SCOPING MORTALITY RESEARCH
(REPORT OF THE MORTALITY RESEARCH STEERING GROUP)

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ABSTRACT

The Actuarial Profession is currently undertaking a review of its research strategy, and has decided to focus more resources on researching mortality developments. It is important that the profession is involved in partnerships with researchers from outside of the profession, bringing actuarial expertise into closer contact with other disciplines. We believe that collaboration between these different areas of expertise will provide important new insights in understanding mortality trends. This report represents the first step by the Mortality Developments Scoping Project Steering Group to map current research into mortality developments across a wide range of disciplines. The steering group is aware that the themes and literature discussed in this report are not exhaustive; however it does include areas of research not normally covered by the Actuarial Profession. The steering group welcomes comments on the report and suggestions for any areas which may not yet have been covered.

The main aim of this report is to provide an overview of the key areas of research into mortality developments across a wide range of disciplines, as well as areas of overlap and gaps in the research. The literature described is compiled from recommendations received by the Mortality Developments Scoping Project Steering Group from experts from different disciplines working in the area of mortality.

Key themes identified from recommended literature:

— the role of medicine in mortality reduction;
— the role of lifestyle and environment in mortality reduction, including smoking, socio-economic conditions and obesity;
— causes of death contributing to mortality reduction, in particular coronary heart disease;
— mortality reduction attributable to differing age groups;
— the relationship of active life expectancy to total gains in life expectancy;
— evidence of cohort effects on mortality improvement; and
— future trends in mortality developments.

Areas of overlap identified from recommended literature are:

— the overlap between literature examining the role of medicine in mortality decline and the influences on the decline in mortality from coronary heart disease; and
— the areas of overlap between various disciplines working in the field of mortality developments.

Gaps identified in recommended literature are:

— a lack of recommendations from social policy;
— few papers recommended on the role of lifestyle and behavioural factors on mortality;
— few papers recommended on causes of death other than coronary heart disease; and
— few papers recommended on potential threats to future mortality improvement.

KEYWORDS

Mortality Improvements; Cohort Effects; Cause of Death; Ageing; Longevity; Life Expectancy

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1. Introduction

Mortality developments is an area in which the Actuarial Profession has a particular interest and has conducted research. However, at present many within the profession are unaware of research which has been undertaken by other disciplines in the field of mortality developments. The main aim of this report is to provide a multi-disciplinary study of mortality developments research, highlighting the key factors underlying mortality improvements (and impairments), and identifying the core questions which excite the different disciplines studying mortality. In particular, any gaps and overlaps in the research will be discussed. It is intended that this report will be of value, not only to members of the Actuarial Profession, but also to researchers in other disciplines, by providing an overview of the main issues in current mortality research.

2. Methods

2.1 The time inherent in a scoping project created a number of challenges when developing a methodology to review the large field of mortality developments across several different disciplines. It was decided, at an early stage in the project, that it would not be practical to perform an in-depth search of several different literature databases to identify high quality, relevant papers. Instead, the Scoping Project Steering Group adopted an alternative approach. First, the disciplines which the study intended to cover were identified. These were: medicine, epidemiology, genetics, gerontology, demography, health economics, medical sociology, social policy and psychology. It was decided that the researcher would contact key 'experts' working in each of these disciplines, to ask them what they believed were the five most important pieces of research in mortality developments at the moment. The original list of experts was devised from suggestions from members of the Scoping Project Steering Group. As the project progressed many of those contacted went on to suggest additional experts who they thought could provide help. Initially, 38 experts working in the field of mortality developments, in eight different disciplines, were contacted. Of these, 22 contributed a list of what they viewed as the five most important pieces of research in mortality developments. Three experts initially agreed to help, but did not send in a list of recommendations. A further three experts expressed an interest in the project, but did not feel able to recommend

papers to the steering group. Ten of those contacted failed to respond to requests for help. The papers recommended by the experts were entered into a literature database, and generated a list of over 90 studies focused on the area of mortality developments, including articles, books and research currently in progress. These studies were reviewed, and from these a list of the major themes in mortality developments was compiled. These themes are listed in Section 3. An earlier version of this report was presented at a meeting of mortality experts held at Staple Inn in March 2008. Following this meeting, those who attended were contacted and asked if they had any additional literature recommendations for inclusion in the final report. Eight of those contacted responded, recommending a further 40 papers, which have been incorporated into this version of the report. The key issues identified in this review, as well as any gaps in, and overlaps with, actuarial research and other disciplines, are discussed in Section 4.

2.2 There are a number of strengths and weaknesses associated with the approach which the scoping project took to provide a review of mortality research. The main aim of the project was to provide an overview of the key issues in mortality developments research across a number of different disciplines. Contacting experts working within the field provided an insight into what those at the centre of current research believe is important. As the papers included within this report are derived from experts' recommendations, we can be fairly confident that these are high quality, relevant papers. Given the time available to the scoping project, it is unlikely that this number of papers would have been identified through the searching of individual literature databases. In addition, the identification of key people working in the field has created an informal network of 'experts' working across a wide range of disciplines who are aware of the Actuarial Profession's interest in mortality developments.

2.3 The main drawback of this study is that it is not a comprehensive review of the literature on mortality developments. There are two main risks involved in the methods which this scoping project has adopted. The first is the possibility of bias in the selection of experts working in the field of mortality developments. The second problem may be that not all the key research into mortality developments has been recommended. However, it should be remembered that this is a scoping project aimed at providing an overview of research into mortality developments across a large number of disciplines. Several of the experts who were contacted were recommended by a number of different people, suggesting that many of the key people in the field have been identified. These experts represent a wider range of disciplines than those which would normally work with the Actuarial Profession. In addition, many of the key themes discussed in the following section, and indeed many individual papers, were recommended by several different experts, indicating that these issues are regarded as important by many in the field.

3. Themes

The key themes to emerge from the literature recommended to the scoping group are described below.

3.1 *The Role of Medicine*

3.1.1 One of the longest running themes in mortality developments is the role which medicine has played in the decline of all-cause mortality. Several studies dealing with this theme were recommended to the scoping project from experts in medicine and medical sociology. A number of different methodologies are employed in these studies, to assess the relative contribution which medicine has made to all-cause mortality decline.

3.1.2 The origins of the modern debate of the role of medicine lie with the work of McKeown; prior to this the assumption had been that mortality had declined as a result of medical advances. McKeown published most widely in the 1960s and 1970s, culminating in the publication of the book *The Role of Medicine* (1979). McKeown's approach was to calculate what percentage of the total decline in mortality was attributable to specific causes. He established that, between the start of death registration in England and Wales in 1848 to 54 and 1971, 74.4% of the total decline in mortality was attributable to infections and 25.6% to degenerative diseases. Looking at the 20th century (between 1901 and 1971) he argued that 56% of the decline in infections had occurred before the 1930s, which was when sulphonamides, the first effective treatments against a variety of infections, became available. These findings allowed McKeown to argue that medicine was not responsible for the vast majority of the decline in mortality until the 1970s, as mortality had declined in the absence of effective treatments. Instead, McKeown stressed the role played by improving standards of living, and, in particular, diet, in reducing mortality.

3.1.3 The 'McKeown Thesis', as McKeown's work is now known, has sparked a debate on the role of medicine in the decline of mortality in the late 20th and early 21st century. Most commentators agree with McKeown's assessment of the role of medicine pre-1971. However, they argue that it is unfair to apply these findings to later time periods, when many new technologies have become available. Those studies examining the recent role of medicine which have been recommended to the scoping project are discussed below.

3.1.4 A number of the studies have employed the approach of measuring the contribution of 'amenable or avoidable' mortality to measure the contribution of medicine to the decline of all-cause mortality. The concept of 'amenable or avoidable' mortality was first devised by Rutstein in the 1970s. Essentially, this involves a list of those causes of death for which it is accepted that medicine can prevent death. The percentage of the total decline in mortality attributed to these causes is then viewed as having been brought about by

medical advances. The number of medical technologies on this list is not rigid, and various studies which have adopted the concept of 'amenable or avoidable' mortality have adapted it to meet their own requirements.

3.1.5 One of the best known studies which has looked at the role of 'amenable or avoidable' mortality is that of Mackenbach (Mackenbach *et al.*, 1988; Mackenbach, 1996). Mackenbach estimated the contribution of medicine to the decline in mortality in the Netherlands between 1950 to 54 and 1980 to 84. Mackenbach compiled a list of the causes of death for which it could be proven that death could be avoided by adequate preventative or therapeutic interventions, and he then attributed the decline in these causes to medicine. He acknowledged that it was possible that not all of the decline in mortality from these conditions could be attributed to medicine, but argued that any over estimation was compensated for by the absence of treatments for ischemic heart disease from his analysis. Mackenbach accredited a gain of 2.96 years in male life expectancy, and a 3.95 year gain in female life expectancy, to medicine.

3.1.6 The concept of 'amenable or avoidable' mortality is pursued further in a publication by Nolte & McKee (2004). This publication has two main aims. The first is to provide a review of all studies which have used amenable mortality as a means to empirically measure the role of medicine. A literature review found 72 studies. Nolte & McKee (2004) reviewed these studies to highlight the benefits and drawbacks of using amenable mortality as a measure of the effectiveness of health care systems. In light of these findings, Nolte & McKee (2004) then employed a revised concept of amenable mortality to analyse mortality in European Union countries during the 1980s and 1990s, using routinely available data. The list of amenable mortality, compiled by Nolte & McKee, consisted of 34 causes of death which they considered amenable to health care. They considered ischemic heart disease (IHD) separately, as they claimed that the precise contribution of health care to IHD is unresolved, and that the large number of deaths involved with IHD could obscure results.

3.1.7 Nolte & McKee (2004) provide details of their findings for each of the E.U. countries which they considered. In the case of the United Kingdom they calculated that the increase in life expectancy during the 1980s was 1.32 years for men, of which they estimated that declining mortality from amenable causes contributed 32%, for women they calculated that life expectancy increased by 0.80 years in the 1980s, of which 58% was due to amenable causes. However, if the results for IHD are included with those for other amenable causes, an even greater percentage of the increase in life expectancy is accounted for, increasing a further 37% for men in the 1980s. Amenable mortality accounted for slightly less of the overall improvement in life expectancy in the 1990s, at only 19% for males and 43% for females, mainly amongst the over 40s. However, once again, if the gains in life expectancy associated with IHD are included, the combined percentage

attributable to amenable and IHD in the 1990s are 60% for males and 70% for females.

3.1.8 Nolte & McKee's (2004) main finding is that there is clear evidence that improvements in access to effective health care have had a measurable impact in many countries during the 1980s and 1990s. They do stress that these results vary between different countries and time periods. In particular, those parts of Europe which began the 1980s with low rates of infant mortality saw a proportionately greater gain in life expectancy amongst those aged over 40. Two Office of National Statistics (ONS) documents, which described the use of 'amenable' or 'avoidable' mortality in the study of pre-mature mortality, were also recommended to the scoping group following the March 2008 experts meeting (Wheller *et al.*, 2006; ONS, 2006).

3.1.9 A different approach to measuring the contribution of medicine to mortality decline was employed by Bunker (1995, 2001). Bunker considered the role of medical treatment on the increase in life expectancy in the United States of America between 1950 and 1989. He calculated that life expectancy had increased by 7.1 years. He then devised an inventory approach to calculate the contribution of specific medical treatments to this increase in life expectancy. He identified 13 (clinical) preventative services and 13 curative services. Data from clinical trials and meta analysis were used to establish the effectiveness of these interventions. Bunker then identified the population 'at risk', and estimated the percentage of the population which received the intervention. From this, the gain in months or years to life expectancy which may be attributed to specific interventions was estimated. Bunker concluded that 3.5 to 4 years of the gain in life expectancy could be attributed to curative services and 1.5 years to clinical prevention.

3.1.10 An alternative way of viewing the role of medicine in mortality decline is presented in another study which was recommended to the scoping project. Cutler *et al.* (2006) considered the role of medicine in the decline of mortality in the U.S.A. in terms of financial value. They examined the period 1960 to 2000, during which time life expectancy in the U.S.A. increased by 6.97 years, and, on average, spending on health care increased by 10% per year. This study projects medical spending for four age groups for each decade from 1960 to 2000. It makes the assumption that 50% of total gains in life expectancy are due to medical care.

3.1.11 Overall, Cutler *et al.* (2006) calculated that life time spending adjusted for inflation increased by $69,000 between 1960 and 2000, with an overall cost of $19,000 for every year of life saved, ranging from $7,400 for each year of life saved in the 1970s to $36,000 by the 1990s. The cost per year of life saved also varied for each of the age groups, ranging from $31,600 per year of life gained at age 15 to $84,700 at age 65. Cutler *et al.* (2006) concluded that increases in medical spending between 1960 and 2000 have given reasonably good value. However, they emphasised that, since 1980,

increased spending in medical care for the elderly has been associated with high costs per year of life gained.

3.2 *Lifestyle and Environment*

This is a catch-all theme, which describes the recommended research on factors which increase the risk of mortality.

3.2.1 *Smoking*

The impact of smoking behaviour on mortality is also discussed in Section 3.3.1, describing the literature on heart disease. However, it is interesting that, when asked, several of the experts from the Actuarial Profession recommended the work of Doll on smoking dating from the 1950s, illustrating the importance which this work still has in mortality developments research. Doll was one of the first epidemiologists to link smoking behaviour with the incidence of lung cancer (see Doll & Hill, 2004, for an overview). A number of other pieces of research on smoking were recommended to the scoping project by members of the Actuarial Profession. These include a presentation by Humble & Wilson (2008), which described a model which examines the influence of alternative scenarios of smoking behaviour on mortality. In addition, a study which has attempted to estimate the contribution of smoking-related causes of death to hospital admissions and all-cause mortality was recommended (The Information Centre, 2006). It was found that, in 2004/05, approximately 1.4 million admissions were made to NHS hospitals with a primary diagnosis of a disease which can be caused by smoking. This is a rise of 300,000 admissions since 1995/96. This study also estimated that, out of a total of 500,755 deaths in England and Wales in 2004, amongst adults aged over 35, 88,800, or 18%, were caused by smoking. The specific link between smoking and cancer mortality is discussed further in a book recommended to the scoping group (Swerdlow *et al.*, 2001). The relationship of the cohort and socio-economic groups to smoking behaviour is the subject of another ONS paper recommended to the scoping group (Davy, 2007). Davy found that people born between 1926 and 1950 living in manual households were more likely to become smokers than those in non-manual households. However, both groups later gave up smoking at similar rates. Those cohorts born between 1956 and 1985 were less likely to start smoking, but were also less likely to give up. The rate of giving up amongst the non-manual group declined slightly; however, the vast majority of manual men and women who started smoking remained smokers. The relationship between socio-economic group and mortality is described further in Section 3.2.2.

3.2.2 *Socio-economic circumstances*

3.2.2.1 The relationship between socio-economic group and mortality was the subject of a number of articles recommended to the steering group by experts in medical sociology and demography. Lynch *et al.* (2000) discuss

the link between income inequality and health. They describe three interpretations of the way in which income inequality can negatively impact on health. The first of these is individual poverty; this is when health and mortality are determined by an individual's income. In psychosocial poverty there are wide inequalities in wealth, and an individual's position in the social hierarchy determines health and mortality. Finally, there is neo-materialistic poverty. In this case, health and mortality are influenced by individual resources and levels of investment in infrastructure. In this interpretation, the dangers associated with lack of personal income can be avoided if sufficient funds are invested in public services to allow equality of access to areas such as health care, education, transport and housing. Lynch *et al.* (2000) recommend that the best way to reduce health inequalities and improve public health in the 21st century is by strategic investment in neo-material conditions via a more equitable distribution of public and private resources. The increasing trend of income and health inequality is also discussed by Shaw *et al.* (2005). This study considers the impact of New Labour's policies to reduce health inequalities. Shaw *et al.* found that, although standards of living may have improved amongst some of the poorest in Britain, inequalities in wealth, and health continue to grow.

3.2.2.2 A study from the U.S.A., recommended by an expert from the Actuarial Profession and demography, considered whether the impact of socio-economic group decreases with age (Hoffman, 2005). This study found that socio-economic mortality differences remained stable across ages. However, socio-economic differences declined with decreasing health.

3.2.2.3 Following the March 2008 experts meeting, a number of additional articles examining socio-economic conditions and mortality were recommended. These included a number of ONS publications looking at mortality amongst men (White *et al.*, 2007), the effect of area deprivation on mortality (White *et al.*, 2005), inequalities in infant mortality (Maher & Macfarlene, 2004) and trends in cause-specific mortality by social class (White *et al.*, 2003). A forthcoming book by Shaw *et al.* (2008), which provides a comprehensive overview of the geographical pattern of mortality in Britain, was also recommended.

3.2.3 *Obesity*

A paper on obesity was recommended to the scoping project by an expert from demography and the Actuarial Profession. Gibbs (2005) questions the prevailing wisdom that an epidemic of obesity in the U.S.A. will harm health in the future. He presents a summary of current arguments that the risk of obesity is being exaggerated. This includes one study by Campos, who states that those in the overweight category have a lower risk of premature death than those in the healthy weight category. A recent U.K. government report (Butland *et al.*, 2007) was recommended by a member of the Actuarial Profession. This report is the product of a government obesity project, which

was set up in 2005. The project modelled data which indicated that, by 2050, 60% of adult men and 50% of adult women could be obese. In turn, this would increase the risk of developing type 2 diabetes, stroke, coronary heart disease, cancer and arthritis, leading to a seven-fold increase in costs to the NHS by 2050. The report also examined the biological and behavioural causes of obesity and the effect of the current environment, in the form of energy-dense food, motorised transport and sedentary lifestyles. Population-level policies to promote healthier diets and promote walking were recommended to tackle obesity, as well as cultural shifts around food and activity. A member of the Actuarial Profession also recommended a paper by Peeters *et al.* (2003). This study used data from the Framingham Heart Study to consider the effect of obesity and overweight at 40 years of age. A paper by Kopelman & Grace (2004), which provides an overview of thinking on obesity, was also recommended.

3.2.4 *Diet*

Following the initial request for recommendations from experts, no literature which looked specifically at diet and mortality was recommended to the steering group. Experts who attended the March 2008 meeting expressed surprise at this apparent gap, as they stated that a large body of literature exists, however, none of the experts who the steering group contacted included this literature in the list of the most important literature on mortality developments. Following the meeting, one expert went on to recommend a number of papers on the relationship between nutrition in early life and the later risk of disease which have been included with Section 3.6 as part of the discussion of literature on early life influences. A member of the Actuarial Profession also recommended a review paper which looked at the role of diet in the prevention of cancer (Cummings & Bingham, 1998).

3.2.5 *Physical activity*

No papers were recommended.

3.2.6 *Alcohol*

No papers on alcohol and mortality developments were recommended by the experts contacted by the scoping group. However, members of the steering group are aware of material published in *Health Statistics Quarterly*, which covers this area. These include data on alcohol-related deaths by occupation (Romeri *et al.*, 2007) and the geographical variation in alcohol related deaths in the U.K. (Breakwell *et al.*, 2007).

3.3 *Causes of Death*

In Section 3.1 those articles which consider the role of medicine on overall mortality decline were described. In this section recommended articles

which consider factors influencing the decline of specific causes of death are described.

3.3.1 *Coronary heart disease (CHD)*

3.3.1.1 CHD is the leading cause of death in the developed world; however, it has been in decline in most developed nations since approximately the 1970s. Articles which have investigated the factors underlying this decline have been recommended to the scoping project by experts from a number of different fields. Of particular note are a series of articles produced by Capewell and colleagues (Capewell *et al.*, 1999, 2001; Kelly & Capewell, 2004; Capewell, 2006). In some instances experts recommended individual articles in this series, whilst others drew the attention of the steering group to the body of work as a whole. These articles were recommended by experts from medicine, medical sociology, epidemiology, demography and the Actuarial Profession. This was one of the most popular areas of research on mortality developments recommended to the scoping project.

3.3.1.2 The body of work by Capewell and colleagues examines the role which identified medical interventions, for both the primary and secondary prevention, and risk factor reduction has had on the CHD mortality in a variety of geographical locations. To achieve this, Capewell and colleagues developed the IMPACT model. This model combines and analyses data on cardiological treatment and risk factors trends. The data employed in this model include patient numbers, data on uptake of treatment and treatment effectiveness, as well as population risk factor trends acquired from social survey data. These calculations allow Capewell and colleagues to estimate the contribution of each factor to overall changes in mortality within a defined time period.

3.3.1.3 The IMPACT model was first validated in Scotland (Capewell *et al.*, 1999). In this study, Capewell *et al.* calculated that 6,205 fewer CHD deaths had occurred in 1994 than would have been expected if the death rate had remained the same as it was in 1975. The IMPACT model was then used to calculate how many deaths had been prevented as a result of specific medical and surgical treatments or risk factor reduction. It was estimated that 32% of the decline in CHD in the time period was due to either primary or secondary medical interventions. However, the majority of the decline (60%) was attributed to the changes in the rates of smoking, cholesterol, blood pressure, physical activity and poverty. The residual decline was attributed to an 'other' category.

3.3.1.4 This model was extended to consider the influences on the decline in CHD in England and Wales, where it was calculated that 68,230 fewer CHD deaths had occurred in 2000 compared to the 1981 death rate (Unal *et al.*, 2004). The results are similar to those seen in Scotland, with 42% of the decline in mortality being attributed to medical and surgical

treatment. Risk factor reduction was credited with 58% of the decline. The number of risk factors considered was extended in this study, although an adverse trend was seen for obesity and diabetes, as well as for physical activity. Unal *et al.* (2005a) also presented their findings for England and Wales in term of life years gained. They found that modest reductions in major risk factors led to gains in life years four times higher than those for cardiological treatments. Related to this, they also considered the relative importance of risk factor reduction amongst the apparently healthy population (primary prevention) and existing patients (secondary prevention) (Unal *et al.*, 2005b). It was calculated that, of the 45,370 fewer deaths attributed to smoking, cholesterol and blood pressure, 81% of the mortality decline had occurred amongst the healthy population and 19% amongst existing patients.

3.3.1.5 The IMPACT model has also been used to measure the influences on CHD mortality in a population which has seen an increase in mortality. Critchley *et al.* (2004) examined CHD mortality in Beijing, and calculated that in 1999 there were an additional 1,397 deaths in the age group 35 to 74 compared to 1984. In this case, the model calculated the number of additional deaths which had been prevented because of the introduction of cardiological treatments in this time period. The increase in mortality was attributed to substantial increases in total cholesterol levels, as a result of a growing uptake of a 'western diet', as well as increases in diabetes and obesity.

3.3.1.6 One of the most interesting features to emerge from the work of Capewell and colleagues is the role which risk factors have played in the reduction of CHD mortality in the U.K., and, in the case of Beijing, the increase in mortality which was seen as risk factors increased. In every study, changes in population level risk factor profiles had a greater overall effect on mortality than medical or surgical treatment. Based on these findings, Kelly & Capewell (2004) have made recommendations for the way to reduce CHD mortality in the future. They argue that, if 80% of eligible patients received appropriate medication, this would result in 20,000 fewer CHD deaths each year. However, they believe that a modest reduction in smoking, cholesterol and blood pressure could result in 50,000 fewer deaths in England and Wales, or a halving of current levels, with results being seen within 12 to 24 months, leading to recommendations for population-wide policies aimed at risk factor reduction.

3.3.1.7 A paper recommended to the scoping group by a member of the Actuarial Profession has advanced an alternative approach for CHD mortality reduction. Wald & Law (2003) investigated the potential for developing a single pill, or polypill, designed to reduce cardiovascular disease risk. This study aimed to find a way to reduce four of the main risk factors simultaneously: LDL cholesterol, blood pressure, serum homocysteine and platelet function. A combination of drugs was identified using clinical trial data and meta analyses. These drugs could then be combined into a single pill to be taken daily. Wald & Law (2003) stress that this pill would not only be

targeted at an identified high risk population, instead they advocate that it should be taken by all the population aged over 55, as well as any one younger identified as high risk. The use of this treatment amongst the general population is theoretical; however, Wald & Law (2003) argue that its use would have a greater impact than any single cardiovascular disease intervention, leading to an 80% decline in cardiovascular disease.

3.3.1.8 Another body of work on CHD mortality was recommended by an expert from medical sociology/epidemiology. This is the global project by the World Health Organisation (WHO), called MONICA which monitors trends and determinants in CHD. At its peak, between the mid 1980s and mid 1990s, this study encompassed 38 populations, in 21 countries, across 4 continents. It measured basic disease, risk factors and medical care measurements (Tunstall-Pedoe, 2003). The study assessed the extent to which changes in risk factors explained the variation in trends in coronary events across populations (Kuulasmaa *et al.*, 2000; Tunstall-Pedoe *et al.*, 2000). It found that, between the mid 1980s and mid 1990s, there was a 27% fall in CHD mortality, with 21% of the decline due to incidence and 6% to a decline in case fatality. As with the studies conducted by Capewell and colleagues, the changes in classic risk factors were seen as partly responsible for the variation in population trends. This led to recommendations in support of prevention policies based on the classic risk factors, although the study does suggest that there is potential for prevention beyond these.

3.3.1.9 A member of the Actuarial Profession recommended a study which examined a link between the 1918 influenza pandemic and the expansion of a population prone to CHD during the early part of the 20th century (Azambuja, 2004). This study proposes that the immune inflammatory mechanism responding to the infection left survivors predisposed to the future development of CHD.

3.3.1.10 The prediction of risk of heart disease can be calculated using a variety of different algorithms. A paper was recommended by a member of the Actuarial Profession which has assessed the use of a new cardiovascular risk score (QRISK) for the U.K. Hippesley-Cox *et al.* (2007) have validated its performance against the established Framingham algorithm and a newly developed Scottish score ASSIGN. The effectiveness of the algorithms at predicting a ten-year risk of developing cardiovascular disease was tested on U.K. patients aged 35 to 74 years who were initially free of heart disease. The Framingham algorithm over-predicted cardiovascular disease risk by 36%, Assign by 36% and QRISK by 0.4%. Both Framingham and ASSIGN tended to over-estimate risk. The authors found that QRISK is likely to provide more appropriate estimates to identify high risk patients, helping to ensure that treatment is directed at those most likely to benefit. However, they also state that the tool requires further validation.

3.3.1.11 Possibilities for the future of cardiology are considered in a paper recommended by a member of the Actuarial Profession. Flower *et al.*

(2000) used current breakthroughs and research, as well as extrapolations from current research, to describe potential future scenarios in the prevention and treatment of heart disease for the first half of the 21st century. The first time period considered by Flower *et al.* (2000) is the period up to 2009. In this time the authors predict the initial effects of the unravelling of the human genome on cardiovascular medicine. The results of this may include the ability to identify gene mutations predictive of heart disease via the use of a hand held device, as well as the introduction of powerful new pharmaceuticals. They envisage that surgery will become minimally invasive, and also the beginning of the use of swine hearts in transplant surgery. The next era which Flower *et al.* consider is 2009 to 2024. They foresee a decline in the use of surgery as the genomic revolution leads to the development of drugs designed to bring much of heart disease treatment under pharmaceutical control. Swine hearts may have become common in older people. By 2024 to 2049, Flower *et al.* (2000) foresee a scenario where heart replacement surgery is almost non-existent, as few hearts become damaged enough to require replacing. Research on the genomic roots of heart disease may bring a rapid improvement in prediction, diagnosis and pharmaceutical therapies. The authors do stress that these potential scenarios are speculation; however, they are based on current research and the possibilities which this research brings.

3.3.1.12 Since the drafting of this report, a series of papers by Chatterjee *et al.* (2007a, 2007b, 2007c) have become available. These describe a model which considers the development of major risk factors, such as smoking and obesity, and an individual's life time risk of developing and dying from IHD and stroke.

3.3.2 *Stroke*

3.3.2.1 The WHO MONICA project on stroke was also recommended to the scoping project by another expert from epidemiology. The MONICA project looked at trends in stroke in 15 populations, as stroke and CHD share many of the same risk factors. However, the project found that stroke trends differed from those of CHD mortality in males, whilst there were significant differences in stroke and CHD event rates for both males and females (Truelsen *et al.*, 2003). This highlighted the relative difference which risk factors have on the incidence and mortality from stroke and CHD.

3.3.2.2 The theme of the role of traditional cardiovascular risk factors is explored further in two papers recommended by an expert from epidemiology. Possible explanations for the differing risk factor profile of CHD and stroke are explored in a study by Lawlor and colleagues (Lawlor *et al.*, 2002; Lawlor *et al.*, 2003). This study traced trends in CHD and stroke mortality throughout the 20th century. Stroke is made up of two subtypes; cerebral infarct and cerebral haemorrhage. The differential diagnosis of these subtypes on death certificates is frequently inaccurate. Lawlor *et al.* (2002,

2003) were able to calculate the ratio of cerebral infarcts to haemorrhages using data from autopsy studies. These indicate that mortality from cerebral haemorrhage declined throughout the 20th century, while cerebral infarct mortality increased up to the 1970s before falling. As cerebral infarct follows a similar trend to CHD, this suggests that they have common causes. The differing pattern seen for cerebral haemorrhage points to other causes, and may explain differing stroke and CHD risk factor profiles. Morris *et al.* (2003) examined the role of traditional risk factors in the north-south mortality gradients for stroke and CHD in the U.K. This was a prospective study which covered the 20 years from 1980. It compared age adjusted incidence of major stroke and CHD events in the south of England with the rest of the U.K., before and after adjustment for established cardiovascular disease risk factors. They found that the incidence of both stroke and CHD was highest in Scottish towns and lowest in southern English towns, but that the magnitude of the gradients diminished once individual risk factors were taken into account, leading once again recommendations for population-wide measures to reduce risk factors.

3.3.3 *Cancer*

No papers were recommended by experts outwith the steering group. However the steering group is aware of a book by Swerdlow *et al.* (2001), which examines cancer incidence mortality in England and Wales. This book brings together data on trends in cancer incidence and mortality. Trends in factors suspected of causing one or more types of cancer are described. A brief description of secular trends, trends by birth cohort, mortality by region and a discussion of these trends are provided for each cancer site. Following the March 2008 experts meeting, attention was drawn to the availability of cancer survival data on the ONS website.

3.3.4 *Dementia and neurodegenerative disorders*

No papers were recommended.

3.3.5 *Chronic obstructive pulmonary disease*

No papers were recommended.

3.3.6 *Other causes*

No papers were recommended.

3.4 *Age Groups*

In this section, all the papers which were recommended to the scoping project which deal with aspects of age-specific mortality developments are described.

3.4.1 *Childhood and younger adults*

No articles covering contemporary developments in mortality amongst children and younger adults were recommended to the scoping group. The effects of early life influences on later life mortality are covered in Section 3.6.

3.4.2 *Middle age*

In Section 3.1, McKeown's study of the role of medicine in the decline of mortality up until 1971 was described. In the time period covered by McKeown the main influence on the increase of average life expectancy was the decline of mortality in infancy and childhood. In England, this situation changed around 1970. During the final three decades of the 20th century, male life expectancy at age 50 increased by more than in the first seven decades. There was a similar, but less dramatic, increase for women. At present there is an absence of research dealing specifically with this area. However, an expert in medical sociology has recommended on-going and proposed research at University College, London, which focuses on this area. This research hopes to uncover which causes of death have contributed to the increase in life expectancy in middle age and the factors which have influenced their decline; this should aid with the prediction of future changes in life expectancy in middle age.

3.4.3 *Oldest-old age*

3.4.3.1 A large number of papers were recommended to the scoping group on the theme of oldest-old mortality. These papers were mainly recommended by experts in demography, genetics and the Actuarial Profession. In general, this literature refers to mortality developments in the population aged over 80, and covers a wide range of issues and conflicting views, including past trends in extreme longevity, potential factors influencing extreme old age and the potential for gains in extreme longevity in the future. These articles are described below.

3.4.3.2 *Past trends in extreme longevity*

3.4.3.2.1 The first group of articles which will be described are those dealing with past trends in oldest-old mortality and life expectancy. A study by Kannisto (1994) was recommended to the steering group by members of the Actuarial Profession. Kannisto (1994) begins by stating that, in the past, octogenarians were unusual and centenarians rare. However, by the late 20th century half of all female deaths and a third of male deaths in developed countries occurred in those aged over 80. Kannisto refers to this as a new stage in the mortality transition. In order to study this trend, a database was established in 1992 containing death and population counts since 1950 for 30 countries; this allows the estimation of death rates after age 80. In this study Kannisto (1994) presents the initial analyses of these data. His main findings are that, in the last two to three decades, there has been an

unprecedented decline in age-specific mortality amongst the oldest-old themselves, leading to an increase in life expectancy at ages 80, 90 and even 100. Aggregated data for 12 countries between 1950 and 1990 revealed that the numbers of octogenarians had grown four-fold, nonagenarians eight-fold and centenarians twenty-fold. Kannisto (1994) does stress that the age of onset of this mortality improvement varied between countries, with the improvement generally seen earlier for women than for men. This study did not look in depth at factors which may have influenced the decline in oldest-old mortality rates, nevertheless it does suggest possibilities, including medical advances and improving living conditions.

3.4.3.2.2 Another study investigating past mortality trends was recommended to the scoping project by an expert in demography. Thatcher (1999) agrees with the views expressed by Kannisto (1994) that, until recently, although there were spectacular improvements in mortality at lower ages, there was little change in the possibility of dying after age 80. Thatcher (1999) discusses a variety of models for predicting the likelihood of dying, such as the 'law of mortality' discovered by Gompertz in 1825. This showed that the likelihood of dying increases with each successive year soon after age 30. He also describes Fries' theory on rectangularisation. Rectangularisation suggests that, as the likelihood of dying at younger ages is reduced, the mortality curve becomes more rectangularised as mortality is compressed into a narrow band. Fries advances an upper limit for human life of about 85. In the remainder of this article Thatcher (1999) attempts to model maximum life expectancy dating back to the middle ages. He does this by utilising a number of published life tables from a variety of historical periods. He concludes that it was likely that the age of 90 was attained in the mediaeval period and that the age of 100 years was probably attained at the end of the 17th century. He uses these findings to claim that there is probably some high age which it is unlikely for humans to exceed, but that it is not predetermined or fixed and definite.

3.4.3.2.3 Mesle & Vallin (2006) (recommended by an expert in demography/Actuarial Profession) argue that in most advanced countries child and under the age of 60 adult mortality have fallen so low that further improvements in life expectancy rely on mortality decline at old ages. Mesle & Vallin (2006) are interested in trends in female aged 65+ life expectancy in high income countries between 1955 and 1996. They claim that, although life expectancy has improved in almost all countries, some divergence in trends of improvement can be identified. In the case of the U.S.A., the Netherlands, France and Japan they identify a trend of improving life expectancy up until the early 1980s, when the life expectancy of these countries converge. After this point, although life expectancy continued to improve in all four countries, the levels in the U.S.A. and the Netherlands were significantly lower than in Japan and France. Mesle & Vallin attempt to explain this divergence in trends by considering the contribution of different causes of

death to mortality. They found that, up until 1984, the main contributor to mortality decline in all countries was a decline in mortality from cardiovascular diseases. However, between 1984 and 2000, the U.S.A. experienced important increases in mortality from mental disorders, infections and respiratory diseases, which jeopardised the gains made from cardiovascular causes. In France and Japan these losses were small. In addition, Japan and France saw an increase in the relative contribution of the decline in mortality at ages 80+ to the total decline of mortality at ages 65+ after 1984. Mesle & Vallin (2006) suggest that differences in health care systems and possibly attitudes towards the appropriateness of using medical interventions on the oldest-old may underlie this trend.

3.4.3.2.4 The issue of the rectangularisation of the human mortality curve is considered in more depth in a number of papers recommended by an expert in genetics. It has been stated that, as deaths become compressed in old age, this leads to the rectangularisation of mortality curves, if it is accepted that there is a maximum life expectancy. However, if there is variation in age of death, either from a number of deaths taking place at young ages or from an increase in the maximum age of death, this can lead to less rectangularisation. Wilmoth & Horiuchi (1999) have considered the variability in the age of death using data from Sweden during the period from 1751 to 1991-95. At the start of this time period average life expectancy was 35, however, this disguised an enormous variation in the age of death, spread from infancy to old age. The rapid reduction in infant and child mortality led to an era of enormous compression from the late 1870s to the early 1950s. However, after this point an unprecedented reduction in late adult mortality led to near constant levels of variability in the age of death from 1950 to the 1990s. In Wilmoth *et al.* (2000) the question of whether there is an immutable life-span limit is considered. Again using Swedish data, they found that the maximum age of death rose from 101 years in the 1860s, to 108 years during the 1990s. They also found that the pace of increase accelerated from 0.44 years per decade before 1969, to 1.11 years per decade thereafter. In addition, they attributed only a small part of the increase to the increasing size of the cohort. The expert who recommended these papers stressed, in correspondence with the steering group, that this indicated that a maximum age at which most deaths would be compressed of 85 is probably wrong.

3.4.3.3 *Factors influencing extreme longevity*

3.4.3.3.1 None of the papers recommended to the scoping project answered satisfactorily the question of why longevity amongst the oldest-old has increased. However, a number of papers have been recommended by experts in epidemiology and genetics which have explored the genetics of ageing, which may help to explain why some individuals live longer than others.

3.4.3.3.2 Christensen *et al.* (2006) reviewed the literature on the genetic determinants of longevity. They found that studies of twins reveal that genetic differences account for around a quarter of the variation in adult human lifespan. In most of the studies which they reviewed they found inconclusive evidence for individual genes determining ageing. Possible explanations offered for this were that ageing involves numerous genes which may have small effects, or it may have been due to the small scale of many of the studies reviewed. The only gene which they found to be consistently associated with longevity was APOE. The review also identified studies which found a negative correlation between telomere length and the replicative potential of cultured cells. Telomeres are the protective ends of a cell nucleus; each time a cell divides the telomere becomes shorter and eventually the cell dies. However, they found a lack of consistency in the studies' findings. The association between telomere shortening, ageing and mortality is the subject of another article recommended by an expert in epidemiology. Cawthon *et al.* (2003) assessed the association between telomere shortening and mortality amongst individuals aged over 60. Their main finding was that individuals with shorter telomeres in blood DNA had poorer survival, partially due to a higher mortality rate from heart disease. The authors argue that this lends support to the hypothesis that telomere shortening contributes to mortality in many age-related causes of death.

3.4.3.3.3 Oxidation, free radical theory and ageing are the subject of two papers recommended by an expert in genetics. The first of these (Tyner *et al.*, 2002) considered the relationship between p53 protein, cancer and ageing. P53 regulates cell damage and acts as a tumour suppressor. In this study of mice, it was shown that mice with a mutation over-expressing p53 have a reduced incidence of cancer, but also a mortality curve moved to the left. This raises the question of whether p53 has a role in ageing. The second article identifies potential problems with free radical theory. According to free radical theory, ageing occurs as cells accumulate oxidative damage over time. Andziak *et al.* (2006) have looked at the naked mole rat, which, despite being similar to a mouse, has a life span nine to ten times longer, living to around 28 years. The rat tolerates enormous amounts of oxidative damage, which the expert who recommended this paper states does not makes sense, given the current knowledge of cumulative damage. The expert indicated that this strikes at the core of modern gerontology, making it important to future research.

3.4.3.4 *Future trends in extreme longevity*

3.4.3.4.1 In this sub-section articles recommended to the scoping project which have attempted to project the future of maximum longevity and the factors which may influence future gains in longevity are described. Once again, these papers were recommended by experts from demography, genetics and the Actuarial Profession.

3.4.3.4.2 In 2005 *Ageing Horizons* dedicated an issue to the theme of extreme longevity. In the editorial, the findings of the United Nations long-range population projections were described (Howse, 2005). These suggested that, by 2300, 51 countries will have a life expectancy at birth of over 100, with few countries having a female life expectancy of under 90. These projections are based on the continuation of current trends for the next three centuries.

3.4.3.4.3 Experts from demography and the Actuarial Profession recommended the paper by Vaupel & Kistowski (2005). These authors argue that many official forecasts have assumed too low figures for future longevity projections. Vaupel & Kistowski (2005) examined trends in life expectancy since 1840, and argue that there has been a linear rise in life expectancy since that time as a result of the interplay of income, salubrity, nutrition, education and medicine. They extrapolate from this past linear increase that life expectancy will continue to rise, aided by advances in prevention, diagnosis and treatment of age related diseases. Vaupel & Kistowski then consider the view that there is a biological maximum or 'looming limit' to human life expectancy. They refer to theories on senescence, that, after a reproductive period, humans enter a period of decline. However, Vaupel & Kistowski (2005) argue that: "there is no empirical evidence of a proximate limit to human longevity" (p8). They use the example of improving mortality rates in England and Wales amongst the oldest-old from the 1950s, and, in particular, from the 1970s, to show that improvements in mortality will come from within the elderly population (Vaupel, 1997). In addition, they consider the role which calorific reduction and genetic engineering may have on future reductions.

3.4.3.4.4 The findings of Vaupel and colleagues have been challenged in a number of articles by Olshansky and colleagues (Olshansky, 2005; Carnes *et al.*, 2005); which were recommended to the scoping group by experts from demography and the Actuarial Profession. Olshansky and colleagues argue that there is no scientific evidence to support Vaupel's claim that life expectancy will exceed 100 years in the 21st century. They provide a number of reasons for this opinion. First, they claim that Vaupel's estimates are based on flawed methodology; that is his use of extrapolation from past trends to predict future rises in life expectancy, in particular the use of the straight line forecasting to argue that, as life expectancy had increased in a linear fashion for the past 160 years, it will continue to do so. Olshansky states that these estimates are based on a composite of world records. Olshansky also points out the difficulty of replicating past gains in life expectancy, as most of these gains came from the decline of mortality rates in infancy and childhood, which are now low in most developed nations. In addition, Olshansky identifies a number of factors which may threaten future gains in life expectancy. These include the rise in obesity and related causes of death (such as type 2 diabetes, CHD, and cancer) and the rise of the infectious diseases death rate (such as HIV, hospital-acquired infections and a potential influenza pandemic). The second part of Vaupel and colleagues'

work which Olshansky and colleagues question is their prediction that advances in biomedical technology will accelerate the decline in death rates amongst older persons. Olshansky points out that these technologies do not exist yet, and that there is no guarantee that they will in the future.

3.4.3.4.5 Olshansky and colleagues also consider whether there is a maximum biological limit to life expectancy. They draw on modern evolutionary theory provided by Medawar, that the body is not immortal, but that genetic information is, and is passed on through reproduction. Therefore, the human body is designed to invest in reproduction and not in longevity. Under this theory gene mutations cause ageing, with the timing of death dependent on when the mutation occurs in the lifespan. Natural selection means that the advantageous genes are brought forward early in the lifespan (to allow reproduction). The senescence of ageing is due to the accumulation of damaging genes in the post-reproductive period of life, or 'genetic dustbin'. Olshansky also refers to the work of Kirkwood, arguing that, as: "external mortality is controlled and survival beyond the end of the reproductive period becomes common occurrence, senescence and senescence-related diseases and disorders have the opportunity to be exposed" (p22). According to Olshansky, this process means there is a natural limit to human longevity, with individuals having a 'biological warranty period'.

3.4.3.4.6 The possibility of extending this life-span via age-reversal therapies is the subject of an article recommended to the scoping project by an expert in genetics. Phoenix & de Grey (2007) have introduced the concept of the 'longevity escape velocity'. This claims that ageing can be functionally defeated long before there are comprehensive age-reversal therapies, as each improvement buys time for beneficiaries which can be spent developing the next improvement.

3.4.3.4.7 Two experts from genetics recommended papers which have considered whether traditional methods of calculating mortality risk are appropriate to the modern population. Based on their investigation of trends in mortality decline in France, Japan, Sweden and the U.S.A., Yashin *et al.* (2001) call for a revision of existing theoretical concepts of ageing and mortality. An alternative method for calculating survival/mortality trajectories is introduced by de Grey (2003).

3.5 *Active Life Expectancy*

3.5.1 Related to the work which has been conducted on oldest-old life expectancy is a body of research which has considered active life expectancy. A number of papers in this area were recommended by experts from demography, genetics and the Actuarial Profession. These papers mainly consider the extent to which the increase in life expectancy discussed above has influenced the proportion of the lifespan spent in good health.

3.5.2 Robine & Jagger (2005) argue that, as the previous view that life expectancy was fixed at around age 85 is no longer tenable, the crucial

question is now whether the extra years gained are healthy years. In this study they present the various theories on the relationship of healthy life expectancy to total life expectancy which have developed since the 1970s. Gruenberg (1977) predicted an epidemic of chronic diseases as the progression of medical care led to the extension of life of those with disease and disability, as well as the extension of life to an age when disease and disability are more likely. Fries (1980) proposed an alternate theory, where behaviour change and prevention postpone the onset of disease and disability closer to the end of life. According to his prediction that there was a limit to life expectancy of about 85 years, this would result in the compression of disability. An intermediate view was advanced by Manton (1982). This was dynamic equilibrium, where the prevalence of disability may increase as mortality falls, but the severity of this disability is reduced.

3.5.3 Robine & Jagger (2005) also consider some of the literature published in recent years in this area. One of the main problems which they identified was a lack of consistency in the definitions of healthy life expectancy and also the way in which these definitions are defined; these include active life expectancy (ALE) and disability free life expectancy (DFLE). Their main finding was that the compression of disability, or increase in ALE, is most likely to occur in those countries where disability was originally high and where life expectancy is increasing slowly. Another area which they consider is the gender gap in life expectancy and ALE. Robine & Jagger (2005) describe the widening of the gender gap in life expectancy throughout the 20th century, which meant that, by the end of the century, females lived, on average, seven years longer than males. They found no satisfactory explanation for this gender gap, although the possible influence of traditional masculine and feminine roles in the 20th century is considered; that is that traditional male behaviours, such as smoking, heavy drinking, fast driving and delaying seeking medical attention, undermine longevity, whilst traditionally female behaviours, such as wearing seat belts, health screening and taking vitamins, may improve longevity. Robine & Jagger found that this gap was not present in ALE, or disability; that is, although a female may live longer, the years of ALE are similar between the sexes. However, few studies have looked at both the longevity gap and the disability gap.

3.5.4 Two articles by Manton *et al.* (2006a, 2006b) were recommended to the scoping group. In these studies, Manton *et al.* consider life expectancy and healthy life expectancy in the U.S.A. in terms of the contribution of, and the cost to, Medicare, Medicaid and the social security system. Using a number of different sources, they considered trends in life expectancy and healthy life expectancy from the 1930s and predicted trends forward until 2080. They found that, between 1935 and 1982, healthy life expectancy or ALE at age 65 grew at the same rate as life expectancy. However, the rate of decline in disability prevalence accelerated between 1982 and 1999, from the earlier rate of 0.6% to 0.8%. The effect of this was that the proportion of

total life expectancy at age 65 spent in good health increased from 72.8% to 78.5%. These rates are projected to increase further to 84.5% by 2022, and 88.1% by 2080. Manton *et al.* also estimated dramatic increases in ALE as a percentage of total life expectancy amongst the over 85s, with the ratio increasing from 23.3% in 1935 to 46.9% in 1999, reaching 63% in 2022 and 75% in 2080.

3.5.5 Based on these findings, Manton *et al.* made a number of recommendations. The first of these concerned raising the retirement age. When social security was first introduced in the U.S.A. in 1935, on average, at age 65 people could expect to live a further 8.8 years in a socially and economically productive state. This compares with 13.9 years by 1999 and a predicted 16.4 years in 2022. Manton *et al.* recommend that the retirement age should be raised to 70 for 2005/06, to 72 by 2022 and to 77 by 2080. These recommendations would still provide the 8.8 years of social security in an active state, which the original beneficiaries of social security received in 1935. In the case of Medicare and Medicaid, Manton *et al.* do not recommend any increase in the age of entitlement, as they argue that these measures are partly responsible for the increases in ALE seen since their introduction. Instead, they suggest that the age of entitlement is lowered, as this will help to keep the population healthier at older ages and allow further increases in the retirement age.

3.6 *Cohort Effect*

3.6.1 Most of the members of the Actuarial Profession who were asked to recommend papers for the scoping project chose actuarial papers which, at least in part, considered the 'cohort effect'. In the context of actuarial research, the cohort effect refers to a specific cohort who were born between 1925 and 1945 who experienced greater improvement in all-cause mortality than those cohorts born before or after. This phenomenon was described as part of the findings on mortality projections performed by the Government Actuary's Department, which looked at the effect of year of birth on mortality improvement (OPCS, 1995).

3.6.2 The cohort effect is explored in a series of working papers by the Actuarial Profession's Continuous Mortality Investigation Bureau (CMIB). These papers describe the process of developing a methodology for future mortality projection, and, in particular, the significance which this cohort effect may have on future mortality projection. Their main finding was that a cohort effect exists, centred upon those born around 1926 who experienced an especially rapid improvement in mortality since the early 1980s, and that the cohort effect can be used to project forward (CMIB, 2002a; CMIB, 2002b; CMIB, 2006; CMIB, 2007). See Appendix 1 for more details.

3.6.3 Richards *et al.* (2007) used the methodologies discussed in the working papers to analyse the relative importance of the cohort or period

effect in predicting mortality. They identified the previously described cohort effect, this time centred on those born in the year 1931. In addition, they identified an increase in mortality improvement with advancing age, that is, there was a greater improvement in mortality within this cohort in 2001 than in 1991. This paper revealed that, in the U.K. cohort effects are more likely to predict mortality improvement than period effects.

3.6.4 In their 2007 paper Richards *et al.* investigated whether the cohort effect is unique to the U.K. They considered whether the cohort or period effect dominated for seven countries by analysing mortality data for adult populations. This study found that the strength of the cohort effect varies across different countries. In the case of Japan, Germany and the U.S.A. cohort effects dominated for males. The cohort effect also dominated for females in Sweden, Germany and U.S.A.; elsewhere period effects dominated.

3.6.5 In general, the papers by the Actuarial Profession have focused on the trends in mortality data as opposed to the factors which may have been driving this trend. Willets (2004) expanded this research to look, in more depth, at the influences on the cohort effect. Willets again identified the cohort born between 1925 and 1945 (centred on the year 1931). He then conducted a multi-disciplinary review, covering epidemiology, social science and demography, to identify factors which could have influenced this trend. Willets argues that within the 1925 to 1945 cohort there are two sub-cohorts on which different influences on mortality improvement may have acted. For those born before 1935, Willets points to the role played by smoking behaviour. Different generations have different smoking behaviours with the lifetime consumption of cigarettes related to year of birth. Lung cancer is one of the diseases most closely associated with smoking, and Willets argues that, for males, lung cancer deaths increased for those born from 1870 onwards, peaking with those born between 1900 and 1905, with the greatest improvement in lung cancer mortality amongst those men born in the period 1930 to 1935. For those born in the later half of the cohort, Willets suggests that other factors may be more important, in particular the role which diet and early life influences may have had on declining heart disease mortality.

3.6.6 Although Willets (2004) examined possible factors influencing the 1925 to 1945 cohort effect, overall the Actuarial Profession's interest in cohort effects is attributable to their usefulness in predicting future mortality trends. Experts from epidemiology and medical sociology also recommended papers which looked at cohort effects. These papers differed in a number of ways from the work performed by the Actuarial Profession. First, they do not focus on one particular cohort; instead, they tend to look at mortality trends in successive cohorts. Also, they focus more on the factors which underlie cohort effects, in particular early life influences.

3.6.7 The role of early influences on later mortality has been considered by Catalono & Bruckner (2006). This study tested the 'diminished entelechy hypothesis'. The bases of this hypothesis is that suffering many or virulent

environmental insults during childhood reduces the subsequent lifespan of the survivors of that cohort. In order to test this theory, Catalono & Bruckner (2006) measured the association between mortality in the first five years of life, which they used as an indicator of environmental conditions, and life expectancy at age five. Cohort life table data were analysed for those born in Sweden (1751 to 1912), Denmark (1835 to 1913) and England and Wales (1841 to 1912). This study concluded that suffering many or virulent environmental insults in childhood did affect subsequent cohort lifespan.

3.6.8 Gerontologists Crimmins & Finch (2006) also examined the link between early life and a cohort's later mortality risk. Although this study acknowledged the link between diet in early life and a cohort's mortality risk in later life, this study focused on the link between inflammation and later life risk. Crimmins & Finch tested the 'cohort morbidity phenotype' theory; that birth cohorts with lower early life mortality due to infections experience lower mortality throughout life. They considered whether exposure to inflammation through the life course could lead to the development of atherosclerosis, even in the absence of a high fat diet. This study again used childhood mortality as a direct index of high environmental exposure to infections, and so inflammation. This study examined the link between early life mortality and later mortality for four north European countries, using data from 1751 to 1899. The study restricted itself to cohorts born before the 20th century to avoid the effects of smoking, immunisation and antibiotics. The study concluded that mortality decline amongst older persons occurred in the same cohorts which experienced mortality decline as children.

3.6.9 Some of the studies recommended to the scoping project have examined the role of cohort effects for cause-specific mortality. Davey-Smith *et al.* (1998) looked at the association between social circumstances in childhood and mortality from coronary heart disease, stroke, lung cancer, stomach cancer and respiratory disease. After adjustments for adult socio-economic circumstances and risk factors, this study showed an association between early life and stroke and stomach cancer, and, to a lesser degree, to coronary heart disease and respiratory disease.

3.6.10 The work of Gavrilov & Gavrilova (2001), on early life influences, was recommended by an expert from the Actuarial Profession. Gavrilov & Gavrilova have considered the initial damage which can be done to an individual's DNA. They propose that some individuals are born with a high initial damage load, meaning that they are further along the ageing process than others.

3.6.11 One of the main figures in early life influences research is Barker; however, none of the experts contacted by the scoping group specifically recommended any papers by Barker. Barker developed the foetal origins hypothesis. This hypothesis looks at the relationship between foetal undernutrition in middle to late gestation and the risk of developing coronary heart disease in later life. The highest risk was found amongst those who

were born small (Barker, 1994). Further literature on the foetal origins hypothesis is available at the BMJ topics website. It has been proposed that elevated blood cholesterol is one of the outcomes of impaired foetal growth. This relationship is the subject of a systematic review recommended by an expert in genetics. Huxley *et al.* (2004) identified 79 relevant studies; however, their main finding was that impaired foetal growth does not have any effects on blood cholesterol levels which would have a material impact on vascular disease risk.

3.6.12 Additional papers which consider early life influences were recommended following the March experts meeting. One of these examined the relationship between diet in early life and later life mortality (Kuzawa *et al.*, 2007). A study by Gluckman (2007) explored the idea of a trans-generational inheritance of risk, that is that environmental influences which affect one generation may continue to have a significant impact on the next generation.

3.7 *Actuarial Views on the Future of Longevity*

3.7.1 All of the members of the Actuarial Profession who were contacted by the scoping group on the future of mortality recommended papers by Willets (1999) and Willets *et al.* (2004). These documents provide an overview of the profession's main interests in mortality developments, and what the profession thinks is likely to happen to longevity in the near future. One of the most striking features of these reports is that many of the areas covered are included in the themes described above. As these themes are based on the recommendations of experts from a number of different disciplines, this suggests that many in the Actuarial Profession are aware of research being conducted elsewhere. However, it is noteworthy that none of the experts from outwith the Actuarial Profession recommended actuarial papers. The paper by Willets *et al.* (2004) covers three main areas: past trends in mortality; projections for longevity in the 21st century; and the possible financial implications of longevity increase.

3.7.2 One of the main trends highlighted by Willets *et al.* has already been described in the previous section. This is the cohort effect, where those people born around 1931 have seen greater improvements in mortality than those generations born on either side. Willets *et al.* also consider age and cause-specific mortality trends for the latter part of the 20th century. They draw particular attention to the gains seen in the age group 50 to 79, mainly from heart disease. The international experience of cohort effects and variations in rates of improvement are also discussed. One area which Willets *et al.* cover, which was not referred to by experts contacted in other fields, is the potential threat to longevity advance from infectious disease. The risk of disease spread as a consequence of technological advances, such as rapid global travel and the emergence of drug resistant disease strains, is considered.

3.7.3 Willets *et al.* (2004) analyse how mortality is likely to change in the future, drawing out key trends and identifying what they think is likely to drive mortality shifts in the future. They project that it is highly probable that, in the first few decades of the 21st century, mortality rates for the elderly population in the U.K. will improve faster than ever before, with the expectation of post-retirement lifespan increasing dramatically. Reasons for these potential gains include the cohort effect. As those born between 1925 and 1945 enter old age they should see a continuation of the mortality improvement seen amongst this cohort in the past. Based on the past prevalence of smoking they predict falls in smoking-related causes of death, as well as the continuation of the steady trend of falling circulatory and cancer mortality. The accelerating pace of medical advances, as well as the expansion in the application of medical technology amongst the elderly, are also highlighted. In addition, life expectancy in the U.K. is currently relatively low at age 65, compared with other developed countries, meaning that there is potential for improvement in this age group. Based on these projections, Willets *et al.* consider the possible financial implications of increasing longevity. However, Willets *et al.* also emphasise the uncertainty which is involved in predicting future mortality trends.

4. Discussion

4.1 The main aim of this scoping project has been to provide an overview of research being undertaken by a number of different disciplines into the field of mortality developments. In addition, any areas of overlap or gaps in the research were to be identified. The approach taken has been to contact experts working within the field and to ask them to nominate what *they* believe are the most important articles, or pieces of research, on mortality developments. This generated a good response, and both the content and the structure of the report have been based on these recommendations.

4.2 The first area of research which was considered was the role of medicine in the decline of all cause mortality. Medical sociologists recommended all the papers in this area. The key questions which emerged from this literature were: what role does medicine play in mortality decline and what role will medicine play in the future of mortality decline? Of particular concern to researchers currently publishing in this field was the need to judge the overall efficacy of medicine on the contribution currently being played by medicine in mortality reduction, as opposed to any role which medicine may have played in the past. The theme heading lifestyle and behaviour was designed to encompass that literature which covered non-medical risk factors on mortality. Somewhat surprisingly, there were not many recommendations in this area from the experts contacted by the steering group. A number of papers were recommended on smoking.

However, these were all recommended by members of the Actuarial Profession. Very few papers were received covering the other well known health risk factors, such as obesity, diet, physical activity or alcohol and drug abuse. One risk factor which was highlighted by experts from medical sociology and demography was the influence of socio-economic group on mortality risk. The issue of deprivation and risk is one which is seen in a number of the themes covered by the expert recommended literature, indicating that this is an influence on mortality currently receiving attention.

4.3 One of the most popular areas identified by experts was the literature surrounding CHD, in particular the research conducted by Capewell and colleagues. This research appeared to be relatively well known across a number of different disciplines, including medical sociology, epidemiology and the Actuarial Profession. Key questions raised in this literature include: what are the main influences on the decline of CHD and what will be the main influences on any future decline? It is of note that the scoping project received very few recommendations for research into the decline of many of the other major causes of death, such as cancer and chronic obstructive pulmonary diseases. There are a number of possible explanations for this. One is that a great deal of research has been conducted on CHD, as it was the leading cause of death in much of the developed world throughout most of the 20th century. The large scale epidemiological studies undertaken in the mid 20th century, such as Framingham, identified many of the main risk factors for the disease. These studies provided, not only a great deal of research directly from their own findings, but provided the background for many other studies looking at the influences on CHD mortality. Cancer, on the other hand, is made up of a large number of individual cancer types, many of which have their own distinct set of risk factors, some of which are currently known, whilst the causes of others still remain obscure. This has made it more difficult to carry out large scale research on cancer as a whole, as opposed to CHD, with its identified risk factors and good sources of data. It is possible that a body of work does exist which has looked at the overall decline of other causes of death, but that it was not recommended to the scoping project by the experts contacted. However, if this is the case, it is noteworthy that the experts overwhelmingly recommended papers on CHD, indicating that this is an area currently at the forefront of research on mortality developments.

4.4 It is interesting how many of the themes covered in Section 3 were dominated by certain disciplines recommending papers. In the case of mortality rates and longevity amongst the oldest-old, almost all the papers were recommended by experts from either demography, genetics or the Actuarial Profession. The content of this theme differed from studies looking at influences on overall life expectancy; instead, this looked specifically at mortality amongst the oldest-old. Most of the studies recommended agreed

that mortality rates had declined, and life expectancy increased amongst the population aged over 80 since around 1950, with an acceleration in this trend after 1970. However, there was a lack of consensus in almost all other areas concerning oldest-old mortality. A number of key issues and questions have emerged from this debate. These include, what has caused the recent increase in longevity amongst the over 80s? What causes ageing? Is ageing a separate condition from disease? Is ageing an underlying cause of death? Is there a maximum limit to human longevity? Will longevity continue to increase in the future? Will it be possible to extend human lifespan in the future via age-reversal therapies? Many of these questions are still at the stage of theoretical debate, as the true nature of ageing and influences on ageing are not yet fully understood.

4.5 A number of key issues and questions have also been identified from the literature recommended on the cohort effect. In the case of the Actuarial Profession, the key question has been: "Will the cohort born between 1925 and 1944 continue to see greater mortality improvement than those born on either side of these dates?" Amongst the papers recommended by experts from medical sociology and epidemiology the key issues are different. Their interest in the cohort effect is mainly in the effect of early life influences on the later mortality of different cohorts, this was a question also raised in the papers recommended on stroke. It is of note that, amongst the various papers recommended on the cohort effect and early life, none of the experts recommended any papers by Barker, who has published extensively in this area.

4.6 Many of the research areas discussed above overlap with each other, with several of the papers reviewed easily falling into more than one category. Perhaps the most obvious area of overlap is between the themes on the role of medicine and on the causes of death, in particular influences on the decline of CHD. CHD has been the largest contributor to the decline in mortality in most developed nations, and many of the studies which were recommended considered the role which medicine had in this decline. Another area of overlap is between work carried out by the Actuarial Profession on mortality developments and other disciplines. The most obvious example in this case is the profession's work on the cohort effect, which was the most commonly recommended area of actuarial research. It is of interest, however, that although other disciplines research cohort effects, it is only the Actuarial Profession which has focused on the specific cohort born between 1925 and 1944. Those members of the profession working on mortality developments who recommended papers did seem to be aware of the major areas of research undertaken by other disciplines. Under almost every theme listed in Section 3 (with the exception of the role of medicine), members of the profession recommended papers.

4.7 One of the key objectives of the steering group was to identify gaps in the research on mortality developments. This is quite a difficult subject to

discuss, as the nature of a gap means that no one has recommended it. A number of issues have come to light during the progress of this project. Of note are overall gaps in the knowledge on mortality developments. This was most obviously the case amongst those experts contacted from the field of social policy. Although all those contacted in social policy expressed an interest in the project and a willingness to help, none felt able to recommend papers to the project. The main reason for this appears to be that social policy's interest in mortality lies, not in what may be influencing mortality, but in the influence which changes in mortality may have on social policy; for example, the effect which increasing longevity has had on the number of elderly people requiring social care or pensions. This interest led some in social policy to recommend literature which dealt with this area, such as the Wanless (2006) Report, which sets out different scenarios for meeting the different care needs for the growing elderly population in the future. Following the experts meeting (March 2008), an expert from social policy recommended a number of additional papers. Once again these did not look specifically at factors which may influence mortality trends, instead these focused on the area of bereavement which the expert reported is of particular interest at the moment (see Corden *et al.*, 2001; Drakeford, 1998; McLaughlin & Ritchie, 1994; Holden & Brand, 2004; Chesson & Todd, 1996; Jenkinson, 2003; Law Commission, 2007; Stroebe *et al.*, 2006; Cabinet Office, 2005). A Lords Report on the scientific aspects of ageing was also recommended (House of Lords Science and Technology Committee, 2008). Again this report does not look specifically at influences on mortality, rather it provides a comprehensive overview of the ageing process.

4.8 The final type of gap considered by this project concerns overall gaps in the research into mortality developments. Some of these gaps have already been mentioned in the above discussion of the literature recommended by experts. These include: a lack of papers recommended on lifestyle and behavioural influences on mortality; and on leading causes of death other than CHD. A number of other potential gaps were identified during discussion within the steering group, these are areas which the multi-disciplinary group wished to know more about, but which were not covered in the literature recommended. With regard to causes of death, the lack of attention paid to dementia was noted, especially as this is an important cause of death which is often not recorded as a primary cause of death on the death certificate. Related to this was the lack of understanding of some researchers and policy makers regarding the inadequacy of current death certification, which does not allow for multiple co-morbidities to be listed as the cause of death. In addition, members of the steering group wished to know more about other causes of death which may influence mortality decline in the future. Another area which members of the steering group wished to see covered was the relationship between frailty in older people and mortality, and also the relationship between prescribing new drugs and antibiotics and mortality.

4.9 As well as factors which may influence the decline in mortality, interest was also expressed in learning more about factors which may retard further declines. This issue was touched on in the work of Olshansky (2005) in respect of the potential role which obesity may play in future mortality rates, as well as the potential re-emergence of infections as a major cause of death. However, no other possible influences which might impede future mortality decline emerged. The role of climate change in future mortality developments was another area about which the steering group wished to know more. Interest was also expressed in the factors underlying the differing trends seen in male and female mortality, as well as the differences in mortality trends seen between the developed and developing world.

4.10 It is possible that these gaps are not real, but rather reflect the limitations of a scoping project, in that it is not possible to cover all aspects of mortality developments in the limited time available. However, if this research does exist, it is interesting that it was not included in the recommendations for the most important research into mortality developments made by the experts contacted by the scoping group.

5. Conclusion

This report represents what many of the leading experts working in the field of mortality developments believe to be the key issues in current research. It has been emphasised that this is not a comprehensive list, or discussion, of the literature in the field; however, it does constitute a first step on the part of the Actuarial Profession to map the wide field of mortality developments. The aim in doing this has been to identify gaps and overlaps in the research, as well as gaps in the Actuarial Profession's and other disciplines' knowledge of the respective fields' research. It is the intention that this report will provide a starting point for inter-disciplinary working in the area of mortality developments, and the steering group welcomes comments on any areas which may have been omitted from the report, and suggestions for future research.

6. Acknowledgements

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The following list includes, not only the works referred to in the paper, but also other publications which did not fall under any of the theme

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APPENDIX 1

THE WORK OF THE CONTINUOUS MORTALITY INVESTIGATION BUREAU

A1.1 *Background*

A1.1.1 The Continuous Mortality Investigation Bureau is a research body of the U.K. Actuarial Profession, and it carries out research into mortality and morbidity experience.

A1.1.2 Traditionally this has encompassed persons covered by long-term risk contracts issued by life assurance offices in the U.K. and the Republic of Ireland. The investigations cover all the main types of life assurance, annuitant, pensioner, critical illness and income protection insurance contracts offered by the market. The base data are supplied by life offices covering the majority of the market. All dealings with individual offices are confidential.

A1.1.3 In June 2006, the CMIB also officially took over research into the mortality of members of self-administered pension schemes (SAPS), based on data submitted by actuarial consultancies.

A1.1.4 The CMIB is funded by contributions from its members, the majority of which also submit data. These members receive results on a regular basis.

A1.1.5 Some research findings are published. Since 1973 these have been in Continuous Mortality Investigation Reports, which have appeared on average once every eighteen months. In December 2002, the CMIB started reporting developments via working papers. These papers allow information to be disseminated quickly, and facilitate feedback and consultation. All published information can be found in the appropriate section of the website accessed through www.cmib.org.uk

A1.1.6 Periodically, the CMIB graduates the raw data to produce mortality and morbidity tables which represent the underlying claims experience, and they are extensively used by U.K. actuaries in pricing and valuing life insurance and pension scheme risks. The most recent tables, published in 2006, reflect the mortality of life insurance companies in the period 1999 to 2002, and these are called the '00' Series tables.

A1.1.7 In recent years, the mortality tables published by the CMIB incorporated projections of future mortality. During its work on the '00' Series tables, the CMIB undertook extensive research into mortality projections, but came to the conclusion that it was unable to present a single view of the future, as had been attempted with preceding mortality tables. The final '00' Series tables, adopted by the U.K. Actuarial Profession with effect from 1 September 2006, did not contain any projections. It soon became clear that the absence of projections left a gap which caused much debate, both within the profession and between the profession and interested

external stakeholders. To try to help fill this gap, and to make its earlier research more accessible to actuaries, the CMIB published a 'library of mortality projections' in draft form in July 2007:

— CMIB Report 12, 1991; the analysis of permanent health insurance data;
— CMIB Working Paper 9, 2004; an analysis of the preliminary results of the mortality of male pensioners of self-administered pension schemes for the period 2000 to 2002 as reported in Working Paper 4;
— CMIB Working Paper 17, 2005; report of the preliminary results of an analysis into mortality experience of pensioners of self-administered pension schemes for the period 2000 to 2003;
— CMIB Working Paper 22, 2006; the graduation of the CMIB 1999 to 2002 mortality experience: final '00' series mortality tables — annuitants and pensioners;
— CMIB Mortality Committee Working Paper 15, 2005; projecting future mortality: towards a proposal for a stochastic mortality methodology; and
— Richards, S.J. & Jones, G.L., 2004. Financial aspects of longevity risk.

APPENDIX 2

THE OFFICE FOR NATIONAL STATISTICS

A2.1 The Office for National Statistics (ONS) publishes a wide variety of mortality data. ONS publishes data for England and Wales and at a U.K. level. Data for Scotland are published by the General Register Office for Scotland. Data for Northern Ireland are published by the Northern Ireland Statistics and Research Agency.

A2.2 Figures currently published by ONS include:

— National Life Tables for the U.K. and constituent countries (the Interim Life Tables);
— life expectancy at birth and at age 65 by area (e.g. by local authority, by ward level);
— healthy life expectancy at birth and at age 65;
— life expectancy by social deprivation for selected ages;
— mortality data by cause of death (including a historical series over the 20th century);
— mortality data by marital status;
— mortality rates by social class; and
— projected mortality rates from the national population projections for the U.K. and constituent countries.

(In some cases the mortality data may be grouped rather than by single year of age.)

A2.3 The ONS also publishes two quarterly series, *Population Trends* and *Health Statistics Quarterly*, which often carry articles on particular mortality topics.

A2.4 *Population Trends* provides population and demographic information. It contains commentary on the latest findings, topical articles on relevant subjects and regularly updated statistical tables and graphs, showing trends and the latest quarterly information on: conceptions, births, marriages, divorces, internal and international migration, population estimates and projections, etc.

A2.5 *Health Statistics Quarterly* covers the latest trends in the U.K.'s health. It presents an overview of the latest news, and a review of related publications for release, and contains commentary on the latest health findings and topical articles. It also highlights trends in health, and details the latest quarterly information on deaths, childhood mortality, cancer survival, abortions, congenital anomalies and morbidity.

A2.6 These are available both on the ONS website (www.statistics.gov.uk) and as published volumes. The population projections database is on the GAD website (www.gad.gov.uk).

BACKGROUND PAPER 1

THE MORTALITY RESEARCH STEERING GROUP

By J. B. Orr

B1.1 This short paper describes the background to the Mortality Research Steering Group. It introduces the Mortality Developments Scoping Study and describes our past, present and planned future activities.

B1.2 *Actuaries and Mortality*

B1.2.1 The origins of the actuarial profession lie in the measurement and management of mortality risk, providing greater financial certainty to the organisations that we advise in the provision of annuities, life insurance, pensions, and health and liability insurance products.

B1.2.2 With lower inflation and interest rates over the last decade or so, the importance of mortality risk to actuarial practice has increased, at the same time as the difficulties in predicting future mortality have become more apparent. Society, as a whole, government and industry are all having to grapple with an ageing population and an increased life expectancy.

B1.3 *Actuaries and Research*

B1.3.1 It is against this background that the Actuarial Profession in the U.K. reconsidered its approach to research.

B1.3.2 For many years, the majority of the research on behalf of the profession has been carried out by volunteer members and by universities, with a limited amount of funding made available to look at specific aspects of actuarial research. Researchers could apply to the profession's Research Steering Committee for funding against a broad range of research themes published in advance; research grants were then awarded in response to the applications received.

B1.3.3 This approach has provided some excellent research and helped support important research initiatives, such as the Actuaries Panel on Medical Advances in their early stages. However, it had become apparent that a more directed approach would help the profession respond to the larger and more complex challenges of the present day.

B1.4 *The Mortality Developments Scoping Study*

B1.4.1 Actuaries have always been active in studying mortality, both through the Government Actuary's Department and through the Continuous Mortality Investigation Bureau. The latter has had a particular focus on the collection, analysis and use of data generated by firms writing insurance business, and, more recently, on pension schemes as well. However, many

other disciplines have an interest in mortality, whether in the provision of medical care or in guiding social policy.

B1.4.2 The profession recognised that there was a great deal of knowledge and research in other fields which it could draw to better understand past, present and future trends in mortality. With this in mind, the Mortality Research Steering Group was formed, drawing on expertise from a wide range of disciplines, including medicine, epidemiology, gerontology, demography and social policy.

B1.4.3 To better understand the current state of knowledge in mortality and to identify the gaps where future research might be required, the steering group commissioned a scoping study by Dr Catriona Macdonald. The study adopted a methodology which surveyed the relevant fields of research, namely those described above plus health economics, medical sociology and psychology, through contacting known and recognised experts, and asking them to recommend five key research papers which best described the current state of knowledge on aspects of mortality. Through this process, a substantial number of experts and research papers were identified, and full details are provided in the paper to be presented at the sessional meeting.

B1.4.4 A particular gap which the research identified related to cancer, where very few papers on the subject were nominated by the experts, with the main reference being provided by an actuarial member of the steering group itself. We hope to identify more material in this vital area in due course, and would seek to direct research towards better understanding the influence of cancer and cancer treatments on mortality experience, if this proves to be a genuine gap in what is known.

B1.5 *Mortality Experts' Meeting*

A key stage in the scoping study was held at Staple Inn on 3 March 2008. At this meeting, we invited the experts identified through the scoping study to receive and review Dr Macdonald's report. This provided a valuable check on the findings of the study, and included a discussion and debate on the best way of supporting a multi-disciplinary effort to progress our understanding of developments in mortality. A summary of the event is also included in Background Paper 2.

B1.6 *Sessional Meeting*

B1.6.1 The sessional meeting on 22 September 2008 is being held to present the results of the scoping study to the actuarial profession plus invited guests from the many other disciplines with an interest in mortality research. We hope that this will help raise awareness amongst the group of the range of material which is available, but also, more importantly, bring people together to share some of their knowledge and to foster working relationships between them.

B1.6.2 We will also bring the audience up to speed with the activities of the Mortality Research Steering Group and our plans for the future.

B1.7 *Multi-disciplinary Conference on Research in Mortality*

B1.7.1 The main focus of the steering group is now on encouraging research on three themes in preparation for a conference to be chaired by Professor Tom Kirkwood, Honorary FFA, in Autumn 2009. Again, the aim will be to bring together a diverse range of disciplines with a shared interest in mortality research, but this time also to bring new research to the group and to enable a deeper exploration of the issues involved.

B1.7.2 The conference will mark the completion of three streams of multi-disciplinary research in mortality. It will take place over one and a half days, and will be open to, and marketed actively towards, actuarial and other professionals in the fields of medicine, epidemiology, gerontology, demography, health economics, medical sociology, social policy and psychology, and to organisations in the private, public and voluntary sectors with an interest in mortality developments.

B1.7.3 The conference will be organised around three themes:

— drivers of mortality change;
— the impact of individualised mortality risk; and
— reasons for differences between cohorts.

B1.7.4 A review paper will be written on each theme by an acknowledged expert, and be published before the conference. Contributed papers will be presented in the thematic sessions, and 'double-header' sessions will be organised to present the differing perspectives of medics and actuaries, or of researchers and practitioners. Contributions will also come from PhD students, either through posters, papers or presentations. The conference papers will be published in a special edition of the *Annals of Actuarial Science*, with a scientific review panel under the chairmanship of Professor Angus Macdonald.

B1.7.5 The emphasis of the conference will be on creating networking opportunities and developing knowledge on the drivers of mortality change, both within the profession and outside. This will, of course, be an excellent opportunity for members of the profession to gain CPD credits focussed on mortality.

B1.8 *Members of the Mortality Research Steering Group*

James Orr (Chairman)
Dr Madhavi Bajekal
Professor David Blane
Adrian Gallop
Martin Hewitt
Professor Angus Macdonald
Dr Catriona Macdonald
Dr Jackie Morris
Brian Ridsdale
Trevor Watkins

BACKGROUND PAPER 2

SUMMARY OF MORTALITY EXPERTS' MEETING HELD ON 3 MARCH 2008 AT STAPLE INN

By A. Gallop

B2.1 *Aim of the Meeting*

B2.1.1 Around 50 invited guests from a range of disciplines attended the Mortality Experts' Scoping Meeting on 3 March 2008 at Staple Inn. The objective of the meeting was to explore how gaps in current research into mortality, identified in the report 'Scoping Mortality Research', prepared by Dr Catriona Macdonald, under the supervision of the Mortality Developments Scoping Project Steering Group, might be identified and filled. The Project Steering Group recognises that collaboration between the actuarial profession and other disciplines will be beneficial in gaining new insights into mortality trends.

B2.1.2 The meeting opened with a presentation by the Chair, Professor Tom Kirkwood, Director of the Institute for Ageing and Health at the University of Newcastle. He posited three questions for longevity experts:

— Life is getting longer already — do we understand why?
— What is the likelihood of further increases in life span?
— What is likely to happen to age-related health, quality of life and capacity for independent living?

B2.1.3 The presentation addressed these questions in three parts:

— Why does ageing occur?
— Is there a limit to the human life span?
— Do longer lives mean more diseases?

B2.1.4 The three stages of young, middle and old age which were previously compressed into the first 50 years of life now spanned 80 years and more.

B2.1.5 The 'disposable soma theory' suggests that the body uses food energy for metabolism, reproduction and repair and maintenance. The compromise in allocating energy to the repair function causes the body gradually to deteriorate with age. For animals living in the wild, this compromise results in less energy devoted to repair; consequently few animals live to old age. However, for humans living in a protected environment where they can invest more in repairing and keeping their organs going, it results in a much larger proportion of them reaching old age.

B2.1.6 Looking at the ageing process, ageing results from random

molecular damage, arising from stress, environment and bad diet causing cellular damage. However, this damage can be repaired by living a good lifestyle and eating a good diet. Although ageing is governed by genetics, it is not governed by a genetic programme.

B2.1.7 Human ageing is malleable, and can be influenced by decreasing exposure to damage through improved nutrition, healthy lifestyle and a supportive environment, by enhancing natural mechanisms for protection and repair and the use of novel drugs, stem cell therapies, etc. Whilst currently we understand only some of these factors, we will learn more in the future.

B2.1.8 The key factors associated with healthy ageing are genes, nutrition, lifestyle, environment, socioeconomic status, attitude and chance. Professor Kirkwood's own work estimates that genes account for 25% of what determines longevity (Cournil & Kirkwood, 2001)). In terms of diet, studies have suggested that moving to a more Mediterranean type diet leads to reductions in mortality.

B2.1.9 Do longer lives mean more diseases? In sum, we know that:

— for many important diseases, age is the largest single 'risk factor';
— understanding why aged cells and organs are more vulnerable to pathology will open new paths to prevention and cure; and
— at present, we have many medical research institutes, but very few of these include research on the science of intrinsic ageing.

B2.1.10 The coming decades are likely to see greatly expanded research on the mechanisms underpinning both normal ageing and age-related diseases. We are learning that some of the mechanisms which might be part of the disease-generating process — e.g. in heart disease — may be the same as those which are part of the disease generating mechanisms in dementia or in osteoporosis. When we target these diseases, we may be targeting generic-underpinning mechanisms which may have a broad-scale impact.

B2.1.11 Presently, we would expect to target the younger unhealthy population with drug therapies and the average healthy middle age groups with healthy lifestyle and nutrition. In the future, we would expect to extend healthy lifestyle and nutrition interventions, and to reduce drug interventions, for the overall population, including younger age groups, who become healthier by comparison. This would increase population numbers who live longer and healthier lives.

B2.1.12 Beating the biological clock by increasing both biological and chronological ageing then becomes possible, as public policies encourage healthy life style choices and discourage 'unhealthy' lifestyles (e.g. Wanless Reports).

B2.1.13 Understanding the future of mortality patterns requires multi-disciplinary approaches. Other disciplines have much to learn from the

actuarial profession, and vice versa. The question is how to take forward the building of further bridges.

B2.2 *The Actuarial Profession's Involvement in Mortality Research*

B2.2.1 Brian Ridsdale (CMIB) then gave an overview of why the actuarial profession was involved in research into mortality, outlining the large amounts of liabilities currently accruing in life assurance products and in pensions schemes, estimates of the expected payments of which depend on future mortality. Actuarial interest in mortality was focussed mainly in three areas:

— understanding the past;
— projection methodologies; and
— projecting future morbidity and mortality.

B2.2.2 However, there were potential gaps in the actuarial profession's understanding of mortality, including understanding the impact of cause of death and the existence of cohort effects and how they might develop. Old projection methodologies were proving inadequate. There is a need for better understanding and communication of the risks and uncertainties involved and their potential financial impact.

B2.2.3 To help address these, a wide, multi-disciplinary perspective was needed to further research into mortality. The actuarial profession believes that it has useful data, expertise and resources to contribute to this research.

B2.2.4 The mortality scoping study set up by the Actuarial Profession aimed to:

— identify experts in other disciplines;
— survey the state of knowledge across disciplines;
— bring together users and researchers;
— promote understanding areas of common interest — and the barriers to tackling them;
— communicate the decisions; and
— start to tackle the issues.

B2.3 *The Work of the Mortality Developments Scoping Group*

B2.3.1 Dr Catriona Macdonald then outlined the results of the scoping project. The aims of the Mortality Developments Scoping Group had been to provide an overview of research undertaken within the following areas:

— the actuarial profession;
— medicine;
— epidemiology;
— gerontology;
— demography;
— health economics;
— medical sociology;

— social policy;
— psychology;

and to identify overlaps and gaps in the research

B2.3.2 Key experts working in various disciplines were asked to recommend five of the most important pieces of research on mortality and also to identify further experts to contact. This approach has strengths and weaknesses. It did not provide a comprehensive review of the literature and it contained potential for bias in the selection of experts. However, the literature was compiled from expert recommendations, and it created an informal network aware of the actuarial profession's interest in mortality developments

B2.3.3 This approach resulted in 38 experts who were contacted, of whom 22 contributed lists of research, generating a list of over 90 pieces of research. The findings were grouped into several themes. Some areas of overlap were found in the research, e.g. in research conducted by different disciplines and amongst papers recommended by experts in different disciplines.

The research revealed that few, if any, papers had been recommended on:

— diet, obesity, alcohol and physical activity;
— causes of death other than CHD and stroke;
— influences on mortality amongst younger and middle aged adults;
— dementia and frailty;
— death certification;
— adverse influences on future longevity increase; and
— the effect of climate change.

B2.3.4 A variety of points were made in the following discussion, and these are given in the rest of this section:

B2.3.4.1 Other gaps identified included cancer, the developmental origins of health and disease, in particular risks in early life, the prospects for those currently in their 30s and 40s, the availability of social networks and social support. The danger of bias in the methodology was also raised.

B2.3.4.2 It was important to understand the different agendas of different disciplines and how these impact on each other in multi-disciplinary research. There was a need to understand the finely graded social fabric of mortality. For example, recent U.S. studies of obesity and life expectancy show, surprisingly, that high obesity is correlated with long life; whereas there may be a sub-group of the highly obese who do badly.

B2.3.4.3 There was a need to go beyond the broad brush. Models need to use data from more detailed studies.

B2.3.4.4 The question was raised as to whether actuaries doing research have to respond to regulatory pressures or whether can they engage in driving change in research agendas. For example, regarding genomic data in

the context of life insurance, how much could actuaries influence how the data are used. Ten years ago there was concern that life companies were using genetic tests to discriminate between applicants. There is a dilemma here. Early assessment is good for health intervention, but may be damaging when seeking life cover. Therefore, a more detached view of how agendas come together is needed.

B2.3.4.5 Research is undertaken to understand what is happening. Currently, mortality research looks for factors influencing mortality by counting from birth onwards; but an alternative approach worth taking would be to count back from death using whatever data are available, for example, from middle life to later life to decline in old old-age. Last years of life attract the highest health expenditure, because more of this group are dying. Four groups of morbidity which can be monitored by counting back from death are:

— rapid death, e.g. accidental death;
— fairly rapid death, e.g. cancer;
— long period of death, chronic disease; and
— frailty of body or mind.

B2.3.4.6 Part of the problem is trying to put two or more diseases or risk factors together. This leads to difficulties in formulating mathematical models.

B2.3.4.7 There is a tendency to assume a precise science of data fitting; but how accurate are these mechanistic models? Do life companies think that they have got their models wrong? The perception that actuaries have got it wrong is not the same as not anticipating the impact of mortality improvement. There is a useful interface here between the medical insights and mechanistic models used by actuaries.

B2.3.4.8 What actuaries want is a comprehensive causal model, but nobody has produced an interactive model of mortality.

B2.3.4.9 If we can identify a shared agenda, then we are on to a win-win situation. Frailty is an example where loose definitions involving a check list of three to six tick boxes can be used by a physician who wants the basis for a reliable forecasting tool. This is close to the techniques used in actuarial science. Quantitative mathematics has provided an algorithm for coronary heart disease (CHD), based on Framingham data; but these studies overestimated CHD by 36%. Many companies have products based on Framingham data.

B2.3.4.10 We need to start with the right questions. If the CMIB looked at mortality in the 1950s, lung cancer had not made an impact then. So, what are the important start dates? 1970 onwards was suggested, because increasing life expectancy in middle age is seen from that date; a noticeable increase for men; but for women in the twentieth century, the increase is more stable.

B2.4 *Breakout Group Questions*

B2.4.1 The next session saw breakout groups discussing the following four questions:

(1) Models have been developed to measure the contribution of medical interventions and risk factor prevalence to mortality from specific causes of death. The most notable of these is the IMPACT model for use with coronary heart disease. Are such models of use in projecting future mortality from specific causes, and from all-cause mortality?
(2) In what ways can biomedical research be incorporated into methodologies for predicting future mortality?
(3) What are the areas which you think would be most worthwhile for inter-disciplinary research into causes of mortality?
(4) What kind of forum might most usefully bring research communities together? Medical and actuarial studies of mortality have progressed independently over many years. Continuing changes in mortality experience pose serious challenges for both communities, and there is great potential to learn from each other and to share resources. Is there a way of working together to address the gaps in research into mortality developments which is sustainable and to the mutual benefit of all parties with an interest in mortality?

B2.4.2 Feedback from breakout discussions identified the availability and the quality of data as significant issues for research. Participants considered the possibility of sharing data between agencies, including whether the NHS would be prepared to share data with actuaries and whether medical researchers would be interested in analysing CMIB data. It was noted that some biomedical research is not as useful as it might be, because important information, such as age, gender, etc., is often omitted or the age range covered may be limited. Older people are often excluded from intervention studies because of the problems of multiple pathologies. Cause-specific data may be suspect, as the practice in completing death certificates may vary between doctors.

B2.4.3 An important challenge is to estimate the impact of Government initiatives on behaviour change, for example in relation to healthy eating and smoking. The impact of such changes in behaviour, if any, on mortality experience is likely to take many years to emerge. It was pointed out that it took around 40 years for the physiological impact of smoking to be forecast with accuracy.

B2.4.4 Whilst there was a consensus that a cause-specific mortality model, spanning all causes of mortality, could be an excellent long-term objective, the attendees accepted that, at this stage, this is a distant goal, suggesting a need for a methodology which breaks down the project into component parts.

B2.5 *Users and Funders of Research*

B2.5.1 The next session began with a panel discussion by four users and funders of research — two actuaries Richard Willets (Paternoster) and Richard Humble (Legal and General), together with Pat Goodwin (Wellcome Trust) and David Guy (Head of Knowledge Transfer ESRC).

B2.5.2 Pat Goodwin gave a funders' perspective on mortality research. The aim of the Wellcome Trust is to foster and to improve research to improve human and animal health. Relevant current research sponsored by the Trust includes:

— the cellular aspects of ageing;
— the effects of lifestyle on mortality;
— the causes of death in developing countries — the use of surveillance systems (many do not have death certification); 'global autopsies';
— the effect of heatwaves on mortality;
— cohort studies; and
— the U.K. Biobank, which comprises 0.5 million 40 to 65 year olds. At the moment there is only funding for recruitment and basic biometric measurements, but there is potential for a much wider study.

B2.5.3 Richard Humble said that, for Legal and General as a major writer of annuities, future trends in mortality are important for pricing and reserving purposes. The methodologies often used in the insurance sector, based largely on the work by the actuarial profession's body the Continuous Mortality Investigation Bureau (CMIB), involving statistical-based projections of past trends, and these can be very sophisticated. However, they do not seek to identify casual aspects for the trends or to see how such information may affect one's view of the future. For example, changes in smoking habits have been a significant driver of reduced mortality. However, once you have given up smoking, you cannot give up again.

B2.5.4 It should be remembered that high future improvements are, on the one hand, good for insolvency regulators, but, on the other, pose problems for savers, because, using conservative longevity assumptions, people may not have as much in their pension funds as they might require.

B2.5.5 From the insurance actuary perspective:

— projections must be accurate;
— figures are needed by age and gender;
— aggregate figures may be limited in their usefulness (e.g. Doll study) — medical studies need to disaggregate social factors more; for example, the UCL study of strokes disaggregates by age, gender and socioeconomic groups; and
— insurers, more generally, would fund other research, but only if it includes similar levels of detail.

B2.5.6 Richard Willets said that there is a big difference between the financial organisations which need this research and those which are prepared to pay for it. Big companies can afford to subsidise research, but smaller companies may not, even though they also need the research.

B2.5.7 Pension schemes have very sizeable liabilities linked to mortality, and need knowledge about morality trends; similarly for life insurance and investment products. This is a very significant growth area, but who will pay? Research is generally not free, even though much data are available on the internet for nothing. However, the CMIB is an example of an initiative attracting large amounts of money. The cost needs to be spread across the industry; in particular, large expensive projects were needed which would have to be funded by lots of companies.

B2.5.8 David Guy said that research councils support training, development and knowledge exchange, as well as funding research.

B2.5.9 Some research projects are 'responsive', where a good idea has been put forward which is highly rated by peers. Other projects are identified and directed by research councils; for example the 'new dynamics of ageing' project, which it may be worthwhile linking in with. Co-funding arrangements are usually possible.

B2.5.10 Training and development was encouraged through a variety of means such a:

— capacity building for professionals and researchers;
— career development of researchers, and adopting a life course approach for undergraduates and postgraduates;
— knowledge transfer scheme — the joint supervision of a graduate between an academic and a company for two years;
— doctorates CASE projects; and
— postdoctorate CASEs — four-year projects applying the learning undertaken in a PhD to a particular area.

B2.5.11 Knowledge transfer could involve: an interactive process; where the stakeholder identifies key questions and researchers try to answer the questions; seminars/workshops; knowledge intermediaries; brokers and interpreters; journals; electronic dissemination, such as interactive portals and placements or schemes co-funded by academic and business worlds where academics are placed in industry and business persons in academia. The ESRC was keen to engage with stakeholder groups, such as the actuarial profession.

B2.5.12 In the following discussion it was suggested that actuaries and academic researchers are usually interested in exactly the same things, but for different reasons. For example, when looking at socioeconomic differences in mortality, the aim of the academic researcher is to close gaps, whereas the aim of the actuary is to predict the future. There are clear overlaps of interest, and we should be able to cooperate. The fact that we have different skill sets should be a positive thing.

B2.6 *Discussion on Future Direction*

B2.6.1 The final session was a discussion on the future direction. It was felt to have been constructive bringing together experts from various disciplines, looking at the results of the report and listening to the questions raised. There was more work to be done on clarifying the agendas. Was a position paper on current research and burning questions needed? It would be necessary to work on ways to sharing knowledge. This will involve practical issues, such as the ethical concerns about sharing databases. There must be a lot of information available to actuaries which would be of use to epidemiologists, and vice versa, e.g. the bio-bank data.

B2.6.2 Consideration could be given to setting up research programmes based on some of the ideas mentioned during the seminar, such as the ideas factory, ageing, Wellcome Trust, CMIB. This would not need vast amounts of money. If agreed, then careful thought would be needed about setting up a cross-council or cross-funder initiative.

B2.6.3 A suggestion of creating a committee which would accommodate the varying views received mixed support.

B2.6.4 One possible outcome was to use the event as a preliminary/preparatory session for a high profile conference in 2009. An example of a suitable model may be the 'Changing Expectations of Life' conference, held in 2007 — a one-day conference at a prestigious venue with many preparatory sessions (panels met twice before conference), which produced sector panel reports, providing a lot of background information available on the website.

B2.6.5 A series of multidisciplinary seminars might be useful, but this would imply some continuity over time and need sustained momentum to keep going and remain fresh.

B2.6.6 The main outcome of the discussion was that there was general support for a conference with specific terms of reference. The organisers of the seminar would meet, propose some ideas, and invite people to take part. The research councils present were invited to take back the messages of the conference to their councils, and to consider further action and support.

Reference

Cournil, A. & Kirkwood, T.B.L. (2001). If you would live long, choose your parents well. *Trends in Genetics*, **17**, 233-235.

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