Mortality by cause of death and by socio-economic and demographic stratification 2010

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Abstract

There is a wide range of information available on the twin issues of mortality by cause of death and mortality by socio-economic and demographic stratification. The subjects are of interest to actuaries working in fields such as product design, underwriting, valuing portfolios of pensions, annuities and life assurance, developing mortality-based securities, in social policy and in the work of analysing the past and projecting future trends in mortality and longevity.

Drawing from international and national mortality and longevity analyses and actuarial papers, this paper covers, with references, areas of particular interest to actuaries. These include the impact of specific causes of death on historical trends in mortality, international trends in mortality by cause and by socio-demographic classification, the availability and use of data suitable for underwriting, pricing and analysis, modelling of mortality by cause and the use of "by cause" information in mortality projections.

There is a strong relationship between socio-economic group and mortality: poorer, less socially advantaged people are likely to die sooner than their more advantaged peers at every level of the social structure; in other words, there is a society-wide *gradient* in mortality risk. It is important to try to understand the links between socio-economic group and cause of death. Many of the papers we have examined stress that social change and health education can actually contribute more to future improvements in longevity than can medical treatments.

As individualised data becomes available and actuarial and data analysis techniques progress from the group to the individual there are opportunities to pick and choose risks and to project with increasing accuracy the mortality of a particular portfolio. Actuaries and their clients ignore these opportunities at their own risk.

Keywords

Mortality, longevity, actuarial, international comparisons, cause of death, socio-demographic stratification, historical trends, international trends, modelling, projections, underwriting, pricing, analysis.

Content

1. Introduction

The International Actuarial Association Mortality Task Force (MTF) has agreed to bring together leading international contributions on a variety of mortality-related topics with a view to making them available to the wider actuarial community, and to other disciplines interested in the subject. This is one paper in the series proposed by the MTF and it is aimed at non-specialist actuaries and others who have an interest in the course of mortality.

This paper provides an overview on mortality by cause of death and by socio-economic and demographic stratification, and covers the following areas:

- Why is the subject of interest to actuaries?
- What sources of data are useful?
- What can we learn from socio-economic and demographic stratification?
- What can we learn from analysis of mortality by cause of death?
- What risk factors affect mortality by cause?
- What about projections of mortality by cause and other factors?
- How do actuaries use this information?
- Conclusions

It should be thought of as a flight over some familiar and some perhaps less familiar countryside, to give a brief overview of areas that we find interesting. The potential scope is enormous, and the coverage may be limited as much by our knowledge as by the space available. Inevitably we tend to focus on the familiar, i.e. the United Kingdom (UK), in our illustrations. The paper is not the result of a systematic literature review.

It is clear that mortality experienced by different socio-economic and demographic groups is often distinguished by substantial differences in the major causes of death for the groups, and it is not possible to "untangle" all the impacts. Indeed, a key feature of the social gradient in health is the greater degree of co-morbidity among those with greater deprivation, and our attempt to have a section on mortality by socio-demographic stratification and another on mortality by cause of death is doomed to include much cross-referencing.

One of our intentions in writing this paper has been to provide a source of reference to actuaries and other readers to follow up areas of interest. We have therefore endeavoured to provide hyperlinks to the papers included in our reference list. We recognise that some of these hyperlinks may not be permanent and would welcome information about more permanent hyperlinks where these are available. We have marked with an asterisk* certain papers that we think will be of particular value.

We would like to record our thanks to Timothy Lee and Sally Grover who contributed to the research and the organisation. This has been a multi-disciplinary and international exercise and we are most grateful to Madhavi Bajekal, David Blane, Robert Brown, Simon Capewell, Myer Glickman, Peter Goldblatt, Dave Grimshaw, Brian Johnson, Paul Lewis, Mike Murphy, Stephen Richards, Yoshihiro Takahashi and many others for their help.

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2. Why is the subject of interest to actuaries?

This is an area of interest to governments, politicians and the caring and medical professions, and to all who seek to tackle medical and social developments and to overcome the impacts of inequality. This is a significant but not major area of actuarial employment.

An understanding of mortality and the factors that affect change is of interest to actuaries in areas such as product design, underwriting, valuing portfolios of pensions, annuities or life assurance, developing mortality-based securities, in social policy and in the work of analysing the past and projecting future trends in mortality and longevity.

This paper endeavours to cover the areas in the above fields that will be of interest to actuaries and others. In practice, the actuary has to work on the data available to him or her. Socio-economic class, smoking status or height/weight ratio may not be available or may not be in a useable form. However, proxies may be available, and can be used.

2.1. Mortality by socio-economic and demographic stratification

In modern societies, on the whole, wealthier people tend to live longer than poor people, more highly educated people live longer, on average, than people with less education, and where you live can be an indicator of how long you may expect to live. All of these differences will be of interest to actuaries seeking to price the mortality elements of insurance, annuity and pensions products, and to reserve effectively for liabilities.

Sources of data available more specifically to actuaries working in life assurance and pensions include a variety of items of a social and demographic nature.

Historically, social and demographic differentiation was sometimes apparent in the source of business. In the UK, for example, industrial life business showed considerably higher mortality than individual business, and members of “works” pension schemes covering mainly manual workers experienced shorter lifetimes, on average, than those in “office” schemes which covered mainly non-manual workers.

In many markets the subject of selection by social and demographic class has in the past few years assumed greater importance due to a number of factors, including:

- The accessibility of individual rather than grouped data
- The increasing use of select annuities and preferred life policies
- Pensions surplus/deficits influencing company balance sheets
- Competition for the reassurance or sale of pensions and annuity liabilities

The pace of mortality improvements can be different for different social and demographic sectors, so an understanding of these differences is important in understanding overall improvements and forecasting the future.

2.2. Mortality by cause of death

An understanding of the risk factors underlying mortality by cause of death is inevitably of interest to actuaries for underwriting, and there is a large volume of work within life insurance companies and reassurers on premium rates for “substandard lives”. More recently reassurers have developed underwriting programs that will tackle underwriting of lives in a range from “substandard” to “preferred”.

The progress of longevity improvements in developed countries has often been attributable to major reductions in mortality from a relatively small number of major cause groups (this is discussed later.). Those projecting future trends in mortality may wish to take into account trends from the past and will equally recognise that improvements in mortality from some causes can only continue until those causes have been eliminated.

2.3. Combined Studies

There is a strong relationship between socio-economic group and mortality by cause of death: poorer, less socially advantaged people are likely to die sooner than their more advantaged peers at every level of the social structure; in other words, there is a society-wide *gradient* in mortality risk. Although some causes of death are unusual among non-manual workers, manual workers mostly die of the same diseases as the middle class; their disadvantage is that, at any given age, they are more likely to die of one of these diseases than their middle class peers. It is therefore important to attempt to understand the links between socio-economic group and cause of death. Many of the papers we have examined stress that as well as medical research, social change and health education have contributed, and could in the future contribute substantially, to future improvements in longevity.

Analysis by age group, cohort and calendar year of death provide insights into the progress of mortality, and an analysis of cause of death and socio-economic factors is proving useful in understanding the underlying reasons for these changes.

3. What sources of data are useful?

Sources of data for analysis of mortality include:

- Population mortality and morbidity statistics (eg from UK Office for National Statistics)
- Medical research studies (eg UK: General Practice Research Database, USA: Framingham Heart Study)
- Other longitudinal studies (eg the UK ONS longitudinal study and Whitehall II)
- Life assured and annuitant studies, (eg from the UK Continuous Mortality Investigation)
- Pensioner studies (also from the CMI)
- Registers, eg in Nordic countries.

It is important to note that there is a wealth of information available from medical sources and we can only touch the surface in an attempt to highlight some of the most relevant conclusions in this study.

Each of these sources has its strengths and weaknesses, and it is often necessary to apply information from one data source to another data set to obtain useful conclusions.

The main international sources of data include:

- Centre for Disease Control and Prevention
- Human Mortality Database
- World Health Organisation (WHO) Statistical Information System (WHOSIS)
- Three databases from WHO Europe:
    - European Health for All database (HFA-DB),
    - European detailed mortality database (DMDB),
    - Mortality indicators by 67 causes of death by age and sex (HFA-MDB)
- WHO Global Burden of Disease Analysis (GBD)

The Global Burden of Disease project is probably the world’s largest work programme in this area and includes a number of topics such as sensitivity of results to national practices in death coding.

In respect of the Human Mortality Database, Lopez et al (2001) in “Life tables for 191 countries: Data, methods and results” demonstrates how the authors used a wide variety of sources to obtain sufficient information to develop the life tables. It also contains life tables for the 191 countries; although there are considerable weaknesses in some of these.

The majority of national sources are either health departments or statistical offices such as:

- US National Center for Health Statistics
- Australian Bureau of Statistics
- Office for National Statistics (UK)
- Statistics Canada – Vital Statistics and Death database

Web addresses for national sources are available from the WHO website (Links to National Health-Related websites).

Where information sources are mentioned in the paper, they are included in the reference list. A wider reading list can be provided on request. The following web resource may also be helpful: "Longevity Science on Web".

In the UK, census data are separately collected by the Office for National Statistics for England and Wales, the Census Office for Northern Ireland, and The General Register Office for Scotland. As UK statistics are gathered differently by these offices in terms of dates and methods, we have chosen to use England and Wales, rather than UK, for illustration.

3.1. Information on cause of death

Global mortality data by cause of death is available from many of the above sources.

The International Classification of Disease (ICD), published by the World Health Organisation (WHO), is designed to promote international comparability in the collection, processing, classification, and presentation of morbidity and mortality data. It is the international standard diagnostic classification for all general epidemiological purposes, many health management purposes and clinical use. It is used worldwide to classify diseases and other health problems recorded on many types of health and vital records, including death certificates and health records. In addition to enabling the storage and retrieval of diagnostic information, these records provide the basis for the compilation of national mortality and morbidity statistics by WHO member states.

The ICD is revised periodically. The latest version available is ICD-10 which was endorsed by the Forty-third World Health Assembly in May 1990 and came into use in WHO member states from 1994. The first draft of ICD-11 is expected in 2010, with publication following by 2014.

When analysing past trends it is important to allow for changes introduced when the ICD coding changes. For example, significant changes between ICD-9 and ICD-10 include a change in the format of the code, an expansion of the number of codes used, a movement of some diseases and conditions between broad groups and changes to the rules governing the selection of the underlying cause of death, which has had a large effect. The death certificate recommended by the WHO has two parts. Part 1 gives the condition or sequence of conditions leading directly to death; Part II gives details of any associated conditions that contributed to the death but are not part of the causal sequence. The selection of the cause of death is defined by WHO as the disease or injury that initiated the train of events directly leading to death or the circumstances of the accident or violence that produced the fatal injury. Changes in practice within ICD can be substantial as can changes in 'fashion' in coding over time. International comparisons are particularly problematic because of different conventions about coding.

The selection of the underlying cause of death is generally made for the conditions entered in the lowest completed line of Part 1 of the death certificate. However, if there is more than one cause on a single line with no indication of sequence, or the conditions entered are not an acceptable causal sequence, one or more selection rules from ICD-10 are followed. Even if the certificate is correctly completed there are particular cases where rules are applied to select the underlying cause of death. Annual tables analysing deaths by underlying cause are published in England and Wales by the ONS Mortality Statistics Series DR (Deaths Registered) (see Drever).

It is important to note that while many studies are focused on a specific cause of death, multiple causes may be recorded on death certificates. Co-morbidity increases with age and this may add an element of uncertainty to analyses that can only cope with one "cause of death".

An analysis of causes of death among insured lives is available in Australia by Tickle (2004), but in many other countries life assurance and pensions data tends to provide limited information for analysis of mortality by cause. The Continuous Mortality Investigation (CMI) in the UK did start an analysis of mortality of lives assured by cause but decided to drop it as the complexities of coding cause of death made the resulting analyses of little use.

3.2. Purpose of the analysis

Analyses of mortality are driven by a variety of different motives including the analysis of medical and treatment outcomes, the targeting of health strategies and the need to effectively underwrite life insurances or annuities. The transfer of information from results derived in one sphere to use in another can be difficult. For example, medical research may yield details of survival and mortality in respect of a particular condition and its treatment, but not record the subject's age. National statistics may record immediate and/or proximate causes of death, but may have no related information on risk factors that precede the immediate sequence leading to death.

3.3. Pace and complexity of change

Unlike a number of low-income countries, where poverty, conflict and infectious diseases are worsening mortality, the pace of improvement in mortality in many developed countries has improved as a result of increasing prosperity, improved diet and environment, changes in behaviour and public health and medical advances. However, the gaps between rich and poor are, despite government initiatives, sometimes widening rather than narrowing. Increasing obesity is an issue in many countries.

4. What can we learn from socio-economic and demographic stratification?

In many countries researchers have been able to identify mortality characteristics and trends by a variety of different demographic groupings, including: social class, income, education, ethnic group, and location. Some of these factors are strongly interlinked.

4.1. Multi-factor studies

As an indication of the difficulty of separating the analysis of mortality by socio-economic and demographic stratification and the analysis of mortality by cause, our first illustration links the income level of the country with the causes of death in that country.

The Factsheet WHO (2008a)* "Top ten causes of death", divides countries into three groups: high-income, middle-income and low-income. It demonstrates substantial differences in mortality, with highest mortality in the lowest income countries, and whilst some of the principal causes of death are common to all three groups, others differ radically between these three classes of country. The percentage of deaths by age group and income category (low, middle, high) are: age group 0–14, (36%, 10%, and 1%) and for age group 15-69, (43%, 46%, and 29%).

Some of the reasons for the radical differences in mortality by country income group can be seen by examining the different causes of death experienced by those groups.

Figure 1. **The ten leading causes of death by broad income group, 2004**

Low-income countries	% of deaths	Middle-income countries	% of deaths	High-income countries	% of deaths
Lower respiratory infections	11.2	Stroke and other cerebrovascular disease	14.2	Coronary heart disease	16.3
Coronary heart disease	9.4	Coronary heart disease	13.9	Stroke and other cerebrovascular disease	9.3
Diarrhoeal diseases	6.9	Chronic obstructive pulmonary disease	7.4	Trachea, bronchus, lung cancers	5.9
HIV/AIDS	5.7	Lower respiratory infection	3.8	Lower respiratory infections	3.8
Stroke and other cerebrovascular disease	5.6	Trachea, bronchus, lung cancers	2.9	Chronic obstructive pulmonary disease	3.5
Chronic obstructive pulmonary disease	3.6	Road traffic accidents	2.8	Alzheimer and other dementias	3.4
Tuberculosis	3.5	Hypertensive heart disease	2.6	Colon and rectum cancers	3.3
Neonatal infections	3.4	Stomach cancer	2.2	Diabetes mellitus	2.8
Malaria	3.3	Tuberculosis	2.2	Breast cancer	2.0
Prematurity and low birth weight	3.2	Diabetes mellitus	2.1	Stomach cancer	1.8

Source: WHO (2008a), "The top ten cause of death", WHO Fact Sheet No.310

A useful source of information is: Doblhammer (2006) "The effects of age, sex, education, marital status, obesity and smoking on disability and mortality", a report of a systematic literature review which compares results from research papers from many countries, and examines links between, for example, education and marital status on mortality.

Muth et al. (2006, 2007), based on the above, examined trends in mortality in a variety of different countries and include differentials by marital status and educational level. They found that the mortality advantage of married persons of all ages and both sexes was a clear fact that persisted over time. It was not possible to find clear patterns over time for the three non-married states: single, divorced and widowed. The study confirmed the link between higher education and lower mortality for old and young, for males and females. In the period in question, the better-educated experienced stronger mortality declines in most European countries.

In the US, the National Health Intelligence Service (NHIS) (2008) provides a "Mortality Reference list" that is continuously updated to include many relevant studies on the relationship between mortality and socio-economic factors. A number of these studies are referred to in the following sections.

An example of a multi-factor study is Martikainen (2008), which studies the relationship between socio-economic factors such as income, social class, education and home ownership on transitions in living arrangements and death of elderly Finnish people, demonstrating that lower mortality was associated with higher education, higher disposable income, home ownership and white-collar (rather than blue collar) occupations even after controlling for potentially confounding factors.

The WHO Commission on Social Determinants of Health, in issuing its report: "Closing the gap in a generation: health equity through action on the social determinants of health" stated: "Social justice is a matter of life and death. It affects the way people live, their consequent chance of illness, and their risk of premature death. We watch in wonder as life expectancy and good health continue to increase in parts of the world and in alarm as they fail to improve in others. A girl born today can expect to live for more than 80 years if she is born in some countries – but less than 45 years if she is born in others. Within countries there are dramatic differences in health that are closely linked with degrees of social disadvantage. Differences of this magnitude, within and between countries, simply should never happen. These inequities in health, avoidable health inequalities, arise because of the circumstances in which people grow, live, work, and age, and the systems put in place to deal with illness. The conditions in which people live and die are, in turn, shaped by political, social, and economic forces".

4.2. Socio-economic class

In general, people in lower socio-economic classes suffer from higher mortality, and the inverse correlation continues throughout the whole scale from bottom to top. However the extent of difference varies from one country to another. The difference in mortality between different social classes should not come as a surprise. Gregory (2009), in comparing the geographical relationship between mortality and deprivation in England and Wales at the start of the 20th and 21st centuries remarked: "there was no evidence of significant change in the strength of the relation between deprivation and mortality between the start and end of the 20th century."

In a study of socio-economic inequalities in health and mortality in 22 European countries, Mackenbach (2008) found that: "in almost all countries, the rates of death and poorer self assessment of health were substantially higher in groups of lower socio-economic status, but the magnitude of the inequalities between groups of higher and lower socio-economic status was much larger in some countries than in others. Inequalities in mortality were small in some southern European countries and very large in most countries in the eastern and Baltic regions."

In the UK "Atlas of heart disease and stroke", Mackay et al (2009) highlight the tendency for people in lower socio-economic classes to suffer from higher circulatory disease mortality and points to a variety of contributor factors such as smoking, obesity and lack of physical activity. There is a debate about how far these groups are responsible for their poorer health, with some arguments for structural as well as individual factors.

White et al (2007) show that the age-standardised mortality rate for men aged 25-64 in routine occupations in England and Wales in the period 2001-2003 is an amazing 2.8 times higher than that of men in higher managerial occupations. The difference is substantially unchanged since 1991-3.

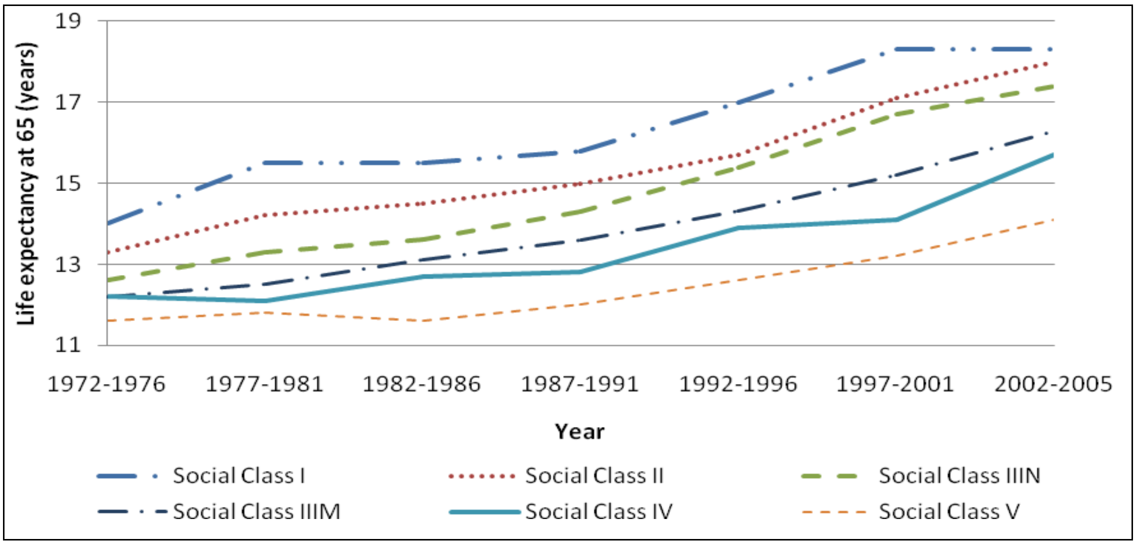
The authors explain that there is a clustering of attributes of advantage among professionals and disadvantage among unskilled manual workers, and their accumulation and intensity over the life course. "Circumstances of disadvantage such as poor quality housing, exposure to environmental pollution in area of residence, occupational hazards, poor diet, smoking, risk of unemployment, and low income were found to be finely graded between the social classes, most concentrated in Social Class V with diminishing levels of exposure for each step up the social hierarchy."

Life expectancy

A study by the UK Office for National Statistics (ONS) (2006) from 1972 to 2005 shows that while period life expectancy has risen for all social classes over the last 30 years, there is a mortality gradient across social classes, with the children of people in professional occupations (Social Class I) having the longest expectation of life, followed by managerial and technical occupations, and so on. Children of people in unskilled manual occupations (Social Class V) have the shortest expectation of life. The gap in period life expectancy at birth between Class I and Class V has stretched from 5.4 years to 7.3 years.

This social gradient appears to persist into older ages as the following graph shows. This applies to females as well as to males. Female life expectancy at age 65 has not increased as fast as men's over the past 30 years. Risk factors affecting mortality at older ages are discussed in section 6.10.

Figure 2. **Trends in male period life expectancy at age 65, 1972-2005, England and Wales**



Source: ONS (2006), "Life Expectancy and Social Class"

4.3. Income

Generally there is a gradient in the level of mortality by level of income, where higher income correlates to lower mortality.

The Continuous Mortality Investigation (CMI) (2007) analyses mortality for its insured annuitants and pensioners separately by "lives" and "amounts", on the understanding that the difference between the mortality of policyholders with small and with large policies may differ. More recently it has been able to analyse the mortality of pensioners in defined benefit occupational pension schemes, and to split the data between groups with different pension sizes, from "£0 to £2,999" to "£13,000+" per year. The resulting differences in mortality, which are likely to be associated with differences in income, are substantial at younger ages, but tend to converge at age 80+.

In comparing mortality experienced in different countries, there is considerable discussion on how strong is the impact of income inequality and the psychosocial environment. Lynch et al (2000, 2001) state that among the wealthier countries studied, higher income inequality was strongly associated with greater infant mortality but associations between income inequality and mortality declined with age at death, and then reversed among those aged 65 years and older.

Rather than focusing on absolute comparisons between countries, Wilkinson and Pickett (2009) in "The spirit level: Why more equal societies almost always do better", comment that the most unequal societies suffer the worst life expectancy. This is independent of the absolute per-capita income of the country. So in countries where there is a large gap between the income of the richest and poorest 20% of the country's population, life expectancy is low, and obesity levels, infant mortality and crime rates are worse as well. The authors researched the world's 20 richest countries, and individually each of the 50 states of the USA.

A paper by Prus et al (forthcoming) confirms that the majority of international studies support Wilkinson's "income inequality-population health" hypothesis. However, it then goes on to test the same question across the life course by examining data from around the year 2000 for 18 wealthy countries and 28 wealthy and non-wealthy countries. It examines the relationship between income inequality and life expectancy for a number of separate age groups: 0+, 25+, 65+, 75+ and 85+, and finds that "overall, the data for wealthy nations *do not* support the hypothesis that high levels of income inequality are directly related to lower levels of population health". On the contrary, it suggests that for older ages, the reverse influence is seen. "The opposite pattern is observed in old age. The inequality-health relationship is statistically insignificant at age 65, but becomes increasingly positive and statistically significant by age 75. Countries with higher levels of income inequality among 75+ and 85+ male-headed households and 85+ female-headed households tend to have higher levels of life expectancy. Average population income does not appreciably account for these relationships."

4.4. Education

Generally there is a gradient in mortality by level of education (higher education implies lower mortality) but patterns may differ. In practice, education is one of the "causes of the causes" of inequality and hence of health inequality. It is therefore both an indicator of adult status difference and a contributory cause of that difference in status.

Mackenbach (2008), in the study of socio-economic inequalities in 22 European countries, demonstrates strong links between higher education and lower mortality. Looking at the overall picture, people with lower levels of education have higher death rates from all causes except, notably, breast cancer. The paper goes on to look at the differences by cause of death, and it becomes clear that mortality from cardiovascular disease, smoking-related conditions, alcohol-related deaths, and obesity is more clearly associated with lower education levels. It concludes (inter alia) that: "inequalities in mortality from selected causes suggest that some variations may be attributable to socio-economic differences in smoking, excessive alcohol consumption, and access to health care."

As mentioned above, an exception to the "higher education lower mortality" rule is breast cancer. Examining breast cancer mortality in 11 European countries during the 1990s, Strand et al (2007) found that the greater risk of breast cancer mortality among women with a higher level of education was a persistent and generalised phenomenon in Europe in the 1990s. Overall, women with a higher educational level had approximately 15% greater risk of dying from breast cancer than those with lower education. This was observed both among never-married women and women who have been married at some stage of their lives.

4.5. Ethnicity and migrants

Mortality studies indicate that ethnic groups living in the same area often display different mortality characteristics, and this can be indicated by vulnerability to certain diseases and other causes of death.

There is a wide variety of papers studying the mortality of migrants and those of different ethnicity. The Medical Research Council (2009) provides a list of publications looking into the effects of ethnicity and migrants on cause-specific mortality in a number of countries. Most conclusions reached highlight the differences when ethnicity-specific mortality is calculated, showing a significant dissimilarity with the dominant local ethnic group.

4.6. Postcode / Zip codes

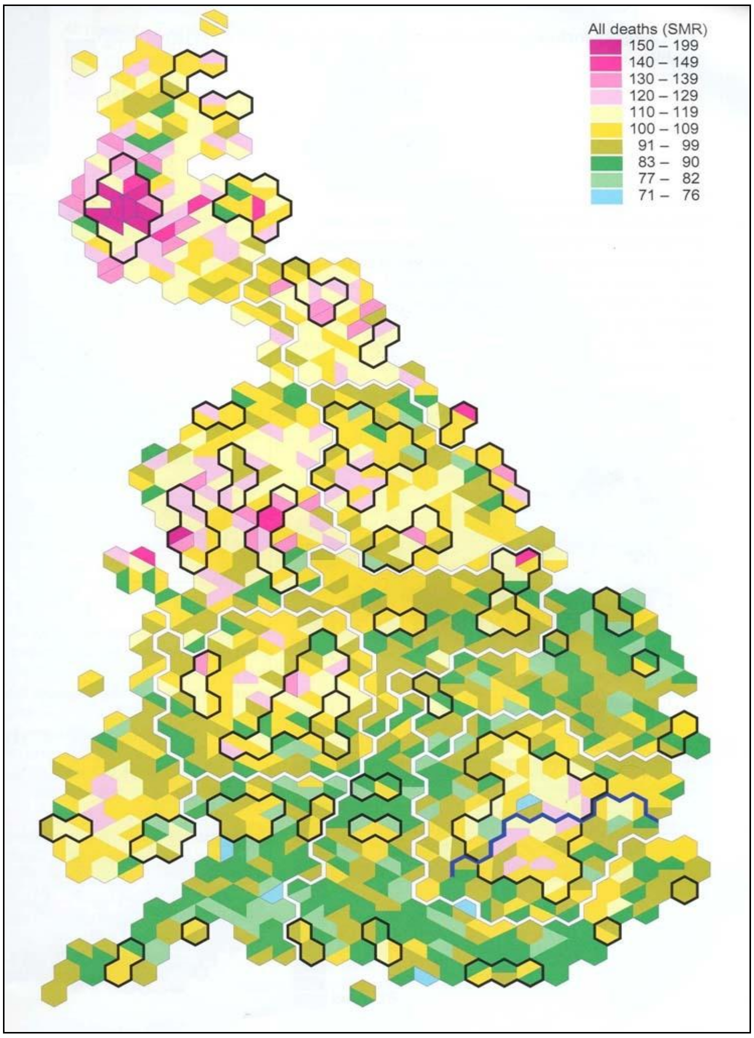
Studies in countries such as the USA and the UK demonstrate substantial differences in mortality between different postcode areas.

In the USA, Smith et al (1996) looked at socio-economic differentials in mortality risk among men who had previously been screened for a multiple risk factor intervention trial. Using Zip code as a marker of socio-economic status it found a strong link between higher status and lower mortality. The analysis of mortality by other factors such as cause of death provides some insight into the reasons for the different levels of mortality.

Post code is an indicator of much more than socio-economic status, as shown in Shaw et al (2008). This provides a pictorial atlas of mortality by cause of death by geographical area (adjusted for age and gender) in Britain. It shows substantial differences in overall mortality and by cause of death in different areas. While some of these differences will be due to differing proportions of people in different socio-economic classes, clear regional differences are also evident.

In some countries, the postal code of residence provides a relatively precise indicator of location: maybe the section of a street with 10 to 20 houses, or a single block of flats. Small locations such as this have proved to be a good indicator of socio-economic class, and models built up for marketing purposes will tend to be based on social class and other common attributes of the residents in the location.

Figure 3. **Patterns of Mortality in the UK (Data from 1981 – 2004)**



Source: The Grim Reaper's road map. An atlas of mortality in Britain, Shaw et al, (2008). Reproduced with kind permission of The Policy Press.

Shaw (2008) says: "This map of mortality from all causes combines in a single image all the influences on our survival. Having taken into account the distribution of the population according to age and sex, the map shows that across these areas a person's chances of dying in a particular year varied from being more than 50% above the national average (a Standardised Mortality Rate, SMR, of 150 as shown on the key) to less than 76% of the national average (with SMRs ranging from 71 to 76 in the lowest mortality category). Thus depending on where you were living over the last quarter of a century, there are neighbourhoods of Britain containing populations of tens of thousands of people where you were more than twice as likely to die than had you lived in other places."

5. What can we learn from analysis of mortality by cause of death?

In this section we focus on mortality by cause of death, with a particular interest in trends. We look first at a few combined studies, and then move on to studies focusing on specific cause of death groups. There is a wide variety of papers on mortality by cause of death such as coronary heart disease (CHD), which is of great interest due to the prevalence and rapid-changing impact of the disease in many countries. Inevitably this paper can only draw from a few of these.

It is important to note that the incidence of various causes of death differs by sex, age group, and by socio-demographic characteristics. Furthermore, most deaths occur at older ages among people who suffer from more than one disease, and the identification of each as proximal, underlying or contributory often is debatable, with outcomes that are influenced by extraneous factors, such as the pressure of work on the certifying physician. Examining the absolute numbers or percentages of deaths by cause, and trends in these figures can serve some purposes, but can lead to oversimplification; particularly as the broad cause of death groups vary greatly in their heterogeneity.

5.1. Developments in the past century by leading causes of death

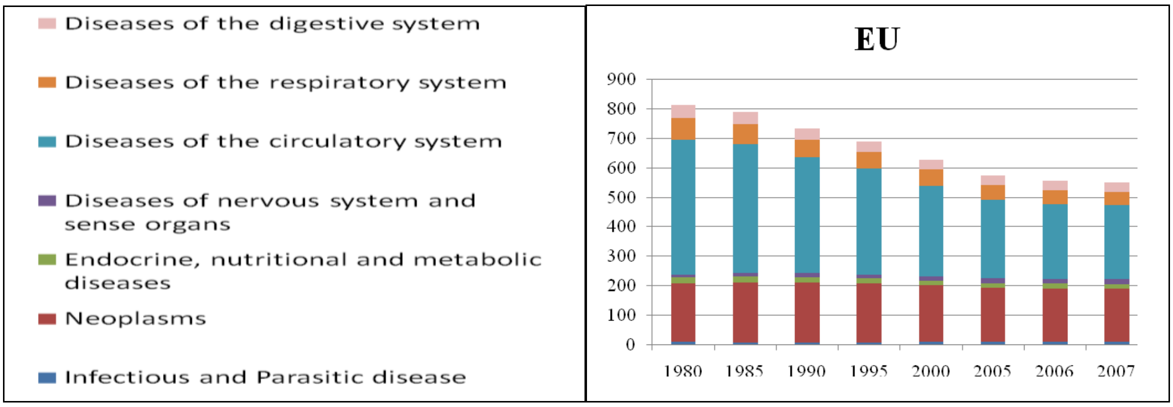
The 20th Century saw tremendous improvements to longevity in many high-income countries. These improvements were mainly the result of substantial falls in a few specific major causes of death groups. In the early part of the century, reductions in the respiratory disease group made substantial inroads, and later in the century reductions in the circulatory disease group had a major impact.

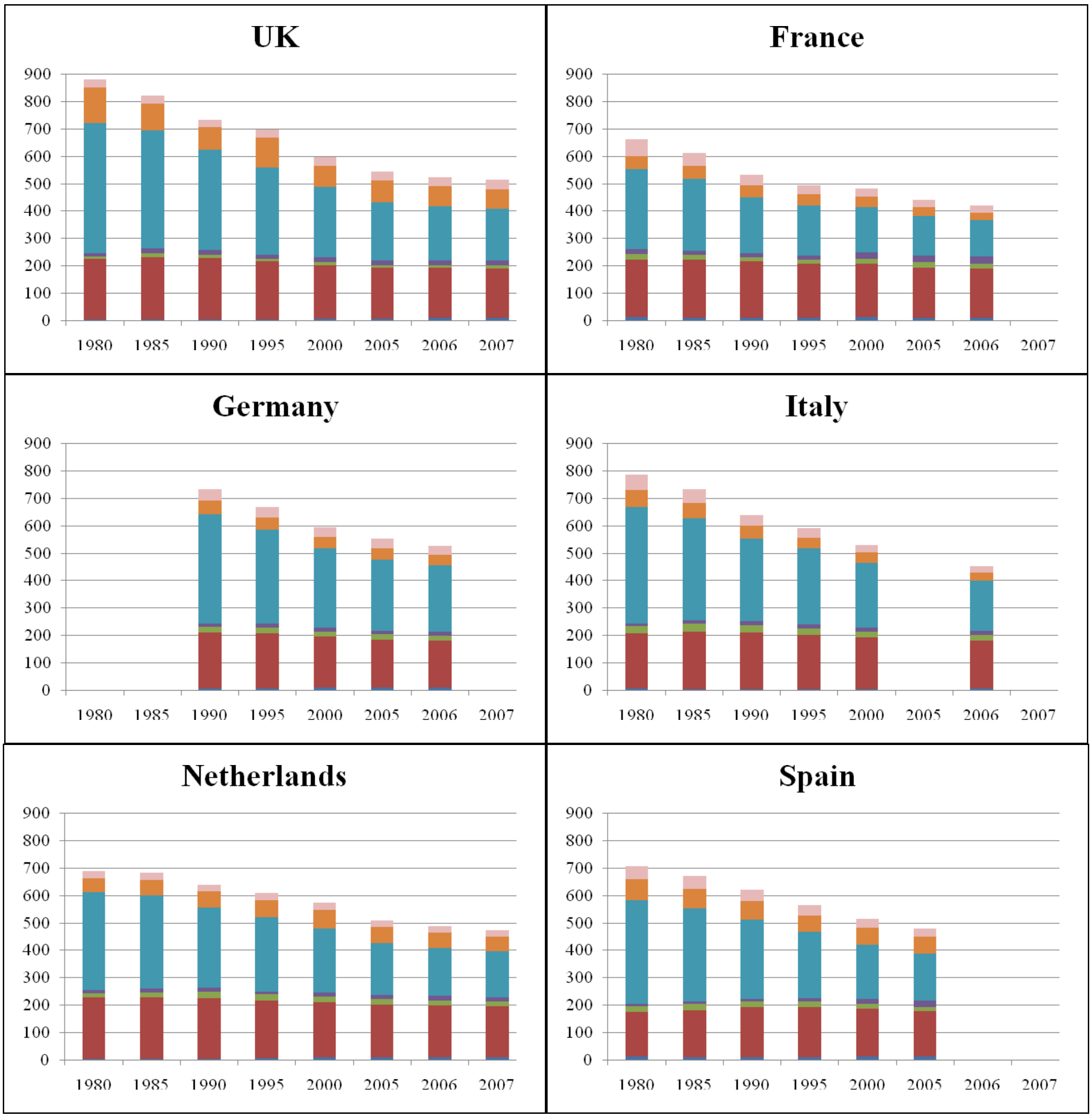
5.1.1. International

As a basic source of materials, the European Mortality Database HFA-MDB (2009) provides data for mortality indicators by 67 causes of death by gender and sex, age groups, and includes both crude rates and standardized death rates. The database holds data for most European countries, from the first submission of each country's national data, to the most up-to-date. For most countries in the European Union, this dates from 1980-2007.

Figure 4 shows trends in age-standardised mortality rates by major cause of death group, using the main ICD categories, for a few selected countries, where the information is available. Note the five-year age intervals in the first part followed by those years available from 2005 which have been shown individually.

Figure 4. **Trends in age-standardised mortality rate per 100,000 population by major cause of death group in European countries between 1980-2007**





Source: European Mortality Database (2008)

The European Public Health Alliance (2006) examined the leading causes of death in the EU and found 41% and 25% of all deaths were caused by circulatory diseases and cancer respectively. Looking at particular age groups:

- Ages 20-44: suicide accounts for 12%, with males being four times more likely to commit suicide than females
- Ages 45-64: cancer accounts for 41% of deaths, cancers of the lungs and throat were the most common among males, while breast cancer was the most prevalent among women.
- Ages 65-84: diseases of the circulatory system account for 42% of all deaths.

5.1.2. Developments in England and Wales

As noted in chapter 4, since UK statistics are gathered differently by country, we use England and Wales merely for illustration.

Looking at the past 110 years, Willets et al (2004a)* analyse trends in mortality by a wide variety of causes of death. The paper considers mortality developments in the population of England and Wales, the CMI assured lives experience, and internationally. It examines the underlying factors that help explain the dramatic reductions in heart disease mortality, and an appendix covers recent trends by cause of death. It draws conclusions about the implications of anticipated increases in life expectancy on: life assurance companies, final salary pension schemes and general insurers; and considers wider social and economic implications and the implications for the actuarial profession.

Figure 5 shows that mortality rates for England and Wales have fallen dramatically over the 20th century:

Figure 5. **Reduction in mortality rate between 1901 and 2007, England and Wales population**

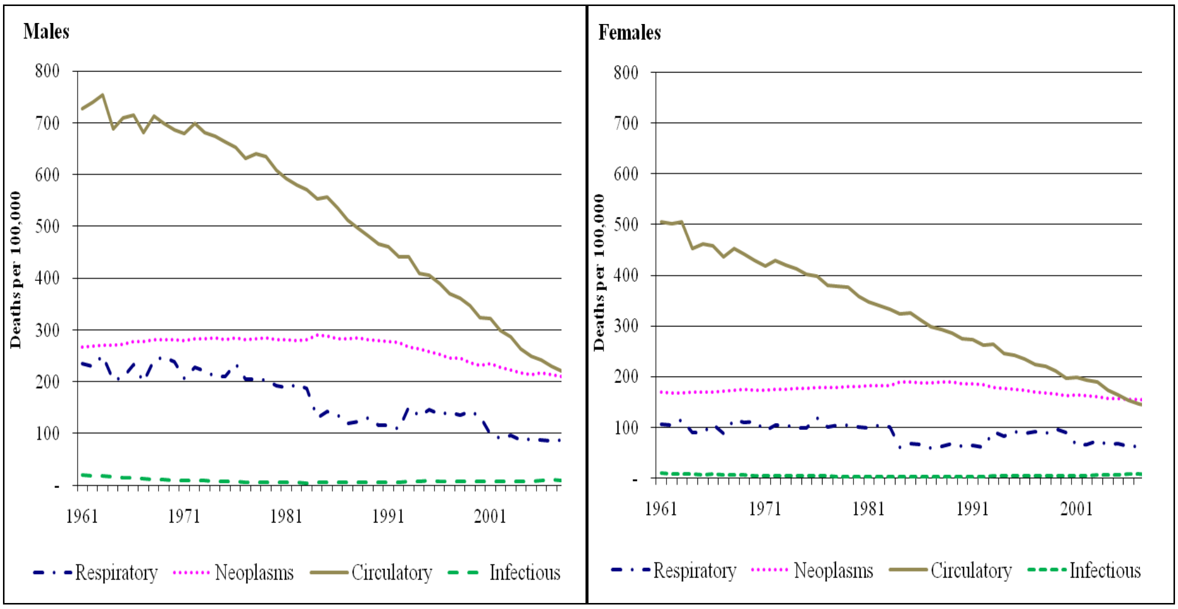
Age	Reduction in mortality rate Male	Female
5	97%	98%
25	82%	92%
45	79%	82%
65	67%	73%
85	45%	53%

Source: Authors own calculations based on ONS data

Improvement has not been regular, and different age groups and sexes have benefited in different ways at different times. Factors driving changes (improvements and setbacks) have included: medical developments, behavioural changes, work, social policy, wealth and wars.

In the UK rapid improvements in mortality over the last 40 years have been largely driven by falls in mortality rates due to circulatory diseases, of around 60% for both males and females. Mortality from cancer for males and females rose gradually to a peak in the early 1980s followed by a decline during the 1990s (see figure 6 below).

Figure 6. **Mortality by major cause group England and Wales, 1961 – 2008, age standardised**



Source: Reproduced from ONS data

The vertical axis in Figure 6, showing units of "deaths per 100,000 population", focuses on the overall impact of falls in mortality on the population, and it is perhaps not so clear that the improvement in male respiratory disease mortality has been very significant. As an aside, the graph poses the question as to where future improvements might come from, if the trends in circulatory and respiratory diseases continue to a much lower level.

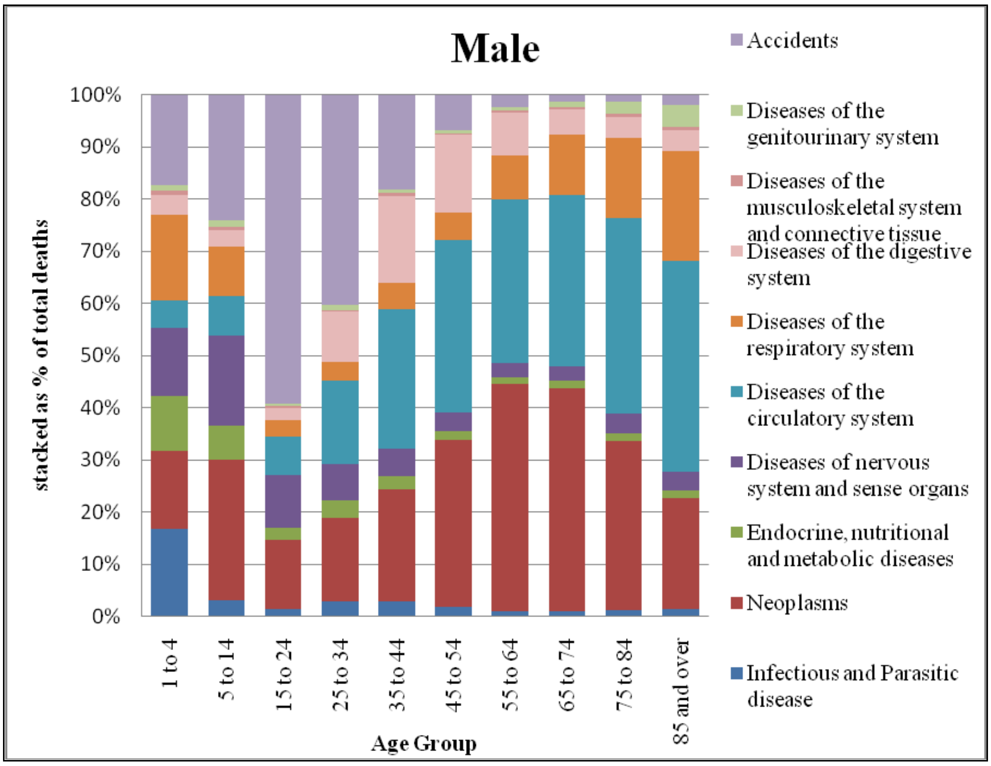
Inevitably the predominant causes of death and mortality rates by cause are quite different in different age groups and, within each age group, differ by sex.

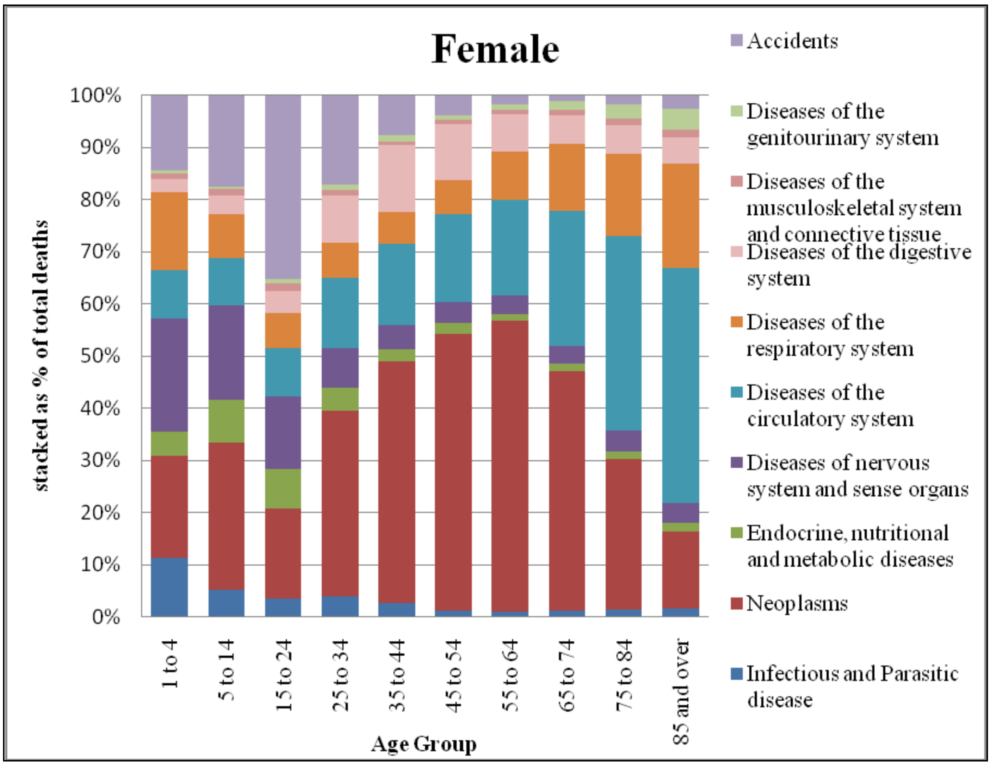
Brock et al (2006) reports on mortality developments in different age groups in the UK for the period from 1979 to 2003:

- Infant mortality rates fell by nearly 60% (cause of death not available due to a change in registration certificate).
- Ages 1 to 14: mortality fell by 57% for boys and 50% for girls, with injury and poisoning rates (the highest cause in 1979) almost halved.
- Ages 15 to 44: for young men, injury and poisoning (by far the highest cause of death) fell only gradually, whereas for young women cancer (the biggest killer) fell by 45%.
- Ages 45-64: circulatory disease was by far the biggest killer of men at the beginning of the period, and the death rate fell by two-thirds, leaving cancer as the biggest killer, despite the death rate for cancer falling by 34%. For women cancer accounted for almost half of all deaths, and circulatory diseases for almost a third. Both causes declined over the period: cancer by 29% and circulatory diseases by 65%.
- Ages 65-84: age-standardised death rates fell by around 40% for men and a third for women. The predominant cause of death for both men and women was circulatory diseases, and the death rate for both sexes fell by 55% over the period. Cancer (but of different types) was the second biggest killer for both sexes, with death rates declining for men but not noticeably for women.
- Ages 85 and over: circulatory diseases and respiratory diseases were the biggest killers, and both declined substantially over the period.

It is important to note that leading causes of death in any population will be different for different age groups. This is illustrated by the following charts after Kuh et al (2010).

Figure 7. **Leading causes of death in 2008 in England and Wales by age groups**



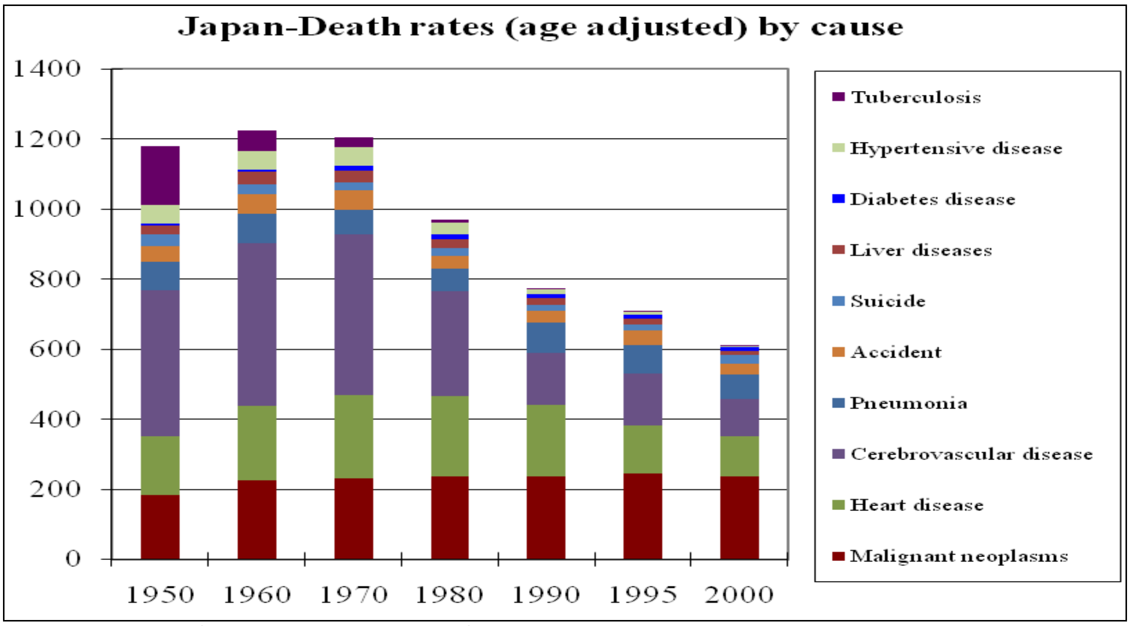


Source: reproduced graphics using Table 3 in ONS (2009a) "Statistical Bulletin – Death registrations in England and Wales, 2008, causes"

5.1.3. Developments in Japan

Japan is the country with the highest life expectancy at birth. It is therefore interesting to look at trends in mortality by cause. The period from 1950-2000 shows a remarkable decrease in age-standardised death rates, particularly between 1970 and 1990 where death from cerebrovascular disease decreased hugely. Other points to note are a significant decrease in heart diseases and the fall in deaths due to tuberculosis in the early years.

Figure 8. **Overall mortality by major causes – Japan 1950-2000**

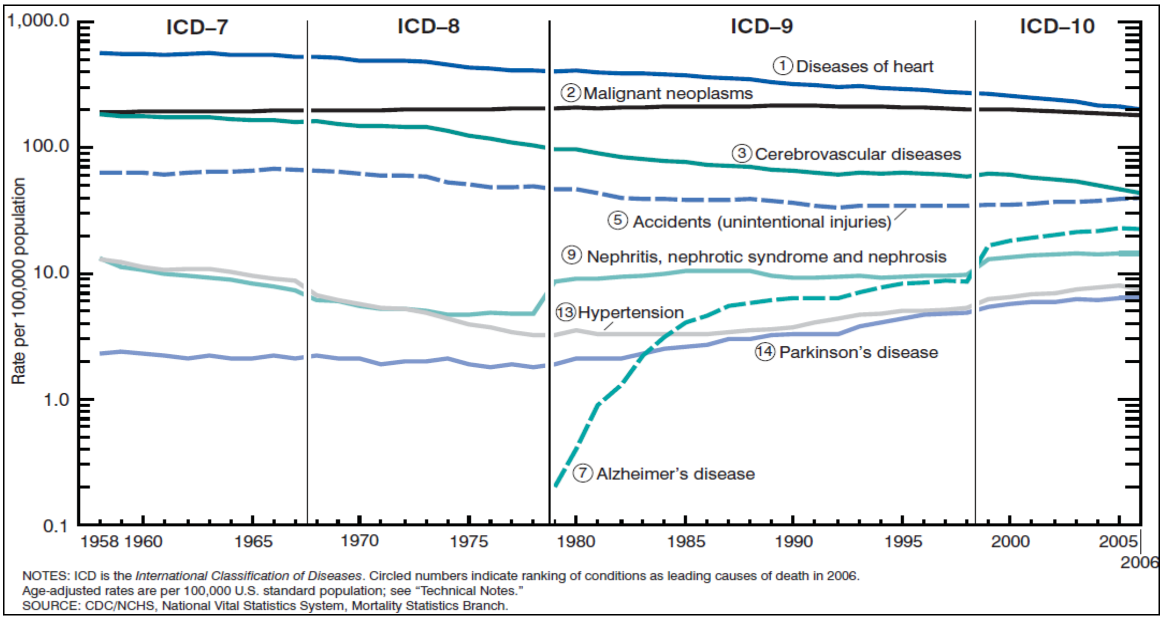


Source: Ministry of Health Labour and Welfare (2007), Statistics Survey, Vital Statistics

5.1.4. Developments in the USA

Heron et al (2009) presents past trends in age-adjusted death rates for selected leading causes of death in the USA. Except for a relatively small increase in 1993, mortality from heart disease has steadily declined since 1980, The age-adjusted death rate for cancer, the second leading cause of death, has shown a gradual but consistent downward trend since 1993, and the rate for stroke has generally declined since 1958 with the exception of 1992-1995. Unlike the above charts, Heron et al (2009) uses a logarithmic scale. This gives less emphasis to changes in the major causes death groups (the reduction in deaths due to "diseases of the heart" is roughly in proportion to the UK experience), and considerably more emphasis to changes in the cause of death groups with lower impact: particularly Alzheimer's disease.

Figure 9. **Age-adjusted death rates for selected leading causes of death: United States, 1958-2006**



Source: Heron et al (2009) in National Vital Statistics Reports, Vol. 57, No 14

The authors observe that the mortality trend for Alzheimer's disease has generally been one of rapid increase but add that some of this was due to improvements in diagnosis, awareness of the condition in the medical community and other factors including the change in coding from ICD-9 to ICD-10.

The paper also compares age-adjusted death rates by cause of death between races: white, black, AIAN (American Indian or Alaska Native), API (Asian or Pacific Islander) and Hispanic and shows that death rates by cause differ substantially between these groups.

5.2. Specific causes of death

This section focuses only on the leading cause of death groups in high income countries.

The subject of mortality by cause of death is covered in Macdonald (2008)*, and this paper does not repeat the discussion. Some further points are developed below.

The World Health Organisation mortality database* contains mortality rates by sex, age group and cause for countries with a population of 500,000 or more. Classification of cause of death by age groups on a standard basis assists international comparisons, subject, of course, to the quality of submitted data and to different recording conventions. The WHO European Mortality database (2009) also provides a tool for extracting similar data in the European region.

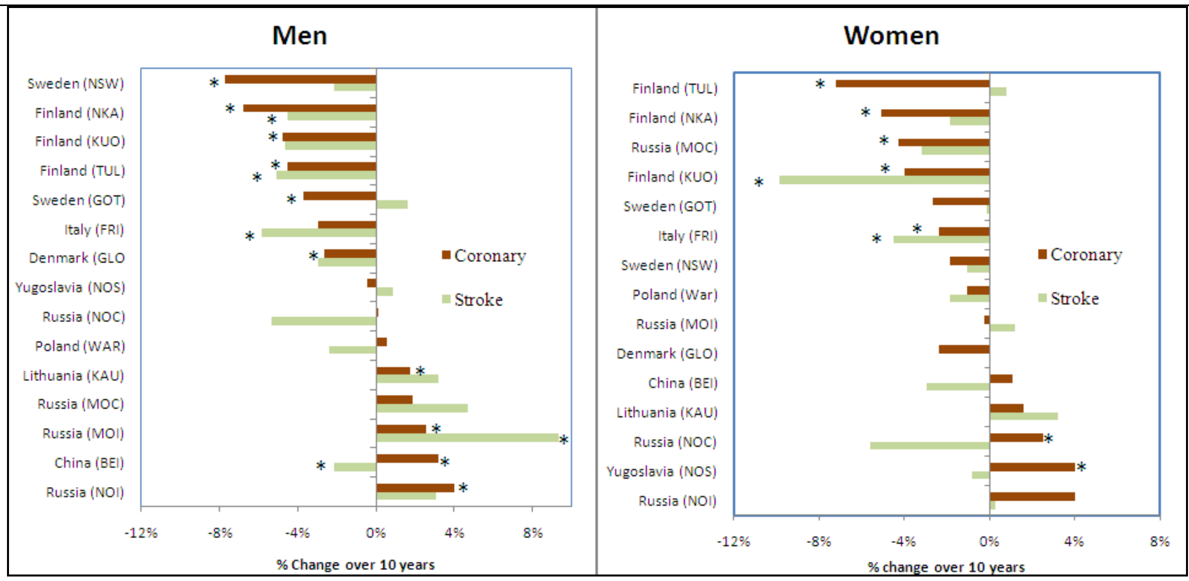
As well as national statistics departments, such as those listed in chapter 4, further sources of data and analyses include regional government health agencies, medical research bodies and other organisations or individuals concerned in particular causes of deaths.

There are few analyses of cause of death among insured or annuitant populations. However, as mentioned earlier, Tickle (2004) "Causes of death among Australian insured lives" reports on causes of death in the period 1995-1999 and compares them with population mortality and with the previous quinquennium.

5.2.1. Circulatory system: Coronary heart disease (CHD) and stroke

Coronary heart disease (CHD) and stroke are leading causes of death and disability. Because they share major common risk factors, it might be expected that trends in mortality and incidence of these two major cardiovascular diseases would be similar. This was the background to research by Truelsen et al (2003) "Trends in stroke and coronary heart disease" in the WHO MONICA Project. The researchers compared 10-year trends in mortality for 15 populations and concluded that trends for CHD and stroke mortality rates, event rates, and case fatality differ substantially between and within the study populations.

Figure 10. **<u>Percentage change over 10 years in age-standardized CHD and stroke case mortality in men and women aged 35 to 64 years.</u>**



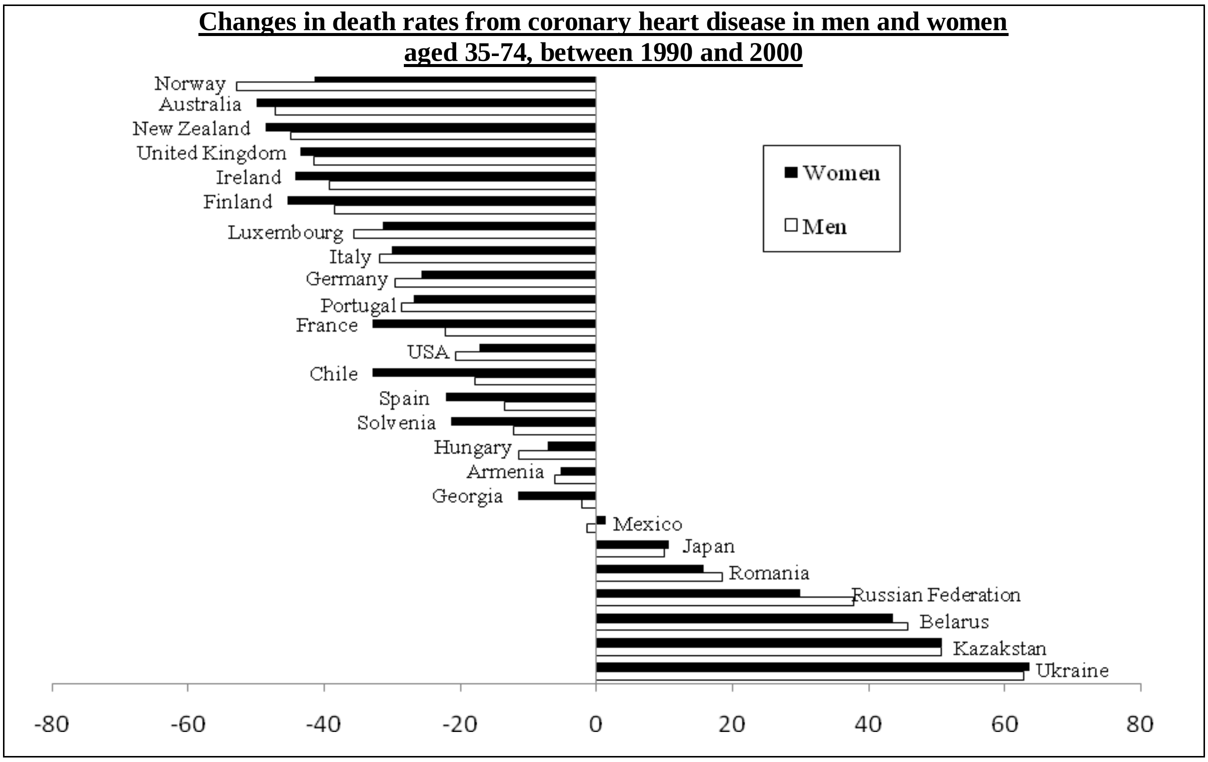
** indicates significant changes*

Source: Truelsen (2003) Trends in stroke and coronary heart diseases, WHO MONICA project, Heart

A comprehensive overview of the risk factors, impact and potential future social policy actions in respect of stroke and heart disease is available from the WHO "Atlas of heart disease and stroke", Mackay et al (2009).

Capewell and O'Flaherty (2008) "What explains declining coronary mortality? Lessons and warnings" shows that while many high-income countries saw major improvements in CHD mortality from 1990 to 2000, some countries (particularly in the former Soviet Union) saw substantial worsening. The following graph, quoted in Capewell (2008), demonstrates this:

Figure 11. **International comparison on mortality improvement by CHD**



Source: Capewell and O'Flaherty (2008), Heart, Volume 94, Issue 9, page 1105-1008

5.2.2. Neoplasms: Cancer

The WHO "World Cancer Report 2008" by Boyle and Levin (2008) states that in the past 30 years the global burden of cancer has more than doubled, with an estimation of over 12 million new cases of cancer diagnosed in 2008, 7 million deaths from cancer, and 25 million persons alive with cancer. The global burden is continuing to rise. The report draws together research on socio-economic, demographic, risk factors and other findings related to cancer.

According to the report, the most frequent types of cancer worldwide (in order of the number of global deaths) are:

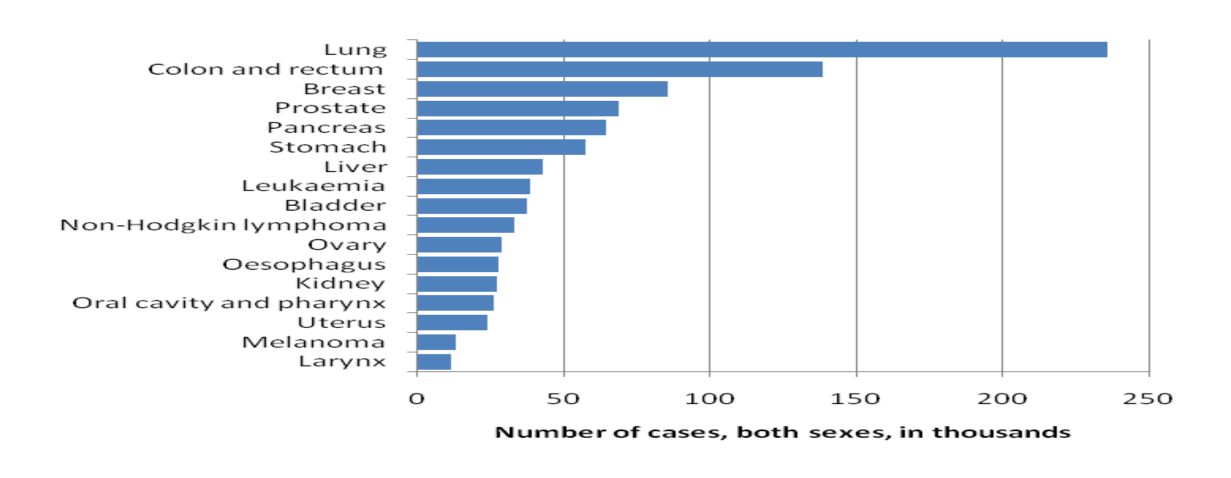
- Among men - lung, stomach, liver, colorectal, oesophagus and prostate
- Among women - breast, lung, stomach, colorectal and cervical.

La Vecchia et al (2009) provide a comprehensive country by country overview of trends in mortality by cause within Europe from 1975 to 2004 using data from the World Health Organisation. The paper states that overall cancer mortality rates peaked in 1988 in the European Union. In the period from 1990-1994 to 2000-2004, overall cancer mortality in the European Union declined by 9% in men and by 8% in women, with larger falls in middle age.

In "Estimates of the cancer incidence and mortality in Europe in 2006", Ferlay et al (2007) demonstrate very substantial differences between different EU states when it comes to mortality from different types of cancer, and discusses the risk factors leading to changes.

The following figure, from the paper, shows estimated mortality from different types of cancer in the EU:

Figure 12. **Estimated mortality from cancer in the European Union, 2006**



Source: Ferlay et al (2006)

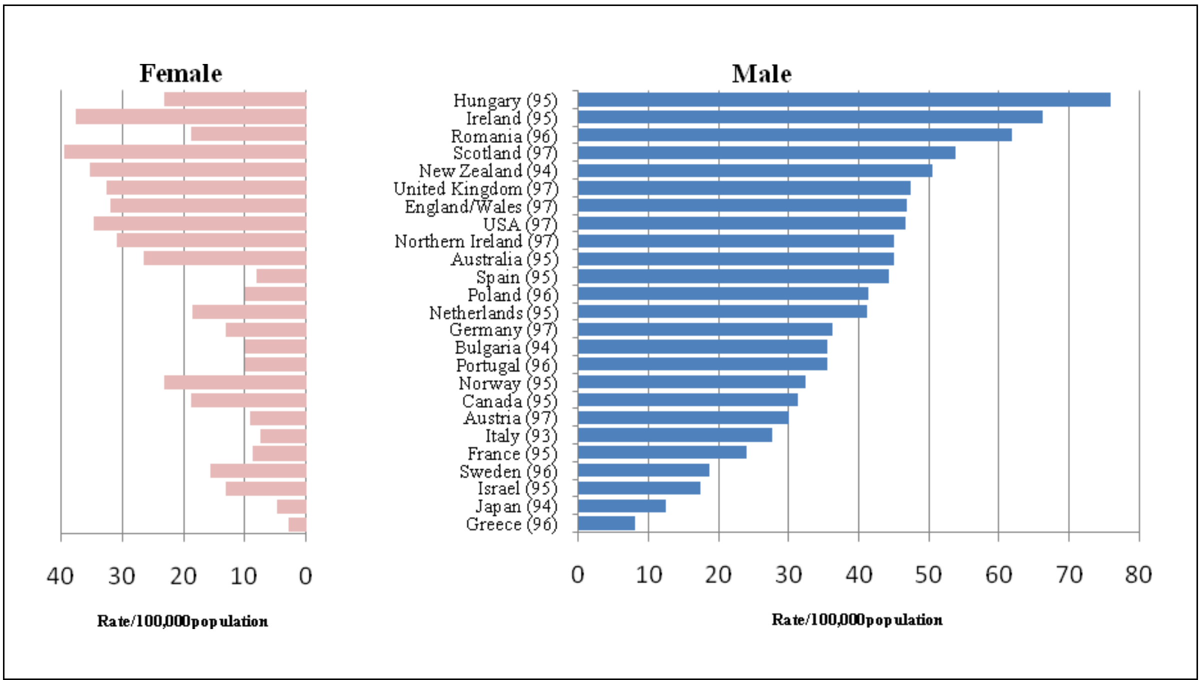
5.2.3. Diseases of the respiratory system: Chronic obstructive pulmonary disease (COPD)

The following information is from WHO (2009a):
COPD is the major killer in Diseases of the Respiratory System, and is "a lung ailment that is characterized by a persistent blockage of airflow from the lungs. It is an under-diagnosed, life-threatening lung disease that interferes with normal breathing and is not fully reversible. The more familiar terms of chronic bronchitis and emphysema are no longer used; they are now included within the COPD diagnosis…. More than 3 million people died of COPD in 2005, which is equal to 5% of all deaths globally that year…. Almost 90% of COPD deaths occur in low- and middle-income countries."

COPD is important for a number of reasons:

- It is the fourth leading cause of death in the world (WHO, 2009), in the United States (Hurd, 2000), and in England and Wales.
- In some countries COPD mortality has increased substantially: in the USA there was a 165% increase in age adjusted COPD death rates from 1965 to 1998. This compares with falls in the same period of 59% for CHD and 64% for Stroke (Mannino et al, 2006).
- Total deaths from COPD are projected to increase by more than 30% in the next 10 years without interventions to cut risks, particularly exposure to tobacco smoke.
- COPD mortality rates in different countries vary by a factor of up to 8 times (Hurd, 2000)

Figure 13. **<u>Age adjusted death rates for COPD by country and sex in individuals aged 35 to 74 years. (Year of data shown in parentheses.)</u>**



Source: World Health Statistics Annual, WHO (unpublished)

5.2.4. Infectious diseases

While infectious diseases in less developed countries still feature among the top causes of death, major improvements have been seen in high-income countries.

In the UK, in the early part of the last century, infectious diseases were the largest cause of death. There was a phenomenal reduction in infectious disease mortality by the end of the century.

Willets et al (2004b) show the proportion of deaths due to infectious diseases by age band as follows:

Figure 14. **<u>Proportion of all deaths due to infectious diseases in the period 1901 to 1910 and for 2001, England and Wales population</u>**

	Proportion of deaths due to infectious diseases			
	1901-1910		2001	
Age group	Male	Female	Male	Female
1-14	43%	47%	6%	6%
15-44	46%	49%	2%	3%
44-64	16%	11%	<1%	<1%
65 and over	4%	5%	<1%	<1%

Source: Willets et al (2004b) and ONS. (2001)

In considering the improvements in longevity in England and Wales, Willets et al state: "The most important factor driving these mortality improvements was the conquest of infectious diseases. This was the single biggest health success of the 20th century. The development of vaccines and the introduction of antibiotics after the Second World War have almost eliminated deaths from this cause. Infectious diseases now account for less than 1.0% of all deaths as shown from data in ONS (2003)."

There is a debate as to how much of this is due to medical advance. Macdonald (2008)* highlights the thesis (McKeown: *The Role of medicine* 1979) that medical advances had little impact on mortality improvements until the 1970s. McKeown emphasized instead the importance of economic growth, rising living standards, and improved nutrition as the primary sources of most historical improvements in the health of developed nations

(Szreter, 2001). Macdonald's paper also refers to later studies to demonstrate the impact of medical advances on mortality post 1970, by Bunker (1995, 2001), and on the financial value of lives saved, by Cutler et al (2006). Szreter (2001) challenges McKeown's view, and argues that: "This interpretation failed to emphasize the simultaneous historical importance of an accompanying redistributive social philosophy and practical politics, which has characterized the public health movement from its 19th-century origins".

6. What risk factors affect mortality by cause?

The previous section has covered proximate cause of death: the cause likely to be recorded by the doctor completing a death certificate. But underlying this will be risk factors such as blood pressure and high cholesterol that may themselves be driven by lifestyle factors such as smoking and lack of exercise. We have seen this to an extent in the earlier sections on mortality by socio-economic and demographic indicators. When trying to determine the effects of risk factors it should be remembered that there are complex issues of co-morbidity, subsidiary causes and the distinction between proximal and underlying causes of death. As mentioned above, most deaths occur at older ages among people who suffer from more than one disease. The relationship between these diseases and the identification of each as proximal, underlying or contributory often is debatable, with outcomes that are influenced by extraneous factors, such as the pressure of work on the certifying physician.

6.1. Risk factors and mortality in general

There are many studies from medical research which demonstrate the key significance of lifestyle on the risk of mortality.

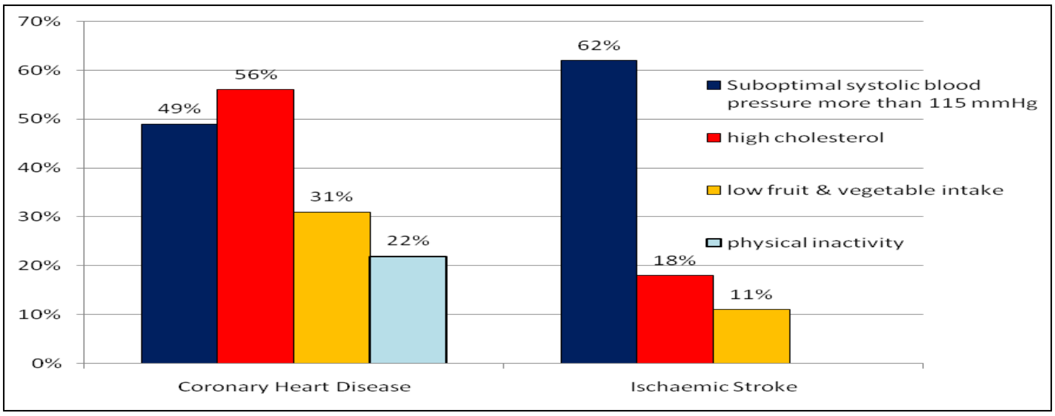
Worldwide, "The leading global risks for mortality in the world are high blood pressure (responsible for 13% of deaths globally), tobacco use (9%), high blood glucose (6%), physical inactivity (6%), and overweight and obesity (5%). These risks are responsible for raising the risk of chronic diseases such as heart disease, diabetes and cancers. They affect countries across all income groups: high, middle and low", quoted from WHO *Global health risks* (2009b).

European Public Health Alliance report (2006) asserts that in Europe, "only 7 risk factors are responsible for most of the burden of diseases. They are largely preventable and well known: high blood pressure, tobacco use, harmful and hazardous alcohol use, high cholesterol, being overweight, low fruit and vegetable intake and physical inactivity".

These statements refer to immediate risk factors, and the WHO report (2008b) "Closing the gap in a generation" (see 6.9) would point to an underlying set of social determinants of health that drive the propensity to adopt these risk factors.

6.2. Risk factors, CHD and stroke

Figure 15. **<u>The World Health Organisation (WHO) summary of the major risk factors, worldwide, that contribute to CHD and Stroke:</u>**



Source: WHO (2002)

Examining a number of countries, writers including Capewell (2006, 2008) and Ford (2007) have pointed to the substantial part the reduction in risk factors (as opposed to medical advances) has played in reducing mortality from coronary heart disease (CHD).

Capewell cites analyses that suggest that for Scotland, England and Wales, Ireland, Finland, New Zealand and the USA we can attribute between 45% and 75% of the CHD mortality decline to changes in risk factors, and the remaining 25% to 55% to treatments.

Ford et al (2007), "Explaining the Decrease in U.S. Deaths from Coronary Disease, 1980–2000" estimate that changes in risk factors contributed to 44% of the decline in mortality and treatments contributed 47%. The paper then subdivides the contribution of these risk factors and treatments. Whilst noting the substantial overall reduction in deaths, the authors estimate the effect of increases in the prevalence of diabetes and increases in body mass index as acting against the trend. The paper quotes research from other countries and concludes (as does Capewell) that the vast majority of studies attribute the greatest proportion of the fall in coronary disease mortality to reduction in risk factors.

The potential impact of future health programmes and social changes in changing future mortality (given the large part played by CHD) can be read in to the title of a paper by Unal et al (2005) "Small changes in United Kingdom cardiovascular risk factors could halve coronary heart disease mortality", although, of course, there may be a significant time lag between the change in some risk factors and their effect on future mortality.

6.3. Risk factors and cancer

On the subject of cancer the WHO (2007) states in "Statistics 2007" key risk factors for cancer that can be avoided are:

- tobacco use - responsible for 1.8 million cancer deaths per year (60% of these deaths occur in low- and middle-income countries);
- being overweight, obese or physically inactive - together responsible for 274 000 cancer deaths per year;
- harmful alcohol use - responsible for 351 000 cancer deaths per year;
- sexually transmitted human papilloma virus (HPV) infection - responsible for 235 000 cancer deaths per year; and
- occupational carcinogens - responsible for at least 152 000 cancer deaths per year.

Other risk factors include a genetic susceptibility to certain cancers, and this is the subject of considerable research.

6.4. Risk factors and COPD

The primary cause of COPD is tobacco smoke (through tobacco use or second-hand smoke), and the disease now affects men and women almost equally, due in part to increased tobacco use among women in high-income countries. Other important risk factors include occupational exposure to dusts and chemicals, lower socio-economic status, and genetic predisposition (Mannino, 2006). The disease is not curable, but treatment can slow the progress of the disease.

COPD sufferers often die of another disease, and Mannino (2006) quotes studies in England and Wales where approximately 60% of deaths were attributed to COPD itself, while 25% of patients died as a result of diseases of the circulatory system and more than 5% of deaths were attributed to neoplasm.

6.5. Smoking

It has been known since 1950 that smoking has a real impact on lung cancer. Since that time it has become evident that smoking is also a contributor to a wide variety of other causes of death. Richard Doll, with Austin Bradford-Hill, documented the link between smoking and cancer in *British Medical Journal*: September 1950, based on a prospective study of UK male doctors. Doll and colleagues kept this study going for 50 years, and in 2004 concluded their study. Among the findings in Doll (2004) were:

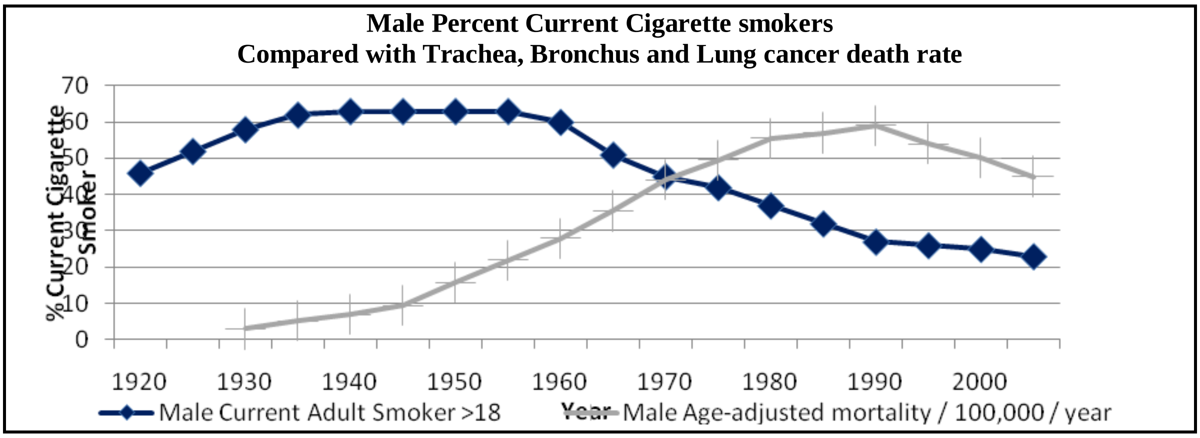
- for men born around 1920, prolonged cigarette smoking from early adult life tripled age specific mortality rates, but cessation at age 50 halved the hazard, and cessation at age 30 avoided almost all of it
- men born in 1900-1930 who smoked only cigarettes and continued smoking died on average about 10 years younger than lifelong non-smokers
- cessation at age 60, 50, 40 or 30 years gained, respectively, about 3, 6, 9 or 10 years of life expectancy.

Smoking is implicated in a wide range of causes of mortality. An international analysis of mortality caused by smoking in developed countries was produced by Peto et al (2006 update)* "Mortality from smoking in developed countries, 1950–2000*"*. It illustrates the extraordinary magnitude of the number of deaths that smoking is now causing. In the 45 developed countries it surveys, smoking is currently responsible for nearly two million deaths a year, about half of which are deaths in middle age (ages 35-69). There is, however, wide variation between one developed country and another in the current death rates from smoking, and in the trends in those death rates.

The CMI in the UK has analysed the experience of life assurance policyholders who took out policies that provided different rates for smokers and non-smokers. CMIR 21 (2004) analysed the excess mortality for smokers over non-smokers who took out temporary life assurance cover. The difference is substantial: the figures for the five years to 2002 show that smokers over 45 generally experience more than double the mortality of non-smokers. Over the period from 1995 both smoker and non-smoker mortality improved by around 40%, leaving the two groups just as far apart. (It is an interesting question, not investigated here, as to why the mortality risk of smokers fell by the same amount as non-smokers.) Since people's smoking status can change after they took out their policies, these figures probably understate the impact of smoking. The most recent figures from CMIR 42 (2009), covering 2003 to 2006, show that for all assurances combined the overall excess mortality for male smokers was over 110% at durations 2+ years, and for female smokers was over 120%. For both sexes, excess mortality was substantially higher at durations of zero and one.

Gutterman (2008) "Human behaviour: An impediment to future mortality improvement: A focus on obesity and related matters" demonstrates graphically how related cancer deaths have followed smoking prevalence in the USA since 1920 (males only for space reasons). It is not clear to us why the time lag between the peaks is so great.

Figure 16. **Male smoking and lung cancer**



Source: Gutterman (2008)

Where countries have adapted their health policies to discourage smoking, reductions in heart disease, stroke and cancer death rates have occurred. Mortality projections based on the continuation of past trends are thus implicitly dependent on assumptions about the prevalence of smoking.

6.6. Diabetes

Type I diabetes (early onset) and Type II diabetes are both killers in their own right, but it is considered that other diseases caused by diabetes substantially outnumber the actual number of deaths that are directly attributable to the disease.

Diabetes mellitus is a recognised risk factor for cardiovascular disease (CVD) and mortality. Franco et al (2007) set out to calculate the association of diabetes after age 50 years with life expectancy and the number of years lived with and without CVD. They found that diabetic men and women 50 years old and older lived on average 7.5 and 8.2 years less respectively than their non-diabetic equivalents.

WHO (2008d) projects that diabetes deaths will double between 2005 and 2030, and highlights simple lifestyle measures that have been shown to be effective in preventing or delaying the onset of type 2 diabetes:

- achieve and maintain healthy body weight;
- be physically active – at least 30 minutes of regular, moderate-intensity activity on most days. More activity is required for weight control;
- eat a healthy diet of between three and five servings of fruit and vegetables a day and reduce sugar and saturated fats intake;
- avoid tobacco use – smoking increases the risk of cardiovascular diseases.

Obesity is a particular risk factor for Type II Diabetes.

6.7. Obesity

There is a common conclusion that there is a "J-shape" relationship between body mass index and mortality. It is not good to have a very low mass index, or a very high one. Mayhew et al (2009) estimates that in the UK: “a 30-year old male with a Body Mass Index (BMI) of 34 is expected to live 4 years less than a 30 year-old male with a BMI of 24. The equivalent figure for females is 2 years which reflects the overall results that suggest obesity is more of a problem for males than females” The paper also concludes that waist-to-height ratio is a better indicator of mortality risk than BMI.

Gutterman (2008)* presents a thorough analysis of trends in obesity prevalence in significant population segments, studies risk factors and diseases, and discusses the potential impact on mortality and morbidity.

The influence of obesity on mortality is an issue that has been contested in the past, with literature suggesting that the prevalence of obesity has been overestimated and that its effects on mortality are also in danger of being overestimated. Gronniger (2005) reported that many studies estimating the relationship between obesity and mortality do so by comparing mortality rates of obese people with those of non-obese people. A technique where the relationship between familial obesity and mortality was investigated suggested that being related to an obese person did not significantly increase the risk of mortality. The paper concluded that traditional estimates may overestimate the association between obesity and mortality, possibly due to unobserved environmental and behavioural factors correlating with obesity.

Olshansky et al (2005) in the aptly-named paper: “A potential decline in life expectancy in the United States in the 21st century” reports “obesity is a multisystem condition associated with an elevated risk of type II diabetes, coronary heart disease, cancer, and other complications.” The paper concludes: “… if the negative effect of obesity on life expectancy continues to worsen, and current trends in prevalence suggest it will, then gains in health and longevity that have taken decades to achieve may be quickly reversed.“

Foresight modelling in the UK indicates that 60% of adult men and 50% of adult women could be obese by 2050 (Mc Pherson, 2007). A literature review including an analysis of obesity drivers and trends is available at Foresight (2009). The review includes a statement which forewarns of potential developments in technology that will undoubtedly influence developments in healthcare and thus mortality over the coming half century. “Technological advances already permit gene-testing and personally tailored healthcare; analysts predict significant advances in drugs, nutrition and genetic modification. Nanotechnology offers the prospect of changing the way our bodies work at the molecular level, but questions of ethical and social acceptability and cost are likely to arise. Developments in pharmaceuticals, genomics, nanotechnology and neuroscience may make use of drugs and manipulation of our bodies more commonplace; demand for drugs and interventions to alter body shape may increase.”

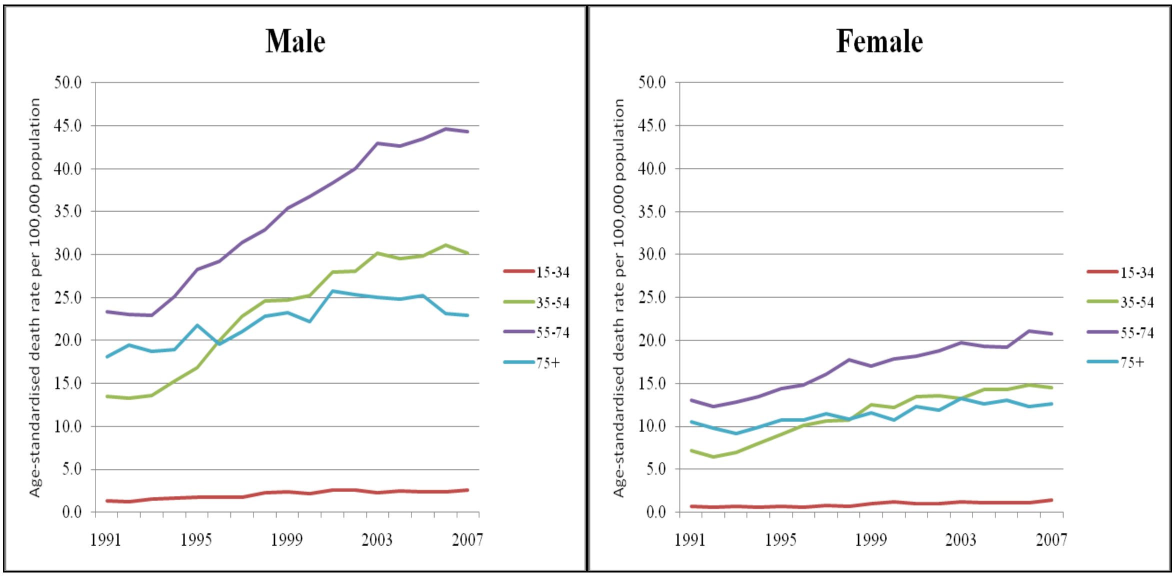
6.8. Alcohol

There is some evidence that a little alcohol is a good thing for overall mortality. In a longitudinal study of a select professional-class group in the UK, Doll et al (2005) "Mortality in relation to alcohol consumption - A prospective study among male British doctors", the authors report a 23-year longitudinal study of 12,000 male British doctors. The study concludes that non-drinkers in the group, even allowing for the possibility that some of them might be reformed heavy drinkers, experienced higher mortality than all but the heaviest drinkers. A number of studies of more representative populations find the same.

In a meta-study of 34 articles on the impact of alcohol on mortality, Castelnuevo (2009) concluded that there is a J-shaped relationship between alcohol and total mortality in both men and women. Consumption of alcohol, up to 4 drinks per day in men and 2 drinks per day in women, was inversely associated with total mortality. However, there remain many who question whether low alcohol consumption per se has any protective effects on mortality.

In the UK the trend in alcohol-related deaths is now levelling out following rapid increases since the 1990s.

Figure 17. **<u>Age-standardised alcohol-related death rates: by sex and age group, 1991-2007</u>**



Source: ONS (2009b), Health Statistics Quarterly 41

The different countries in the UK demonstrate substantial variations, with age-standardised mortality from alcohol-related causes in Scotland in excess of twice the rate in the rest of the UK, for both females and males.

6.9. Lifestyle and other matters

There is substantial literature on risk factors such as diet, physical activity, sexual behaviour, transport and other accidents, violence and other issues. It is not possible to summarise them all in this paper.

In the UK, Acheson et al "Inequalities in health: Report of an independent inquiry" (1998) discussed a wide range of health, lifestyle, social services and other issues, concluding with 39 recommendations aimed at reducing inequalities in health. This led to a Government Health Inequalities strategy with short-term and long-term goals.

Wilkinson et al (2006) in "Social determinants of health: the solid facts" lists 10 topics that can differentiate life expectancy and health: the social gradient, stress, early life, social exclusion, work, unemployment, social support, addiction, food and transport.

Status, or social standing, is considered, by Marmot (2004)* in his book "Status syndrome: How your social standing directly affects your health and life expectancy", as a strong independent factor in longevity. He acknowledges that differences in social standing may often imply differences in wealth, habits (such as smoking) and access to medical care. However, using illustrations from a variety of countries, he demonstrates that where all these things are equal, people with higher social status still live longer. He argues that the ability to control one's life contributes substantially to longevity: "the key to the status syndrome lies in the brain".

In 2008 the WHO launched its report "Closing the gap in a generation: health equity through action on the social determinants of health". The paper points to the substantial differences in health and longevity both within countries and globally. It highlights health inequity as the key issue in resolving problems. It sets out an action plan based on three principles:

- Improve the conditions of daily life – the circumstances in which people are born, grow, live, work, and age.
- Tackle the inequitable distribution of power, money, and resources – the structural drivers of those conditions of daily life – globally, nationally, and locally.
- Measure the problem, evaluate action, expand the knowledge base, develop a workforce that is trained in the social determinants of health, and raise public awareness about the social determinants of health.

Marmot, who chaired the WHO commission, published the "Strategic Review of Health Inequalities in England Post 2010" (Marmot, 2010) in Feb 2010. This focuses on inequalities in health and mortality, and demonstrates that inequalities exist across the social scale, with a gradient in health and mortality from the bottom to the top on a variety of measures: occupation, level of education, housing conditions, and neighbourhood. As an example, people living in the poorest neighbourhoods will, on average, die seven years earlier than people living in the richest neighbourhoods. Even more disturbing, the average difference in disability-free life expectancy is 17 years. "In the poorest neighbourhoods of England, life expectancy is 67, similar to the national average in Egypt or Thailand, and lower than the average in Ecuador, China and Belize. The diseases that contribute to dramatically shortened lives and worse health of those in disadvantage in England are not those associated with absolute destitution. They are heart disease, cancers, diseases related to drugs, alcohol, smoking, poor nutrition and obesity, accidental and violent deaths and mental illness." The paper proposes six wide ranging policy objectives which, it suggests, will make substantial differences.

In a forthcoming paper: "A review of life time risk factors for mortality", Kuh et al (forthcoming) review evidence for the impact on adult mortality of characteristics of the individual's lifetime socioeconomic or psychosocial environment or phenotype (at the behavioural; multi-system (e.g. cognitive and physical function); or body system level (e.g. vascular and metabolic traits)) that may be common risk factors for a number of major causes of death. They examine over the lifetime: socio-economic environment, psychosocial environment, individual temperament and behaviour, lifestyles, body size, physical function, vascular and metabolic traits and cognitive function. They conclude that social class, environment and other characteristics experienced from childhood and before (e.g. birth weight) as well as in adult life can be associated with the risk of premature mortality or the chance of surviving to old age.

Finally, Bajekal (private correspondence) points out that there is a gap in the literature on lag times in terms of interpretative information linking risk factors and mortality by cause. Other than the Doll and Peto studies on smoking and lung cancer there are few studies teasing out the lag times between risk factor and disease inception or conversely, the mortality impact after giving up risky behaviour. She points out that contrary to the classical view, lag times do not always have to be long: slow inception is not incompatible with rapid reversal, and that lag times for different diseases, different age groups and genders may all be quite different (as in smoking).

6.10. Risk factors at older ages

Johnson et al (2009), in "Demographic, behavioural and socio-economic influences on the survival of retired people", reported on a 10 year follow-up study on the UK General Household Survey 1994. The study suggested that of the factors measured, smoking was the most important determinant of prospective mortality risk among the retired.

Smokers at the time of the interview had a mortality risk, on average, 78% greater than non-smokers. Non-drinkers and those who had less than one unit of alcohol per week at the time of the interview appeared to have a higher mortality risk than those who drank between one unit and the recommended government maximum per week. However, further analysis suggested that this result might be a product of the health status of individuals at the time of the interview. Type of housing tenure and region of residence were better predictors of mortality risk than occupation-based social class.

Some papers suggest a reduction in the influence on health and mortality of occupation-based socio-economic position at older ages and others show the opposite. It may be that social differentials in mortality based on occupational status decrease to a greater degree after retirement than those based on a non-work measure. Several studies suggest that wealth is a more persistent discriminator than income or occupational class.

As populations age, diseases such as dementia feature higher on the priority list. Jagger, C (2009) et al modelled the impact of an ageing population in the UK on dementia numbers and conclude that population ageing alone will increase the disabled older population by over 80% and the numbers cognitively impaired by almost 50% over the next 20 years with serious implications for the provision of care. The paper concludes that research priorities should focus on earlier detection of dementia and its risk factors, thereby allowing earlier and more targeted treatment to alleviate its associated disability.

7. What about projections of mortality by cause and by other factors?

The purpose of this brief section is not to cover the wide variety of methodologies available for modelling mortality in detail, but only to point to a few reviews and models that have been used specifically on mortality by cause and that may be of interest to actuaries.

There are various papers providing breakdowns of changes in life expectancy through changes in age and disease-specific mortality. For example,

- Klenk et al (1999) consider the case for Germany
- Conti et al (1999) look at Italian mortality
- Yoshinaga and Une (2005) consider Japanese mortality
- Gomez-Redonda et al (2005) look at Spain

7.1. Projections of cause specific mortality

As well as projecting aggregate mortality there is a wide variety of models proposed for analysing and projecting mortality for specific groups of causes. A systematic review of coronary heart disease policy models is available from Unal et al (2006) “Coronary heart disease policy models: a systematic review”. It examines 42 models and recommends six as meeting its exacting requirements. The appendix provides summaries of the Key Results from the models. It concludes with a warning: “Existing CHD policy models vary widely in their depth, breadth, quality, utility and versatility. Few models have been calibrated against observed data, replicated in different settings or adequately validated. Before being accepted as a policy aid, any CHD model should provide an explicit statement of its aims, assumptions, outputs, strengths and limitations.”

Three papers by Chatterjee et al (2007a, b, c), deal with the development and use of a stochastic model of an individual’s lifetime incorporating diagnosis with ischaemic heart disease. The papers draw a variety of conclusions about the value of Herceptin on longevity of women diagnosed with breast cancer, the impact of giving up smoking on longevity, of statins on the risk of heart disease and stroke, and the impact of obesity on mortality. Conclusions include the following:

- In the body mass index spectrum, the extremes of underweight and morbidly obese have the highest relative risks of mortality, and overweight has the lowest.
- Smoking reduces the expected future lifetime from age 20 by approximately 7 years (males) and 6.3 years (females), but giving up at any age has a significant impact on future expectation of life.

Elkins and Johnson (2003) “Thirty-year projections for deaths from ischemic stroke in the US” uses data on ischaemic stroke mortality to fit a logistic model to predict changes in stroke death rates. Using population projections for the US the numbers of stroke deaths are projected for 30 years on the basis of age, sex and race. If recent trends in ischaemic stroke mortality continue, stroke deaths in the US will outpace population growth with a doubling over 30 years.

It should be noted that many projection methodologies based on past mortality developments may be implicitly making assumptions about the continuation of trends in “by cause” mortality. In areas such as CHD where behaviour changes can have a large impact, it may be difficult to predict the effect future health strategies may have on population mortality. “By cause” projections may help indicate the boundaries of possibility.

7.2. The use of projections by cause of death to influence projections of aggregate mortality

In the context of obtaining good population forecasts, Gallop (2008) "Mortality projections in the United Kingdom" discusses a variety of methods for projecting mortality and states that: "Many of the available methodologies can be applied either to aggregate mortality data or data by cause of death. Projecting mortality by cause of death appears to provide a number of benefits such as providing insights into the ways in which mortality is changing. However, there are problems associated with this approach, in particular:

- deaths from specific causes are not always independent,
- the actual cause of death may be difficult to determine (particularly at older ages where most deaths occur) or may be misclassified and
- changes in the diagnosis and classification of causes of deaths can make analysis of trend patterns difficult."

It is not practical to break the data down into too many 'by cause' groups for projecting separately because of sparse data for some causes, and the difficulties in allowing for correlations between the different cause specific groups. If the ultimate aim is to project aggregate mortality, recombining the separate projections can produce oddities. Given the trajectories of past cause-specific mortality, it is unlikely that a single model would be the best for projecting all the different groupings. However, using different models can lead to anomalies when aggregating the results. Having chosen groupings of causes to project forward, there will be a group of remaining causes which is likely to be difficult to project, partly as they form a disparate group.

Van den berg Jeths (2001) in "A review of epidemiological approaches to forecasting mortality and morbidity" summarises how epidemiological models are used to take disease processes and related risk factors into account in modelling mortality and morbidity. It describes statistical regression models and dynamic multistate models, giving examples, and concludes by discussing the use of such models for research and health policy purposes. The Global Burden of Disease uses a relatively simple model with a few covariates which has been widely applied.

Booth and Tickle (2008) provide a review of different methodologies for projecting mortality and include a brief overview of mortality projection by cause of death. Although forecasting mortality by cause of death has been advocated as a means of obtaining better mortality projections this has not been the case in practice (McNown & Rogers, 1992). Models based on proportional rates of change, such as Lee-Carter, provide higher mortality forecasts when taken as the sum of cause of death forecasts than based on projecting aggregate mortality because the causes of death which are slow to decline come to dominate over the long term (Wilmoth, 1995).

Girosi and King (2008) have developed a Bayesian model to use information on causes of death to project mortality. They suggest that a Bayesian approach provides more accurate projections of cause-specific mortality**.** Such a model may help to mitigate some of the issues described earlier, although it will be a number of years before it can be demonstrated whether this will produce better projections.

Mathers and Loncar (2006) "Projections of global mortality and burden of disease from 2002 to 2030" suggest that models for projecting cause specific mortality fall into two broad groups. One is based on time series analysis of historical trends and relies on good death registration data. The other is structural models which are based on the relationship between mortality and a set of independent variables and are necessarily projections of those variables. Their paper sets out a set of projections of global and regional mortality based on projecting mortality by age group and sex for ten cause of death clusters under three scenarios: baseline, optimistic and pessimistic. The model also considers as risk factors GDP per capita, the average number of years of schooling in adults and time, as a proxy for the impact of technological change on health status, and tobacco use.

Projections carried out by the US Social Security Administration involve projecting by cause of death, as described in "Board of Trustees of the Federal Old-age and Survivors Insurance and Disability Trust Funds report" by Social Security and Medicare Boards of Trustees (2009).

Cause of death analysis has been used to assess potential gains in longevity by producing life tables where mortality from various causes has been assumed to be eliminated or delayed (Manton et al, 1980, Kunst et al, 2002). The delays are typically assessed using expert opinion or epidemiological models.

Olshansky et al (2005) estimate the effect of obesity on the life expectancy of the US population by calculating the reduction in the rates of death that would occur if everybody who is currently obese were to lose enough weight to obtain an "optimal" BMI. The calculation takes into account data on age-, race- and sex-specific prevalence of obesity and death rates.

Goldman et al, (2009) use a dynamic microsimulation model (the Future Elderly Model) to track cohorts over time to project their health status and economic outcomes under various prevention scenarios. Based on American data, the model was used to estimate the potential benefits from the development of successful prevention regimes for diabetes, hypertension, obesity and smoking. The paper concludes that primary prevention could generate significant health and longevity benefits among existing cohorts, perhaps at considerably lower cost than for the disease-specific interventions now being pursued.

Booth and Tickle (2008) observe that the assumption that discrete diseases drive overall mortality has also been questioned and attempts have been made to decompose mortality in other ways. For example, Bongaarts (2006) forecasts life expectancy by decomposing mortality into three components: juvenile and at ages 25+, background and senescent. These do not correspond to standard causes of death. Senescent mortality is further split by attributability to smoking. The main driver of the forecast is senescent mortality which is not attributable to smoking; juvenile and background mortality are relatively stable and mortality due to smoking can be modelled.

Tabeau et al "Predicting mortality from period, cohort or cause-specific trends: A study of four European countries" (2001) fitted dynamic parameterisation models and trend extrapolation to project age and time-specific mortality rates to data for France, Italy, the Netherlands and Norway. Three forecasts were made; projecting overall mortality by period, cause-specific mortality by period and overall mortality by cohort. Different rankings of results by life expectancy were found for different countries and between projections for males and females. "Cause-specific" forecasts were found to work well over the short term but should be used in conjunction with overall period or cohort mortality projections for longer term projections. Projecting by cause of death did not work well at the oldest ages.

Whilst many commentators have suggested that currently it is difficult to project aggregate mortality by projecting cause specific mortality and then combining the results, analysing past mortality data can provide useful information to inform the assumptions underlying projections. In particular, Andreev and Vaupel (2006) comment that an examination of trends in cause-specific mortality appears to be important in producing short-term projections.

7.3. Projections of mortality by other factors

Booth & Tickle (2008) note that there are explanatory models based on structural or causal epidemiological models of certain causes of death involving disease processes and known risk factors, but that these have yet to be fully developed or validated. Often the relationship between risk factors and mortality is not understood and such models are mainly used for simulating the effect on morbidity and mortality of policy changes affecting the risk factors.

MicMac – "Bridging the micro-macro gap in population forecasting" is a EU-funded multistage population projection approach that combines cohort data (usually by age and sex) (macro) with individual biographic data (micro). The paper provides a systematic literature review, focusing on the effects of age, sex, education, marital status, smoking and obesity on various indicators of disability and mortality.

Tabeau et al (2001) detail research carried out to see if cause specific mortality data and information about the relationships between the environment, morbidity and mortality can be used to improve forecasts. Alho (1991) "Effect of aggregation on the estimation of trend mortality", Alho (2007) "Mathematical Population Studies" and "Methods used in drawing up mortality projections" discuss conditions under which decomposition is disadvantageous and those under which it gives similar results to overall mortality forecasting.

Woo et al (BAJ forthcoming) proposes a prospective approach to modelling longevity risk based on stochastic modelling of the underlying causes of mortality improvement due to changes in lifestyle, health environment and advances in medical science in a similar fashion to the development of models for other dynamic insurance risks such as natural catastrophes. Woo points out that fast numerical computation using high quality geographical data has produced models of flood risk which have superseded the traditional statistical insurance loss models and that such an advance could be seen for modelling mortality risk within a decade. Such an approach may prove relevant for modelling influenza and other epidemics.

Van Genugten et al (2001) "Incorporating risk factor epidemiology in mortality projections" compared projections for lung cancer and coronary heart disease mortality in the Netherlands using a demographic disease-specific mortality projection and a dynamic multi-state model based on risk factor prevalence rates and transition rates from these states to and from the disease states. Although the results from the two models were different it was suggested that the understanding the epidemiological processes for developments in risk factors and medical technology were important in carrying out cause-specific mortality projections.

In recent years there has been much research produced by the UK actuarial profession on modelling and projecting mortality, for example:

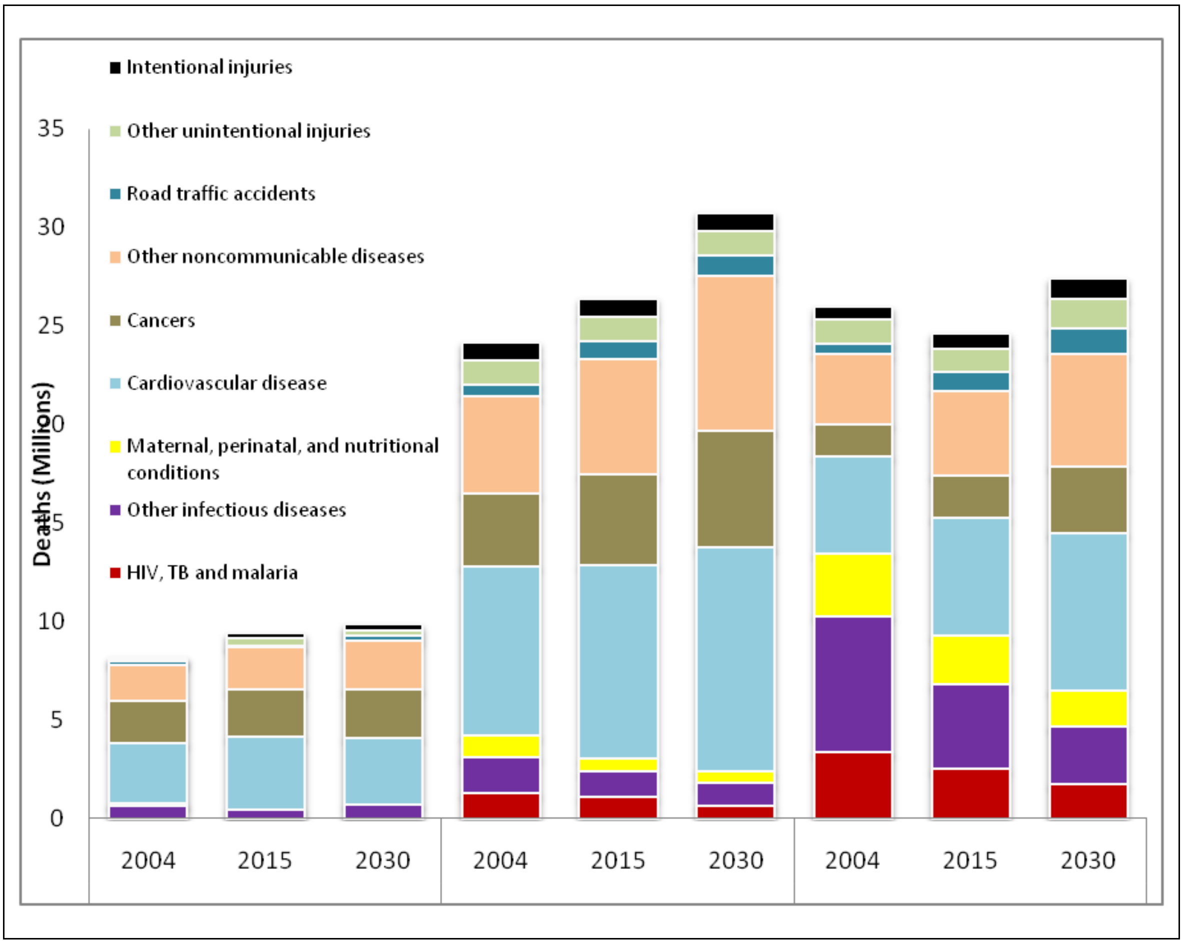
- Willets (2006) looks at the impact of analysis of mortality by cause of death on forecasting in the UK.
- Richards et al (2007) describe patterns and projections for two-dimensional mortality data and consider trends in cause of death mortality for several developed countries.
- Love and Ryan (2007) propose a simple disease-based mortality model centred on ischaemic heart disease. The paper explores how alternative scenarios can be developed based on targets for risk factors and on the expansion and development of medical and surgical treatments.
- Humble et al (2008) present a model that aims to take account of the impact of smoking on the cohort effect in the UK where those born in the period 1925 – 1940 appear to be exhibiting higher improvements in mortality than generations born immediately before or after. The paper suggests that a large part of the cohort effect has in the past been influenced by the prevalence of smoking, and care needs to be taken in assumptions that cohort effects will continue.

A working party has been set up by the UK Actuarial Profession to further investigate the development of projection methodologies based on cause of death which has presented ideas on the interactions between causes of death and mortality projections (Pinington, 2009).

7.4. International projections by cause of death

WHO (2008c), in "Future trends in global mortality", a chapter in "World health statistics 2008" provides the following projections of deaths by cause (N.B. not age-standardised):

Figure 18. **Projected deaths by cause for high-, middle- and low-income countries**



Source: WHO (2008c), World Health Statistics 2008, Page 29

It predicts that ischaemic heart disease and cerebrovascular disease will remain the top two worldwide causes of death. Deaths from cancer will increase as will deaths due to road traffic accidents and by 2030, deaths due to cancer, cardiovascular diseases and traffic accidents will collectively account for 56% of the projected 67 million deaths due to all causes. This increase in deaths from non-communicable diseases will be accompanied by large declines in mortality for the main communicable, maternal, prenatal and nutritional causes, including HIV infection, tuberculosis and malaria. The complete pattern is given on the next page.

As with all mortality projections, it is important to bear in mind the uncertainties involved. The problems identified in section 7.2 will be even more applicable when analysing past trends in global mortality by cause of death. The resulting long term projections of cause of death will be highly uncertain.

Figure 19. **Leading causes of death 2004 and 2030 compared**

2004

disease or injury	**Deaths (%)**	**Rank**
Ischaemic heart disease	12.2	1
Cerebrovascular disease	9.7	2
Lower respiratory infections	7	3
Chronic Obstructive pulmonary disease	5.1	4
Diarrhoeal diseases	3.6	5
HIV/AIDS	3.5	6
Tuberculosis	2.5	7
Trachea, bronchus, lung cancers	2.3	8
Road traffic accidents	2.2	9
Prematurity and low birth weight	2	10
Neonatal infections and other	1.9	11
Diabetes mellitus	1.9	12
Malaria	1.7	13
Hypertensive heart disease	1.7	14
Birth asphyxia and birth trauma	1.5	15
Self-inflicted injuries	1.4	16
Stomach cancer	1.4	17
Cirrhosis of the liver	1.3	18
Nephritis and nephrosis	1.3	19
Colon and rectum cancer	1.1	20
Violence	1	22
Breast cancer	0.9	23
Oesophagus cancer	0.9	24
Alzheimer and other dementias	0.8	25

Rank	**Deaths (%)**	**Diseas**
1	14.2	Ischaemic heart disease
2	12.1	Cerebrovascular disease
3	8.6	Chronic obstructive pulmonary
4	3.8	Lower respiratory infections
5	3.6	Road traffic accidents
6	3.4	Trachea, bronchus, lung cancers
7	3.3	Diabetes mellitus
8	2.1	Hypertensive heart disease
9	1.9	Stomach cancer
10	1.8	HIV/AIDS
11	1.6	Nephritis and nephrosis
12	1.5	Self-inflicted injuries
13	1.4	Liver cancer
14	1.4	Colon and rectun cancers
15	1.3	Oesophagus cancer
16	1.2	Violence
17	1.2	Alzheimer and other dementias
18	1.2	Cirrhosis of the liver
19	1.1	Breast cancer
20	1	Tuberculosis
21	1	Neonatal infections and other
22	0.9	Prematurity and low birth weigh
23	0.9	Diarrhoeal diseases
29	0.7	Birth asphyxia and birth trauma
41	0.4	Malaria

Source: WHO (2008c), World Health Statistics 2008

8. How do actuaries use this information?

In both life assurance and pensions business, the insurer (in the widest sense) will seek to use information to assess and price the risk to be covered. We refer to the process of risk assessment as “underwriting” and the assessment of a portfolio of risks as “reserving”. Both of these processes contribute to the value of an organisation and there is a growing realisation that competitive advantage can be gained by using emerging information about risk factors. Direct information on risk factors may be unavailable for a variety of reasons, and the actuary will seek to use proxies.

In North America, McDaid* (2003) “Factors affecting retirement mortality” reviewed 45 research papers that look at factors that affect mortality after retirement. The factors that seemed to be important in predicting retirement mortality included: age, gender, race and ethnicity, education, income, occupation, marital status, religion, health behaviours, smoking, alcohol, and obesity. The paper highlights the impact expected from each of the twelve variables and suggests that all twelve are important enough to be included in an actuarial model, subject to the availability of information.

In looking for factors that correlate with mortality rates in the UK, the Mortality Research Working Group of the Board of Actuarial Standards (BASMRG 2008)*, prepared a table to help understand the arguments (see figure 20).

The BASMRG found that some factors have a very significant direct impact on mortality rates, but are little used in practice by actuaries working in life assurance or pensions; often because they are unavailable. On the other hand, some factors have very little direct influence, but are extremely useful in practice because they are available.

Figure 20. **Usefulness of risk factors**

Factors correlating with mortality rates	**Direct influence on mortality rates**	**Usefulness as a proxy variable in**	
		life assurance	**pensions**
Age	Very high	Very high	Very high
Gender	Very high	Very high	Very high
Medical history	Very high	Very high	Very low
Genetics	High	Very low	Very low
Smoking status	High	Very high	Very low
Diet	High	Very low	Very low
Obesity	High	Moderate	Very low
Occupation/socio-economic class	High	Low	Moderate
Alcohol consumption	Moderate	Moderate	Very low
Regular exercise	Moderate	Very low	Very low
Exposure to stress	Moderate	Very low	Very low
Wealth	Moderate	Very low	Very low
Marital status	Moderate	Very low	Moderate
Education	Moderate	Low	Low
Degree and method of medical underwriting	Low	High	Very low
Family medical history	Low	High	Very low
Geographical location	Low	Low	Low
Postcode (Zip code)	Low	Moderate	High
Benefit amount	Low	High	High

Source: BASMRG (2008)

8.1. Life assurance

Life assurance underwriters in many countries are able to take into account the prospective life assured's medical history and family history in the underwriting process, although the details permitted to be sought may be different in different countries. For example, in the UK genetic testing information may not be used. In the USA, Rozar et al (2009) studied the mortality experience of a large group of insurance applicants where electronic prescription histories were available. The object was to assess the cost-effectiveness of obtaining prescription history during the underwriting process. As might be expected, they found that the relative mortality risk of applicants taking the highest risk drugs is significantly higher than average. However, they also found that "eligible applicants with no history of filling prescriptions have worse mortality than those who have filled lower risk prescriptions, suggesting the value of regular medical screening and maintenance drugs". Factors such as income and social class may also be relevant.

Given the strong links between socio-economic and demographic indicators and the mortality of individuals, one might wonder why in the past most life companies failed to operate differential pricing, at least for mortality-sensitive products such as term assurance. Part of the answer lies in the distribution of such life products. In the UK, "industrial life business" was aimed at the lower-waged groups, and premiums were substantially higher, taking into account both higher per-policy expenses and higher mortality costs. The "direct sales" channel was aimed largely at the next layer up, and in both cases price competition was not a major factor in decision-making. At the "top end" independent financial advisers competed for life insurance for higher net worth individuals. So the heavier mortality business was naturally segregated from the lighter business, and pricing became more competitive at the higher level both as a result of lower expenses and lower mortality costs. Other factors, such as higher lapse rates also compensated for higher mortality rates in the lower waged groups.

While many life insurance companies and pensions and annuity providers continue writing policies that do not discriminate by socio-demographic group, there is a growing market in many countries for preferred life insurance and substandard annuity products. These are able to make use of socio-demographic data such as postcode in the underwriting and pricing of the product. The growth of these markets must mean that conventional portfolios will become increasingly subject to anti-selection.

In South Africa, traditional individual life products, that is where the sum insured is usually above US$20,000, are underwritten on the basis of four criteria: gender, smoker category, age and rating class. Rating class is also referred to as SEC (socio-economic class). A pricing basis could include education and income. There might be four education classes: "no matriculation", "matriculated", "3 or 4 year diploma or 3-year degree", and "4-year degree or professional qualification", and four income classes. Some companies also use other rating factors such as blood pressure, BMI etc, and they will monitor these and continue to give a discount if the life insured continues to comply with guidelines as set out by the insurance company.

The market for “preferred life” policies is strongest in North America. In "preferred life" business, clients are quoted a premium that depends not only on gender, age and smoking category, but on a variety of other risk factors, typically cholesterol level, blood pressure, build and "moving violations”.

The Society of Actuaries and the American Academy of Actuaries have embarked on a major project to study aspects of the preferred life market in the USA. This includes the study of underwriting criteria (SoA, 2009) and the preparation of mortality tables for categories of preferred lives (SoA, 2008). Analysis of past data has led to the development of “a set of valuation basic mortality tables … for individual life assurance products that reflect standard and preferred underwriting criteria”, Bahna-Nolan (2008).

Klein (2009) “Report of the Society of Actuaries underwriting criteria team” introduces “an algorithm to score every risk class in a preferred risk class structure”. “The scores are intended to allow risk classes with similarly anticipated mortality experience to be grouped together to help form the basis of analysis and development of the new preferred mortality tables”. The algorithm takes into account a variety of factors including preferred underwriting criteria: alcohol and drug abuse, blood pressure, build, cholesterol, family history, motor vehicle records, personal history, tobacco use and other factors.

Preferred life insurance is a significant but not predominant feature of the UK market, and certain socio-economic and demographic factors are taken into account in underwriting, through the use, inter alia, of postcode.

8.2. Annuities

“Substandard annuities are medically underwritten, impaired risk, or age-rated annuities that offer larger payouts for annuitants who are found to have shorter-than-average life expectancies”, LIMRA International (SoA, 2006). The paper: “Substandard Annuities Report 2006” discusses approaches to underwriting on medical grounds, and points out that the approach needed for underwriting longevity risk is substantially different to that used when underwriting standard mortality. The authors report that the companies interviewed as part of the study do not consider lifestyle or other non-medical questions when making their underwriting determinations, on the grounds that it is in the interest of the annuitant to change lifestyle (to a healthier one) after purchasing the annuity.

In the UK, the market for individual life annuities priced on a select life basis has grown rapidly over the past few years, and postcode is a key component in the underwriting. The volume of sales of select life annuities has now reached the stage where the non-select annuity portfolios can expect to experience considerably lighter experience than standard.

Richards (2008a) “Improving annuity pricing with address data” covers a number of risk factors that can be used in the pricing of annuities. These are fundamentally the same as those covered in Richards (2008b), see below.

In a further paper, Richards and Currie (Revised BAJ 2009 to be published in 2010) discuss longevity risk and annuity pricing with the Lee-Carter model, using data that includes postcode and pension size. They point out that traditional methods of analysis, where it is not possible to combine the annuities for one person, can underestimate risk and financial volatility as wealthier people have a greater tendency to have multiple annuities.

8.3. Pensions and annuity portfolios

In the UK postcode is used as a means to include a socio-economic grouping in the valuation of bulk annuity portfolios. It is increasingly used in the valuation of pension portfolio liabilities.

In Richards (2008b) "Applying survival models to pensioner mortality data", the author states that "In addition to the traditional risk-rating factors of age, gender and policy size, we find that geo-demographic profiles based on post code provides a major boost in explaining risk variations". The paper describes the approach used to turn the postcode into a useful mortality risk factor.

In the UK, in practice an average of around 15 residential households are covered by a single postcode, providing a high degree of granularity in determining where a person lives just from their postcode alone. The question then arises: "how do you assess the mortality characteristics of a postcode group, when it is far too small to obtain mortality data?" The answer from Richards is to use socio-demographic profiles. A number of commercial profilers will map UK postcodes onto a smaller number of socio-demographic profiles. Each system has descriptive names and profiles for each category: for example, the postcode EH4 2AB is Mosaic type 02 ("Cultural Leadership"). These socio-demographic profiles were developed primarily for direct marketing purposes, but are particularly effective at predicting mortality differentials.

Records for each pensioner are coded for ordinal factors such as pension size and year of birth as well as for categorical factors such as region, socio-economic group and product type. The pensioner records can then be grouped in a variety of ways for analysis and modelling. Where marital status (married people tend to live longer) is unavailable, postcode is also used to give an indication of probability that the subject is married.

Richards concludes that a model which incorporates both geo-demographic type *and* pension size will usually be better than using either variable on its own.

Madrigal et al (2009) in "What longevity predictors should be allowed for when valuing pension schemes liabilities" suggests geo-demographic profile based on post code is the third most important parameter after age and gender when modelling for mortality in pension liabilities – even more important than the pension size or salary information. The paper provides a multivariable analysis of post-retirement mortality using the detailed information held within occupational pension scheme records and investigates the importance of factors including gender, affluence and lifestyle on the observed period life expectancy of individuals. It states "We describe one approach to constructing a multivariable model for pensioner baseline mortality, showing how such factors explain a variation in observed period life expectancy in excess of ten years. The relative importance of each factor on mortality is analysed and we describe the interactions between these factors and age, answering questions such as whether the impact of a healthy lifestyle or affluence attenuates with age. Further, we highlight the importance of the choice of affluence measure in analysing mortality, and show that the salary at retirement is a better predictor of longevity than the pension amount for male pensioners.

In pointing to the importance of scheme-specific mortality assumptions in pensions valuation the authors note: "For the 91 schemes considered in this paper, the observed period (post-retirement) life expectancy from age 65 ranged, in 2005 to 2007, from under 15 years to over 20 years for men, and from 18 years to almost 25 years for women."

Edwards (2006, 2008, 2009) discusses a Postcode Mortality Model used to model UK pensioner and annuitant mortality. The analysis combined several different methods to cluster postcodes, focusing on mortality and health as well as wealth and lifestyle: 'health clusters' and 'lifestyle clusters' from a market research agency, 'pensioner mortality clusters' (from a data base) and 'population mortality clusters' from the UK Office for National Statistics. The authors identify two further factors: 'Amount effect' (based on pension amounts) and 'Calendar year effect'.

Combining all the factors they find that for male pensioners, postcode can explain a mortality variation of over 350% between the highest and lowest rated postcodes.

We believe there is scope for research on how postcode and other social and demographical data can be used in life insurance and pension business outside the UK. Richards (2008) "Improving annuity pricing with address data" comments: “Similar postcode-driven systems apply in other countries, including the United States of America (zip code), Canada (postal code) and the Netherlands (postal code). As in the UK, these countries use hierarchical systems, so a given postcode can be used to give both regional and socio-economic information.” Richards, refers to other countries where geo-demographic profiling based on full address is possible: France, Germany, Spain, Italy and Japan. We do however recognise that in the UK there is a strong geographical element in the clustering of the social determinants of health, and this may be less evident in other countries.

9. Conclusions

There are many links between mortality by socio-demographic stratification and mortality by cause. Both areas provide clues to understanding the past progress of mortality and the mortality likely to be experienced by an individual or group in future.

9.1. Mortality by socio-demographic stratification

It is clear from studies in many countries that social class and deprivation have a very substantial impact on mortality, and this differential between classes has been an issue for generations, although the magnitude of the differential may vary with time.

9.2. Mortality by cause

WHO demonstrate that the “big two” major causes of death are “stroke and other cerebrovascular disease” and coronary heart disease in high, medium and low income countries. The one exception is that in low-income countries “lower respiratory infections” is the number one killer and stroke comes in fifth.

It is important to note that even within one country the predominant causes of death can be different by age group, socio-demographic groups and, of course, by sex.

Examination of past trends in causes of death is helpful in understanding the overall mortality improvements in populations. In many countries, much of the improvement has been due to substantial reductions in a very few specific cause of death groups. In the case of some cause of death groups, the quantum of improvement has been so significant that further improvements will be limited.

9.3. Projections

A variety of methods have been discussed that produce projections based on mortality by cause data. There are many practical questions as to how effective these are as predictors of future population mortality. The development of credible projections using mortality by cause is a target being pursued by a number of researchers and we look forward with interest to publication of further developments. At the very least, an understanding of mortality by cause and socio-demographic indicators can be used to test the credibility of projections.

It is clear from some of the analyses that human behaviour can influence, to a large extent, mortality improvement and worsening. Since human behaviour can be influenced by government actions or social environment, this demonstrates some limitations on the ability to project future mortality. Nevertheless, in the realms of demographic forecasting, projecting fertility and migration present larger problems.

9.4. Applications in practice

While many life insurance companies and pensions and annuity providers are able to continue writing policies that do not discriminate by socio-demographic group, there is a growing market in many countries for preferred life insurance and substandard annuity products. These are able to make use of socio-demographic data such as postcode in the underwriting and pricing of the product. The growth of these markets means that conventional portfolios must become increasingly subject to anti-selection.

When it comes to the purchase and sale of annuity and pensions portfolios, the use of individualised data to pick and choose risks makes it possible to discriminate with increasing accuracy the relative "weight" of mortality of a particular portfolio. Actuaries and their clients ignore these opportunities at their own risk.

9.5. Future developments

Various causes of death have been the subject of extensive research; others areas which might have a potentially large effect on future morbidity and cause of death, such as dementia, are in future likely to attract more attention and research funding.

Research into the time lags between risk factor and disease inception, and conversely the mortality impact after giving up risky behaviour (Bajekal, see Section 6.9) would be of value from a variety of points of view: demographics, medical and actuarial.

We have referred briefly in section 6.7 to the technological advances that will undoubtedly influence healthcare over the coming forty years. We shall look forward to developments in this field.

Socio-demographic classification and post code are seen as proxies for relative mortality levels and as such are being used as an important competitive element in life assurance and pensions business. It is to be expected that competition will lead to further research and developments in this area. We believe there is scope for research on how postcode and other social and demographical data can be used in life insurance and pension business outside the UK.

We look forward with interest to research on alternative approaches to modelling mortality such as the catastrophe modelling approach to longevity risk analysis proposed by Woo et al.

In a number of markets, critical illness products are growing rapidly. The product comes in a variety of forms, but often includes a combination of life insurance and insurance against contracting a critical illness. We have been unable to find a paper that considers mortality and morbidity on critical illness policies taking into account indicators of social class. Due to the trackability of health inequalities by postcode, there seem to be many opportunities for research. It would be interesting to hear of such research, or to see this area of research undertaken.

The wide range of literature in a wide variety of fields illustrates the potential benefits of involving a multi-disciplinary team of actuaries, epidemiologists, medical professionals and others in interpreting the results and hence in improving our understanding of possible trends in future mortality.

9.6. Further work

We recognise that this is a fast developing field, and also that our ability to select relevant papers has been limited. We will welcome corrections and additions to this paper.

We hope the work will be useful to actuaries, students, and others as a source of reference on our subject and as a pointer to the work we have reviewed.

In addition to the reference list, we have a list of further papers that were recommended to us or we have found, but have not used. We can make this available to readers on application.

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