.5
Belgium	--	5.4	6.5	6.2	--	--	+1.1	-1.7	-0.3	-1.0
Bulgaria	--	3.1	4.9	6.8	--	--	+1.7	-0.9	+2.0	-0.3
Canada	--	4.0	7.2	5.2	--	--	+3.2	-0.9	-2.0	-1.1
New Zealand	--	3.5	6.4	4.7	--	--	+2.9	-0.4	-[‡]1.7	-0.9
Czech Republic	--	--	7.0	6.6	--	--	--	--	-0.4	-1.0
Germany, East (former)	--	--	5.6	6.7	--	--	--	--	+1.1	-1.1
Germany, West (former)	--	--	6.6	4.8	--	--	--	--	-1.8	-0.3
Hungary	--	--	6.1	8.5	--	--	--	--	+2.3	-0.3
Japan	--	--	5.3	6.5[‡]	--	--	--	--	+1.2[‡]	-0.9[‡]
Latvia	--	--	9.1	11.2	--	--	--	--	+2.2	-0.5
Lithuania	--	--	9.7	11.0	--	--	--	--	+1.3	-0.3
Russia	--	--	10.9	13.2	--	--	--	--	+2.4	+1.3
United States	--	--	7.7	6.4[‡]	--	--	--	--	-1.3[‡]	-0.5[‡]

[†] The simulated sex differences in e_0 is derived based on the observed mortality rates for females in the latter decade (e.g., 1940s), but assuming sex ratios remain at the same level as the earlier decade (e.g., 1900). Mortality rates for males in the latter decade are simulated to the levels they would have been if males had experienced the same proportionate changes in mortality as females. Thus, this simulated sex gap represents the sex gap that would have resulted if sex ratios had remained unchanged.

[‡] Data for 2000-03 are not available for Japan and the United States, therefore we use data for the 1990s instead.