# Ageing 1

# Causes of international increases in older age life expectancy

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**In high-income countries, life expectancy at age 60 years has increased in recent decades. Falling tobacco use (for men only) and cardiovascular disease mortality (for both men and women) are the main factors contributing to this rise. In high-income countries, avoidable male mortality has fallen since 1980 because of decreases in avoidable cardiovascular deaths. For men in Latin America, the Caribbean, Europe, and central Asia, and for women in all regions, avoidable mortality has changed little or increased since 1980. As yet, no evidence exists that the rate of improvement in older age mortality (60 years and older) is slowing down or that older age deaths are being compressed into a narrow age band as they approach a hypothesised upper limit to longevity.**

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This is the first in a **Series** of five papers about ageing

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## Introduction

Life expectancy at birth has increased substantially over the course of human history, mostly because of reductions in infant and child mortality, themselves a result of a reduction in infectious disease mortality. Since the 1970s, the main factor driving continued gains in life expectancy in high-income countries has been the decrease in mortality in older people, specifically deaths from non-communicable diseases.[1] Most analyses of worldwide patterns of adult mortality have focused on the age group 15–59 years; analyses for people aged 60 years and older have tended to focus only on high-income countries.[2] We aimed to provide a comprehensive overview of mortality and life expectancy and their trends at older age. We define older adults here as aged 60 years or older.

WHO has estimated life average expectancy at age 60 years for all Member States during the years 1990–2012.[3] Most countries in the Middle East, north Africa, and sub-Saharan Africa do not have usable death registration data, and estimates of mortality at older age rely on the use of model life tables to extrapolate from younger adult mortality and, in some countries, from other sources of mortality data (panel). WHO has estimated that worldwide average life expectancy for women at age 60 years was 21·5 years in 2012, ranging from 17·2 years in sub-Saharan Africa to 26·1 years in high-income countries (table). For men, the worldwide life expectancy at age 60 years was 18·5 years, ranging from 15·7 years in sub-Saharan Africa to 22·3 years in high-income countries. During the past two decades, life expectancy at age 60 years for men and women has risen by 0·9 years for men and 0·8 years for women per decade. The gap in life expectancies between high-income and low-income and middle-income countries has grown. Life expectancy in high-income countries has increased by 1·6 for men and 1·4 years for women per decade compared with 0·7 years for men and 0·8 years for women in low-income and middle-income countries.

We explored these trends in more detail using high quality death registration data. We addressed the following questions: how do recent gains in older adult life expectancy vary by country and region? Is a fixed upper limit for the human life span approaching, with the consequent compression of mortality into a narrowing band of older ages, as proposed by Fries?[23] What are the causes of the recent decreases in death rates in older people? Is there potential for further reductions in mortality at older ages, from which causes, and in which countries and regions? We decided that reliable information on cause-specific mortality and their trends could be calculated from death registration data in the WHO mortality database[24] if the proportion of all deaths (recorded and unrecorded) for which cause-of-death information could be obtained exceeded 80% for at least 80% of data-years available between 1980 and 2011. The appendix describes selection criteria for countries and

### Key messages

- High quality data for levels of and trends in older age (>60 years) mortality are unavailable for all low-income and many middle-income countries
- Life expectancy at age 60 years has improved steadily in the past three decades, with no deceleration in life expectancy improvement or consistent compression in age at death
- For men in high-income countries, the risk of dying between ages 60 years and 80 years has been decreasing at 1·5% a year on average during the past three decades, the same as the average rate of decrease of 1·5% per year for the risk of dying between ages 15 years and 60 years
- For women, the risk of dying between ages 60 years and 80 years has been decreasing at an average annual rate of 1·7%, faster than the risk of dying between ages 15 years and 60 years (1·2% per year)
- The annual average rate of increase in life expectancy at age 80 years was slightly higher for both men and women than that of age 60 years
- Improvements in older age mortality were mainly atrributed to decreases in tobacco use (for men) and in cardiovascular disease mortality (for both men and women)
- Older age mortality can be assessed by comparison with mortality in best-performing so-called frontier countries. Whenever mortality rates are higher than those in the frontier countries, the difference in mortality can be judged avoidable
- Male avoidable mortality has fallen in high-income countries during the past three decades. However, both female avoidable mortality in all regions and male avoidable mortality in middle-income countries have changed little or risen since 1980. Particularly, avoidable mortality in middle-income European countries has increased, showing that these countries are falling behind the best-performing ones

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See **Online** for appendix

methods for data adjustment, interpolation, and extrapolation for missing country years. After exclusion of data series that did not meet quality criteria, and interpolation and extrapolation, our final dataset contained complete (or nearly complete) time series from 1980 to 2011 for 51 countries (appendix). These countries were predominantly high income countries, but the dataset included middle income countries in Europe and Latin America and the Caribbean (appendix). We refer to data meeting the inclusion criteria as high quality; this definition does not necessarily imply that coding of cause or age of death are highly accurate.

**_Panel:_ Mortality at older age (>60 years) in low-income and low-middle-income countries**

Civil registration and vital statistics systems are the main sources of mortality data in high-income countries. No low-income and few low-middle-income countries have functioning registration systems that generate mortality statistics for older people.[4] In the absence of such data, information is based on household surveys and population censuses, which include questions on recent deaths in the household or survival status of the parents of the respondent (orphanhood method).[5] Both methods have drawbacks, and often mortality at older age is improbably low. Under-reporting of deaths and age exaggeration, which are more severe at very high ages, are major factors.[6,7]

Prospective demographic surveillance studies in local populations are an important source of old age mortality data in low-income and low-middle-income countries. Such studies are mostly done in rural populations, with insufficient medical services, in which most deaths occur at home. Life expectancy at age 60 years in 18 of these studies in sub-Saharan Africa was, on average, 16·2 years for men and 17·9 years for women.[8] In household surveys in Ghana (2007)[9] and Bangladesh (2001)[10] life expectancy at age 60 years was reported as 15·6 years for men and 13·7 years for women, which are similar to those of high-income countries in the early 1980s. However, mortality might be underestimated. Long-term trend data are available from very few countries and are limited to long running local demographic surveillance study populations. Mortality in people aged 60 years and older in Matlab, Bangladesh, fell more slowly than mortality at all other ages during 1982–2004.[11,12] Annual data from a rural study in KwaZulu-Natal, South Africa,[13] showed little progress during 2000–09, with mortality at age 65 years and older stagnating at about 60 per 1000 person-years.

In the absence of reliable medical certification of deaths, verbal autopsy based on interviews with the relatives of the deceased is the predominant source of cause-of-death information. Few verbal autopsy validation studies exist for deaths at age 60 years and older. Coexistence of different disorders is likely to complicate ascertainment of cause of death through verbal autopsy of older people.[14] Perhaps as a result, a high proportion of deaths are attributed to unspecified causes of death (such as senility) or are ill-defined. For instance, in a large verbal autopsy study in India, senility was the second most common cause of death (16·0% in rural and 14·3% in urban India) during 2001–03.[15]

Although cardiovascular diseases are the leading cause of death in people aged 60 years and older in most verbal autopsy studies in low-income settings,[12,16,17] infectious diseases also seem to be associated with substantial mortality at older age, presumably because of high incidence and case fatality rates due to compromised immunity. These diseases include febrile illness or malaria, acute respiratory infections, diarrhoeal diseases, tuberculosis, and HIV/AIDS.[16] In populations with high malaria transmission, acute febrile illnesses can emerge as the leading cause of death at older age.[18,19] HIV or AIDS mortality rates peak before age 60 years and are a less common cause of death after 60 years of age,[16,20] although one study in a high prevalence area in rural Kenya showed that HIV/AIDS was the leading cause of death for adults aged 50 years and older.[21] HIV/AIDS mortality can change if antiretroviral treatment coverage is high, extending survival of people living with HIV/AIDS into their 60s and beyond. For all infectious diseases, the relative contribution to mortality in older people as part of the specific infectious disease burden is likely to increase during the coming decades because of the ageing of the population.

## Life expectancy trends at older ages

Mortality rates in 5-year age intervals from age 15 years up to 85 years and older were extracted from death registration data to construct abridged life tables. We expanded the open ended age interval of 85 years and older using the Thatcher–Kannisto method (appendix). Potential biases introduced by incomplete recording of deaths at older ages in some countries, age misreporting on death certificates, and issues with population estimates for older age groups, mean that life table indices for older ages should be interpreted with caution at a country level, particularly for developing countries because of lower completeness of registration of deaths and less accurate age reporting at older ages. By 2011, the life expectancy of a person aged 80 years in a high-income country was 8·7 years for men and 11·0 years for women compared with 6·2 years for men and 7·7 years for women in 1980. In high-income countries, the middle-income countries of Europe, and Latin America and the Caribbean, the annual average rate of increase in life expectancy at age 80 years was slightly higher than at age 60 years for both men and women.

The appendix summarises trends in life expectancy by country at ages 60 years and 80 years. Where available, trends for 1955–80 are shown. Average rates of increase in life expectancy at age 60 years ranged from close to zero for some former Soviet countries to greater than 2 years per decade during 1980–2011 for some high-income countries. For these highest performing countries, average rates of increase for age 60 years was more than double that of the earlier period of 1955–80. Countries with the greatest average annual gains in life expectancy at age 60 years include New Zealand (0·22 years) and Australia and the UK (0·21 years) for men, and Japan (0·24 years) and Malta (0·23 years) for women. To put these numbers into context, life expectancy for women aged 60 years in Japan has been increasing by an average of almost a quarter of a year per year, or 6 h per day. This statistic is close to the overall average rate of increase of life expectancy at birth over the past century in the countries representing the frontier of life expectancy.[25]

During the past three decades, mortality has fallen substantially in older people (appendix). This decrease is a historic change in the development of worldwide health status, and such a sustained trend has never been seen before for national populations; older age mortality remained essentially static as countries went through the epidemiological transition (with rapidly decreasing infant and child mortality). Yet, beginning about 30 years ago, older age mortality has fallen in nearly all the countries in this analysis, with some eastern

European countries remaining static or increasing. In high-income countries, mortality has fallen faster in older (≥60 years) than younger (15–59 years) age groups. For men in high-income countries, the risk of dying between ages 60 years and 80 years has been decreasing at 1·5% a year on average, the same as the average rate of decrease of 1·5% per year for the risk of dying between ages 15 years and 60 years. For women, the risk of dying between ages 60 years and 80 years has been falling at an average annual rate of 1·7%, faster than the risk of dying between ages 15 years and 60 years (1·2% per year). By contrast, for middle-income countries in the Americas, mortality risks at older ages have not been decreasing as fast as those for younger adults in the past three decades. In the middle-income countries of Europe, mortality rates have decreased only marginally for men at younger and older ages, and at a somewhat higher rate for women at older ages than for those at younger ages (appendix). The stagnation in male life expectancies at ages 60 years and 80 years in the middle-income countries of eastern Europe shows the increases in mortality rates that occurred after the collapse of the Soviet Union in 1991, particularly for cardiovascular diseases, injuries, and alcohol-related causes.[26–29] Reductions in mortality rates at ages 60–79 years have been the main contributors to the rise in life expectancy of men aged 60 years in high-income countries: age groups 60–69 years and 70–79 years each contributed close to 40% of the gains in life expectancy during 1980–2011 (appendix). By contrast, the gain in female life expectancy at age 60 years was mainly due to falling mortality at ages 70–79 years (39%) and 80 and older (38%). Similar patterns of age contribution were noted for men in Latin America and the Caribbean, and for women in the middle-income countries of Europe and in Latin America.

| | Men | | | Women | | |
|---|---|---|---|---|---|---|
| | 1990 | 2012 | Average increase per decade (years) | 1990 | 2012 | Average increase per decade (years) |
| **High income countries** | | | | | | |
| All | 18·7 | 22·3 | 1·6 | 23·1 | 26·1 | 1·4 |
| **Low-income and middle-income countries** | | | | | | |
| All | 15·8 | 17·3 | 0·7 | 18·3 | 20·0 | 0·8 |
| Sub-Saharan Africa | 14·4 | 15·7 | 0·6 | 15·7 | 17·2 | 0·7 |
| Middle East and north Africa | 16·1 | 17·3 | 0·5 | 17·8 | 19·5 | 0·8 |
| Asia and Pacific | 15·8 | 17·4 | 0·7 | 17·9 | 19·7 | 0·8 |
| Latin America and Caribbean | 17·8 | 20.0 | 1·0 | 20·5 | 23·1 | 1·2 |
| Europe | 15·4 | 15·9 | 0·2 | 19·7 | 21·0 | 0·6 |
| **Worldwide** | | | | | | |
| All | 16·6 | 18·5 | 0·9 | 19·7 | 21·5 | 0·8 |

Data taken from world health statistics 2014.[3,22]

***Table:* Life expectancy at 60 years of age, with increase per decade, by sex, country income group, and region, from 1990 to 2012**

## Compression of mortality in older age

Wilmoth and Horiuchi[30] reviewed indicators that have been proposed to measure and summarise compression of mortality. They recommended use of the IQR, estimated from the distribution of deaths by single year of age in the period life table. Kannisto[31] recommended use of the C50 indicator—the smallest age range in the life table that includes 50% of deaths. C50 is always less than or equal to the IQR and has the advantage that for countries with low mortality in children and younger adults, it focuses on the age range at older ages, in which most deaths are concentrated. We have computed the Kannisto C50, the one-sided standard deviation of deaths above the modal age at death, and report trends for other measures (mode, median, first and third quartiles, and interquartile range) by country (appendix).

The Kannisto C50 index—the smallest age interval that includes 50% of deaths—measures the degree of concentration of deaths into a small age range, and, in addition to measuring compression, is a measure of inequality in ages of death. The Kannisto C50 index provides no clear evidence for compression of mortality in any region on the basis of aggregated data for 50 countries (figure 1). C50 is more stable for high-income countries than for other countries, with a slight compression across the period for both men and women, but quite different patterns for Latin America, eastern Europe, and central Asia. Latin American countries show a rapid improvement until around 1990, followed by a sharp upturn in inequality for women but not men, stabilising in the mid-to-late nineties. C50 has risen for men and women in eastern Europe and central Asia, particularly in the periods around 1990–95, followed by a period of high C50 until the mid 2000s, with a fall in recent years for both men and women.

Inequality as measured by C50 differs from the typical high-income regional pattern for the USA and Denmark (figure 1). C50 in 1980 was, on average, 2·5–3 years higher for the USA than for other high-income countries for both men and women, and remained constant until 2011. By contrast, C50 fell for men in Denmark by 1·3 years, higher than the 0·5 year fall for other high-income countries. For Danish women, C50 was higher than for other high-income countries, but no overall decrease occurred. C50 rose by 1·2 years for women in Latin America, by contrast with almost a year decrease for men. Stabilisation or increased C50 in recent years could be associated with increasing survival to very high ages (mortality extension) offsetting compression at earlier ages.

The epidemiological transition from high mortality to low mortality dominated by non-communicable diseases at older ages has been accompanied, in most of the high-income countries, by a shift in the median and modal ages of death to quite advanced ages (eg, the


*Figure 1:* **Trends in mortality inequality (Kannisto C50)[30] at age 60 years and older, selected countries and regions, by sex, in 1980–2011**
The group Europe and central Asia consists of middle-income countries only. Data taken from the WHO Mortality Database.[24]

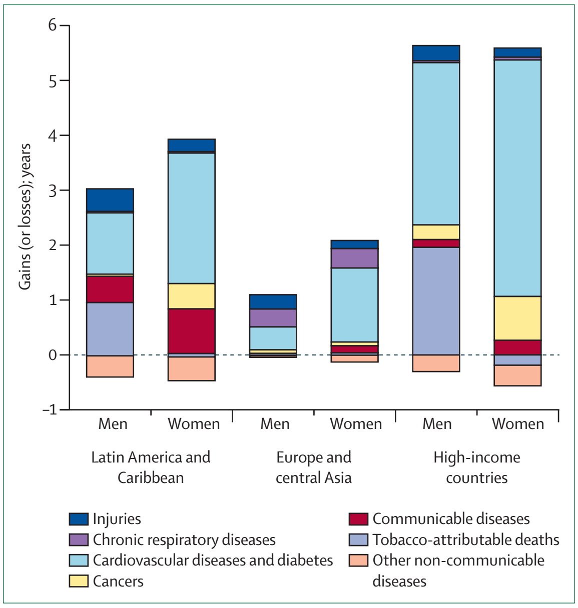


*Figure 2:* **Cause contributions* to gains in life expectancy at age 60 years from 1980 to 2011**
Aggregated regional populations for high-income countries, for middle-income countries of Europe and central Asia, and for Latin America and the Caribbean (with available death registration data for both periods) are shown. *Tobacco-attributable deaths for specific disease causes are subtracted from the disease cause categories and shown as a single cause group. Thus, for example, the cancers category excludes tobacco-caused cancers.

median age at death in Japan now exceeds 81 years for men and 89 years for women). This shift has not been accompanied by any clear compression across countries, showing that mortality rates at ages 70–79 years and 80 years and older are declining along with mortality rates at the younger-older ages (60–69 years). This decreasing mortality at the oldest ages suggests that we have not yet reached any limit to the human lifespan, even in the regions with highest life expectancies.

## Causes of rising life expectancy in older people

For countries with death registration data meeting our selection criteria, we decomposed gains in life expectancy between 1980 and 2011 into age group and cause contributions using the methods set out by Beltrán-Sánchez and colleagues.[32] We analysed the contribution of the following six broad cause categories to increases and differentials in life expectancy at older age: communicable diseases and nutritional deficiencies, cancers, cardiovascular diseases and diabetes mellitus, chronic respiratory diseases, other non-communicable diseases, and injuries. The appendix shows definitions for these cause categories. To clearly identify the contribution of tobacco-caused deaths, we calculated total deaths attributable to tobacco smoking across all causes of death using the method of Peto and colleagues,[33] who proposed that present mortality for lung cancer can be used as an indicator of past exposure to tobacco smoke. Briefly, we calculated the smoking impact ratio by comparing lung cancer mortality in each population analysed with those of non-smokers and smokers seen in the American Cancer Society II study.[34–37] Although Danaei and colleagues[34] did not include the effect of smoking on hypertensive heart disease in their main analysis, the effect is consistently reported.[35] Because of the importance of hypertensive heart disease worldwide, we included this effect in our analysis. In the analyses presented here, tobacco-caused deaths are grouped into a single cause category, and the other six cause categories exclude tobacco-caused deaths.

Figure 2 summarises our analysis of the contributions of decreases in cause-specific death rates to the overall rises in life expectancy at age 60 years in 1980–2011 for the countries meeting our criteria for completeness and quality of death registration data for years close to 1980 and 2011. In high-income countries, reduction in non-tobacco cardiovascular disease and diabetes


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mortality contributed most to gains in life expectancy at age 60 years between 1980 and 2011 (3·0 years for men and 4·3 years for women). Reductions in tobacco-caused mortality had an important role for men, contributing 2·0 years of increased life expectancy, but for women, deaths caused by tobacco rose, resulting in a reduction in life expectancy of 0·2 years. For women, non-tobacco cancer mortality also fell, leading to a 0·8 year rise in life expectancy; for men, reductions in non-tobacco cancer rates only contributed 0·3 additional years of life. Patterns in cause-specific mortality reductions were similar in the middle income countries of the Americas, with decreases in cardiovascular disease and diabetes mortality contributing most to increases in life expectancy (1·1 years for men and 2·4 years for women), followed by tobacco-caused deaths for men (0·9 years). Rises in life expectancy at age 60 years were much smaller in middle-income countries of Europe than in other countries analysed, with smaller improvements across most causes. The appendix shows similar analyses for individual countries.

We conclude that for men (but not women) in high-income countries, the peaking of the tobacco epidemic, typically in the 1970s, and subsequent reduction in tobacco-attributable mortality has made an important contribution to overall increases in life expectancies at older ages. The different timing of the tobacco epidemics in men and women in these countries could explain why the improvement in older age life expectancy has, uniquely, been greater for men than women in these countries. Both men and women in high-income countries (and the Latin America and Caribbean region) have benefited from downshifting of the population blood pressure distribution.[38–40]

In opposition to these trends, however, has been the growth in obesity and consequential type 2 diabetes epidemics, which could limit future rates of improvement in older age mortality, but which probably have had a small effect until now.[41,42] Within the wide range of health-care innovations introduced since 1970, which are likely to have already affected older age mortality, treatments (medical and surgical) for cardiovascular disorders (coronary heart disease, stroke, valvular disease, dysrhythmias, and heart failure) stand out. Roughly half of the substantial reduction in cardiovascular mortality is thought to have resulted from treatment of established disease (the other half resulted from risk factor reduction, including smoking, blood pressure, and cholesterol).[43,44] Cancer mortality has also begun to fall in these mainly high-income countries because of improvements in management of colorectal cancer, breast cancer, testicular cancer, Hodgkin's disease, and acute lymphoblastic leukaemia, and in screening and early detection of some cancers.[45,46] Nevertheless, for those high-income countries that have already achieved low levels of tobacco use and cardiovascular mortality in both sexes, further reductions in mortality could come more slowly. With rapid structural ageing of these populations over the next three-to-four decades, a rising tide of dementia could further constrain progress in older age mortality, unless dementia risk can be rapidly reduced through further shifts in distributions of cardiovascular risk factors, or novel pharmaceutical treatments.[47]

The slower improvement in older age mortality until now in middle-income than in high-income countries is a result of the so-called double burden of simultaneous communicable disease and non-communicable disease epidemics in these countries, the growing tobacco epidemics of many of these countries, the slow decrease in cardiovascular mortality not attributable to tobacco, and, more generally, the lower effective coverage of (primary and secondary) health care in middle-income than in high-income countries. The reasons for the temporary reversal of progress in countries of the former Soviet Union since 1991 are well known[26–29] and apply to both older and younger age groups. In many low-income and middle-income countries, older people will account for an increasingly large share of infectious disease morbidity and mortality because of the ageing population and changes in epidemiology of some diseases such as HIV/AIDS or tuberculosis.

## Avoidable mortality

In 1976, Rutstein and colleagues[48] proposed that health-system performance could be assessed with mortality from sentinel disorders that would not occur if appropriate care was provided. Studies[49] done after that one[48] included a broader range of potentially fatal disorders for which health-system interventions (eg, treatment after myocardial infarction) can substantially reduce mortality. This work classified a constant proportion of selected causes of death, when they occurred under age 75 years, as potentially avoidable using personal health-care interventions (eg, 50% of ischaemic heart disease deaths). Deaths avoided in this way are referred to as amenable.[50] Deaths can also be avoided through control of risks to reduce the incidence of potentially fatal disorders (eg, fall prevention, dietary salt reduction to reduce population blood pressure, and reduction of tobacco use). Deaths that can be avoided in this way are referred to as preventable.[50]

We propose that avoidable deaths, consisting of both preventable and amenable deaths, can be calculated for older adults on the basis of a so-called unavoidable mortality profile derived from mortality recorded in the best performing (or frontier) countries.[51] We calculated mortality that can be judged avoidable by subtracting the frontier mortality rate from death rates recorded, after first removing smoking-attributable deaths, because these deaths can be regarded avoidable during the entire period studied and can obscure other patterns of interest. We set the frontier at the 10th percentile of the tobacco-free country mortality to avoid undue effects from outliers, which could result from incomplete adjustment for

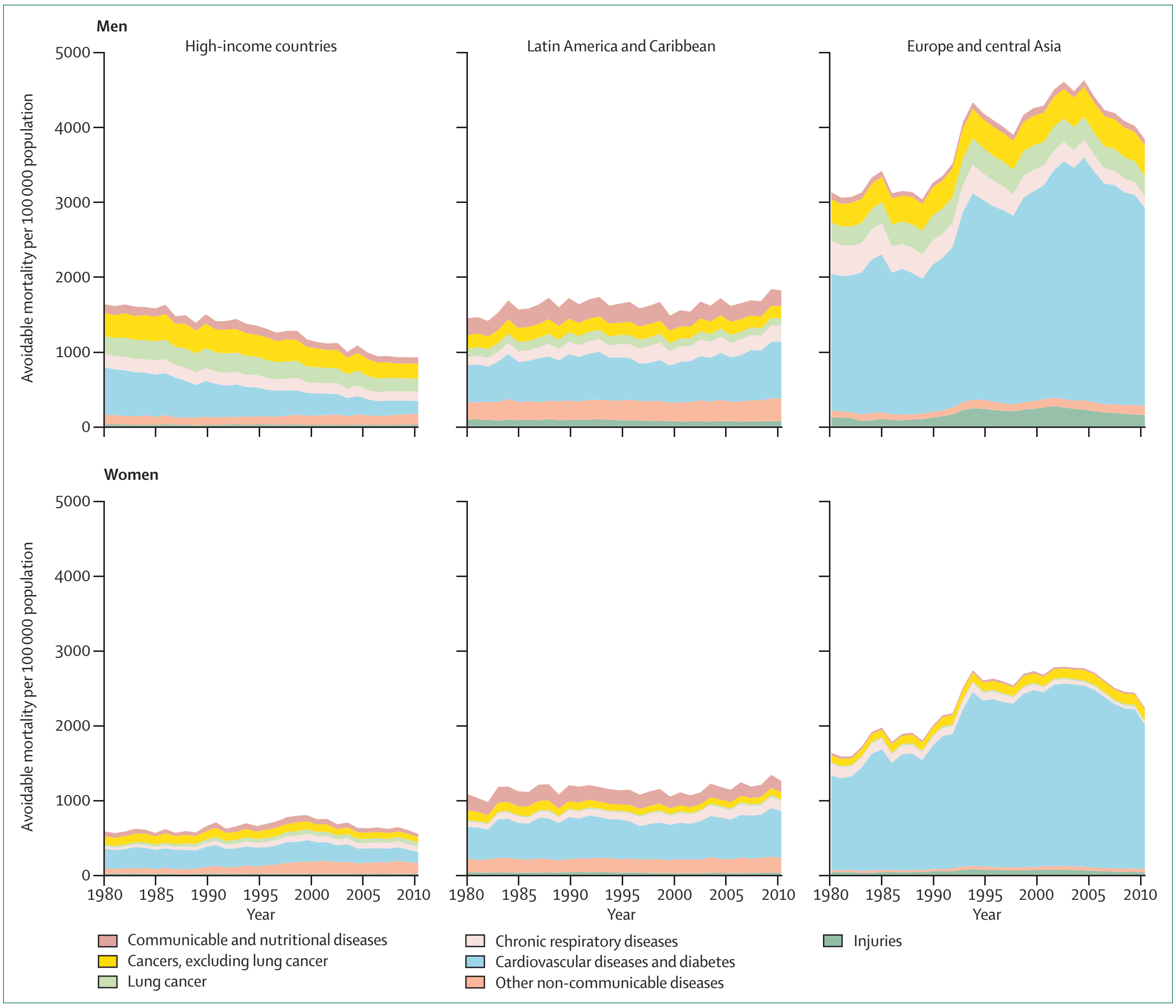


*Figure 3:* **Avoidable mortality rate per 100 000 population aged 60 years and older in 51 selected countries by cause, sex, year, and region, in 1980–2011**
Europe and central Asia consists of middle-income countries only.

mortality under-reporting or from peculiarities in mortality coding practices. We established the frontier for each age, sex, and year, for 1980–2011, for each of six major cause groups, and for all causes. We then calculated avoidable mortality as the excess mortality in non-frontier countries (appendix). The all-cause lowest-achievable, or frontier, mortality rates are falling for all ages and sexes, from 38 deaths per 1000 men aged 60 years and older in 1980 (age standardised) to 22 per 1000 in 2011, and 29 per 1000 in 1980 to 17 per 1000 in 2011 for women. These frontier mortality rates fell 1·6% per year for men and 1·7% for women. The cardiovascular frontier decreased at the highest rate: 3·1% per year for women and 2·7% for men.

In 1980, 35% of male and 22% of female deaths aged 60 years and older were avoidable in the 51 included countries, increasing to 38% of male deaths and 29% of female deaths in 2011. Of the avoidable deaths in people aged 60 years and older in 2011, 28% occurred in people aged 60–69 years, 38% in those aged 70–79 years, and 34% in those aged 80 years and older. The causes of and trends in avoidable mortality vary by region (figure 3). In high-income countries in 1980, the leading causes of avoidable mortality were cardiovascular diseases (39% in men and 45% in women) and cancers (33% in men and 23% in women). Avoidable mortality due to cardiovascular diseases fell in these countries from 1980 to 2011. In 2011, the leading causes of avoidable mortality in high-income countries were cancers (40% of avoidable deaths for men and 23% for women)—mainly lung—and cardiovascular diseases (18% for men and 27% for women). In the Latin American and Caribbean countries, cardiovascular diseases made up a dominant proportion of avoidable deaths in 2011: 42% in men and 50% in women. In this region, we did not note any clear trend in avoidable mortality rates or causes (figures 3, 4). In the middle-income countries in Europe and central Asia, avoidable mortality rose from 31 per 1000 in 1980 to 38 per 1000 in 2011 for men, and from 16 to 22 per 1000 in women. Most of these avoidable deaths were due to cardiovascular disease (figure 3).

In 1980, the avoidable mortality rates of men aged 60 years and older were less than 40 per 1000 in all countries other than Mauritius (selected countries shown in figure 4); by 2011, Belarus, Moldova, Kazakhstan, and Russia had avoidable mortality rates that were 44 per 1000 or higher. In 2011, the female avoidable mortality rates of Kyrgyzstan, Kazakhstan, and Moldova were 34 per 1000 or higher, whereas in 1980, all countries' avoidable mortality was lower than 30 per 1000. In 2011, Japanese women had the lowest avoidable mortality at 0·2 per 1000, with French women having the second lowest (one per 1000). The avoidable mortality rate decreased for both men and women in 21 countries between 1980 and 2011, of which 14 were high-income countries. The female avoidable mortality rate increased substantially in several high income countries: Norway (3·4% annual rise), Sweden (3·5%), the USA (3·6%), Iceland (4·4%), and Netherlands (5·0%). In 15 countries, the avoidable mortality rate rose for both men and women—nine of these countries were in Europe and central Asia. Greece was the only high income country in which avoidable mortality increased for both men (0·4% annual rise) and women (0·7% annual rise).

Our approach to calculate avoidable mortality has several strengths compared with list-based approaches, which classify a fixed proportion of selected causes of death when they occur under an age limit as avoidable.[48,49,52,53] Our frontier approach can be applied to estimated death rates in countries with low quality civil registration data, it encompasses both preventive and curative services with a broad definition of health systems, and it does not need subjective assessments of avoidability by cause. This method allows for a time-dependent frontier as the lowest achievable mortality rate changes over time in response to advancing medical care and increasing public health knowledge. Most importantly for this analysis, this approach can be applied to all age groups, including the very old, and is thus more appropriate for measurement of potential for improvement in old-age mortality, and is less sensitive to differences in cause-of-death assignment practices, which are often challenging at older ages because of the presence of many comorbidities. Some challenges remain: first, this method might be sensitive to the total number of countries included (eg, if data from several well performing countries were not available, the frontier would change). We have set the frontier at the 10th percentile of mortality rates, rather than the lowest mortality rate seen, to avoid undue effect of outliers. Second, inaccuracies in age reporting of older adults, especially in developing countries, could affect calculated mortality rates. Third, the method does not distinguish between preventable and amenable deaths.

## Conclusions

The detailed analysis of trends in older age mortality presented here is largely limited to high-income countries and middle-income countries in two regions.

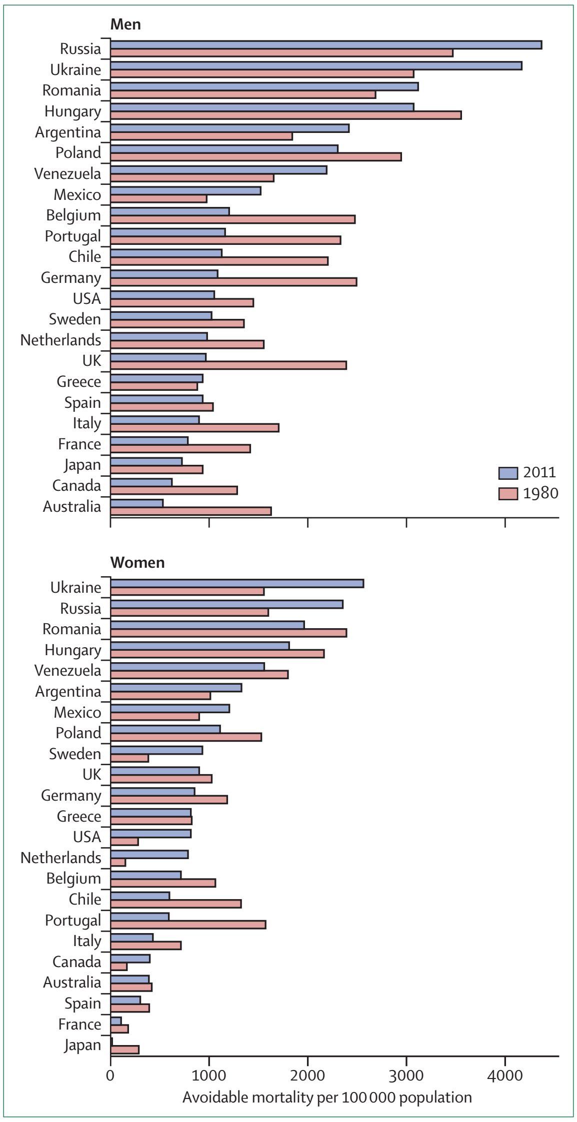


*Figure 4:* **Avoidable mortality rate per 100 000 population aged 60 years and older in 23 countries by sex, year, and country**
Selected countries with a 2011 population aged 60 years and older greater than 2 million are shown.

The absence of functioning systems for registration of deaths and underlying causes of deaths for most of the world's population is increasingly recognised as a high priority for worldwide public health action. However, the data analysed here do show that over the past three decades, a historic change in the progress of population health status has occurred, with mortality now decreasing in older age groups in many countries—probably the first time this decrease has happened across broad populations. This trend has been steepest in high-income countries, where about half the decrease has resulted from improvement in effectiveness and coverage of health care, and the other half from improvements in exposure to risk factors, particularly tobacco and blood pressure. As yet, our analysis shows no evidence that the rate of improvement in older age mortality is slowing down in these countries.

What are the reasons for this historic change? Although improvements in both effectiveness and coverage of health care, and reductions in exposure of populations to environmental, behavioural, and biological risk factors are likely to have played a part, their relative contributions are not fully understood.[44,52] Progress has been slower in low-income and middle-income countries (and very much slower in sub-Saharan Africa and eastern Europe) than high-income countries. These countries face the double hazard of continuing communicable disease epidemics (accentuated by progressive shifting of the burden of infectious diseases such as HIV/AIDS and tuberculosis into older age groups in these populations) and growing epidemics in non-communicable diseases. Prospects for these countries are not positive.

Yet, our analysis of avoidable mortality from age 60 years shows that some countries have been more successful than others in reduction of older age mortality, despite similar economic and other constraints, and that much scope for further health gain clearly remains. Bidirectional linkage between non-communicable diseases and development was a core theme of the High Level Meeting on non-communicable diseases held by the UN in New York (USA) on Sept 19–20, 2011.[54] With greater political awareness of and commitment to control of non-communicable diseases, and continuing commitment of member states to implementation of the WHO Framework Convention on Tobacco Control,[55] low-income and middle-income countries could repeat the recent reductions in older age mortality that have been noted in high-income countries. In fact, our work supports the view that substantial increases in life expectancy at older age could be achieved in countries at all income levels in the next decade, mainly through improvements in control of non-communicable diseases and their established risk factors.

**Contributors**

CDM did the life expectancy compression analyses. GAS and RAW did the avoidable mortality analysis and prepared and analysed the death registration data. TB and MIT contributed to overall planning and development of the analyses, and discussion of the results. All authors contributed to writing the report and approved the final version for publication.

**Declaration of interests**

We declare no competing interests.

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