Australian
Life Tables
2015-17

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DEFINITIONS OF SYMBOLS

Australian Life Tables 2015-17 sets out the following functions:

l_x = the number of persons surviving to exact age x out of 100,000 births

d_x = the number of deaths in the year of age x to (x + 1) among the l_x persons who are alive at the beginning of that year

p_x = the probability of a person aged exactly x surviving the year to age (x + 1)

q_x = the probability of a person aged exactly x dying before reaching age (x + 1)

μ_x = the force (or instantaneous rate) of mortality at exact age x

$\mathring{e}_x$ = the complete expectation of life (that is, the average number of years lived after age x) of persons aged exactly x

L_x = the total number of years of life experienced between age x and (x + 1) by l_x persons aged exactly x

T_x = the total number of years of life experienced after age x by l_x persons aged exactly x

NOTE: Figures in the Tables are rounded and hence the usual identities between these functions may not be satisfied exactly.

INTRODUCTION

This publication presents the *Australian Life Tables 2015-17* (the Tables), which are based on the mortality of male and female Australians over the three calendar years centred on the 2016 Census of Population and Housing (the Census).

The report discusses the major features of the 2015-17 Life Tables and reviews developments in mortality since the previous Australian Life Tables and also over the longer term. A number of measures of longevity are considered and the historic rates of decline in mortality rates are used to estimate mortality improvement factors. The impact of mortality improvement on life expectancies and the lifespan distribution is also considered.

This discussion is followed by the Tables themselves, together with the technical notes on their construction. The appendices include supporting information referred to in the text.

The Tables are also available on the AGA website (www.aga.gov.au) together with past mortality rates and life expectancies and the mortality improvement factors referred to in the body of the report.

This is the nineteenth in the series of official Australian Life Tables. Tables were initially prepared by the Commonwealth Statistician, but since the 1946-48 Tables, the construction of the Australian Life Tables has been the responsibility of the Australian Government Actuary (or Commonwealth Actuary as the position was formerly designated). The first three Tables, for the years 1881-90, 1891-1900 and 1901-10, took into account deaths over a ten year period and incorporated information from two Censuses. All subsequent Tables have been based on deaths and estimates of population over a period of three years centred on a Census. Since 1960-62, the Censuses, and hence the Tables, have been produced quinquennially.

Guy Thorburn FIAA
Australian Government Actuary

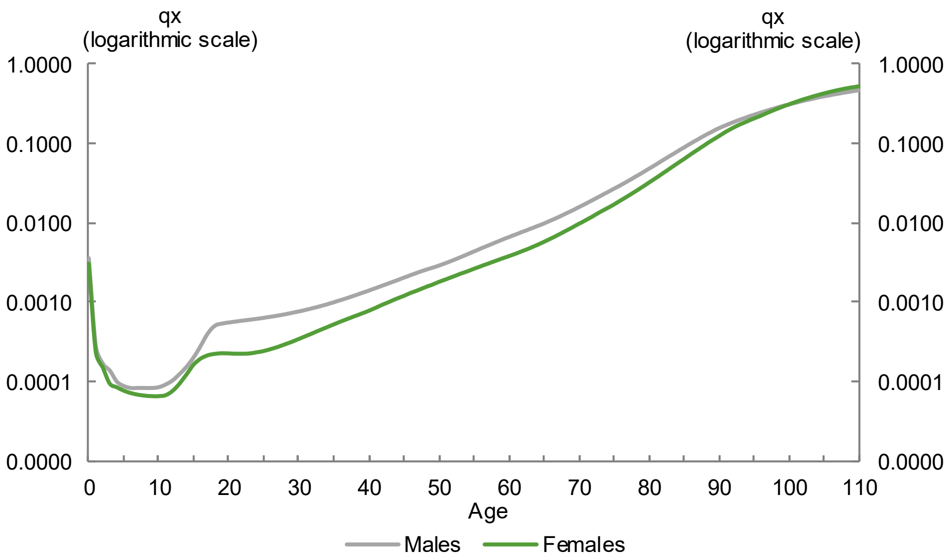
December 2019

1. Mortality of the Australian population

1.1 Results for 2015-17

Figure 1 shows the mortality rates reported in the 2015-17 Life Tables on a logarithmic scale.

Figure 1: Mortality rates 2015-17



The pattern of mortality observed in Figure 1 is typical of developed countries. Mortality rates during the first year of life are relatively high for both males and females, primarily due to congenital abnormalities and perinatal conditions. After the first year of life, an increasing capacity to ward off disease and limited exposure to life threatening situations results in rapidly dropping mortality rates. The mortality rates reach a minimum during school ages (6 to 12 years) where the probabilities of dying within the year are all less than 1 in 10,000 for both males and females.

Accidents are the single largest cause of death in childhood. With the developing autonomy of the teenage years, mortality attributable to accidental or self-inflicted causes increases steeply, particularly for males. This growth slows in the early twenties (and for females is briefly reversed), before rates start to rise again as the falling mortality from accidents is more than offset by increasing rates of death due to disease.

The shape of the curves around ages 18 to 21 has not changed greatly since the 1990-92 Tables, when the previous 'accident hump' flattened for the first time in several decades.

The shapes of the mortality curves for males and females are similar, but the absolute rates are different, with female mortality being less than male mortality at all but the oldest ages. This difference is consistent with a number of factors, including:

- a greater level of risk-taking behaviour by young males;
- the greater hazards associated with some occupations which have traditionally been dominated by men (such as mining and construction);
- the differences in the incidence of some diseases between men and women; and
- the differences in fatality from diseases which affect both genders.

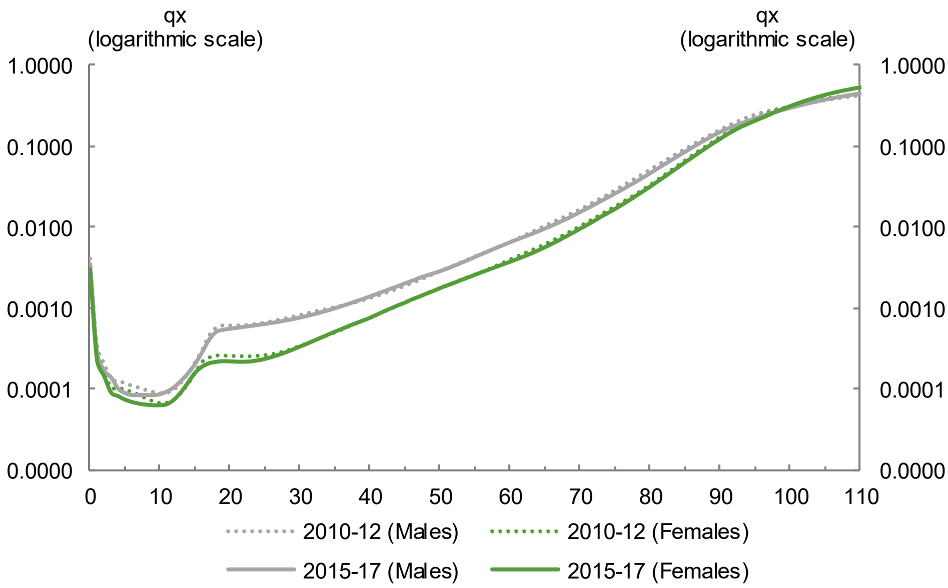
The first two of these factors relate to behavioural differences, including gender stratification in the labour force, rather than physiological differences between men and women. Physiological differences may, however, in part explain the behavioural divergence. The latter two factors could be expected to be the result of both physiological and lifestyle differences.

Mortality rates at the very oldest ages are subject to a higher level of uncertainty due to the smaller cohort of Australians reaching these ages. The ‘crossover’ observed in Figure 1 has occurred to some degree in each of the Australian Life Tables since the 1990-92 Table and also occurred periodically in earlier tables.

1.2 Changes since 2010-12

Figure 2 charts the mortality rates from the current Tables together with those reported 5 years earlier. It shows that mortality rates have fallen at almost all ages. There are two exceptions where mortality rates have increased slightly, the first being males in their forties and the second occurring for both males and females at very advanced ages. The increase in mortality rates at advanced ages was also observed in the last two reports.

Figure 2: Mortality rates 2010-12 and 2015-17



Infant mortality continued to fall, as it has in every set of published Tables. Since the previous Tables, infant mortality has fallen by around 3 per cent and 2 per cent per annum for males and females respectively.

Mortality in the childhood years has also improved; however, the number of deaths observed at these ages is very small. The predominant causes of death during childhood were injuries and cancer. There is a high variability in the number of deaths reported at these ages. As a consequence, the shape of the smoothed mortality curve may be impacted by this variability and a limited significance should be attached to the changes in mortality at individual ages.

Whilst there has been limited improvement in mortality in the early teenage years, both male and female mortality rates have decreased more substantially over the later teenage and young adult ages, most notably for females in their late teens and early twenties. Three and four decades ago, there was a clear peak in male mortality around age 20, with mortality rates roughly comparable to those applying to males 20 years older. This phenomenon is known as the accident hump. A similar, but less distinct peak also existed in female mortality. While rates still increase substantially over the teenage years, the improvement in mortality for those in their early twenties means there is no longer the same distinct peak. This is, however, the age group with the greatest disparity between male and female rates and, as illustrated in Figure 4 overleaf, the gap remains significant.

Over the period since 2010-12 there has been a small improvement for females in their late thirties and early forties; however, male mortality deteriorated slightly in the late thirties and forties. There was also a noticeable improvement in mortality rates between ages 65 and 95 for both males and females.

Figure 3 shows the average percentage improvement in mortality rates over the 5 years following the 2010-12 Tables by gender for 5 year age bands.

Figure 3: Percentage improvement in mortality since 2010-12 by gender

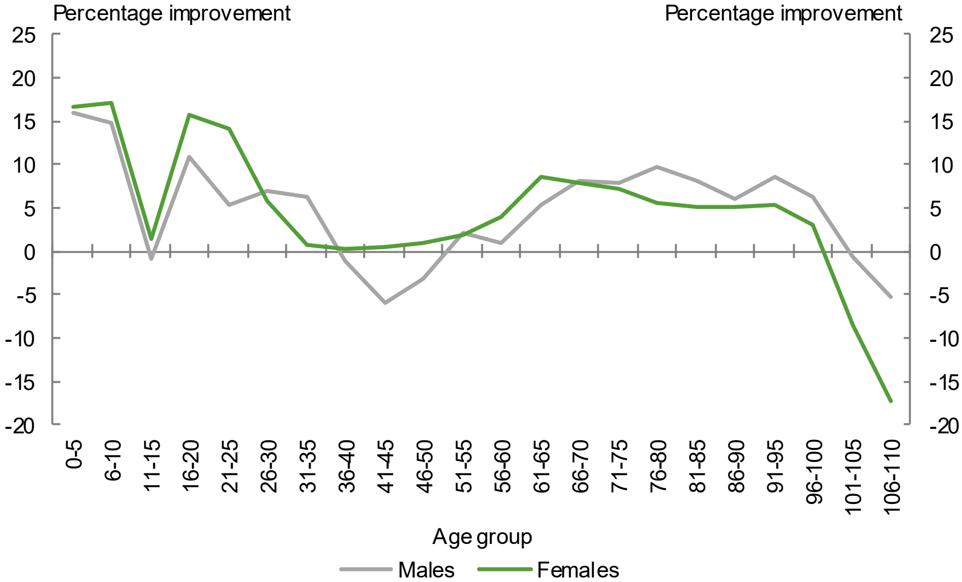
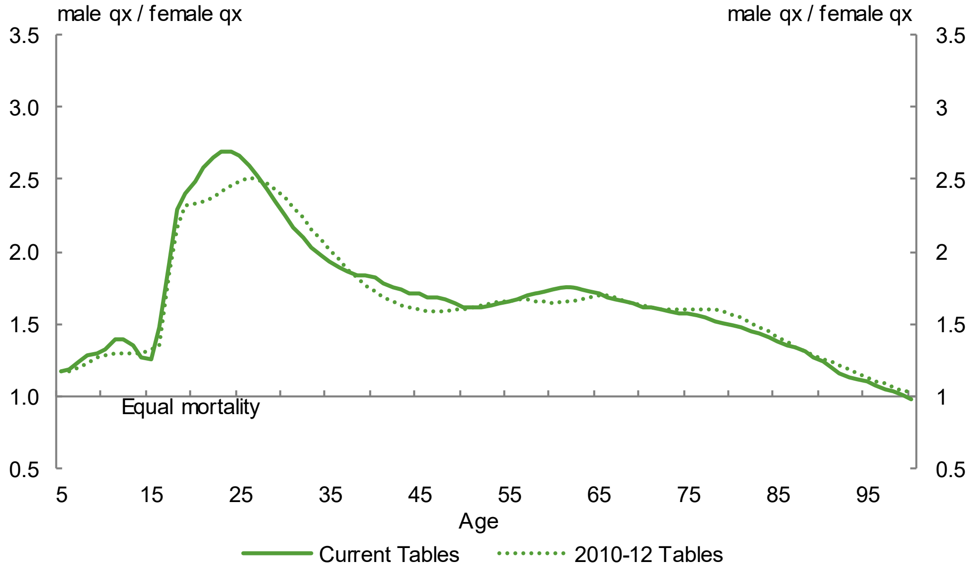


Figure 3 suggests that the improvement in mortality has primarily occurred in three main age groups: ages up to 10, ages 16 to 30, and ages 60 to 99. There is mortality deterioration or negligible mortality change for males aged 38 to 49 and females aged 36 to 50. In general, mortality rates have improved at a slower rate over the 5 year period since 2010-12 compared with the preceding 25 years. In particular, mortality improvement slowed from age 30 to 95.

In last two Life Tables there was evidence of mortality deterioration at the mid and late nineties, but this trend has not persisted. Mortality rates have improved for these ages compared with the previous Table. For centenarians, however, we continue to find evidence of mortality deterioration, as occurred in the previous two reports. We do not currently have enough evidence to verify the recent trend of mortality rates for advanced ages, but it will be interesting to see whether this trend at the oldest ages persists.

Figure 4 compares the gender differential in mortality rates for the current and previous Table. At most ages there has been little change, indicating that male and female mortality rates have broadly been improving in tandem. One noticeable exception is the early adult years where higher rates of improvement in female mortality have led to a noticeable increasing of gap relative to the previous table.

Figure 4: Ratio of male to female mortality rates — Ages 5 to 100, 2010-12, 2015-17



1.3 Past improvements in mortality

The first official Life Tables for Australia were prepared based on data from the period 1881-90 and there is now a history of 130 years of mortality data. Figure 5 plots the change in mortality rates over time expressed as a percentage of the rates reported in 1881-90. The data for the four ages shown clearly illustrates the diversity of experience for different ages and genders.

Figure 5: Improvements in mortality at selected ages

Age 0

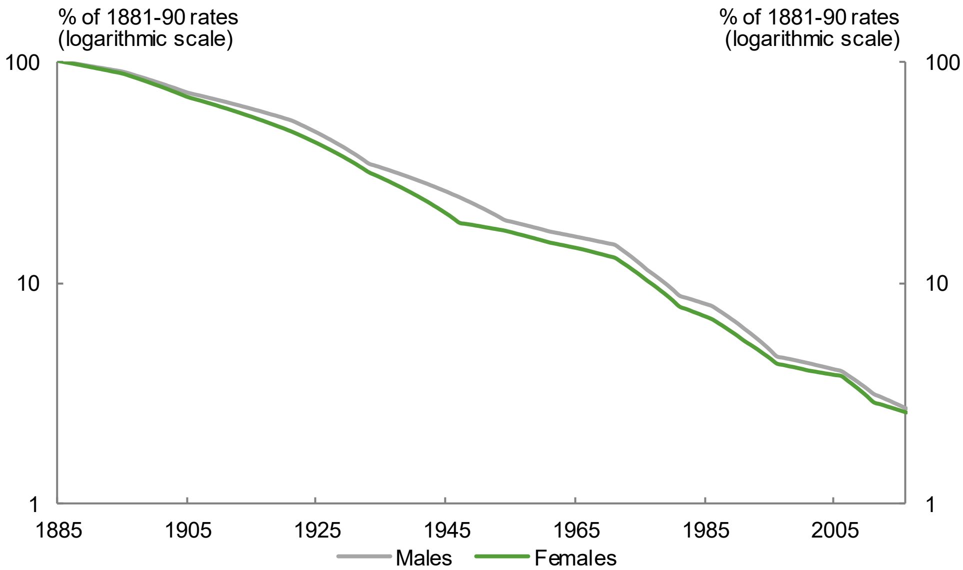
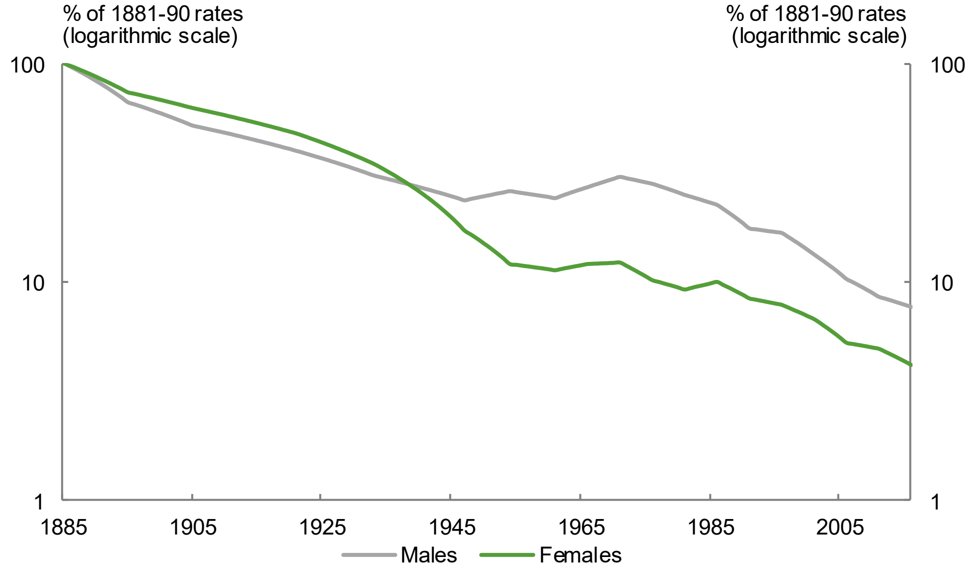


Figure 5: Improvements in mortality at selected ages (continued)

Age 20



Age 65

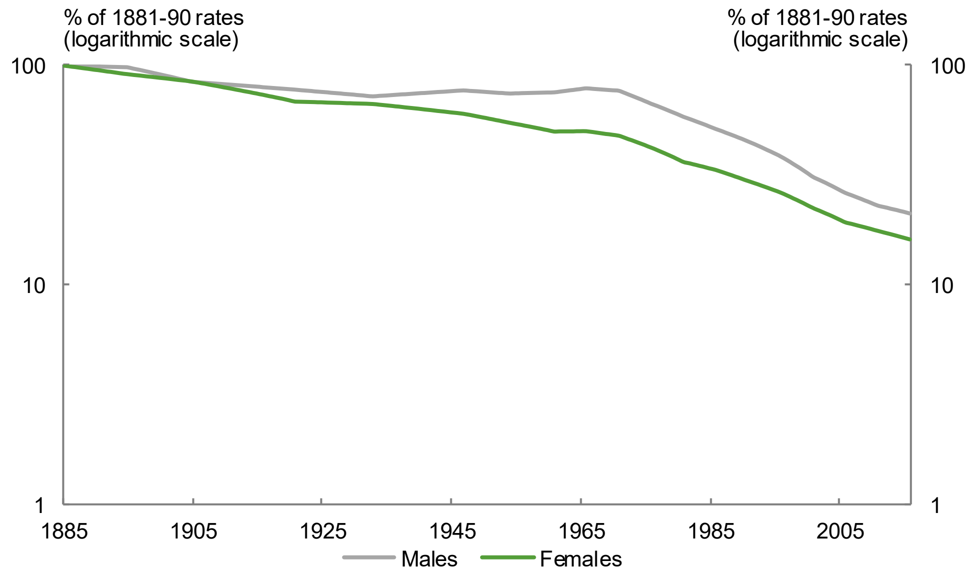
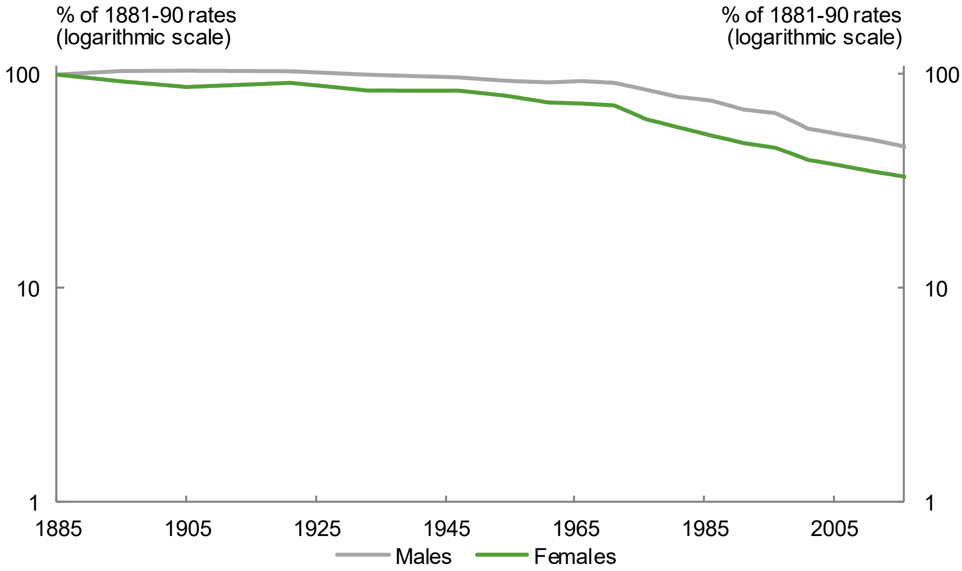


Figure 5: Improvements in mortality at selected ages (continued)
Age 85



Infant mortality has shown a sustained and substantial improvement over the entire period, with the improvement for males and females moving closely in parallel. The rates for both males and females are now around 2.6 per cent of their level in 1881-90 and are still steadily declining. They do not appear to have reached an underlying minimum rate.

The picture at age 20 is quite different, with male rates initially improving marginally more quickly than female rates but then deteriorating from about 1945 to 1970 as the accident hump emerged, before declining again as the accident hump subsided and then disappeared. For females at this age, the biggest improvements occurred from the 1930s to the 1950s and probably reflected improved maternal mortality experience as medical procedures were reformed and became accessible to more of the population. Mortality rates for 20 year old females are about 4 per cent of the corresponding rates from 130 years ago. For males of the same age, the relativity is around 8 per cent.

At age 65, the rate of improvement was relatively slow for both males and females until around 1965. This is consistent with the benefits of medical advances up to that time primarily accruing to the young. Since the mid-1960s, however, mortality rates for 65 year olds have been reduced by two-thirds. Male rates for 65 year olds in the 2015-17 Tables are about a fifth of the corresponding rates from the original Tables, while for females the 2015-17 rates are around 16 per cent of the corresponding rates.

The final chart shows the improvement in rates at age 85. Again, mortality rates at this age showed minimal improvement until the mid-1960s. Since then, there has been a steady improvement in mortality leading to mortality rates for males that are roughly half what they were 130 years ago. For females, the rates are now a third of what they were.

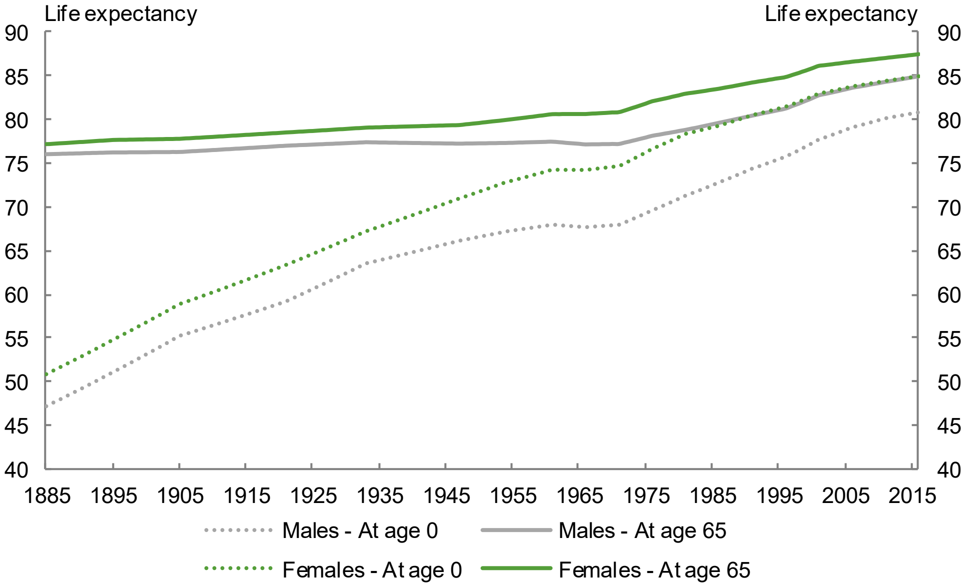
1.4 Longevity

One natural corollary of improving mortality is increasing longevity. Increased longevity has significant implications, both for individuals trying to estimate the resources needed for retirement and governments dealing with rising pension and health and aged care obligations.

There are a number of measures of longevity. The most commonly used is life expectancy, which measures the average number of years that would be lived by a representative group of individuals of the same age if they experienced mortality at given rates.

Figure 6 shows how the improvements in mortality described in the previous section have translated into longer life expectancies as reported in the relevant Life Tables (Appendix A sets out the numbers on which this figure is based). Note that these reported life expectancies are known as period life expectancies and do not make allowance for any future improvements in mortality which might be experienced over a person's lifetime. In other words, they are based on the assumption that the mortality rates reported in a particular set of Tables would continue unchanged into the future and, as such, represent a summary of mortality at a particular point in time rather than a projection of mortality over future periods. The impact of continuing mortality improvement is discussed in the next section.

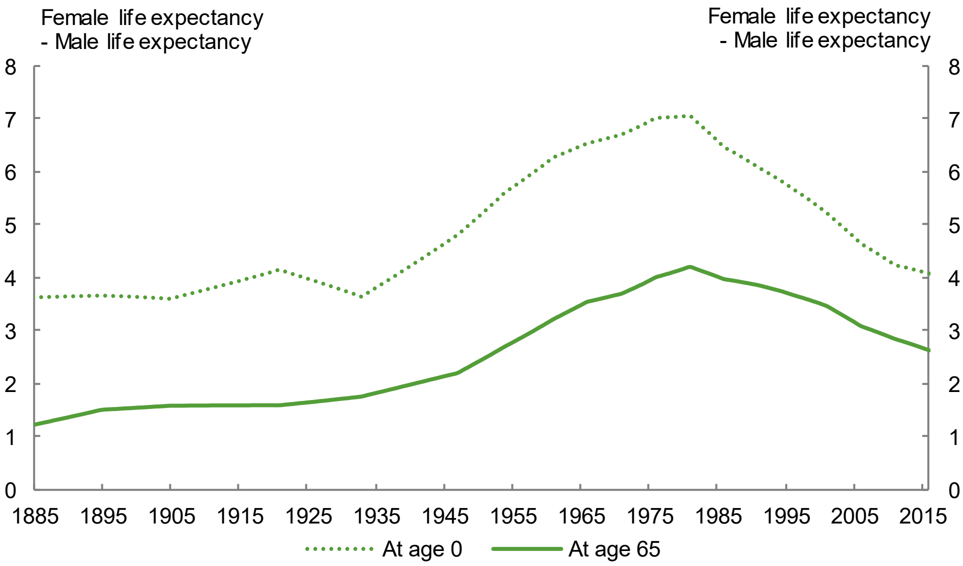
Figure 6: Total life expectancy at selected ages



Period life expectancy at birth has shown dramatic improvement since the inception of the Life Tables, increasing by over 30 years for both males and females. Even at older ages, the substantial improvements in mortality rates for this group over the past 40 years have flowed through into significantly increased life expectancies. For example, life expectancy at age 65 has increased by nearly nine years (nearly 80 per cent) for males and ten years (more than 80 per cent) for females.

Figure 7 plots the gap between reported male and female life expectancies at birth and age 65. It shows that over the first third of the twentieth century, male and female life expectancies moved roughly in parallel, with the gap at birth steady at around four years. The gap at age 65 was steady at around one and a half years during this period. From about 1930, the gap widened for both ages, reaching a maximum in the 1980-82 Tables. Since then, the differential has been declining for both ages. At birth, the gap has declined by almost three years from its peak, falling to levels last seen around 75 years ago.

Figure 7: Gender differentials in life expectancy at selected ages

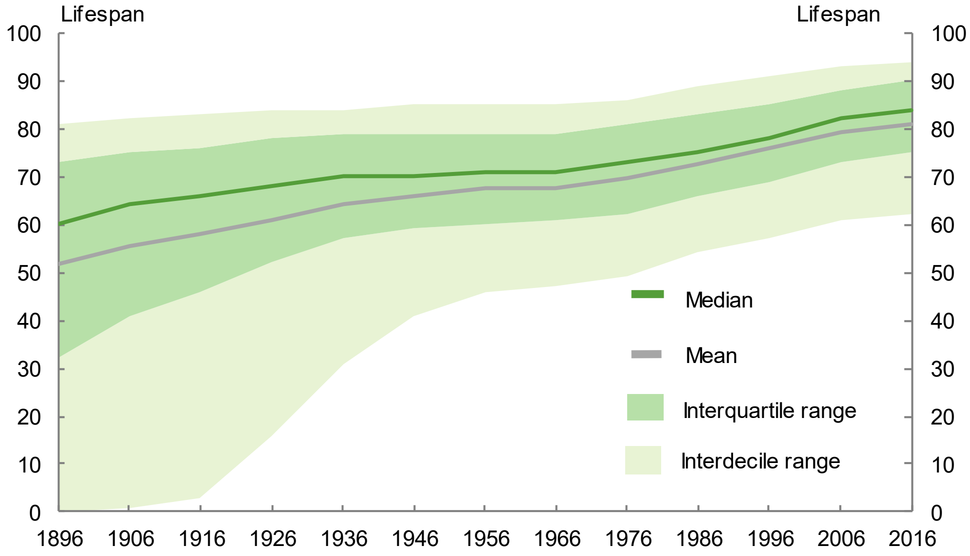


Life expectancy at birth is a commonly used measure to describe population mortality. However, as a single summary statistic, it cannot provide information on the diversity of outcomes. For example, under the mortality rates reported in the current Tables, around 60 per cent of both males and females would be expected to survive beyond the reported life expectancy. This result is separate from the issue of mortality improvements that might occur over an individual's life, which is discussed in the following section.

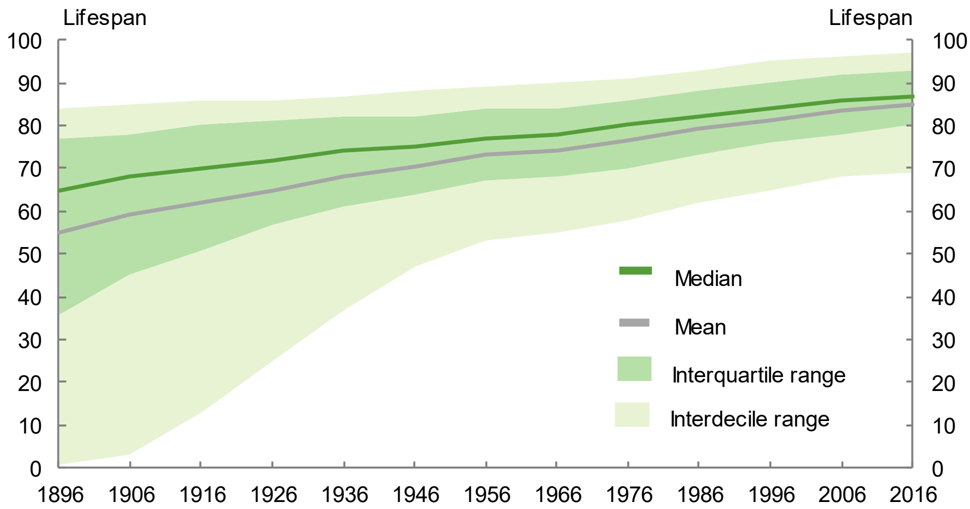
Figure 8 shows how the distribution of lifespan has changed over the past 120 years. The distributions shown here are based on the prevailing mortality rates and do not make allowance for future mortality improvement. The chart shows the period life expectancy (represented by the mean), the median of the lifespan distribution and the interquartile and interdecile ranges.

Figure 8: Distribution of lifespan at birth

Males



Females



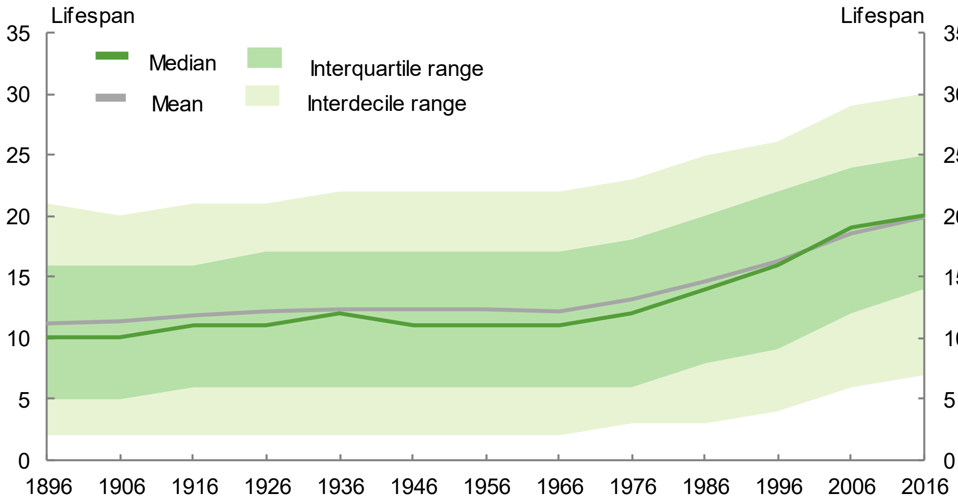
It can be seen that the reported life expectancy and median age of death have moved roughly in parallel. However, since 1896, the gap between the two measures has declined by around six years for males and eight years for females, reflecting the dramatic improvements in infant mortality that have had a greater impact on life expectancy than on median age at death.

While improving mortality at younger ages has tended to concentrate the age of death within a narrower range, outcomes for individuals can still vary widely. The interdecile range, for example, spans a range of over 30 years for males, from 62 to 94, and only slightly less for females, from 69 to 97.

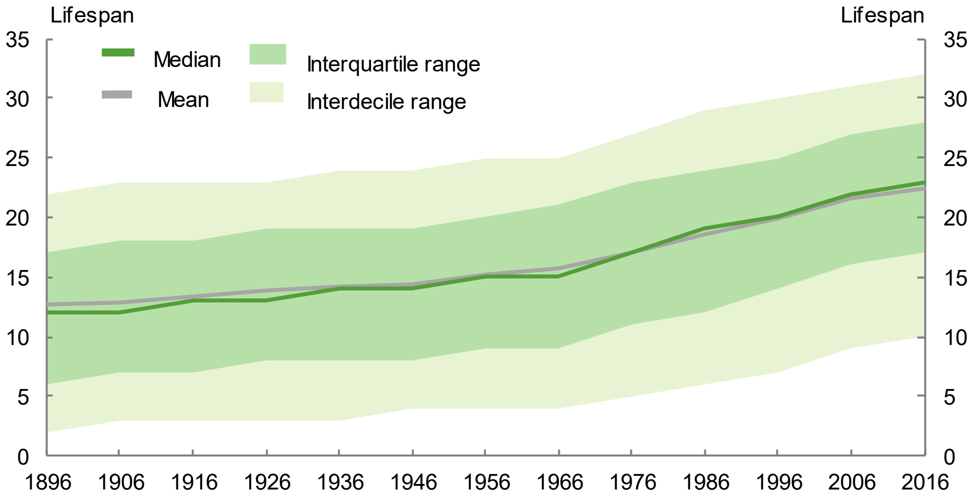
Figure 9 reproduces the distribution of lifespan charts based on the expected outcomes at age 65 rather than birth.

Figure 9: Distribution of lifespan at age 65

Males



Females



A number of differences are apparent compared with the former graphs. Firstly, the lifespan distribution is relatively symmetrical at this age and as a result the mean and median are more closely aligned. Secondly, while the interdecile range is significantly less at age 65 than at birth, it has increased slightly over time rather than narrowing. In other words, outcomes at retirement are no more predictable today than they were 120 years ago.

1.5 Allowing for future improvements in mortality

The figures reported in section 1.4 are all based on cross-sectional mortality rates from a single set of Life Tables. Section 1.3 also highlighted the substantial changes in mortality that could be expected to occur over an individual's life time. By way of illustrating the interaction between these two elements, the life expectancy of a boy born in 1886, as reported in the 1881-90 Tables, was 47.2 years, based on the rates in those Tables persisting throughout his life. However, his actual life expectancy would have been some six years higher. This estimate can be obtained by applying the rates reported in subsequent Tables that would be appropriate given his age and the year.

As a result, any realistic measure of longevity needs to consider the possible improvements in mortality that may occur in the future. This section focuses on life expectancy, considering the impacts of future mortality improvement. The limitations outlined in the previous section of any summary measure such as life expectancy which obscure the diversity of outcomes should continue to be borne in mind.

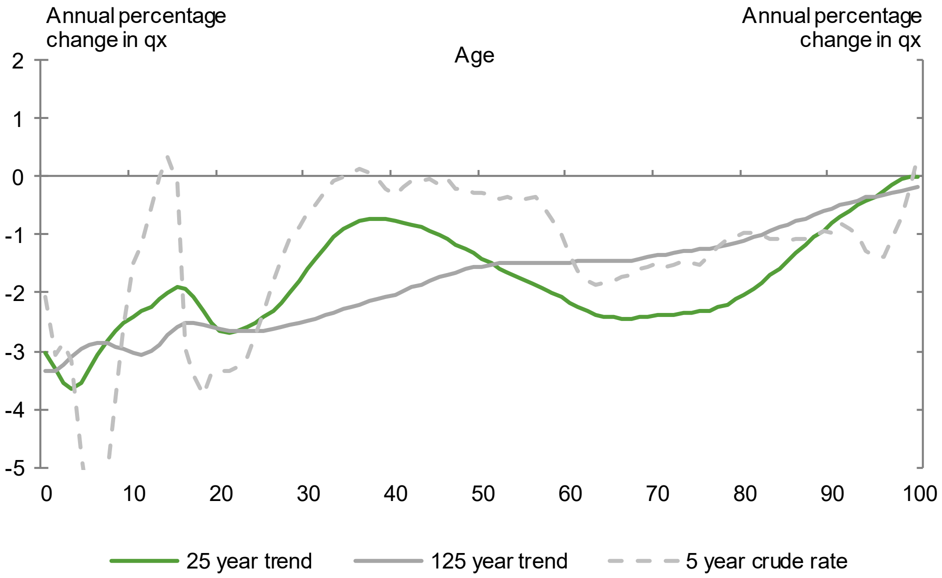
The issues associated with attempting to estimate more realistic life expectancies by allowing for future mortality improvements were discussed in some detail in the 1995-97 Tables. Those Tables included improvement factors derived from the ratio of the mortality rates in the Tables to those reported in the Tables from 25 and 100 years previously. The current Tables continue the practice of reporting two sets of factors, one based on experience over the last 25 years and the other using the improvement in mortality over 125 years. Details on the methodology used is provided in Section 2.4 and the resulting rates set out in Appendix E.

Figure 10 presents the historical rates of improvement expressed as an annual percentage change in the probability of death at a given age. Note that the lower the value, the higher that the improvement in mortality has been. It can be seen that the improvements over the 125 year period have generally been less than the improvements over the past 25 years for ages between 50 and the mid-nineties. On the other hand, for ages from 30 to 50 the rates of improvement over the past 25 years have generally been less than over the preceding 100 years for both males and females.

The 25 year improvement factors for the oldest ages (101 and above for males, and 99 and above for females) have been constrained to be zero. Mortality improvements since 2010-12 from age 95 up to these ages reversed the trend for this age group compared to the last two reports. The 125 year improvement factors have been similarly constrained at the oldest ages (106 and above for males and 105 and above for females). The actual trends for mortality improvement for very old ages remain unclear as there is a paucity of data; I have therefore decided to set the factors to zero for these advanced ages until further evidence emerges.

Figure 10: Historical mortality improvement factors derived from the Australian Life Tables
Males

Figure 10: Historical mortality improvement factors derived from the Australian Life Tables
Females



There are two ways of taking account of mortality improvement in projecting future life expectancies. The first is to apply the same number of years of improvement to the mortality rates at all ages, effectively estimating what future Life Tables might report as life expectancy. This provides for improvement to the date of the calculation, but no further improvement thereafter. This measure is known as the period or cross-sectional life expectancy. It makes no allowance for improvements over an individual's future lifetime and was discussed in the previous section. For example, when calculating a period life expectancy for the year 2025 based on the 2015-17 Tables, nine years of improvement would be allowed for at all ages. The following tables show the projected period life expectancies at ages 0, 30 and 65 using the 25 and 125 year improvement factors.

Projected period life expectancies at selected ages under two improvement scenarios

Males

	Age 0		Age 30		Age 65	
	25 year	125 year	25 year	125 year	25 year	125 year
2016	80.8	80.8	81.6	81.6	84.9	84.9
2020	81.7	81.3	82.4	82.1	85.5	85.1
2030	83.7	82.5	84.3	83.1	87.0	85.8
2040	85.6	83.6	86.0	84.1	88.3	86.5
2050	87.2	84.6	87.5	85.0	89.5	87.1
2060	88.6	85.5	88.8	85.8	90.6	87.7

Females

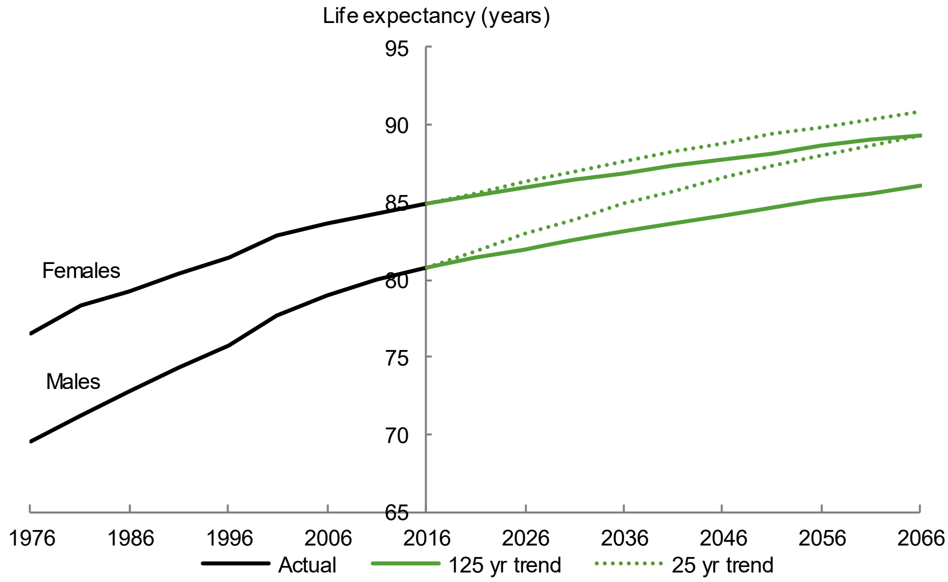
	Age 0		Age 30		Age 65	
	25 year	125 year	25 year	125 year	25 year	125 year
2016	84.9	84.9	85.4	85.4	87.5	87.5
2020	85.5	85.3	86.0	85.8	87.9	87.7
2030	86.9	86.3	87.3	86.7	89.0	88.4
2040	88.1	87.3	88.5	87.5	90.0	89.0
2050	89.3	88.1	89.5	88.3	90.8	89.6
2060	90.3	88.9	90.5	89.1	91.6	90.2

The 2010-12 Tables projected a period life expectancy at birth for a boy born in 2016 of 81.3 years under the 25 year improvement scenario and 80.6 years under the 125 year improvement scenario. The current Tables estimate a male life expectancy closer to that which would had been expected in 2012 after applying the 125 year improvement factors reported in the 2010-12 Tables. For a girl born in 2016, the equivalent estimates from the 2010-12 Tables were 85.2 and 84.9 years respectively. The current estimate is thus consistent with the 125 year improvement factors reported in the 2010-12 Tables.

Following on from this trend, the projected period life expectancies in these Tables, using the 25 year improvement factors, are marginally lower than those projected in the previous Tables, except for a male aged 65, where the projected life expectancy is marginally higher. Under this scenario, the experience of the last 5 years carries greater weight. The rate of improvement in mortality over the five years to 2016 was, on average, slightly lower than over the 5 years to 1991. Whilst this is not uniform at all ages, this continues the observed general trend of slowing mortality improvement observed over the last three decades.

Figure 11 shows how the period life expectancy at birth would change over time under these two improvement scenarios.

Figure 11: Actual and projected period life expectancy at birth — 1976 to 2066



The second measure of life expectancy is what is termed cohort life expectancy. This measure takes into account the improvements that could be experienced over the future lifetime of the individual. For example, when calculating the cohort life expectancy of a child born in 2025 based on the 2015-17 tables, 9 years of mortality improvement will be applied to the mortality rate at age 0, 10 years at age one and so on. In the example provided at the beginning of this section, the life expectancy for a child born in 1886 calculated using the mortality rates as they changed over his lifetime is a cohort life expectancy. Cohort life expectancies can be thought of as being a more realistic representation of the unfolding mortality experience of the Australian population. Regardless, the uncertainties around future rates of mortality improvement need to be kept in mind with any projection of future mortality.

The following tables show the cohort life expectancies at ages 0, 30 and 65 using the 125 year improvement factors.

Projected cohort expectation of life at selected ages under the 125 year improvement scenario

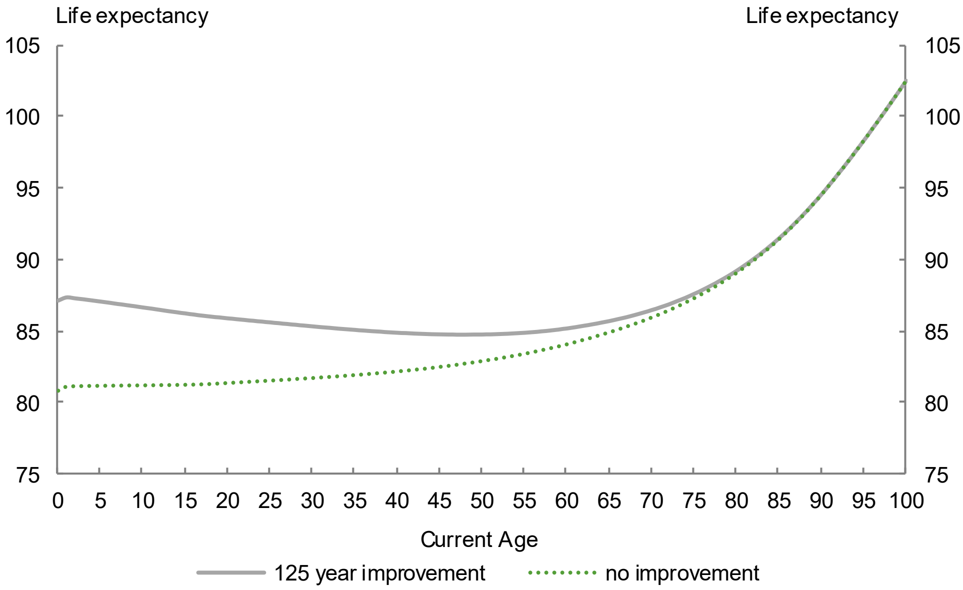
	Age 0		Age 30		Age 65	
	Males 125 year	Females 125 year	Males 125 year	Females 125 year	Males 125 year	Females 125 year
2016	87.1	90.5	85.3	88.9	85.7	88.4
2020	87.5	90.9	85.7	89.2	86.0	88.7
2030	88.4	91.6	86.6	90.0	86.6	89.3
2040	89.2	92.2	87.4	90.7	87.3	89.9
2050	89.9	92.8	88.2	91.3	87.9	90.5
2060	90.5	93.3	88.9	91.9	88.5	91.0

Male mortality rates have improved at a faster rate than female rates over the last three decades. However, using short term mortality improvement factors (for example, over 25 years) to project cohort life expectancy (which is inherently a long term projection) may not be appropriate. Therefore, in this report, cohort life expectancies were calculated only under a 125 year mortality improvement scenario. A comparison with the cohort life expectancies reported in the 2010-12 Tables shows that, on these improvement assumptions, male cohort life expectancies have increased by around one year. Female cohort life expectancies also show a marginal increase.

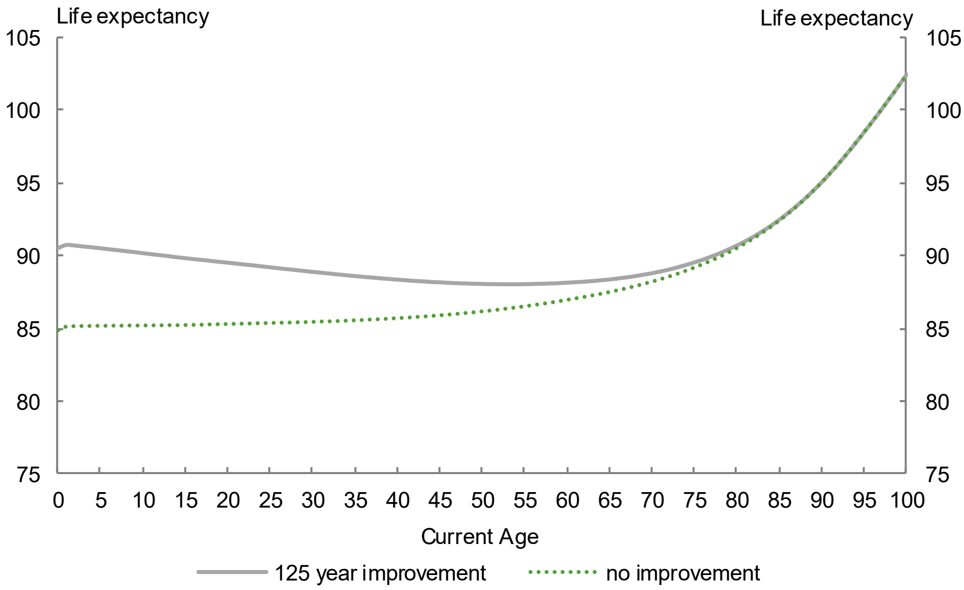
Figure 12 shows the cohort life expectancies for those currently alive in the Australian population. It highlights the considerable gap between the period life expectancies reported in these Tables and the outcomes that would arise if the rates of mortality improvement observed in the past are maintained in the future. The additional life expectancy (the gap between the 'no improvement' curve and 125 year improvement curve) reduces with increasing age, reflecting the shorter period for improvements to have an impact. At very old ages, the gap has disappeared but the curve rises, reflecting the fact that these people have already reached an advanced age.

Figure 12: Cohort life expectancies by current age

Males



Females



The period and cohort life expectancies set out above illustrate what would occur if mortality continued to improve at the rates observed in the past. Actual mortality improvement can change appreciably between successive Tables. This can particularly affect the improvement factors derived from the most recent 25 years of experience where the earliest period is removed from the calculation and the experience from the most recent five years incorporated. So, for example, at age 45 for males the 25 year improvement factor has reduced from 1.72 per cent per annum to 0.97 per cent per annum, reflecting the fact that mortality at this age improved by 12 per cent between the 1985-87 and the 1990-92 Tables but mortality deteriorated by 6 per cent between 2010-12 and 2015-17 Tables.

Furthermore, the effects of these movements are magnified in mortality projections because the projections assume that mortality improvement will be constant for a particular age. This is not a major issue in the short term. One year into the future, for example, the difference in mortality rates at age 45 under the two assumptions is less than 1 per cent. However, when considering cohort life expectancy at birth, the projected mortality rate to be used at age 45 will include 45 years of mortality improvement and the mortality rate under the 2015-17 assumption is about 40 per cent higher than it would have been under the 2010-12 assumption.

The sensitivity to changes in mortality improvement is also evident in the projected distribution of deaths, as illustrated in Figure 13. The two improvement scenarios presented are both based on 25 year improvement factors.

Figure 13: Distribution of deaths for those age 65 allowing for cohort mortality improvement
Males

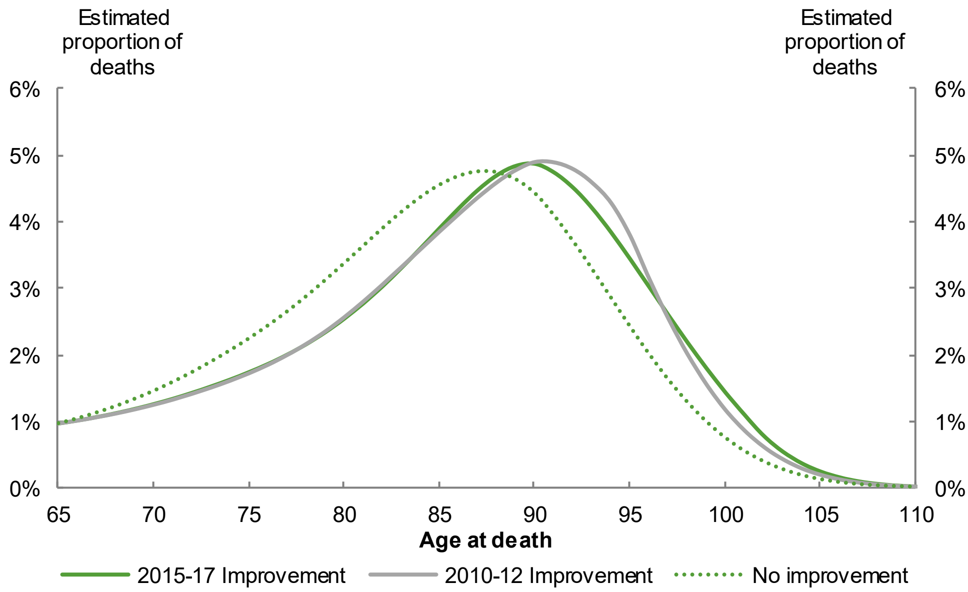
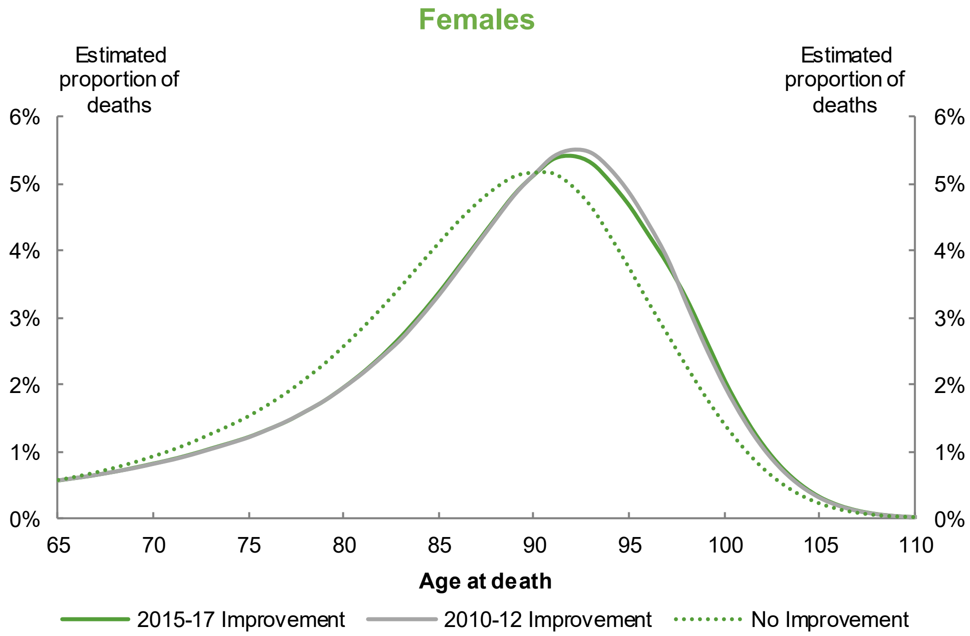


Figure 13: Distribution of deaths for those age 65 allowing for cohort mortality improvement (continued)



This chart also suggests that the range of lifespans under credible mortality improvement scenarios is at least as wide as the range where no allowance for mortality improvement was made. In other words, making an allowance for future improvements in mortality does not decrease the challenges individuals face in dealing with longevity risk in retirement.

History demonstrates that mortality improvement is not constant at a particular age and, indeed, can vary within a quite considerable range. The choice of the period over which mortality is measured will also affect the estimates of mortality improvement. Thus, the estimates of cohort mortality included here must be accepted as projections of outcomes under assumptions which have a certain historical basis. They should be regarded as indicative rather than firm forecasts of life expectancy.

AUSTRALIAN LIFE TABLES 2015-17: MALES

Age	l_x	d_x	p_x	q_x	μ_x	$\mathring{e}_x$	L_x	T_x
0	100,000	355	0.996453	0.003547	0.000000	80.76	99,680	8,075,879
1	99,645	28	0.999721	0.000279	0.000362	80.05	99,630	7,976,212
2	99,617	17	0.999832	0.000168	0.000210	79.07	99,609	7,876,581
3	99,601	14	0.999862	0.000138	0.000147	78.08	99,594	7,776,973
4	99,587	10	0.999900	0.000100	0.000118	77.09	99,582	7,677,379
5	99,577	9	0.999912	0.000088	0.000091	76.10	99,573	7,577,797
6	99,568	8	0.999917	0.000083	0.000085	75.11	99,564	7,478,225
7	99,560	8	0.999917	0.000083	0.000083	74.11	99,556	7,378,661
8	99,552	8	0.999917	0.000083	0.000083	73.12	99,548	7,279,105
9	99,544	8	0.999917	0.000083	0.000083	72.12	99,539	7,179,557
10	99,535	8	0.999915	0.000085	0.000083	71.13	99,531	7,080,018
11	99,527	9	0.999908	0.000092	0.000088	70.14	99,522	6,980,487
12	99,518	10	0.999896	0.000104	0.000097	69.14	99,513	6,880,964
13	99,507	12	0.999875	0.000125	0.000113	68.15	99,501	6,781,452
14	99,495	15	0.999845	0.000155	0.000138	67.16	99,487	6,681,951
15	99,479	20	0.999798	0.000202	0.000174	66.17	99,470	6,582,463
16	99,459	28	0.999718	0.000282	0.000236	65.18	99,446	6,482,993
17	99,431	40	0.999598	0.000402	0.000340	64.20	99,412	6,383,547
18	99,391	50	0.999498	0.000502	0.000459	63.23	99,367	6,284,135
19	99,341	53	0.999465	0.000535	0.000526	62.26	99,315	6,184,768
20	99,288	55	0.999448	0.000552	0.000545	61.29	99,261	6,085,453
21	99,233	56	0.999433	0.000567	0.000560	60.32	99,205	5,986,192
22	99,177	58	0.999417	0.000583	0.000575	59.36	99,148	5,886,986
23	99,119	59	0.999402	0.000598	0.000591	58.39	99,090	5,787,838
24	99,060	61	0.999385	0.000615	0.000606	57.43	99,030	5,688,748
25	98,999	63	0.999367	0.000633	0.000624	56.46	98,968	5,589,718
26	98,937	65	0.999347	0.000653	0.000643	55.50	98,904	5,490,750
27	98,872	67	0.999325	0.000675	0.000664	54.53	98,839	5,391,846
28	98,805	69	0.999300	0.000700	0.000687	53.57	98,771	5,293,007
29	98,736	72	0.999272	0.000728	0.000714	52.61	98,700	5,194,237
30	98,664	75	0.999240	0.000760	0.000744	51.65	98,627	5,095,536
31	98,589	78	0.999204	0.000796	0.000778	50.68	98,550	4,996,909
32	98,511	82	0.999163	0.000837	0.000816	49.72	98,470	4,898,359
33	98,428	87	0.999117	0.000883	0.000860	48.77	98,385	4,799,889
34	98,341	92	0.999066	0.000934	0.000908	47.81	98,296	4,701,504
35	98,249	97	0.999008	0.000992	0.000962	46.85	98,201	4,603,208
36	98,152	104	0.998943	0.001057	0.001024	45.90	98,101	4,505,007
37	98,048	111	0.998872	0.001128	0.001092	44.95	97,994	4,406,907
38	97,938	118	0.998793	0.001207	0.001167	44.00	97,879	4,308,913
39	97,819	127	0.998705	0.001295	0.001250	43.05	97,757	4,211,034
40	97,693	136	0.998610	0.001390	0.001342	42.10	97,626	4,113,277
41	97,557	146	0.998505	0.001495	0.001442	41.16	97,485	4,015,651
42	97,411	157	0.998390	0.001610	0.001552	40.22	97,334	3,918,166
43	97,254	169	0.998266	0.001734	0.001672	39.29	97,171	3,820,833
44	97,086	181	0.998131	0.001869	0.001801	38.35	96,996	3,723,662
45	96,904	195	0.997985	0.002015	0.001942	37.43	96,808	3,626,666
46	96,709	210	0.997828	0.002172	0.002094	36.50	96,605	3,529,858
47	96,499	226	0.997658	0.002342	0.002258	35.58	96,387	3,433,253
48	96,273	242	0.997485	0.002515	0.002432	34.66	96,153	3,336,866
49	96,031	257	0.997325	0.002675	0.002598	33.75	95,904	3,240,713
50	95,774	274	0.997142	0.002858	0.002765	32.84	95,639	3,144,809
51	95,500	294	0.996922	0.003078	0.002967	31.93	95,355	3,049,170
52	95,206	317	0.996669	0.003331	0.003204	31.03	95,050	2,953,815
53	94,889	343	0.996381	0.003619	0.003475	30.13	94,720	2,858,766
54	94,546	373	0.996060	0.003940	0.003781	29.24	94,362	2,764,046

AUSTRALIAN LIFE TABLES 2015-17: MALES (CONTINUED)

Age	l_x	d_x	p_x	q_x	μ_x	$\mathring{e}_x$	L_x	T_x
55	94,173	404	0.995706	0.004294	0.004120	28.35	93,974	2,669,684
56	93,769	439	0.995321	0.004679	0.004491	27.47	93,552	2,575,710
57	93,330	476	0.994904	0.005096	0.004894	26.60	93,095	2,482,158
58	92,854	515	0.994458	0.005542	0.005328	25.73	92,600	2,389,063
59	92,340	556	0.993982	0.006018	0.005792	24.87	92,065	2,296,462
60	91,784	599	0.993477	0.006523	0.006285	24.02	91,488	2,204,397
61	91,185	643	0.992944	0.007056	0.006808	23.17	90,867	2,112,908
62	90,542	690	0.992381	0.007619	0.007358	22.33	90,201	2,022,041
63	89,852	739	0.991770	0.008230	0.007947	21.50	89,487	1,931,840
64	89,113	794	0.991093	0.008907	0.008593	20.67	88,721	1,842,353
65	88,319	854	0.990330	0.009670	0.009316	19.86	87,897	1,753,633
66	87,465	922	0.989460	0.010540	0.010137	19.04	87,010	1,665,735
67	86,543	998	0.988465	0.011535	0.011076	18.24	86,051	1,578,725
68	85,545	1,084	0.987325	0.012675	0.012153	17.45	85,010	1,492,675
69	84,460	1,181	0.986021	0.013979	0.013387	16.67	83,879	1,407,665
70	83,280	1,288	0.984534	0.015466	0.014799	15.90	82,645	1,323,786
71	81,992	1,407	0.982844	0.017156	0.016410	15.14	81,299	1,241,141
72	80,585	1,536	0.980934	0.019066	0.018238	14.39	79,828	1,159,842
73	79,049	1,677	0.978785	0.021215	0.020304	13.66	78,222	1,080,014
74	77,372	1,828	0.976380	0.023620	0.022626	12.95	76,471	1,001,791
75	75,544	1,988	0.973687	0.026313	0.025228	12.25	74,564	925,321
76	73,556	2,160	0.970632	0.029368	0.028166	11.57	72,491	850,756
77	71,396	2,347	0.967126	0.032874	0.031531	10.90	70,239	778,265
78	69,049	2,549	0.963084	0.036916	0.035419	10.25	67,792	708,026
79	66,500	2,765	0.958423	0.041577	0.039923	9.63	65,136	640,234
80	63,735	2,992	0.953063	0.046937	0.045137	9.02	62,259	575,098
81	60,744	3,224	0.946926	0.053074	0.051156	8.44	59,151	512,840
82	57,520	3,455	0.939940	0.060060	0.058073	7.89	55,811	453,688
83	54,065	3,674	0.932036	0.067964	0.065981	7.36	52,245	397,877
84	50,391	3,872	0.923151	0.076849	0.074977	6.86	48,470	345,632
85	46,518	4,036	0.913229	0.086771	0.085153	6.39	44,512	297,162
86	42,482	4,154	0.902219	0.097781	0.096604	5.95	40,412	252,650
87	38,328	4,213	0.890080	0.109920	0.109429	5.54	36,224	212,238
88	34,115	4,202	0.876834	0.123166	0.123708	5.16	32,010	176,014
89	29,913	4,106	0.862732	0.137268	0.139352	4.81	27,848	144,005
90	25,807	3,921	0.848068	0.151932	0.156162	4.50	23,826	116,156
91	21,886	3,626	0.834304	0.165696	0.173023	4.22	20,046	92,330
92	18,260	3,284	0.820158	0.179842	0.189584	3.96	16,588	72,284
93	14,976	2,910	0.805672	0.194328	0.207049	3.72	13,489	55,697
94	12,066	2,523	0.790870	0.209130	0.225235	3.50	10,772	42,208
95	9,542	2,140	0.775782	0.224218	0.244142	3.29	8,441	31,436
96	7,403	1,773	0.760438	0.239562	0.263769	3.11	6,487	22,995
97	5,629	1,436	0.744874	0.255126	0.284105	2.93	4,885	16,509
98	4,193	1,136	0.729129	0.270871	0.305137	2.77	3,602	11,624
99	3,057	877	0.713245	0.286755	0.326842	2.62	2,599	8,022
100	2,181	660	0.697268	0.302732	0.349192	2.49	1,834	5,423
101	1,520	485	0.681247	0.318753	0.372150	2.36	1,265	3,589
102	1,036	347	0.665233	0.334767	0.395668	2.24	852	2,324
103	689	242	0.649280	0.350720	0.419693	2.14	561	1,471
104	447	164	0.633444	0.366556	0.444157	2.04	360	911
105	283	108	0.617782	0.382218	0.468985	1.94	225	551
106	175	70	0.602350	0.397650	0.494089	1.86	138	325
107	105	44	0.587205	0.412795	0.519375	1.78	82	188
108	62	26	0.572404	0.427596	0.544733	1.71	48	106
109	35	16	0.558001	0.441999	0.570048	1.64	27	58

AUSTRALIAN LIFE TABLES 2015-17: FEMALES

Age	l_x	d_x	p_x	q_x	μ_x	$\mathring{e}_x$	L_x	T_x
0	100,000	302	0.996980	0.003020	0.000000	84.85	99,730	8,484,908
1	99,698	23	0.999770	0.000230	0.000281	84.11	99,686	8,385,157
2	99,675	15	0.999853	0.000147	0.000184	83.12	99,667	8,285,471
3	99,660	9	0.999908	0.000092	0.000113	82.14	99,656	8,185,804
4	99,651	8	0.999917	0.000083	0.000084	81.14	99,647	8,086,148
5	99,643	7	0.999925	0.000075	0.000079	80.15	99,639	7,986,501
6	99,636	7	0.999930	0.000070	0.000072	79.16	99,632	7,886,862
7	99,629	7	0.999933	0.000067	0.000068	78.16	99,625	7,787,230
8	99,622	6	0.999935	0.000065	0.000066	77.17	99,619	7,687,605
9	99,615	6	0.999936	0.000064	0.000064	76.17	99,612	7,587,986
10	99,609	6	0.999936	0.000064	0.000064	75.18	99,606	7,488,374
11	99,603	7	0.999934	0.000066	0.000064	74.18	99,599	7,388,768
12	99,596	7	0.999925	0.000075	0.000069	73.19	99,592	7,289,169
13	99,589	9	0.999907	0.000093	0.000082	72.19	99,584	7,189,576
14	99,579	12	0.999878	0.000122	0.000106	71.20	99,574	7,089,992
15	99,567	16	0.999839	0.000161	0.000141	70.21	99,559	6,990,419
16	99,551	19	0.999809	0.000191	0.000178	69.22	99,542	6,890,859
17	99,532	21	0.999790	0.000210	0.000202	68.23	99,522	6,791,317
18	99,511	22	0.999781	0.000219	0.000216	67.25	99,500	6,691,795
19	99,489	22	0.999777	0.000223	0.000222	66.26	99,478	6,592,295
20	99,467	22	0.999778	0.000222	0.000223	65.28	99,456	6,492,817
21	99,445	22	0.999780	0.000220	0.000221	64.29	99,434	6,393,360
22	99,423	22	0.999780	0.000220	0.000220	63.30	99,412	6,293,926
23	99,401	22	0.999778	0.000222	0.000220	62.32	99,390	6,194,514
24	99,379	23	0.999771	0.000229	0.000225	61.33	99,368	6,095,123
25	99,357	24	0.999762	0.000238	0.000233	60.35	99,345	5,995,755
26	99,333	25	0.999748	0.000252	0.000244	59.36	99,321	5,896,411
27	99,308	27	0.999732	0.000268	0.000260	58.37	99,295	5,797,090
28	99,281	29	0.999712	0.000288	0.000277	57.39	99,267	5,697,795
29	99,253	31	0.999689	0.000311	0.000299	56.41	99,237	5,598,528
30	99,222	34	0.999662	0.000338	0.000324	55.42	99,205	5,499,291
31	99,188	36	0.999633	0.000367	0.000352	54.44	99,170	5,400,085
32	99,152	40	0.999600	0.000400	0.000383	53.46	99,132	5,300,915
33	99,112	43	0.999564	0.000436	0.000418	52.48	99,091	5,201,783
34	99,069	47	0.999526	0.000474	0.000455	51.51	99,046	5,102,692
35	99,022	51	0.999485	0.000515	0.000494	50.53	98,997	5,003,646
36	98,971	55	0.999440	0.000560	0.000537	49.56	98,944	4,904,649
37	98,916	60	0.999394	0.000606	0.000583	48.58	98,886	4,805,705
38	98,856	65	0.999344	0.000656	0.000631	47.61	98,824	4,706,819
39	98,791	70	0.999293	0.000707	0.000681	46.64	98,756	4,607,995
40	98,721	76	0.999235	0.000765	0.000734	45.68	98,684	4,509,239
41	98,645	83	0.999162	0.000838	0.000800	44.71	98,605	4,410,555
42	98,563	90	0.999083	0.000917	0.000877	43.75	98,518	4,311,950
43	98,472	98	0.999000	0.001000	0.000958	42.79	98,424	4,213,432
44	98,374	107	0.998911	0.001089	0.001044	41.83	98,321	4,115,008
45	98,267	116	0.998821	0.001179	0.001133	40.88	98,210	4,016,687
46	98,151	127	0.998711	0.001289	0.001234	39.92	98,089	3,918,477
47	98,024	136	0.998611	0.001389	0.001339	38.97	97,957	3,820,389
48	97,888	148	0.998491	0.001509	0.001448	38.03	97,815	3,722,432
49	97,741	159	0.998371	0.001629	0.001569	37.08	97,662	3,624,616
50	97,581	173	0.998232	0.001768	0.001698	36.14	97,496	3,526,954
51	97,409	186	0.998092	0.001908	0.001839	35.21	97,317	3,429,458
52	97,223	200	0.997942	0.002058	0.001982	34.27	97,124	3,332,141
53	97,023	216	0.997772	0.002228	0.002144	33.34	96,916	3,235,017
54	96,807	232	0.997603	0.002397	0.002314	32.42	96,692	3,138,100

AUSTRALIAN LIFE TABLES 2015-17: FEMALES (CONTINUED)

Age	l_x	d_x	p_x	q_x	μ_x	$\mathring{e}_x$	L_x	T_x
55	96,575	250	0.997413	0.002587	0.002492	31.49	96,451	3,041,408
56	96,325	269	0.997204	0.002796	0.002693	30.57	96,192	2,944,957
57	96,056	289	0.996994	0.003006	0.002904	29.66	95,913	2,848,765
58	95,767	310	0.996765	0.003235	0.003122	28.75	95,614	2,752,852
59	95,457	333	0.996516	0.003484	0.003363	27.84	95,293	2,657,239
60	95,124	356	0.996257	0.003743	0.003617	26.93	94,948	2,561,946
61	94,768	382	0.995968	0.004032	0.003889	26.03	94,580	2,466,998
62	94,386	412	0.995639	0.004361	0.004199	25.14	94,183	2,372,418
63	93,975	444	0.995271	0.004729	0.004546	24.24	93,755	2,278,235
64	93,530	483	0.994833	0.005167	0.004949	23.36	93,292	2,184,480
65	93,047	527	0.994336	0.005664	0.005419	22.47	92,787	2,091,188
66	92,520	577	0.993759	0.006241	0.005956	21.60	92,236	1,998,400
67	91,943	635	0.993094	0.006906	0.006579	20.73	91,630	1,906,164
68	91,308	701	0.992319	0.007681	0.007303	19.87	90,963	1,814,534
69	90,606	775	0.991446	0.008554	0.008132	19.02	90,225	1,723,571
70	89,831	858	0.990445	0.009555	0.009078	18.18	89,409	1,633,346
71	88,973	947	0.989356	0.010644	0.010127	17.35	88,507	1,543,937
72	88,026	1,050	0.988070	0.011930	0.011318	16.53	87,510	1,455,430
73	86,976	1,166	0.986589	0.013411	0.012727	15.73	86,402	1,367,920
74	85,809	1,286	0.985011	0.014989	0.014277	14.93	85,176	1,281,517
75	84,523	1,417	0.983239	0.016761	0.015953	14.15	83,827	1,196,341
76	83,106	1,573	0.981078	0.018922	0.017945	13.39	82,334	1,112,514
77	81,534	1,743	0.978627	0.021373	0.020288	12.64	80,678	1,030,181
78	79,791	1,939	0.975694	0.024306	0.023030	11.90	78,838	949,503
79	77,852	2,150	0.972380	0.027620	0.026217	11.18	76,796	870,664
80	75,702	2,392	0.968399	0.031601	0.029951	10.49	74,526	793,869
81	73,309	2,650	0.963854	0.036146	0.034348	9.81	72,007	719,343
82	70,659	2,928	0.958563	0.041437	0.039427	9.16	69,219	647,336
83	67,732	3,221	0.952440	0.047560	0.045359	8.54	66,146	578,117
84	64,510	3,528	0.945314	0.054686	0.052300	7.94	62,772	511,971
85	60,982	3,829	0.937208	0.062792	0.060339	7.37	59,093	449,199
86	57,153	4,123	0.927866	0.072134	0.069632	6.83	55,115	390,106
87	53,031	4,379	0.917420	0.082580	0.080282	6.32	50,861	334,991
88	48,651	4,595	0.905544	0.094456	0.092404	5.84	46,370	284,130
89	44,056	4,753	0.892115	0.107885	0.106420	5.40	41,688	237,761
90	39,303	4,798	0.877923	0.122077	0.121867	4.99	36,906	196,073
91	34,505	4,785	0.861335	0.138665	0.139404	4.61	32,105	159,167
92	29,720	4,604	0.845097	0.154903	0.158726	4.28	27,398	127,062
93	25,117	4,312	0.828320	0.171680	0.178268	3.97	22,930	99,664
94	20,805	3,896	0.812728	0.187272	0.197873	3.69	18,820	76,733
95	16,908	3,453	0.795779	0.204221	0.217598	3.43	15,143	57,913
96	13,455	2,981	0.778427	0.221573	0.239114	3.18	11,926	42,770
97	10,474	2,536	0.757848	0.242152	0.263181	2.94	9,169	30,844
98	7,938	2,092	0.736486	0.263514	0.291278	2.73	6,855	21,675
99	5,846	1,670	0.714384	0.285616	0.320816	2.53	4,977	14,819
100	4,176	1,288	0.691684	0.308316	0.352230	2.36	3,503	9,842
101	2,889	957	0.668556	0.331444	0.385426	2.19	2,385	6,339
102	1,931	685	0.645191	0.354809	0.420271	2.05	1,568	3,955
103	1,246	471	0.621808	0.378192	0.456573	1.91	995	2,386
104	775	311	0.598641	0.401359	0.494062	1.80	608	1,391
105	464	197	0.575936	0.424064	0.532392	1.69	358	783
106	267	119	0.553944	0.446056	0.571139	1.59	202	426
107	148	69	0.532908	0.467092	0.609800	1.51	110	223
108	79	38	0.513055	0.486945	0.647815	1.43	58	113
109	40	20	0.494618	0.505382	0.684559	1.37	29	55

2. Construction of the Australian Life Tables 2015-17

There are three main elements in the process of constructing the Australian Life Tables. The first is the derivation of the exposed-to-risk and crude mortality rates from the information provided by the Australian Bureau of Statistics (ABS). The second is the graduation of the crude rates and associated statistical testing of the quality of the graduation. The final task is the calculation of the Life Table functions. This chapter discusses each of these steps in turn and concludes with a discussion of the methodology used to estimate the mortality improvement factors.

2.1 Calculation of exposed-to-risk and crude mortality rates

The calculation of mortality rates requires a measure of both the number of deaths and the population which was at risk of dying — the exposed-to-risk — over the same period. The raw data used for these calculations was provided by the ABS and comprised the following:

(a) Estimates of the numbers of males and females resident in Australia at each age last birthday up to 115 years and over, as at 30 June 2016. These estimates are based on the 2016 Census of Population and Housing adjusted for under-enumeration and the lapse of time between 30 June 2016 and 9 August 2016 (the night on which the Census was taken). They differ from the published official estimates of Australian resident population which contain further adjustments to exclude overseas visitors temporarily in Australia and include Australian residents who are temporarily absent.

(b) The numbers of deaths occurring inside Australia for each month from January 2015 to December 2017, classified by sex and age last birthday at the time of death. This data covers all registrations of deaths to the end of 2018 and is considered to be effectively a complete record of all deaths occurring over the three year period.

(c) The number of registered births classified by sex in each month from January 2011 to December 2017.

(d) The number of deaths of those aged 3 years or less in each month from January 2011 to December 2017, classified by sex and age last birthday, with deaths of those aged less than one year classified by detailed duration.

(e) The numbers of persons moving into and out of Australia in each month from January 2015 to December 2017 for those aged 4 or more, and from January 2011 to December 2017 for those aged less than 4, grouped by age last birthday and sex.

Appendix B includes summary information on the population, number of deaths and population movements. Appendix C provides detailed estimates of the population at each age last birthday at 30 June 2016, and the number of deaths at each age occurring over the three calendar years 2015 to 2017.

The ABS conducts a five-yearly Census of Population and Housing. Adjusted population estimates based on a particular Census will usually differ from those produced by updating the results of the previous Census for population change (that is, for births, deaths and migration) during the following 5 years. The difference between an estimate based on the results of a particular Census and that produced by updating results from the previous Census is called intercensal discrepancy. It is caused by unattributable errors in either or both of the starting and finishing population estimates, together with any errors in the estimates of births, deaths or migration in the intervening period.

The Australian Life Tables are based on the most recent Census population estimates. This is consistent with the view of the ABS that the best available estimate of the population at 30 June of the Census year is the one based on that year's Census, not the one carried forward from the previous period. Intercensal discrepancy can, however, affect the comparability of reported mortality rates, and consequently life expectancies and improvement factors.

The crude mortality rates are calculated by dividing the number of deaths at a particular age by the exposed-to-risk for that age. It is essential, then, that the measure of the exposed-to-risk and the number of deaths should refer to the same population. Effectively, this means that a person in the population should be included in the denominator (that is, counted in the exposed-to-risk) only if their death would have been included in the numerator had they died.

The deaths used in deriving these Tables are those which occurred in Australia during 2015-17, regardless of usual place of residence. The appropriate exposed-to-risk is, therefore, exposure of people actually present in Australia at any time during the 3 year period. The official population estimates published by the ABS (Australian Demographic Statistics, ABS Catalogue No 3101.0) are intended to measure the population usually resident in Australia and accordingly include adjustments to remove the effect of short-term movements, which are not appropriate for these Tables. Adjustment does, however, need to be made to the exposed-to-risk to take account of those persons who, as a result of death or international movement, are not present in Australia for the full 3 year period.

The base estimate of the exposed-to-risk at age x, which assumes that all those present on Census night contribute a full three years to the exposed-to-risk, was taken to be:

$$\frac{1}{8}P_{x-2} + \frac{7}{8}P_{x-1} + P_x + \frac{7}{8}P_{x+1} + \frac{1}{8}P_{x+2}$$

where P_x is the population inside Australia aged x last birthday as measured in the 2016 Census adjusted only for under-enumeration and the lapse of time from 30 June to Census night.

This estimate was then modified to reduce exposure for those who arrived in Australia between January 2015 and June 2016, or who died or left Australia between July 2016 and December 2017. Similarly, exposure was increased to take account of those who arrived between July 2016 and December 2017 or who died or left Australia between January 2015 and June 2016.

Figure 14 compares the Census population count with the exposed-to-risk after all adjustments have been made. It can be seen that the exposed-to-risk formula smooths to some extent the fluctuations from age to age apparent in the unadjusted population count. The impact of net inward migration over recent years can be seen in the fact that the exposed-to-risk sits above the Census population count, particularly for student and working ages.

Figure 14: Comparison of census population count and exposed-to-risk
Males

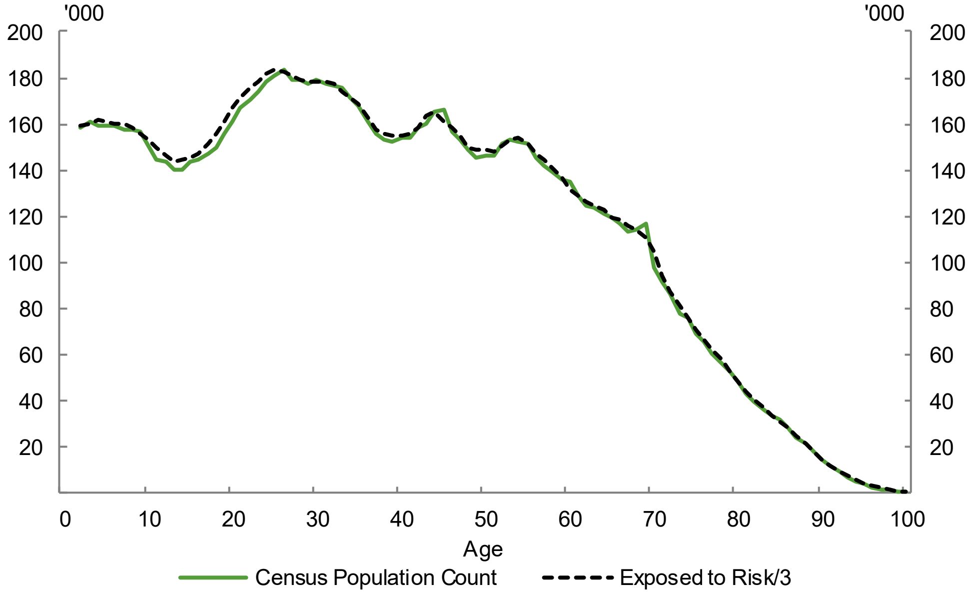
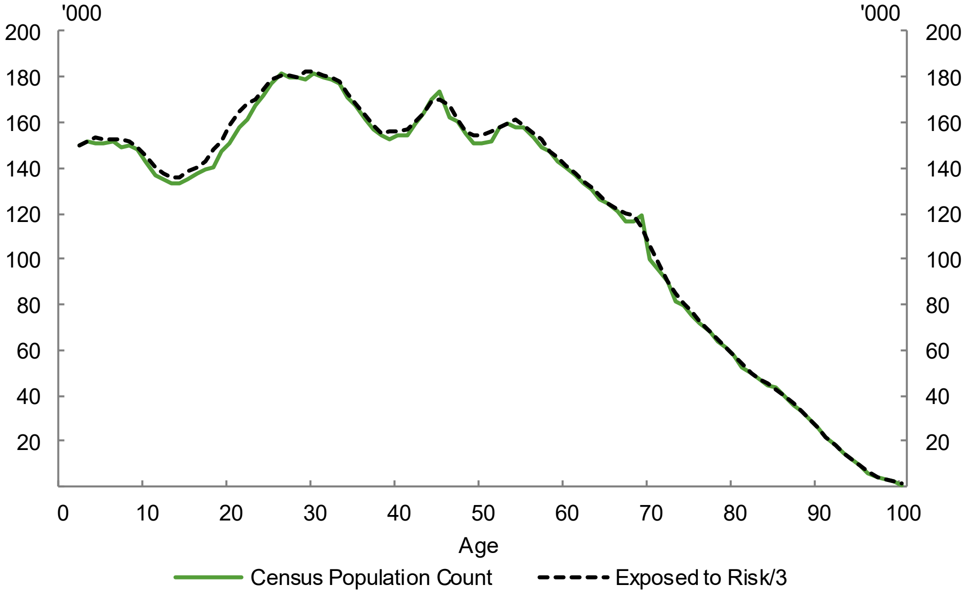


Figure 14: Comparison of census population count and exposed-to-risk Females

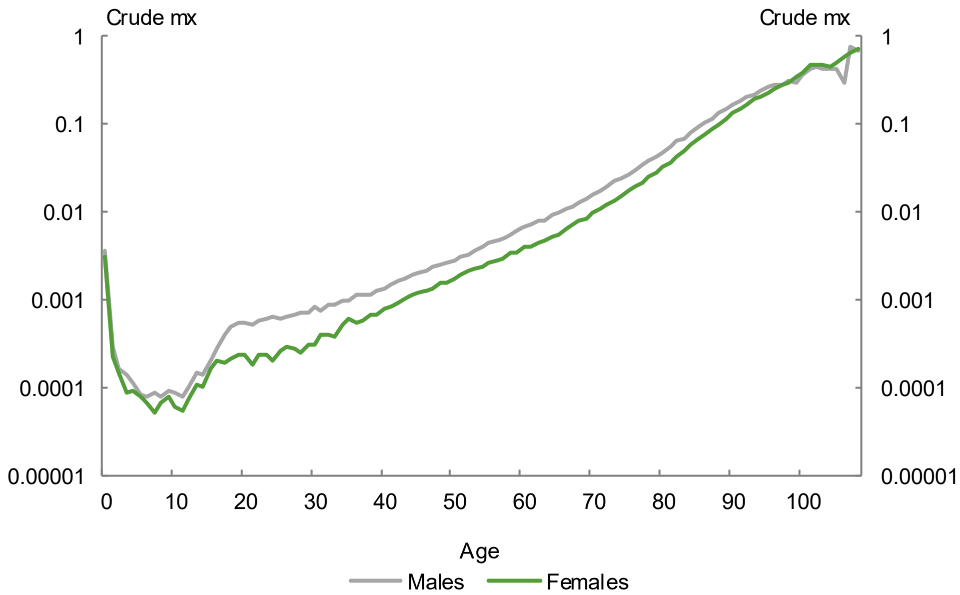


For ages two and above, the crude central rate of mortality at age x, m_x, was calculated by dividing the deaths at age x during 2015, 2016 and 2017 by the relevant exposed-to-risk. The exposed-to-risk for ages 0 and 1 was derived more directly by keeping a count of those at each age for each month of the three year period using monthly birth, death and movement records from 2011 to 2017. Because of the rapid fall in the force of mortality, μ_x, over the first few weeks of life, q_x, rather than m_x, was calculated for age 0. The formulae used are available on request.

2.2 Graduation of the crude mortality rates

Figure 15 shows the crude mortality rates. The crude central rates of mortality, even when calculated over three years of experience, exhibit considerable fluctuation from one age to the next, particularly among the very young and very old where the number of deaths is typically low. From a first principles perspective, however, there is no reason to suppose that these fluctuations are anything other than a reflection of the random nature of the underlying mortality process. Hence, when constructing a life table to represent the mortality experience of a population, it is customary to graduate the crude rates to obtain a curve that progresses smoothly with age.

Figure 15: Crude central mortality rates



As with previous Life Tables, a combination of manual graduation and fitted cubic splines was used. Cubic splines were fitted over all but the two youngest ages and the very top of the age distribution. At the oldest ages, there is little exposure and few deaths, so a different approach is required. This is discussed below.

The method of cubic splines involves fitting a series of cubic polynomials to the crude rates of mortality. These polynomials are constrained to be not only continuous at the 'knots' where they join, but also to have equal first and second derivatives at those points. This constraint, of itself, is insufficient to ensure that the fitted curve is smooth in the sense of having a low rate of change of curvature. A large number of knots or closely spaced knots would allow the curve to follow the random fluctuations in the crude rates. At the same time, large intervals between the knots can reduce the fitted curve's fidelity to the observed results. The choice of the number and location of knots, therefore, involves a balance between achieving a smooth curve and deriving fitted rates that are reasonably consistent with the observed mortality rates.

For a given choice of knots, the criterion used to arrive at the cubic spline was that the following weighted residual sum of squares (an approximate χ^2 variable) should be minimised:

$$\sum_{x=x_{min}}^{x_{max}} w_x(m_x - \hat{m}_x)^2$$

where:

m_x is the crude central mortality rate at age x;

$\hat{m}_x$ is the graduated value of the central mortality rate at age x, produced by the cubic spline;

w_x is a weight for each age, which gives more weight to those observations with higher exposure to risk and which accounts for non-constant variance in the data (in particular, $w_x = \frac{E_x}{m_x^1(1-m_x^1)}$, where E_x is the central exposed-to-risk at age x);

m_x^1 is a preliminary value of $\hat{m}_x$, obtained by minimising the above sum of squares with weights given by $w_x = \frac{E_x}{m_x(1-m_x)}$;

x_{min} is the lowest age of the range to which the cubic spline is to be fitted; and

x_{max} is the highest age of the range to which the cubic spline is to be fitted.

An initial choice of knots was based on observation of the crude data and the knots selected in the previous report. This choice of knots was then iteratively improved upon, with the objective of reducing the χ^2 value above. A series of statistical tests were also performed to assess the adequacy of the graduated rates. This is necessary as a singular focus on the χ^2 variable can exhibit a tendency to overfit the graduated rates to the crude rates at some ages. The final ages selected for the knots used in the graduation are shown below.

Males:	7	14	16	18	19	47	48	49	61	74	87	97
Females:	9	14	15	22	39	40	41	59	73	80	90	93

The cubic splines were fitted from ages 3 to 102. In general, a larger number of knots is required at and near the ages where mortality undergoes a marked transition. For males, knots at ages 14, 16, 18 and 19 enabled the construction of a graduated curve that captured the behaviour of mortality rates at the edge of the accident 'cliff'. Similarly, for females, knots were needed at ages 14, 15 and 22 to capture the sharp increase and subsequent flattening in mortality rates over this age range.

The 2006 Census was the first to record individual ages for those aged 100 or more. It also asked for date of birth which allowed the internal consistency of the records to be checked. As result, both the quality and volume of data at very old ages improved and this process has continued in each subsequent Census where a high priority was placed on data integrity for centenarians. Nonetheless, the data remains sparse and an alternative approach is required for graduation at the very oldest ages.

The rates for these ages were constructed by extrapolating the trend of the crude rates from ages where there were sufficient deaths to make the crude rates meaningful. The trend result was determined by fitting a Makeham curve of the form:

$$q_x = 1 - exp[-A - B \times C^x(C-1)/\ln(C)]$$

where *A*, *B* and *C* are constants.

The Makeham curve was fitted to the data using nonlinear least squares. The shape of the resulting curve is highly sensitive to the age range over which the fit is performed. The resulting graduated rates were therefore tested over a range of minimum ages (ranging from 80 to 95) and maximum ages (ranging from 105 to 108). This process involves a necessary degree of judgment. The fitted Makeham curve was used to extrapolate the graduated rates from age 90 for males and age 96 for females.

As has been the case for the last seven Tables, the raw mortality rates for males and females cross at a very old age. The 1990-92 Tables maintained the apparent crossover as a genuine feature, resulting in male mortality rates falling below the female rates from age 103. Since that time, the crossover in both the raw and graduated rates has varied within a fairly narrow range. The following table summarises the experience.

Life Tables	Crossover in crude rates	Crossover in graduated rates
1990-92	100	103
1995-97	96	98
2000-02	96	103
2005-07	99	100
2010-12	100[1]	103
2015-17	99	100

[1] The male crude rates cross below female rates for the first time at age 100, but female rates are lower at ages 104 and 105. Male rates are lower at all subsequent ages.

A negligible percentage of death registrations in 2015-17 did not include the age at death (less than 0.0005 per cent for all ages), and consequently no adjustments were considered necessary to the graduated rates.

A number of tests were applied to the graduated rates to assess the suitability of the graduation. These tests indicated that the deviations between the crude rates and graduated rates were consistent with the hypothesis that the observed deaths represented a random sample from an underlying mortality distribution following the smoothed rates. Appendix D provides a comparison between the actual and expected number of deaths at each age.

2.3 Calculation of life table functions

As noted above, the function graduated over all but the very youngest ages was the central rate of mortality, m_x . The formulae adopted for calculating the functions included in the Life Tables were as follows:

$$q_x = \frac{m_x \left[1 - \frac{1}{12}\frac{q_{x-1}}{p_{x-1}}\right]}{1 + \frac{5}{12} m_x}$$

$$d_x = l_x q_x$$

$$l_{x+1} = l_x - d_x$$

$$p_x = 1 - q_x$$

$$\mu_x = \frac{1}{12 l_x}[7(d_{x-1} + d_x) - (d_{x-2} + d_{x+1})]$$

$$\mathring{e}_x = \frac{1}{l_x} \sum_{i=1}^{120} l_{x+t} + \frac{1}{2} - \frac{1}{12}\mu_x$$

$$L_x = T_x - T_{x+1}$$

$$T_x = l_x \mathring{e}_x$$

l_0, the radix of the Life Table, was chosen to be 100,000.

All of the Life Table entries can be calculated from q_x using the formulae above with the exception of L_0, $\mathring{e}_0$, μ_0 and μ_1. These figures cannot be calculated using the standard formulae because of the rapid decline in mortality over the first year of life. Details of the calculations of L_0, $\mathring{e}_0$, μ_0 and μ_1 can be provided on request.

2.4 Estimation of mortality improvement factors

In the life tables up to and including 2005-07, the improvement factor at any given age was calculated using the following formula:

$$I_x = \left[\left(\frac{q_x(t)}{q_x(t-n)}\right)^{\frac{1}{n}} - 1\right] \times 100$$

where

I_x is the rate of improvement at age x;

$q_x(t)$ is the mortality rate at age x in the current Tables; and

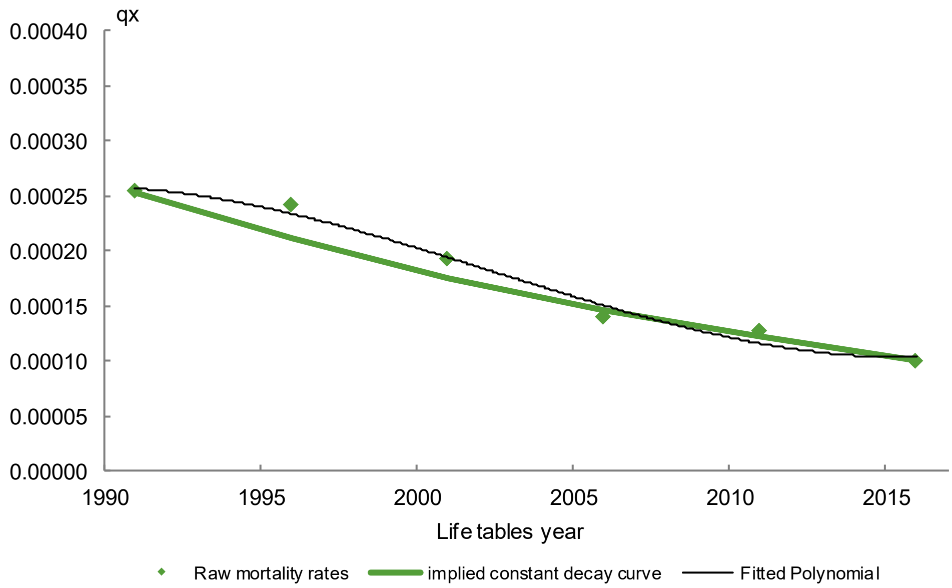
$q_x(t-n)$ is the mortality rate reported for age x in the Tables n years previously.

Whilst this approach was intuitive, this measure depended only upon the mortality rates at the beginning and end of the period and gave no weight to the experience over the intervening period. As a result, this methodology could yield results that did not reflect the general pattern of mortality improvement over the period.

Since 2010-12, the methodology which has been adopted has been to fit a polynomial to the mortality rates for each age over the period of interest (either 25 years or 125 years) and use the fitted values for estimating the mortality improvement.

Figure 16 illustrates this process for a male aged 4 looking at improvement over the last 25 years. In this case, a polynomial has been fitted to the six data points and the values from the fitted function are used to estimate the constant annual improvement that would give rise to the same results.

Figure 16: Estimating mortality improvement for a male aged 4



3. USE OF LIFE TABLES FOR PROBABILITY CALCULATIONS

As well as being the most recent actuarially determined record of mortality rates, the 2015-17 Tables can be used to project the probabilities of persons living or dying at some time in the future. This does, however, require an assumption on what will happen to mortality rates over the intervening period.

The simplest assumption is that mortality rates remain unchanged at the 2015-17 level. However, the continuing improvement in mortality exhibited in these Tables suggests that this assumption will tend to underestimate survival probabilities.

A range of assumptions can be made about future mortality improvements. Appendix E contains the two series of improvement factors derived from the historical trends in Australian mortality improvement over the last 25 years and 125 years. These factors can be applied to the mortality rates included in the current Life Tables to obtain projections of future mortality and life expectancy scenarios.

The process for incorporating future improvements can be expressed in the following mathematical form:

$$q_x(t) = q_x \times \left(1 + \frac{I_x}{100}\right)^{(t-2016)}$$

where

$q_x(t)$	is the mortality rate at age x in year *t*;
q_x	is the mortality rate reported for age x in the current Tables; and
I_x	is the rate of improvement at age x as shown in Appendix E.

Other mortality functions can then be calculated using the formulae given in section 2.3.

An example of how to apply this formula is given below:

Consider a 35 year old female. Her mortality rate in 2016 is given in the current Life Tables as 0.000515. That is, $q_{35}(2016)$ = 0.000515.

The table below sets out the calculation of the projected mortality rate for a 35 year old female in future years — $q_{35}(t)$ for t = 2017, 2020 and 2050 — using the two improvement scenarios.

	25 year improvement factors	125 year improvement factors
$q_{35}(2016)$	0.000515	0.000515
$q_{35}(2017)$	$q_{35}(2016) \times \left(1 + \frac{-0.8173}{100}\right)^{1} = 0.000511$	$q_{35}(2016) \times \left(1 + \frac{-2.2419}{100}\right)^{1} = 0.000503$
$q_{35}(2020)$	$q_{35}(2016) \times \left(1 + \frac{-0.8173}{100}\right)^{4} = 0.000498$	$q_{35}(2016) \times \left(1 + \frac{-2.2419}{100}\right)^{4} = 0.000470$
$q_{35}(2050)$	$q_{35}(2016) \times \left(1 + \frac{-0.8173}{100}\right)^{34} = 0.000390$	$q_{35}(2016) \times \left(1 + \frac{-2.2419}{100}\right)^{34} = 0.000238$

The two sets of improvement factors given in Appendix E should be treated as illustrative rather than forecasts. What the future will bring cannot be known. Using a particular set of factors allows the impact of a given scenario on mortality rates and associated life table functions to be quantified. It cannot say anything about what mortality rates will actually be. The differences in the projected rates under the two scenarios presented here highlight the uncertainty associated with modelling future mortality.

The importance of allowing for future improvements in mortality rates depends on the purpose of the calculations being carried out, the ages involved and the time span that is being considered. Clearly, the longer the time span being considered, the more significant will be the effect of mortality improvements. At the same time, the longer the time span being considered, the greater will be the uncertainty surrounding the projected rates. Similarly, the higher the improvement factors the more quickly the projected rates will diverge from the current rates.

Appendices

Appendix A

The comparisons made in this Appendix are based on the published Australian Life Tables for the relevant years except that revised estimates for the 1970-72 Tables have been preferred to the published Tables, the latter having been based on an under-enumerated population.

Historical summary of mortality rates — males

	Age					
Life Tables	0	15	30	45	65	85
1881-90	0.13248	0.00372	0.00867	0.01424	0.04582	0.18895
1891-00	0.11840	0.00290	0.00698	0.01183	0.04496	0.19629
1901-10	0.09510	0.00255	0.00519	0.01083	0.03859	0.19701
1920-22	0.07132	0.00184	0.00390	0.00844	0.03552	0.19580
1932-34	0.04543	0.00149	0.00271	0.00659	0.03311	0.18864
1946-48	0.03199	0.00115	0.00186	0.00554	0.03525	0.18332
1953-55	0.02521	0.00109	0.00170	0.00478	0.03412	0.17692
1960-62	0.02239	0.00075	0.00157	0.00485	0.03454	0.17363
1965-67	0.02093	0.00079	0.00150	0.00500	0.03603	0.17617
1970-72	0.01949	0.00080	0.00142	0.00479	0.03471	0.16778
1975-77	0.01501	0.00070	0.00128	0.00453	0.03067	0.16043
1980-82	0.01147	0.00057	0.00126	0.00370	0.02671	0.14848
1985-87	0.01030	0.00050	0.00129	0.00291	0.02351	0.14276
1990-92	0.00814	0.00044	0.00131	0.00256	0.02061	0.12975
1995-97	0.00610	0.00039	0.00131	0.00231	0.01763	0.12443
2000-02	0.00567	0.00030	0.00119	0.00218	0.01420	0.10556
2005-07	0.00523	0.00022	0.00095	0.00204	0.01200	0.09907
2010-12	0.004121	0.000215	0.000826	0.001898	0.010505	0.093419
2015-17	0.003547	0.000202	0.000760	0.002015	0.009670	0.086771

Historical summary of mortality rates — females

	Age					
Life Tables	0	15	30	45	65	85
1881-90	0.11572	0.00299	0.00828	0.01167	0.03550	0.18779
1891-00	0.10139	0.00248	0.00652	0.00917	0.03239	0.17463
1901-10	0.07953	0.00219	0.00519	0.00807	0.02998	0.16459
1920-22	0.05568	0.00144	0.00387	0.00606	0.02426	0.17200
1932-34	0.03642	0.00113	0.00279	0.00523	0.02365	0.15837
1946-48	0.02519	0.00061	0.00165	0.00411	0.02133	0.15818
1953-55	0.01989	0.00048	0.00096	0.00341	0.01943	0.15018
1960-62	0.01757	0.00038	0.00082	0.00300	0.01769	0.13927
1965-67	0.01639	0.00041	0.00085	0.00313	0.01774	0.13782
1970-72	0.01501	0.00042	0.00077	0.00299	0.01684	0.12986
1975-77	0.01184	0.00037	0.00062	0.00264	0.01493	0.11644
1980-82	0.00905	0.00031	0.00052	0.00207	0.01283	0.10656
1985-87	0.00794	0.00026	0.00053	0.00180	0.01179	0.09781
1990-92	0.00634	0.00025	0.00051	0.00152	0.01049	0.09021
1995-97	0.00502	0.00022	0.00049	0.00137	0.00929	0.08553
2000-02	0.00466	0.00020	0.00045	0.00130	0.00789	0.07528
2005-07	0.00440	0.00018	0.00038	0.00124	0.00679	0.07088
2010-12	0.003352	0.000162	0.000349	0.001188	0.006203	0.066375
2015-17	0.003020	0.000161	0.000338	0.001179	0.005664	0.062792

Complete expectation of life at selected ages — males

	Age			
Life Tables	0	30	65	85
1881-90	47.20	33.64	11.06	3.86
1891-00	51.08	35.11	11.25	3.79
1901-10	55.20	36.52	11.31	3.65
1920-22	59.15	38.44	12.01	3.62
1932-34	63.48	39.90	12.40	3.90
1946-48	66.07	40.40	12.25	3.84
1953-55	67.14	40.90	12.33	4.01
1960-62	67.92	41.12	12.47	4.08
1965-67	67.63	40.72	12.16	4.07
1970-72	67.81	40.94	12.21	4.13
1975-77	69.56	42.18	13.13	4.45
1980-82	71.23	43.51	13.80	4.67
1985-87	72.74	44.84	14.60	4.89
1990-92	74.32	46.07	15.41	5.23
1995-97	75.69	47.26	16.21	5.40
2000-02	77.64	49.07	17.70	6.11
2005-07	79.02	50.20	18.54	6.03
2010-12	80.06	51.04	19.22	6.06
2015-17	80.76	51.65	19.86	6.40

Complete expectation of life at selected ages — females

	Age			
Life Tables	0	30	65	85
1881-90	50.84	36.13	12.27	3.90
1891-00	54.76	37.86	12.75	4.12
1901-10	58.84	39.33	12.88	4.19
1920-22	63.31	41.48	13.60	4.06
1932-34	67.14	42.77	14.15	4.30
1946-48	70.63	44.08	14.44	4.32
1953-55	72.75	45.43	15.02	4.52
1960-62	74.18	46.49	15.68	4.79
1965-67	74.15	46.34	15.70	4.85
1970-72	74.80	46.86	16.09	5.03
1975-77	76.56	48.26	17.13	5.49
1980-82	78.27	49.67	18.00	5.74
1985-87	79.20	50.49	18.56	6.09
1990-92	80.39	51.48	19.26	6.40
1995-97	81.37	52.30	19.88	6.53
2000-02	82.87	53.72	21.15	7.28
2005-07	83.67	54.44	21.62	7.08
2010-12	84.31	54.96	22.05	7.14
2015-17	84.85	55.42	22.47	7.37

Appendix B

POPULATION

The Australian population as shown by the last thirteen Censuses was:

Year	Males	Females	Total
1954	4,546,118	4,440,412	8,986,530
1961	5,312,252	5,195,934	10,508,186
1966	5,841,588	5,757,910	11,599,498
1971	6,506,224	6,431,023	12,937,247
1976	6,979,380	6,936,129	13,915,509
1981	7,416,090	7,440,684	14,856,774
1986	7,940,110	7,959,691	15,899,801
1991	8,518,397	8,584,208	17,102,605
1996	9,048,337	9,172,939	18,221,276
2001	9,533,996	9,670,962	19,204,958
2006	10,123,089	10,247,880	20,370,969
2011	10,972,862	11,085,920	22,058,782
2016	11,813,095	12,006,320	23,819,415

Figures shown for Censuses before 1966 exclude Aborigines. Figures shown for Censuses from 1971 onwards have been adjusted by the Statistician to allow for under-enumeration. Since 1991, the Census has been held in August. Figures for these years are given at 30 June of the relevant year and have been adjusted for the length of time between 30 June and Census night.

Deaths

Year	Males	Females	Total
2015	80,489	76,782	157,271
2016	81,825	76,653	158,478
2017	83,997	79,019	163,016
Total	**246,311**	**232,454**	**478,765**

These numbers do not include deaths of Australian residents overseas, but do include deaths of overseas residents who are in Australia at the time of their death.

Movements of the population

Year	Males		Females		Total	
	Arrivals	Departures	Arrivals	Departures	Arrivals	Departures
2015	8,977,585	8,862,361	8,602,711	8,540,382	17,580,296	17,402,743
2016	9,579,644	9,436,542	9,410,012	9,330,331	18,989,656	18,766,873
2017	10,130,404	9,983,296	9,997,751	9,938,114	20,128,155	19,921,410
Total	**28,687,633**	**28,282,199**	**28,010,474**	**27,808,827**	**56,698,107**	**56,091,026**

These numbers are not evenly distributed by age and whether arrivals exceed departures or vice-versa may vary from age to age.

Appendix C

Population at 30 June 2016 and deaths in the three years 2015-17, Australia — males

Age	Population	Deaths	Age	Population	Deaths
0	161,649	1,632	52	151,774	1,474
1	157,663	130	53	153,095	1,680
2	157,934	77	54	152,396	1,849
3	160,534	67	55	150,993	1,978
4	159,464	56	56	145,477	2,073
5	159,019	40	57	142,229	2,166
6	159,575	38	58	139,193	2,318
7	157,650	42	59	135,622	2,439
8	157,620	38	60	134,503	2,679
9	156,242	42	61	128,458	2,720
10	150,711	41	62	124,699	2,939
11	144,795	35	63	123,850	3,025
12	143,391	44	64	121,017	3,321
13	140,481	63	65	119,445	3,502
14	140,033	61	66	116,686	3,769
15	143,370	90	67	113,434	4,011
16	144,047	123	68	114,114	4,444
17	146,653	184	69	116,417	4,640
18	149,262	233	70	97,685	4,833
19	155,449	268	71	91,757	4,873
20	160,723	281	72	86,590	4,969
21	167,254	270	73	77,260	5,368
22	170,106	308	74	75,745	5,411
23	174,127	324	75	69,002	5,635
24	177,972	350	76	65,199	5,862
25	181,102	341	77	60,658	6,254
26	183,470	346	78	56,051	6,487
27	179,463	366	79	52,531	6,572
28	178,919	372	80	48,262	6,902
29	176,986	378	81	42,941	7,314
30	179,096	444	82	39,635	7,527
31	177,011	409	83	36,113	7,499
32	176,331	462	84	33,433	8,051
33	175,457	447	85	31,234	8,391
34	171,157	489	86	28,179	8,699
35	167,596	489	87	24,016	8,497
36	160,742	541	88	21,019	8,225
37	155,804	548	89	17,362	7,900
38	153,143	541	90	14,600	7,061
39	152,435	584	91	11,442	6,377
40	153,987	631	92	8,940	5,510
41	154,336	707	93	6,649	4,536
42	158,635	795	94	5,076	3,753
43	160,424	830	95	3,615	2,933
44	165,350	928	96	2,477	2,125
45	166,088	974	97	1,462	1,423
46	156,550	1,001	98	1,030	1,010
47	153,278	1,114	99	629	611
48	148,755	1,146	100 and over	737	1,105
49	144,896	1,196			
50	145,831	1,250	Not stated		5
51	145,798	1,400	Total	11,813,095	246,311

Population at 30 June 2016 and deaths in the three years 2015-17, Australia — females

Age	Population	Deaths	Age	Population	Deaths
0	152,539	1,311	52	157,432	984
1	149,757	100	53	159,172	1,068
2	150,115	65	54	157,551	1,165
3	152,089	40	55	157,662	1,237
4	150,918	43	56	153,045	1,293
5	150,906	36	57	148,920	1,311
6	151,905	31	58	147,549	1,485
7	149,359	24	59	143,204	1,494
8	149,598	30	60	140,526	1,676
9	147,762	36	61	136,375	1,625
10	142,695	27	62	132,880	1,792
11	136,502	23	63	130,552	1,844
12	134,764	31	64	126,126	1,970
13	133,367	45	65	124,072	2,080
14	133,113	42	66	120,951	2,284
15	135,377	69	67	116,254	2,554
16	137,421	86	68	116,166	2,803
17	139,050	83	69	118,788	2,904
18	140,437	96	70	99,676	3,082
19	146,877	105	71	94,990	3,117
20	151,165	115	72	90,513	3,200
21	157,477	89	73	81,610	3,464
22	161,270	119	74	80,094	3,622
23	167,692	119	75	74,935	3,902
24	172,112	104	76	71,466	4,143
25	177,539	143	77	68,083	4,409
26	181,278	155	78	64,288	4,878
27	179,446	146	79	60,982	5,118
28	179,802	137	80	57,424	5,529
29	178,797	167	81	52,780	5,865
30	181,561	168	82	49,505	6,427
31	179,981	212	83	47,111	6,830
32	178,771	211	84	44,404	7,639
33	176,730	203	85	43,424	8,455
34	171,250	271	86	40,338	8,882
35	167,482	301	87	36,127	9,458
36	160,946	261	88	33,199	9,707
37	156,657	279	89	29,530	9,907
38	153,995	309	90	26,022	10,236
39	152,669	318	91	22,041	9,761
40	153,918	364	92	18,300	9,291
41	154,742	385	93	14,916	8,522
42	159,422	440	94	11,918	7,554
43	163,577	492	95	9,226	6,317
44	169,979	585	96	6,298	5,048
45	173,365	613	97	3,881	3,743
46	162,363	629	98	2,991	2,744
47	160,609	635	99	2,007	2,133
48	155,444	738	100 and over	2,787	4,404
49	150,863	738			
50	151,207	811	Not stated		3
51	151,569	915	Total	12,006,320	232,454

APPENDIX D

Comparison of actual and expected deaths in the three years 2015-2017, Australia — males

Age	Actual Deaths	Expected Deaths	Deviation +	Deviation -	Accumulation +	Accumulation -
2	77	91		14		14
3	67	66	1			13
4	56	49	7			5
5	40	43		3		8
6	38	40		2		10
7	42	40	2			8
8	38	40		2		9
9	42	39	3			6
10	41	39	2			4
11	35	41		6		11
12	44	45		1		12
13	63	54	9			3
14	61	67		6		9
15	90	88	2			7
16	123	125		2		9
17	184	182	2			7
18	233	235		2		9
19	268	258	10		0	
20	281	277	4		5	
21	270	292		22		17
22	308	307	1			16
23	324	320	4			12
24	350	335	15		3	
25	341	348		7		4
26	346	358		12		16
27	366	366	0			16
28	372	376		4		20
29	378	390		12		33
30	444	407	37		4	
31	409	427		18		13
32	462	446	16		3	
33	447	460		13		10
34	489	480	9			1
35	489	501		12		13
36	541	516	25		12	
37	548	533	15		27	
38	541	563		22	4	
39	584	602		18		13
40	631	645		14		27
41	707	699	8			19
42	795	767	28		8	
43	830	851		21		13
44	928	926	2			10
45	974	974		0		11
46	1,001	1,031		30		41
47	1,114	1,089	25			16
48	1,146	1,132	14			2
49	1,196	1,196	0			2
50	1,250	1,276		26		28
51	1,400	1,370	30		2	

Comparison of actual and expected deaths in the three years 2015-17, Australia — males (continued)

Age	Actual Deaths	Expected Deaths	Deviation		Accumulation	
			+	-	+	-
52	1,474	1,506		32		30
53	1,680	1,665	15			14
54	1,849	1,825	24		10	
55	1,978	1,957	21		31	
56	2,073	2,069	4		35	
57	2,166	2,213		47		12
58	2,318	2,354		36		49
59	2,439	2,476		37		86
60	2,679	2,588	91		5	
61	2,720	2,738		18		13
62	2,939	2,901	38		25	
63	3,025	3,089		64		39
64	3,321	3,288	33			6
65	3,502	3,488	14		7	
66	3,769	3,757	12		19	
67	4,011	4,042		31		12
68	4,444	4,379	65		53	
69	4,640	4,683		43	10	
70	4,833	4,888		55		45
71	4,873	4,869	4			41
72	4,969	5,018		49		90
73	5,368	5,234	134		44	
74	5,411	5,434		23	20	
75	5,635	5,672		37		17
76	5,862	5,906		44		60
77	6,254	6,186	68		7	
78	6,487	6,461	26		33	
79	6,572	6,682		110		77
80	6,902	6,905		3		80
81	7,314	7,131	183		104	
82	7,527	7,442	85		188	
83	7,499	7,767		268		79
84	8,051	8,024	27			52
85	8,391	8,423		32		84
86	8,699	8,607	92		8	
87	8,497	8,505		8		0
88	8,225	8,221	4		4	
89	7,900	7,816	84		88	
90	7,061	7,176		115		28
91	6,377	6,383		6		34
92	5,510	5,432	78		44	
93	4,536	4,490	46		90	
94	3,753	3,659	94		184	
95	2,933	2,882	51		235	
96	2,125	2,137		12	223	
97	1,423	1,499		76	146	
98	1,010	1,027		17	129	
99	611	696		85	44	
100	444	449		5	39	
Total	243,883	243,844				

The expected deaths are the number of deaths under the assumption that the graduated rates are correct. Deviation refers to the difference between the actual and expected number of deaths. Accumulation at age x is the sum of the deviations from age 2 to age x. Note that this table does not cover ages 0 or 1, as the exposure to risk for these ages was calculated in a different way.

Comparison of actual and expected deaths in the three years 2015-17, Australia — females

Age	Actual Deaths	Expected Deaths	Deviation +	Deviation -	Accumulation +	Accumulation -
2	65	66		1		1
3	40	42		2		3
4	43	38	5		2	
5	36	34	2		3	
6	31	32		1	2	
7	24	31		7		4
8	30	29	1			4
9	36	29	7		4	
10	27	28		1	3	
11	23	28		5		2
12	31	31		0		2
13	45	38	7		5	
14	42	50		8		3
15	69	67	2			1
16	86	80	6		5	
17	83	90		7		2
18	96	97		1		3
19	105	102	3		0	
20	115	106	9		9	
21	89	109		20		11
22	119	111	8			3
23	119	113	6		3	
24	104	120		16		13
25	143	128	15		2	
26	155	137	18		20	
27	146	145	1		21	
28	137	155		18	3	
29	167	170		3		0
30	168	185		17		17
31	212	199	13			3
32	211	216		5		8
33	203	233		30		38
34	271	246	25			13
35	301	260	41		29	
36	261	274		13	16	
37	279	288		9	6	
38	309	305	4		11	
39	318	330		12		2
40	364	359	5		4	
41	385	395		10		7
42	440	441		1		8
43	492	493		1		9
44	585	552	33		24	
45	613	603	10		34	
46	629	647		18	17	
47	635	671		36		20
48	738	709	29		9	
49	738	757		19		9
50	811	822		11		20
51	915	895	20		0	

Comparison of actual and expected deaths in the three years 2015-17, Australia — females (continued)

Age	Actual Deaths	Expected Deaths	Deviation		Accumulation	
			+	-	+	-
52	984	976	8		9	
53	1,068	1,066	2		11	
54	1,165	1,160	5		16	
55	1,237	1,232	5		21	
56	1,293	1,306		13	8	
57	1,311	1,377		66		58
58	1,485	1,432	53			5
59	1,494	1,512		18		24
60	1,676	1,590	86		62	
61	1,625	1,670		45	18	
62	1,792	1,762	30		47	
63	1,844	1,871		27	21	
64	1,970	1,994		24		4
65	2,080	2,119		39		43
66	2,284	2,291		7		50
67	2,554	2,496	58		8	
68	2,803	2,756	47		55	
69	2,904	2,942		38	16	
70	3,082	3,051	31		47	
71	3,117	3,109	8		55	
72	3,200	3,242		42	13	
73	3,464	3,448	16		30	
74	3,622	3,659		37		7
75	3,902	3,898	4			3
76	4,143	4,163		20		24
77	4,409	4,405	4			20
78	4,878	4,792	86		66	
79	5,118	5,134		16	51	
80	5,529	5,533		4	46	
81	5,865	5,958		93		47
82	6,427	6,360	67		21	
83	6,830	6,871		41		21
84	7,639	7,607	32		11	
85	8,455	8,299	156		167	
86	8,882	8,987		105	62	
87	9,458	9,443	15		77	
88	9,707	9,749		42	35	
89	9,907	10,064		157		121
90	10,236	10,048	188		67	
91	9,761	9,859		98		31
92	9,291	9,287	4			26
93	8,522	8,533		11		37
94	7,554	7,525	29			8
95	6,317	6,330		13		22
96	5,048	4,964	84		62	
97	3,743	3,794		51	11	
98	2,744	2,837		93		82
99	2,133	2,105	28			54
100	1,579	1,487	92		38	
Total	228,215	228,177				

The expected deaths are the number of deaths under the assumption that the graduated rates are correct. Deviation refers to the difference between the actual and expected number of deaths. Accumulation at age x is the sum of the deviations from age 2 to age x. Note that this table does not cover ages 0 or 1, as the exposure to risk for these ages was calculated in a different way.

Appendix E

Future percentage mortality improvement factors — males

Age	25 Year	125 Year	Age	25 Year	125 Year
0	-3.4620	-3.2886	56	-2.1483	-1.3897
1	-3.5259	-3.2854	57	-2.2479	-1.3795
2	-3.5676	-3.1854	58	-2.3485	-1.3717
3	-3.5700	-3.0406	59	-2.4505	-1.3650
4	-3.5224	-2.9186	60	-2.5531	-1.3583
5	-3.4318	-2.8162	61	-2.6538	-1.3520
6	-3.3086	-2.7388	62	-2.7495	-1.3469
7	-3.1634	-2.6966	63	-2.8362	-1.3444
8	-3.0075	-2.6871	64	-2.9096	-1.3449
9	-2.8511	-2.6897	65	-2.9664	-1.3480
10	-2.7031	-2.6779	66	-3.0047	-1.3500
11	-2.5838	-2.6269	67	-3.0239	-1.3472
12	-2.5191	-2.5433	68	-3.0253	-1.3367
13	-2.5338	-2.4430	69	-3.0116	-1.3176
14	-2.6121	-2.3463	70	-2.9861	-1.2927
15	-2.7260	-2.2704	71	-2.9523	-1.2652
16	-2.8428	-2.2151	72	-2.9128	-1.2378
17	-2.9382	-2.1753	73	-2.8697	-1.2118
18	-3.0204	-2.1485	74	-2.8227	-1.1856
19	-3.0887	-2.1367	75	-2.7708	-1.1573
20	-3.1348	-2.1289	76	-2.7113	-1.1253
21	-3.1440	-2.1138	77	-2.6415	-1.0887
22	-3.1134	-2.0940	78	-2.5589	-1.0470
23	-3.0448	-2.0740	79	-2.4619	-1.0002
24	-2.9469	-2.0563	80	-2.3497	-0.9495
25	-2.8292	-2.0386	81	-2.2226	-0.8966
26	-2.6989	-2.0173	82	-2.0820	-0.8428
27	-2.5605	-1.9902	83	-1.9300	-0.7889
28	-2.4175	-1.9577	84	-1.7698	-0.7354
29	-2.2717	-1.9220	85	-1.6057	-0.6827
30	-2.1245	-1.8878	86	-1.4420	-0.6314
31	-1.9774	-1.8572	87	-1.2837	-0.5820
32	-1.8320	-1.8313	88	-1.1358	-0.5352
33	-1.6901	-1.8106	89	-1.0033	-0.4918
34	-1.5535	-1.7941	90	-0.8890	-0.4525
35	-1.4246	-1.7802	91	-0.7942	-0.4179
36	-1.3052	-1.7668	92	-0.7156	-0.3871
37	-1.1975	-1.7523	93	-0.6473	-0.3591
38	-1.1033	-1.7369	94	-0.5834	-0.3325
39	-1.0244	-1.7199	95	-0.5187	-0.3061
40	-0.9628	-1.7012	96	-0.4481	-0.2797
41	-0.9203	-1.6823	97	-0.3680	-0.2533
42	-0.8986	-1.6640	98	-0.2787	-0.2269
43	-0.8991	-1.6463	99	-0.1817	-0.2005
44	-0.9228	-1.6282	100	-0.0808	-0.1741
45	-0.9697	-1.6091	101	0.0000	-0.1478
46	-1.0392	-1.5888	102	0.0000	-0.1214
47	-1.1299	-1.5681	103	0.0000	-0.0950
48	-1.2379	-1.5482	104	0.0000	-0.0686
49	-1.3584	-1.5293	105	0.0000	-0.0422
50	-1.4844	-1.5099	106	0.0000	0.0000
51	-1.6089	-1.4884	107	0.0000	0.0000
52	-1.7280	-1.4654	108	0.0000	0.0000
53	-1.8406	-1.4424	109	0.0000	0.0000
54	-1.9468	-1.4212	110	0.0000	0.0000
55	-2.0486	-1.4035	111	0.0000	0.0000

Future percentage mortality improvement factors — females

Age	25 Year	125 Year	Age	25 Year	125 Year
0	-3.0278	-3.3478	56	-1.8658	-1.4816
1	-3.3164	-3.3495	57	-1.9359	-1.4794
2	-3.5489	-3.2543	58	-2.0090	-1.4767
3	-3.6411	-3.1058	59	-2.0856	-1.4737
4	-3.5365	-2.9722	60	-2.1634	-1.4701
5	-3.3109	-2.8853	61	-2.2390	-1.4660
6	-3.0543	-2.8518	62	-2.3076	-1.4620
7	-2.8341	-2.8692	63	-2.3638	-1.4591
8	-2.6521	-2.9151	64	-2.4042	-1.4578
9	-2.5074	-2.9747	65	-2.4286	-1.4567
10	-2.3995	-3.0325	66	-2.4378	-1.4516
11	-2.3138	-3.0574	67	-2.4348	-1.4389
12	-2.2282	-3.0158	68	-2.4240	-1.4187
13	-2.1165	-2.8928	69	-2.4100	-1.3927
14	-1.9938	-2.7322	70	-2.3961	-1.3646
15	-1.9035	-2.5934	71	-2.3824	-1.3373
16	-1.9312	-2.5253	72	-2.3686	-1.3133
17	-2.0766	-2.5204	73	-2.3558	-1.2939
18	-2.3011	-2.5553	74	-2.3440	-1.2773
19	-2.5181	-2.6002	75	-2.3274	-1.2608
20	-2.6457	-2.6308	76	-2.2995	-1.2408
21	-2.6769	-2.6487	77	-2.2553	-1.2139
22	-2.6435	-2.6580	78	-2.1945	-1.1797
23	-2.5797	-2.6608	79	-2.1184	-1.1392
24	-2.5037	-2.6574	80	-2.0289	-1.0935
25	-2.4132	-2.6463	81	-1.9281	-1.0440
26	-2.3016	-2.6267	82	-1.8183	-0.9917
27	-2.1626	-2.6007	83	-1.7005	-0.9374
28	-1.9928	-2.5685	84	-1.5766	-0.8819
29	-1.8006	-2.5298	85	-1.4483	-0.8256
30	-1.5988	-2.4863	86	-1.3177	-0.7691
31	-1.4001	-2.4397	87	-1.1858	-0.7125
32	-1.2146	-2.3906	88	-1.0541	-0.6559
33	-1.0511	-2.3401	89	-0.9250	-0.5996
34	-0.9175	-2.2899	90	-0.8014	-0.5448
35	-0.8173	-2.2419	91	-0.6874	-0.4928
36	-0.7520	-2.1969	92	-0.5863	-0.4455
37	-0.7215	-2.1550	93	-0.4993	-0.4037
38	-0.7204	-2.1136	94	-0.4190	-0.3671
39	-0.7403	-2.0697	95	-0.3361	-0.3332
40	-0.7681	-2.0201	96	-0.2435	-0.2998
41	-0.7996	-1.9655	97	-0.1438	-0.2663
42	-0.8352	-1.9074	98	-0.0422	-0.2329
43	-0.8816	-1.8488	99	0.0000	-0.1995
44	-0.9391	-1.7919	100	0.0000	-0.1660
45	-1.0060	-1.7387	101	0.0000	-0.1326
46	-1.0808	-1.6896	102	0.0000	-0.0991
47	-1.1614	-1.6449	103	0.0000	-0.0657
48	-1.2448	-1.6047	104	0.0000	-0.0323
49	-1.3289	-1.5692	105	0.0000	0.0000
50	-1.4121	-1.5388	106	0.0000	0.0000
51	-1.4946	-1.5148	107	0.0000	0.0000
52	-1.5751	-1.4981	108	0.0000	0.0000
53	-1.6524	-1.4887	109	0.0000	0.0000
54	-1.7261	-1.4847	110	0.0000	0.0000
55	-1.7967	-1.4832	111	0.0000	0.0000