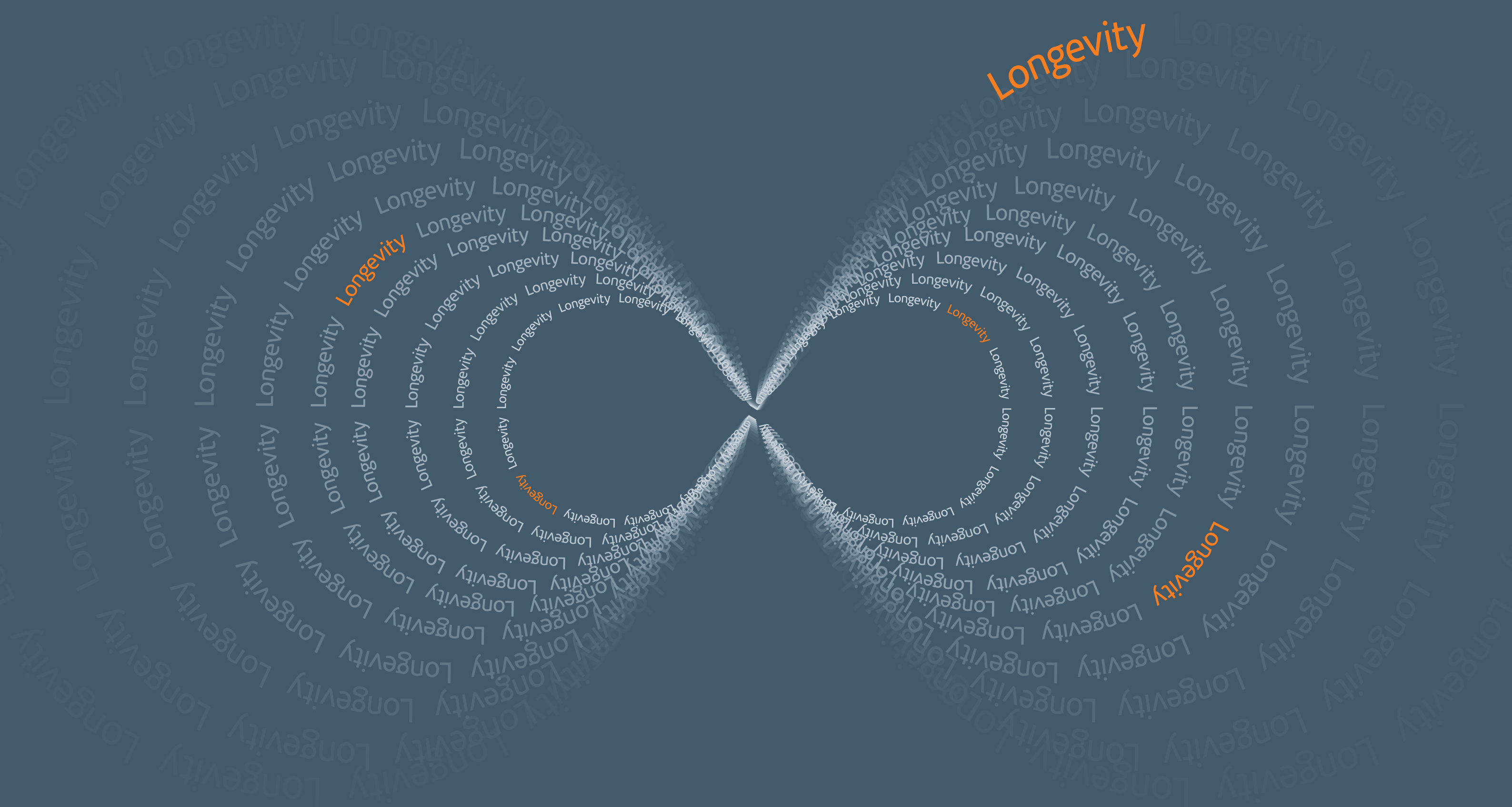
The Actuarial Profession
making financial sense of the future

Longevity Bulletin

From the Institute and Faculty of Actuaries



Issue 03 – May 2012

Contents:

1. Editorial: Variation or inequality?
2. Focus on: Variation in longevity
3. Longevity research news
4. News from the Institute and Faculty of Actuaries
5. Sources

1. Editorial:
Variation or inequality?

longevity *n.*

Pronunciation: **/lɒnˈdʒɛvɪti/**

Long life; long duration of existence (Oxford English Dictionary)

Life expectancy is a fundamental measure of human progress and there is a large literature on the variation of life expectancy between and within countries. A great deal of work continues on one aspect of this variation: avoidable health inequalities, inequities or disparities. In particular, epidemiologists and others investigate the association of health inequalities with socio-economic position. The World Health Organisation's Commission on Social Determinants of Health is a major example of this.

What can actuarial theory add to this large body of work? The *Focus* article in this issue of *Longevity Bulletin* sets some basic actuarial relationships between average lifespan and the variation of lifespan within a population in the context of some emerging theories from recent studies in demography. There may not be a unifying theory of variation in longevity yet, although we look back to 1825 for still-relevant insights. However, there are some perhaps surprising trends that give pause for thought about whether increasing average lifespans can be accompanied by reducing variation.

Longevity Bulletin aims to provide a regular guide to the prospects for long lives. It presents and explains actuarial perspectives on population longevity and looks outside the profession for statistics, research and the latest thinking on related subjects. It is not intended as a comprehensive guide to everything new in longevity research but rather as a helpful companion for those interested in a most intriguing subject.

We hope the *Bulletin* is read by actuaries, users of actuarial services and anyone with a technical, professional or personal interest in longevity.

To receive future issues of *Longevity Bulletin*, email: longevitybulletin@actuaries.org.uk.

2. Focus on:
Variation in longevity

Discussion of longevity or mortality often focuses on an average measure. Usually the measure is life expectancy, which is the average remaining lifespan of a population. Life expectancy is often used as a proxy measure for the overall health of a population. But for a full profile of population longevity or health the extent of variation needs to be investigated. Within demography, this is often examined by looking at how age at death, or length of life, varies within a population.

This *Focus* article:

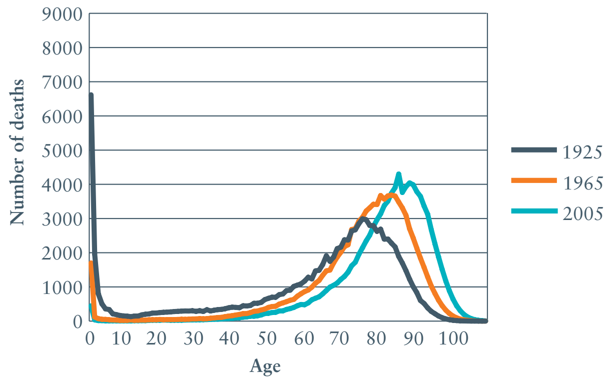
- Describes how and why length of life varies.
- Shows how variation in length of life generally has reduced as populations live longer.
- Considers what this may mean for the variation of longevity in future.

How and why length of life varies

Life expectancy at birth is the average total lifespan, or equivalently average age at death, for a defined population within a defined time period.

Chart 1 shows how age at death for females in the UK has changed over recent decades, using data consistent with the period measure of life expectancy (see *Longevity Bulletin 02* for why this is a hypothetical rather than realistic measure of actual lifespans). As discussed in *Longevity Bulletin 02*, the pattern of an increasingly dominant single most common age at death (the mode) is replicated in most developed countries. The curve has shifted to the right as more people survive to older ages. However, maximum lifespan has increased more slowly, and this causes what has been called compression of mortality, where the peak narrows and the mode appears limited in how far it shifts.

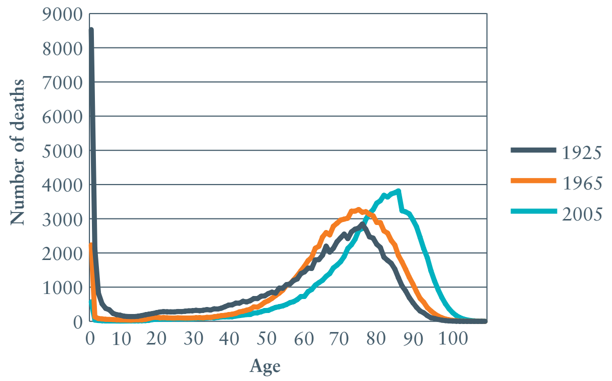
Chart 1



Curve of deaths for females in the UK from period life tables: numbers dying at each age from 100,000 births experiencing mortality rates of the specified year at each age.

Source: *Human Mortality Database period life tables,* **www.mortality.org**.

Chart 2



Curve of deaths for males in the UK from period life tables: numbers dying at each age from 100,000 births experiencing mortality rates of the specified year at each age.

Source: *Human Mortality Database period life tables,* **www.mortality.org**.

Table 1:
Factors associated with mortality or longevity, all other factors being equal.

Factor	Association
Gender	Mortality rates for females are lower at each age than those of men. Women live longer than men, on average.
Marital status	Married people have lower mortality rates than never married, divorced or widowed people do.
Socio-economic factors	Mortality rates worsen as socio-economic status worsens, even within small populations.
Education	The evidence that education acts directly to improve mortality independent of socio-economic status is said to be under-appreciated outside of demography.
Ethnicity or migrant status	Mortality rates have a complicated relationship with ethnicity or migrant status, which may also be associated with socio-economic status. Migrant mortality appears to vary not only as a result of differences in average mortality between host and home countries but also healthy selection for migration or return and length of residence in host country.
Relatively poor conditions in utero, at birth or in very early childhood	Observed to be associated with higher mortality rates even at advanced ages.
Lifestyle factors	Higher mortality rates have been observed for those who smoke, eat an unhealthy diet, are obese, take inadequate exercise, drink excessive alcohol, or participate in hazardous sports or other risky behaviour compared to those who do not, although the degree of additional mortality risk is often not linear.
Genetic disposition	There appears to be a genetic component to exceptional longevity.
Medical technology	The use of preventative pharmaceuticals such as statins to lower blood cholesterol, has significantly contributed to the lowering of mortality rates for certain diseases.

Sources: *Baker et al (2011); Barker (2007); Eriksson (2005); Harper and Howse (2008); Kuh et al. (2009); Marmot (2005); O'Connell and Dunstan (2009); Willcox et al. (2006).*

The reasons why age at death varies within a population are complex, because age at death for any one individual is due to a combination of many different factors affecting mortality rates at any time. Analysis of these factors is generally done one by one, so that we know which factors are associated with mortality rates being higher or lower than average. A lower mortality rate than average at a specific age would mean, all other things being equal, a longer life or higher age at death.

Table 1 lists some of the factors known to be associated with the level of mortality rates or longevity. Note that even if an association between a factor and the level of mortality has been observed, it is often the case that the way in which the association may operate is not understood. Causality has been proven in few of these associations.

The associations shown in Table 1 are on the basis of each factor operating independently; all other factors being held constant. Any individual will of course be exposed to multiple factors in different combinations. It is not fully understood how these factors work together to produce the overall mortality risk for any individual, but one proposal for how the variation in adult lifespans could be explained is set out in Table 2.

Table 2:

Hypothesis of relative contributions of factors to variation in adult lifespans.

Type of factor	Contribution
Genetic factors	One quarter
Early life conditions	One quarter
Conditions in later life, including lifestyle	One half

Source: *Vaupel et al. (1998).*

There has been little further comment on this hypothesis, but it is probable that there is no generalisable formula. Genetic and environmental factors could be more important when economic conditions in early life are poor while lifestyle factors become more important for people born in times of better economic conditions (van den Berg et al. 2011). In most developed countries, early life factors have become less important as infant and child mortality rates are now close to zero, so later life conditions would be expected to have become more important in the variation of lifespan mortality (Su 2009). Finally, overlaying all the influences of different measurable factors and the interplay between them, individual mortality prospects are to some extent a matter of chance (Kuh et al. 2009).

If what we know about how or why longevity varies between individuals is incomplete, another approach to the subject is to investigate how longevity varies within populations. For the remainder of this *Focus* article, we turn to data and theories about how the variation in longevity changes over time within populations.

As life expectancy has increased, variation in length of life has fallen…

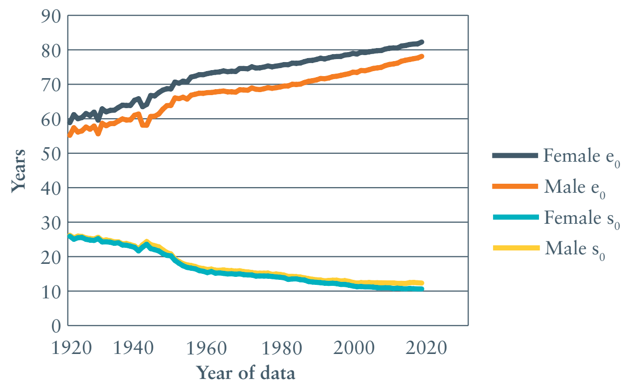
Charts 1 and 2 show the pattern in most developed countries over recent history: the strengthening of the peak age at death and the reduction in the numbers of deaths at young ages. The trend of increasing average lifespans has been driven by fewer people dying at young ages. More people have been surviving to older ages and dying closer to the most common age. In other words, the ages at which people die have become less variable.

Is there a relationship between variation in lifespan and average lifespan for a given population? This can be explored using a time series of population actuarial life tables. The variation in length of life for survivors from a given age can be calculated and compared to life expectancy at that age. Smits and Monden (2009) made such an analysis using a database of actuarial tables from 212 countries dating back at least to 1950 and for some countries to the 18th century. They demonstrated a high negative correlation between life expectancy at young ages and the variation in age at death. While average life expectancy generally increased, variation in lifespans reduced.

Chart 3 illustrates this using UK data on period life expectancy at birth and the corresponding variation, measured here by standard deviation in age at death. The negative correlation is clear from the diverging trend lines.

Much of the reduction in variation in age at death over recent decades has been because deaths at young ages have reduced. And as a single mode of the age at death distribution becomes more pronounced, so compression of mortality is consistent with a reduction in variation.

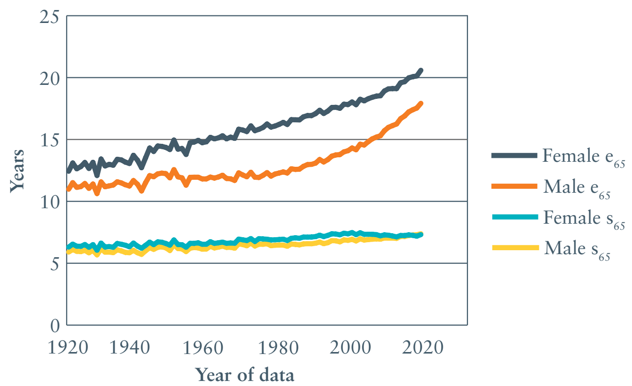
Chart 3



Life expectancy at birth (e_0) and standard deviation in age at death from birth (s_0), data from period tables for UK males and females 1922-2009.

Source: *Calculations using period tables in Human Mortality Database; standard deviation of age at death from Engelman et al (2010).*

Chart 4



Life expectancy at age 65 (e_{65}) and standard deviation in age at death from age 65 (s_{65}), data from period tables for UK males and females 1922-2009.

Source: *Calculations using period tables in Human Mortality Database; standard deviation of age at death from Engelman et al (2010).*

…except at the oldest ages

However, the mode has also been shifting to the right, and the chances of living to age 90 or 100 have increased. Could mortality shifting have tempered mortality compression so that the variation in ages at death among the highest ages has increased?

There is evidence that this is indeed the case. Engelman et al (2010) examined the changing distribution of ages at death from 23 national populations over the last 5 decades at different ages. They found that while the variance in age at death reduced for the full population, and for survivors to age 10, the variance among survivors to older ages slightly increased. They attribute this to a shifting of health variance from younger to older ages as a result of the success of early life mortality improvements. This leads to a wider range of frailty among older survivors in high life expectancy populations compared to lower life expectancy populations.

Chart 4 shows the same analysis for the UK as in Chart 3, using the same source data, but for the populations aged 65 and over only. As is well known, period life expectancy at age 65 has increased markedly, but the variation in age at death among the over-65s has been flat at best. This suggests that mortality shifting has had the upper hand over compression, to the extent that variation in lifespans for the survivors to age 65 has not been able to improve even as the average lifespan for that group has.

So in countries with a recent history of increasing life expectancy and high average total lifespans, variation in total lifespan has reduced. However, at the same time, variation in the age at death for the oldest survivors has at best stayed the same if not increased. The inverse correlation between life expectancy and variance breaks down at older ages. This is consistent with new observations in high life expectancy countries of the curves of deaths shifting to the right, with the peak not continuing to narrow endlessly (Ouellette and Bourbeau 2011). Mortality compression appears to be tempered by mortality shifting.

What does this mean for longevity variance in future?

The recent demographic analyses discussed in this article reveal more complexity in longevity trends than simple observations of increasing average lifespans suggest. It also means that interpretations of variations in age at death or lifespan have to be made understanding the connection between life expectancy and variance.

Smits and Monden (2009) suggest that their finding of a strong negative correlation between life expectancy and variance means that variation or inequality in age at death cannot be compared across populations at different stages of life expectancy development. And if we consider a large population to be made up of sub-populations at different phases of life expectancy development then we cannot expect variations of lifespan to be the same for each sub-group.

Further, if both trends of mortality compression and mortality shifting continue in high life expectancy countries, then increasing average lifespan still further might not be achievable without also increasing variation in lifespans. And this then may be interpreted as increasing inequality.

"...although frailer people have "caught up" to their counterparts in reaching older ages, there is still a great deal of uncertainty about their subsequent survival and health in later life. Without devaluing the achievement of higher life expectancies, one must also recognize the exacerbation of health inequalities in later life that may accompany this success."

Engelman et al (2010) p. 535

The work within demography on variation in lifespan focuses on total measurable variation. Work in different disciplines, for example epidemiology, focuses on avoidable variation, referred to as inequality, inequity or disparity, in health or mortality within populations. So is there a base level of 'unavoidable variation' in mortality or lifespan, which can inform the study of avoidable variation?

An intriguing insight to this question comes from analysis of one of the earliest actuarial equations. Gompertz Law attempts to theorise the shape of mortality rates in a population and has been proven to hold for different populations and periods at all ages except the youngest and oldest, usually taken to be between ages 20 and 60 (Gompertz 1825; Olshansky and Carnes 1997). Gompertz Law is represented by the following equation:

$$\mu_x = ke^{\beta x}$$

In the above, μ_x is the force of mortality (similar to a mortality rate) at age x, k is a constant and β is the slope of the graph of the logarithm of the force of mortality drawn with age, sometimes called the rate of ageing. A simple interpretation of Gompertz Law is that as age increases linearly, so mortality rates increase geometrically.

Tuljapurkar and Edwards (2011) show that the variance in age at death for a population following Gompertz law is a function only of the parameter β, and that the rate of ageing is inversely related to the variance in length of life.

$$\text{Variance in age at death} \cong 1/\beta^2$$

Why this should be so, or what this means for future trends, is unclear. However, since ß is a finite number, there will be some non-zero variance in age at death within a population which follows Gompertz Law. This can be seen as a natural or inherent variance in age at death within a population, so not all variance will be avoidable inequity. Alternatively, it is a reminder that there is an element of chance in the way biological processes operate.

In developed countries, most of the increase in average life expectancy and reduction in variance of age at death has been due to reducing premature deaths. Improvements in life expectancy for older people have not contributed significantly to reducing variance in remaining lifespan. This suggests that increasing life expectancy and reducing variance in age at death may be seen as competitive policy goals, or may focus resources away from mortality improvements at older ages (Howse 2012; Vaupel et al. 2011). The discussion above alerts us to the strong associations between variance and life expectancy, and that these measures behave differently over time at different ages, as appears to have been the case in the way that variance of lifespan has changed less at older ages than at younger ages. Interpretation of inequality data should be informed by an understanding of the associations between the measures used and their expected behaviour over time.

Summary of this *Focus* article:

- The amount of variation in age at death for a population tends to reduce over time, as average lifespans increase.
- At the same time, the variation in age at death among older people may increase, consistent with survivors benefiting from better mortality but being more disposed to frailty, relative to populations with lower average lifespans.
- Not all variance in age at death will be avoidable inequality, as some variance will be present in all populations.
- In populations where there have been successful early life mortality improvements, variation in age at death has shifted from younger to older ages. In these populations, can we both reduce variation in age at death and continue to increase average lifespans?

3. Longevity research news

This section highlights some recently published research. Each item is selected for its relevance to longevity knowledge and interest to *Bulletin* readers. Check the links and the Sources section at the end of this *Bulletin* to follow up on a reference.

Further investigation fails to explain the "golden cohort". The reasons why UK-resident cohorts born around 1930 have consistently shown higher rates of mortality improvement than cohorts before and after were examined in a recent article in *Population Trends*, published by the Office of National Statistics (ONS). Goldring et al (2011) attempted to match trends for successive cohorts in the composition of the population by various characteristics (marital status, percentage in employment, social class, education level and housing tenure) with those shown in mortality improvement, using data from the ONS Longitudinal Study. However, despite this data-intensive analysis, no clear explanation for the golden cohort's mortality improvement advantage emerged. The explanations previously suggested but not tested therefore remain as likely contenders: the golden cohort avoided the perils of the First World War (1914-18) and the influenza pandemic (1918-21) and was the first generation to benefit from a step improvement in infant nutrition and care.

Compression of morbidity is shown among supercentenarians. Few studies are available on the health status of supercentenarians, because people who live to be aged 110 or more are so rare. Yet as longevity increases, and more people live to the oldest ages so the health prospects of the oldest become more of a concern (Harper 2011). A recent study by Andersen et al (2011), investigated health and mortality for centenarians (age 100-104 years), semisupercentenarians (age 105-109 years) and supercentenarians. Although the sample used has limitations for how far findings can be interpreted, the evidence points to exceptionally long-living people becoming afflicted by health problems late in life. It was found that in general, the older the age group, the older the age at onset of the major age-related health issues, including cancer, cardiovascular disease, dementia, stroke and cognitive and functional decline.

The findings support the theory of compression of morbidity, that is, the proportion of life spent in ill-health decreases as the limit of lifespan is approached. However, if the limit of lifespan is in the range given by supercentenarian years to the maximum lifespan recorded (110 to 122 years) then improvements in rates of disability or ill-health at the population level will not become apparent until average life expectancy improves far beyond current levels.

A greater focus on men's health is suggested to narrow the gap between male and female mortality. It is well-known that women live longer than men. A recent report from the European Commission (White et al. 2011a) showed marked differences in health outcomes for men compared to women across Europe. The gap between male and female period life expectancy at birth ranges from 3.3 years in Iceland to 11.3 years in Latvia. Men on average have worse health and mortality than women not only because of biological factors, but also because male lifestyles are more detrimental to health, including smoking, excessive alcohol, poor diet, less use of health services and greater likelihood of injury. Few countries consider men as a separate group for health policy planning, although many public health policies may have a greater effect on men's health than on women's, for example those curbing road traffic and workplace accidents. Discussion articles in the *BMJ* suggest more public health policy and practice designed for men is necessary (Malcher 2011; White et al. 2011b).

The Office for National Statistics recently revised population projections for the UK to be more optimistic on longevity prospects. The 2010-based projections contain two years more of demographic information than the previous 2008-based projections. The projections (ONS 2012a) depend on assumptions of future fertility, migration and mortality. Tables 3 and 4 update the mortality projection assumptions and results that were summarised in *Longevity Bulletins 01* and *02* respectively.

Table 3:

Summarised assumptions for the annual rate of reduction (improvement) in mortality rates in UK population projections.

	Low variant	Principal estimate	High variant
2008-based	Varies by age until reaches 0% by 2033. Thereafter, 0%[1].	Varies by age until reaches 1% by 2033. Thereafter, 1%[1]. Average 2008-2083: 1.3% (m) 1.4% (f).	Varies by age until reaches 2% by 2033. Thereafter, 2%[1].
2010-based	Varies by age until reaches 0% by 2035. Thereafter, 0%[2].	Varies by age until reaches 1.2% by 2035. Thereafter, 1.2%[2]. Average 2010-2085: 1.4% (m) 1.5% (f).	Varies by age until reaches 2.4% by 2035. Thereafter, 2.4%[2].

Source: *ONS (2012b) and additional data from ONS.*

Table 4:

Life expectancy indicators, period and cohort examples, UK, 2010-based projections.

		Period 1981	Cohort born 1981	Period 2010	Cohort born 2010	Period 2035	Cohort born 2035
At birth	Male	70.9	84.7	78.5	90.2	83.4	94.2
	Female	76.9	89.1	82.4	93.7	87.0	97.2
At age 65	Male	13.0	25.3	18.1	n/a	22.1	n/a
	Female	16.9	27.8	20.7	n/a	24.6	n/a

Source: *ONS Period and cohort expectation of life tables (2010-based) for United Kingdom, principal projection only. Based on historic mortality rates for 1981-2010 and thereafter assumed mortality rates consistent with 2010-based principal projection.* **www.ons.gov.uk/ons/rel/lifetables/period-and-cohort-life-expectancy-tables/2010-based/index.html**.

Note: *n/a means data not available as ONS do not publish cohort life expectancies for calendar years after 2060.*

Cohort life expectancies - the most intuitive measure of actual lifespans - are projected to lengthen by more than previously anticipated. The new projections add nearly one and a half more years to the central estimate of expected average lifespan of people born in 2010, which in round numbers is 90 years for males and 94 years for females. The main reason these new projections show longer expected lifespans is the increase in the assumed long-term annual rate of mortality improvement from 1 per cent to 1.2 per cent. The average improvement over the last hundred years or so in mortality rates across all ages (taking account of the changing age profile of the population) has been around 1.2 per cent a year for both males and females.

[1] | *Higher rates of improvement are assumed for those born between 1923 and 1940.*
[2] | *Higher rates of improvement are assumed for those born between 1925 and 1938.*

4. News from the Institute and Faculty of Actuaries

Improved mortality rates lead to 20,000 fewer deaths in 2011

The Actuarial Profession issued a media release on 3 February 2012 highlighting an exceptionally high improvement in mortality rates in England and Wales in 2011. The Continuous Mortality Investigation analysed preliminary mortality data from the Office for National Statistics (ONS) and found an improvement of 4 per cent in mortality rates in 2011, compared to the average over the 10 years to 2010 of 2.4 per cent. The Profession illustrated the significance of this by saying there were 20,000 fewer deaths in 2011 than would have been expected if the mortality rate had not seen this exceptional change. The "golden cohort" of people born around 1931 continued to show strong mortality improvements of nearly 5 per cent in 2011. Although one year's mortality data is not enough to show a trend, it is striking and suggestive of continuing improved longevity.

CMI report

The Continuous Mortality Investigation (CMI) carries out research into the mortality and morbidity experience of insurance portfolios and pension schemes in the UK market. The CMI's latest mortality working papers cover statistics on the morbidity experience of critical illness and income protection policies. All publications and the CMI mortality projections model are available on the CMI website: **www.actuaries.org.uk/cmi**.

British Actuarial Journal

The *British Actuarial Journal* is published in partnership with Cambridge University Press. It contains the sessional research programme of the Institute and Faculty of Actuaries along with transcripts of the discussions and debates, Presidential addresses, memoirs and papers of interest to practitioners. Three parts are published annually in March, July and September. The back catalogue (from 1995), latest issues and FirstView articles can be found at **http://journals.cambridge.org/BAJ**.

Annals of Actuarial Science

The Annals of Actuarial Science is also published in partnership with Cambridge University Press. It contains original research, review papers, case studies and book reviews covering all areas of actuarial science. It is published, twice yearly, in the spring and autumn. Papers are a mix of theoretical and applied work. The back catalogue (from 2006), latest issues and FirstView articles can be found at **http://journals.cambridge.org/AAS**.

For your diary

Mortality and Longevity Seminar 12 June 2012, 09.00 - 16.50, Hilton London Tower Bridge, London.

This seminar is open to all (booking required), but aimed at actuaries in the life and pensions industries. The pervading theme of the day will be the exploration and understanding of hot topics in the mortality and longevity arena. The majority of the sessions will focus on practical issues including:

- the practical issues in longevity de-risking
- the impact of impaired annuities
- gender discrimination on the life and pensions industries
- how actuaries can use information from other disciplines.

The day will also include more technical sessions, looking at the challenges facing actuaries in modelling and the uncertainty in mortality and longevity.

Sessional research event

The Profession's sessional research meetings allow discussion of (preliminary) results or ideas from evidence-based research among actuaries. On 24 September 2012, 17.30 – 19.00 in Staple Inn, there will be a discussion on *Mortality improvement by socio-economic circumstances in England (1981 to 2007)*, research led by Joseph Lu, Wun Wong and Madhavi Bajekal.

More information on the Profession's events can be found at: **www.actuaries.org.uk/events**.

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