Office for National Statistics

Statistical bulletin

English Life Tables No.17: 2010 to 2012

Graduated life tables which give statistics on national life expectancy for England and Wales. Published once every ten years.

Contact:
Julie Mills
lifetables@ons.gsi.gov.uk

Release date:
1 September 2015

Next release:
To be announced

Table of contents

1. Main points

- Over the last 100 years life expectancy at birth has increased by nearly 3 years per decade
- For males, life expectancy at birth increased from 51 years in 1910-1912 to 79 years in 2010-12, while for females it increased from 55 to 83 years
- Much of this increase is due to improvements in infant and child mortality in the first half of the 20th century, while gains in life expectancy at older ages have mainly occurred in the last 50 years
- People aged 60 could expect to live around 9 years longer in 2010-2012 than 100 years earlier

2. Summary

ONS has released today the English Life Tables No. 17 (ELT17), the decennial life tables for England and Wales. These tables are the seventeenth in the series which began in 1841. They provide period life expectancy for males and females by single year of age for the 3-year period centered on a census. ELT17 is produced using data from the 3-year period 2010, 2011 and 2012. The previous set of English Life Tables (ELT16) for 2000-2002 was published in June 2009.

3. Introduction

Fully graduated (smoothed) life tables have been prepared every 10 years (decennial life tables), based on the 3 years of data around a census year. They provide graduated mortality rates and statistics on period life expectancy by age and sex. These decennial life tables for males and females have been constructed based on the mortality experience of the population of England and Wales during the 3 years 2010, 2011 and 2012. The tables, denoted as ELT17, are the seventeenth in a series known as the English Life Tables which are associated with decennial population censuses. ELT17 continues a long tradition of decennial life tables; this series has been produced for 170 years beginning with the 1841 Census. The idea was conceived by William Farr, the first Medical Statistician for the General Register Office who himself produced ELT 1, 2 and 3 between 1843 and 1864. ONS commissioned the University of Southampton to prepare the English Life Table No. 17, 2010-2012.

The decennial life tables show the increasing longevity of the population of England and Wales over a long period, and they can be compared with the experience of other countries and other groups of people.

Decennial life tables have not been calculated this time for the UK constituent countries. The response to consultation with the devolved administrations indicated that there was insufficient user demand for these tables.

4. Data and construction of the English Life Table No. 17

The English Life Tables for 2010-2012 are based on data for England and Wales centered on the census year, 2011. A 3-year period is normally of sufficient length to smooth out most of the effect if the mortality experience of the census year itself happens not to be typical of the general level of mortality at the beginning of the decade.

Mortality rates are calculated from deaths and population data. The deaths are extracted from the annual deaths registration database. Apart from the calculation of mortality rates during the first year of life and at ages 90 and over, the mid-year estimates of the population for the calendar years 2010 to 2012, which take into account the results from the 2011 Census, are used to calculate age-specific death rates. The number of live births is used in the calculation of the infant mortality rate (age under 1). For ages 90 and over, single year of age population estimates which have been calculated using the Kannisto-Thatcher[1] method are used; this is a different methodology to that used for the mid-year population estimates.

For the decennial life tables, the purpose of smoothing (or graduation) is to replace the crude mortality rates by a series of graduated rates which, while forming a smooth progression over the whole age range covered, still preserves the general shape of the mortality curve. Various means of carrying out this smoothing have been applied in constructing the English Life Tables in the past. Producing the decennial life tables allows for new methods of smoothing to be developed. For the current graduation, a methodology developed by Dr Jakub Bijak, Dr Erengul Dodd, Professor Jonathan J Forster and Professor Peter W F Smith of the Statistical Sciences Research Institute, University of Southampton[2], has been used. This is explained in more detail in the section Graduation Methodology and in English Life Tables No. 17 Methodology.

As well as the usual life tables constructed from single sex mortality rates, a life table for persons has been calculated. This notional life table has been constructed assuming that 100,000 persons born are divided in the ratio 105:100 between males and females and that the resulting male and female populations develop in line with the respective single sex life tables. This table is useful for both historical and international comparisons where there are no separate figures for males and females. This table cannot be used to derive mortality rates for persons which would have any general application, since they would only reflect the mortality of a population which at any particular age has the same ratio of males to females as underlies the 'persons' table.

Notes for Data and construction of the English Life Table No. 17

1. Thatcher AR, Kannisto V and Andreev K (2002). The survivor ratio method for estimating numbers at high ages. Demography 6.

2. Bijak J, Dodd E, Forster J J and Smith P W F (2015). Statistical Sciences Research Institute, University of Southampton.

5. English Life Tables No. 17

Table 1 provides data from the English Life Tables No. 17 for selected ages. Data files of the complete life tables and an explanation of the methodology used to graduate these rates are available on the ONS website.

Table 1: Data for selected ages from English Life Table 17, 2010-12, England and Wales

Age	Males			Females		
	l_x	q_x	e_x	l_x	q_x	e_x
0	100,000	0.00475	78.97	100,000	0.00381	82.80
10	99,403	0.00009	69.43	99,516	0.00007	73.19
20	99,195	0.00050	59.57	99,393	0.00020	63.27
30	98,636	0.00073	49.87	99,141	0.00036	53.42
40	97,668	0.00147	40.31	98,599	0.00086	43.68
50	95,635	0.00311	31.05	97,292	0.00214	34.19
60	90,975	0.00802	22.35	94,082	0.00533	25.17
70	80,300	0.02069	14.56	86,773	0.01331	16.81
80	57,096	0.05740	8.22	69,035	0.04070	9.65
90	19,903	0.16814	4.07	31,496	0.13509	4.72
100	1,098	0.36187	2.05	2,823	0.32134	2.29

Source: Office for National Statistics

Notes:

1. lx is the number of survivors to exact age x of 100,000 live births of the same sex who are assumed to be subject throughout their lives to the mortality rates experienced in the three year period 2010-2012

2. qx is the mortality rate between age x and (x +1), that is the probability that a person aged x exactly will die before reaching age (x +1)

3. ex is the average period expectation of life at exact age x, that is the average number of years that those aged x exactly will live thereafter based on the mortality rates experienced in the 3-year period 2010-2012

ELT17 shows that female life expectancy is higher than male life expectancy at every age, although the differential decreases by age; at birth a female would have had an extra 3.8 years to live compared to a male, but by age 60 this had decreased to 2.8 years.

Table 1 also shows that as we age, the probability of surviving to older ages increases. For example a female aged 70 in 2010-12 could, on average, expect to live a further 16.8 years to age 86.8, a further 4 years than at birth. Based on the mortality experience for 2010-12 analysed in this life table 20% of males and 31% of females are expected to survive to celebrate their 90th birthdays.

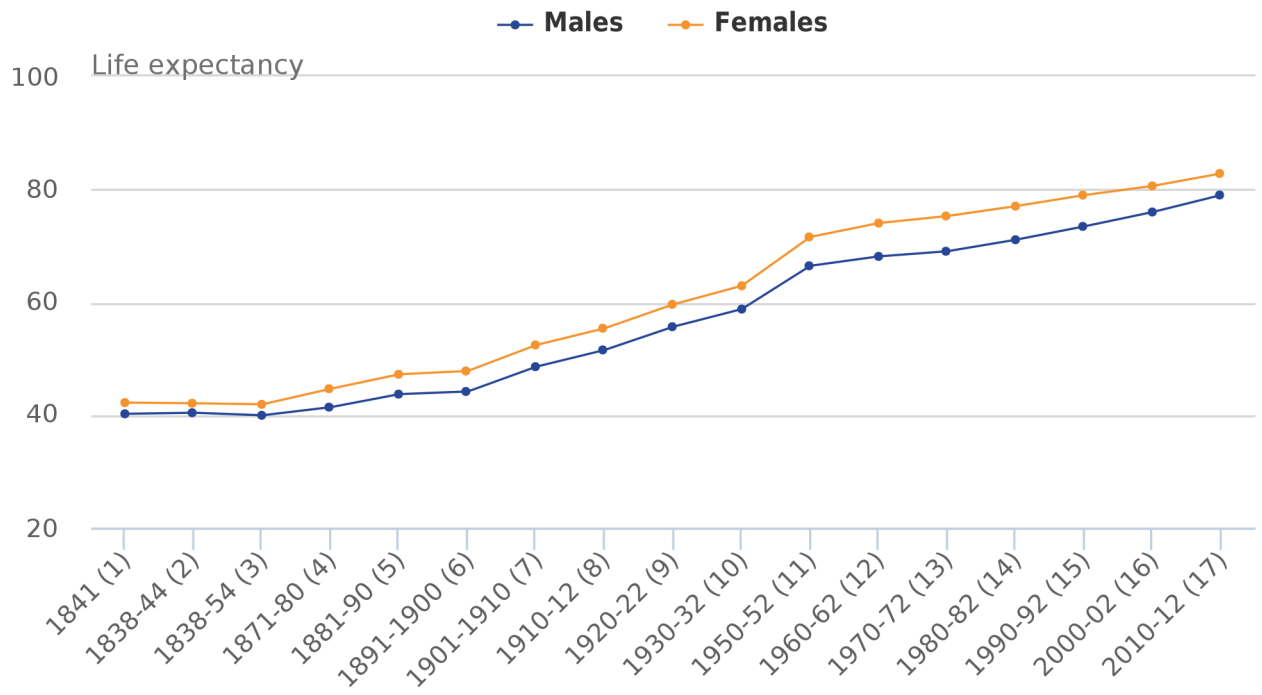
Changes in life expectancy

The data presented in the decennial life tables represent a snapshot of the mortality of the population in England and Wales at a particular point in time; they do not show the likely experience of any particular generation. However, in spite of this, expectations of life based on such period measures (period expectations of life) form a convenient summary measure of the overall effects of changes in mortality.

One way of illustrating the reductions in death rates is to show the increase in expectation of life at birth. Figure 1 shows how period life expectancy at birth has changed since the first ELT for 1841. There are 3 distinct periods of change, a slow increase over the last half of 19th century followed by faster increases during the first half of the 20th century, then returning to a slower, but steady increase since 1950. The larger increases seen in the first half of the 20th century are mostly because of the reduction in infant and childhood mortality, while the continued increases since 1950 are mainly driven by improvements in mortality at older ages, due to, for example, a decline in smoking prevalence and improvements in medical technology.

Figure 1: Period expectation of life at birth (years), from English Life Tables (ELT) No.s 1 to 17

Based on data for England and Wales, 1841 to 2010-2012



Source: Office for National Statistics

Table 2 presents the period expectations of life for England and Wales over the last hundred years 1910-12 to 2010-12. The figures are taken from the English Life Tables derived from the mortality experience in each of the periods shown.

Table 2: Period expectation of life, England and Wales, 1910-12 to 2010-12

Age x	ELT8	ELT10	ELT11	ELT12	ELT13	ELT14	ELT15	ELT16	ELT17
	1910-1912	1930-1932	1950-1952	1960-1962	1970-1972	1980-1982	1990-1992	2000-2002	2010-2012
Males									
0	51.50	58.74	66.42	68.09	69.00	71.04	73.41	75.96	78.97
10	53.08	55.79	59.24	60.21	60.74	62.19	64.20	66.53	69.43
20	44.21	46.81	49.64	50.57	51.08	52.50	54.45	56.73	59.57
30	35.81	38.21	40.27	41.06	41.51	42.90	44.88	47.16	49.87
40	27.74	29.62	30.98	31.62	32.01	33.34	35.35	37.66	40.31
50	20.29	21.60	22.23	22.68	23.11	24.26	26.16	28.45	31.05
60	13.78	14.43	14.79	15.06	15.41	16.38	17.85	19.90	22.35
70	8.53	8.62	9.00	9.29	9.50	10.12	11.19	12.56	14.56
80	4.90	4.74	4.86	5.25	5.54	5.78	6.44	7.11	8.22
Females									
0	55.35	62.88	71.54	74.00	75.25	77.00	78.96	80.59	82.80
10	55.91	58.87	63.87	65.77	66.71	67.97	69.61	71.08	73.19
20	47.10	49.88	54.17	55.95	56.89	58.12	59.75	61.19	63.27
30	38.54	41.22	44.68	46.23	47.13	48.34	49.94	51.37	53.42
40	30.30	32.55	35.32	36.69	37.52	38.67	40.24	41.66	43.68
50	22.51	24.18	26.34	27.57	28.41	29.39	30.85	32.23	34.19
60	15.48	16.50	18.07	19.11	19.98	20.89	22.08	23.32	25.17
70	9.58	10.02	10.97	11.78	12.56	13.41	14.49	15.24	16.81
80	5.49	5.46	5.83	6.39	6.98	7.50	8.41	8.71	9.65

Source: Office for National Statistics

Over the 100 years covered by Table 2, the period expectation of life at birth, rose from 51 to 79 years for boys and 55 to 83 years for girls, an increase of more than 27 years for both. More than half of the gain in life expectancy at birth occurred in the first 50 years of the table, mainly due to the improvements in infant and childhood mortality discussed above. In 1910-12 (ELT8) life expectancy at age 10 was higher than at birth reflecting the higher rates of infant and childhood mortality. Similarly when looking at life expectancy by single year of age, life expectancies for males at ages below 10 are higher than at birth. For example, in 1920-22 at ages up to 8, then in 1930-32 up to ages 6 and it is not until 1980-82 (ELT14) that life expectancy at birth is higher than at age 1.

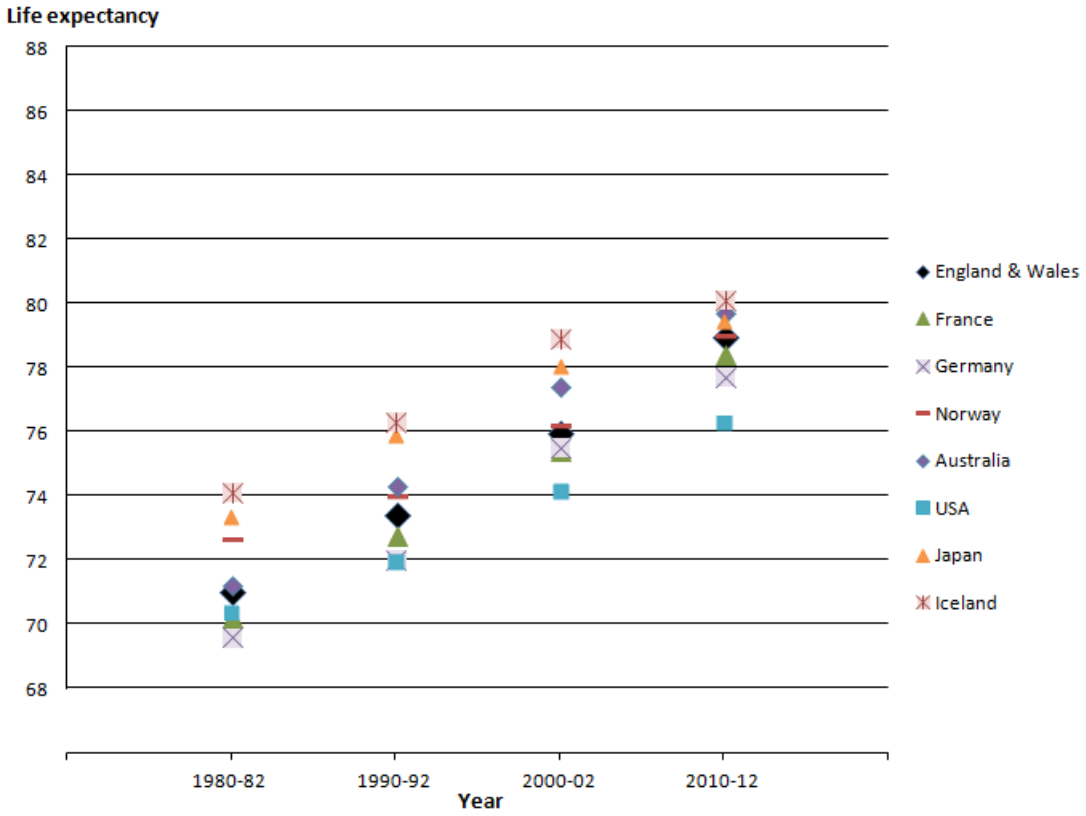
For both men and women, life expectancy at age 60 has increased by around 9 years since 1910-12. The gains in life expectancy at older ages have mainly occurred in the last 50 years, particularly for males.

6. International comparison of life expectancy at birth

Figures 2 and 3 compare the life expectancy at birth in England and Wales with that seen in a number of countries (selected on the availability of data) from around the world.

Figure 2: Life expectancy at birth (years) for selected countries, per decade, 1980-82 to 2010-12

Males



Sources: Australian Bureau of Statistics, Statistics Bureau of Japan, Statistics Norway, ONS, Federal Statistical Office of Germany, National Institute of Statistics and Economic Studies - France, Statistics Iceland and U.S Census Bureau

Notes:

1. Countries selected by availability of data
2. Life expectancies for England and Wales are from ELT17

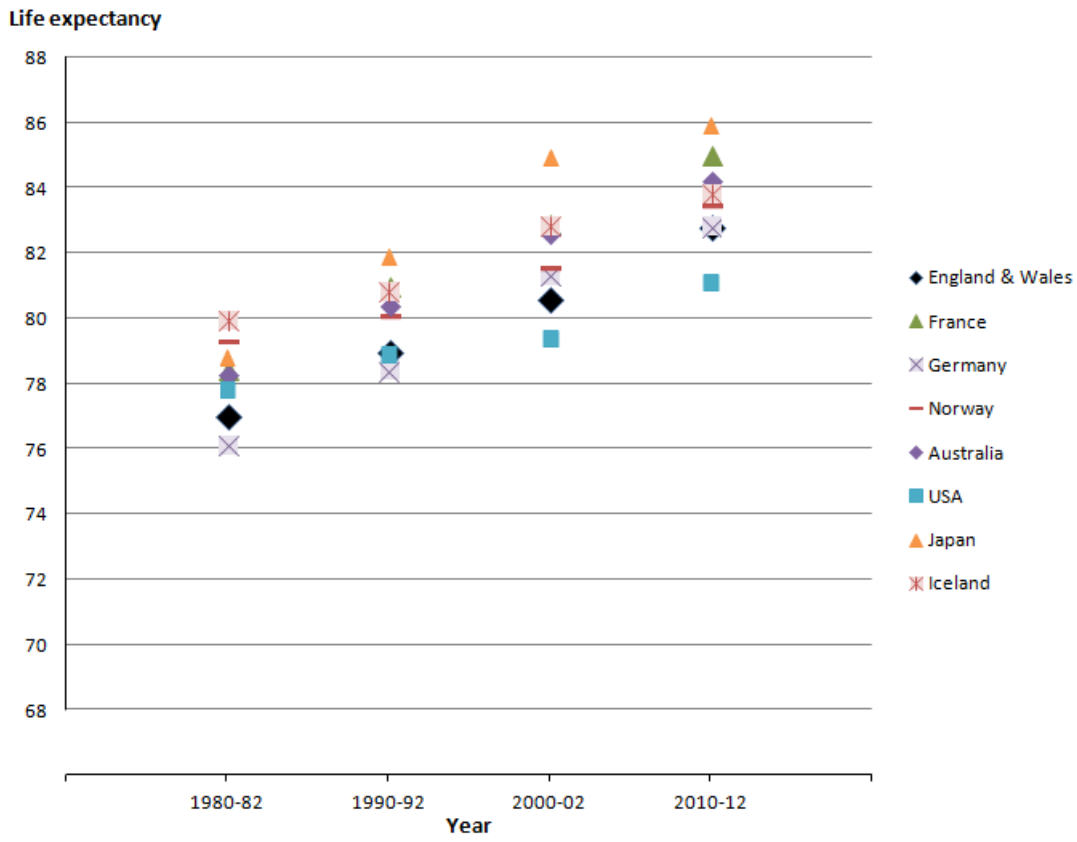
Over the 30 year period since 1980-82, period life expectancy at birth has risen in every country shown in Figure 2. In relation to the other 7 countries shown, males in England and Wales remained about mid-table although with an increase of 8 years they have moved closer to Iceland, the longest lived country shown, and have ‘caught up’ with Norway. In 1980-82 life expectancy at birth for males in Norway was 1.6 years higher than for males in England and Wales; in 2010-12 there was little or no difference.

However, some of the other countries have seen substantial changes. For example Australia which had a similar life expectancy at birth to England and Wales in 1980-82, has had the largest increase of the 8 countries (8.5 years) in the 30 years since 1980-82. By 2010-12 Australia, at 79.7 years, had a life expectancy at birth above that of Japan (79.4) whereas in 1980-82 it was 2.1 years lower. At the other end of the table, the USA has fallen back relative to the other countries. In 2010-12, the USA, at 76.3 years, was lagging 1.4 years behind Germany’s 77.7 years. In 1980-82 it was a different story, with Germany’s life expectancy at birth for males being 0.8 years below the USA.

France, Germany and Australia have all experienced similar increases to that for males in England and Wales, while Iceland and Japan had lower increases of just 6 years. Perhaps this indicates a certain level of catching up for males in England and Wales with Iceland and Japan and certainly shows the potential for future rises in life expectancy.

Figure 3: Life expectancy at birth (years) for selected countries, per decade, 1980-82 to 2010-12

Females



Sources: Australian Bureau of Statistics, Statistics Bureau of Japan, Statistics Norway, ONS, Federal Statistical Office of Germany, National Institute of Statistics and Economic Studies - France, Statistics Iceland and U.S Census Bureau

Notes:

1. Countries selected by availability of data
2. Life expectancies for England and Wales are from ELT17

For females there have been increases in period life expectancy at birth in each of the countries shown in Figure 3. Females in England and Wales do not appear to be doing as well relative to the other countries as their male counterparts and have remained second lowest in 3 of the periods shown. In 1990-92 England and Wales just edged above females in the USA by 0.1 years and by 2000-02 the USA replaced Germany at the bottom of the table. Life expectancy at birth for all the countries shown has been higher for females than males in every decade, however the increases over the 30 years since 1980-82 have mostly been smaller than those seen for males. Only in Japan has the increase been larger for females than males.

Japan has had the largest increase of 7.1 years from 78.8 years in 1980-82 to 85.9 years in 2010-12. For females in England and Wales life expectancy at birth rose by 5.8 years, from 77.0 years to 82.8 years over the same period. Of the 8 countries shown in Figure 3, Japanese females have risen from third highest to highest and Icelandic females have fallen from highest to fourth highest.

7. National Life Tables

The English Life Tables provide a valuable time series which can be used to monitor trends in mortality in England and Wales over a long period of time. However, these tables are only calculated once every 10 years and the graduation process carried out is usually complex. The Office for National Statistics also produces annual life tables, known as National Life Tables, for the United Kingdom and constituent countries. These are based on mortality data for 3 consecutive calendar years combined (as for the decennial life tables). However the mortality rates used in these tables are not graduated, so that we can produce them in a more timely fashion. Mortality rates in these tables are only published to age 100 as the crude mortality rates at older ages are very variable both between ages and between years because of the low numbers of people alive and, correspondingly, the low numbers of deaths at ages above 100. The tables are closed off at age 110 (that is, it is assumed that everyone dies by age 110). Hence the National Life Tables do not provide a good indicator of the levels of and trends in mortality rates at the very oldest ages.

Table 3 presents life expectancy figures from the English Life Tables and the National Life Tables covering the same periods for males and females for selected ages. The differences in the life expectancy figures calculated in the 2 tables are small. This begs the question as to why we calculate the decennial life table, when the National Life Tables are calculated using a much simpler methodology and are more timely.

Table 3: Comparison of period life expectancy in the English and National Life Tables, England and Wales

Age x	ELT14	ELT15	ELT16	ELT17			National Life Tables	
	1980-1982	1990-1992	2000-2002	2010-2012	1980-1982	1990-1992	2000-2002	2010-2012
Males								
0	71.04	73.41	75.96	78.97	71.04	73.36	75.86	78.96
10	62.19	64.20	66.53	69.43	62.19	64.14	66.44	69.43
20	52.50	54.45	56.73	59.57	52.49	54.40	56.66	59.57
30	42.90	44.88	47.16	49.87	42.90	44.84	47.11	49.87
40	33.34	35.35	37.66	40.31	33.33	35.32	37.62	40.31
50	24.26	26.16	28.45	31.05	24.26	26.13	28.42	31.05
60	16.38	17.85	19.90	22.35	16.39	17.82	19.87	22.34
70	10.12	11.19	12.56	14.56	10.12	11.16	12.54	14.56
80	5.78	6.44	7.11	8.22	5.78	6.38	7.11	8.22
Females								
0	77.00	78.96	80.59	82.80	77.00	78.87	80.53	82.79
10	67.97	69.61	71.08	73.19	67.97	69.52	71.03	73.19
20	58.12	59.75	61.19	63.27	58.12	59.66	61.15	63.27
30	48.34	49.94	51.37	53.42	48.34	49.85	51.34	53.42
40	38.67	40.24	41.66	43.68	38.67	40.15	41.63	43.68
50	29.39	30.85	32.23	34.19	29.39	30.76	32.21	34.19
60	20.89	22.08	23.32	25.17	20.89	21.98	23.29	25.16
70	13.41	14.49	15.24	16.81	13.41	14.38	15.22	16.80
80	7.50	8.41	8.71	9.65	7.50	8.26	8.71	9.64

Source: Office for National Statistics

Firstly, although the life expectancies are very similar, the crude mortality rates in the National Life Tables are very variable from age to age particularly at the youngest and oldest ages. Indeed one of the reasons for producing graduated mortality rates is to smooth fluctuations in the progression of mortality rates by age.

The tables are also of historical significance. All the decennial life tables have produced graduated mortality rates (albeit using different methods) which better reflect the underlying mortality rates in the population for the periods in question. Hence, they form a long series which can be used for a variety of research purposes such as determining trends in mortality rates in the England and Wales population.

Furthermore the research that accompanies the production of the decennial life table has wider application. As the population estimates produced around a census are generally thought to be the most accurate, the years around a census year provide the best data to produce graduated life tables. When producing the decennial life tables, current methods and new developments regarding the graduation (smoothing) of mortality data are explored, which are currently not used in the calculation of the National Life Tables. This allows the latest modelling techniques to be investigated and used to produce estimates of the underlying mortality rates, particularly at the oldest ages, where data are sparse, and extrapolated to very high ages. For ELT17 mortality rates were modeled up to age 125 (although there are no actual data above age 114). Mortality rates in the National Life Tables are only published up to age 100 due to the uncertainty of mortality rates at very high ages. The decennial life tables provide a better progression of mortality rates at these ages and, indeed, are the only officially published mortality rates by single year of age above age 99. The methodology used for graduating the life tables can be used in a variety of other circumstances and is in itself of interest to researchers. There is currently a lot of interest in mortality at the oldest ages and the estimates of mortality rates at the oldest ages can be very helpful to demographers, academics and other researchers working in this area.

Finally comparisons of the figures in the decennial life tables and the National Life Tables provide assurance that the National Life Tables are ‘fit for purpose’.

8. Graduation Methodology

English Life Tables have been produced on a regular basis since 1843. Over that time the opportunity has been taken to use different methods for graduating the data as statistical methodologies have become more sophisticated and computation more straightforward.

As in previous decennial life tables, the values graduated are the crude central rates of mortality, m_x, where m_x = sum of the deaths aged x at death in 2010, 2011 and 2012 divided by the sum of the mid-year population estimates aged x in 2010, 2011 and 2012. For ELT17 it is firstly assumed that the number of deaths at each age, Y_x, can be modelled using a negative bionomial where

$$Y_x \sim NB(E_x^C m_x, \alpha)$$

where m_x are smooth underlying central mortality rates and is a measure of the dispersion, or heterogeneity, of the data. A generalised additive model, specifying log mx as a linear combination of basis splines is then fitted to the data using a method to provide an optimal fit to the data but allowing for a specified degree of smoothness. This is done by incorporating a term in the fitting process which is a function of the roughness of the resulting fit. The amount of penalisation chosen controls the smoothness of the resulting fit and in this case was chosen by a method of cross validation. The graduated estimates of m_x are simply the fitted values from this generalised additive model.

This approach provides a reasonably smooth function which also fits acceptably well to the crude mortality rates in the observed data for most ages. However, at the oldest ages there is considerable uncertainty about the mortality rates given the low numbers of people and deaths. Estimating mortality rates at the very oldest ages requires extrapolation of the splines which can be problematic where data are sparse.

In order to extrapolate mortality rates at the oldest ages, two models for mortality at the ages above x_0 (some threshold age to be determined), are considered:

Model 1: Gompertz model where

$$\log m_x = \beta_0 + \beta_1 x$$

for $x >= x_0$, and

Model 2: Logistic model where

$$m_x = \exp(\beta_0 + \beta_1 x)/[1 + \exp(\beta_0 + \beta_1 x)]$$

for $x >= x_0$.

For both models, the graduated mortality rates are provided by the generalised additive model fitted values for $x < x_0$.

This provides a set of models depending on a choice of threshold age, x0 , where the model transitions to the assumed model for old age mortality and a choice of a Gompertz or logistic model for the old age mortality.

Each model is then evaluated on the basis of how well it predicts a set of data (the validation data) using a separate set of data (the training data). In this case the number of deaths by age for 2010 and 2012 formed the training data and the numbers of deaths for 2011 the validation data. Probabilities are then computed, which account for the extent to which the data support different values of threshold age, x_0, and each of the two models, using a Bayesian approach. The final graduations of m_x then represent a weighted average of the values produced by each model and threshold age. This method is carried out separately for males and for females.

This method is explained in more detail in English Life Tables No. 17 Methodology [1].

Notes for Graduation Methodology

1. Bijak J, Dodd E, Forster J J and Smith P W F (2015). Statistical Sciences Research Institute, University of Southampton

9. Uses of life tables

Life tables provide analysis of the mortality experience of a population and are used to calculate average life expectancy.

Key uses:

- to study the course of mortality throughout the life cycle,
- as an indicator of the health of the nation,
- to inform policy regarding state pension age, and
- to assess risk for life assurance and pension liability.

Within ONS, life tables are used to inform the assumptions of future mortality for the National Population Projections.

Other organisations that use life tables include:

Other government departments:

- Government Actuary's Department,
- Department of Work and Pensions,
- Department of Health and Health Authorities,
- National Records of Scotland, Northern Ireland Statistics and Research Agency, and Welsh Assembly, and
- HM Treasury.

Non-government organisations:

- universities – academics and students,
- news media,
- financial advisors/consultants,
- insurance companies and actuarial professions, and
- the general public.

10. Background notes

1. Figures in the tables in this bulletin and commentary are rounded to one decimal place. Calculations in this bulletin use unrounded figures.

2. The English Life Tables for the years 2010-2012 take into account the rebased population estimates following the 2011 Census.

3. Details of the policy governing the release of new data are available by visiting www.statisticsauthority.gov.uk/assessment/code-of-practice/index.html or from the Media Relations Office email: media.relations@ons.gsi.gov.uk

   These National Statistics are produced to high professional standards and released according to the arrangements approved by the UK Statistics Authority.