U.S. Mortality, Life Expectancy, and Active Life Expectancy at Advanced Ages: Trends and Forecasts

by

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I. Introduction

In this paper we conduct a coupled life expectancy – active life expectancy analysis using National Long Term Care Survey (NLTCS) and linked Medicare data to produce estimates of life expectancy (LE) and active life expectancy (ALE) at various dates to examine the relative rate of change in total LE and ALE over time to see the effects of improvements in elderly health and longevity. We will focus attention to the changes in LE and ALE for persons aged 85 years and older, and mortality patterns at extreme (i.e., age 95 to 110) ages.

Estimates of disability declines suggest the rate of disability improvement accelerated over the period 1982 to 1999 (e.g., 1989-1994 it was 1.5%, and 1994 to 1999, 2.6%, overall 1982 to 1999 the change is 1.7% per annum; Manton and Gu, 2001). This acceleration might have been anticipated given the eventual impact of the introduction of Medicare funding of health care in 1965 (and later Medicaid state programs) providing universal health care coverage for the U.S. elderly population and the period of time necessary for its full implementation in the U.S. elderly population and adoption by the U.S. health care system.

II. Methods

Active life expectancy calculations are frequently used to determine the period of time expected to be lived free of serious disability (Robine et al. 2003). This is qualitatively different from methods where some type of subjective weight is applied to differentiate the period of time lived with some degree of functional impairment. Classically, ALE is calculated from multiple data sources, i.e., vital statistic and Census data on age and sex specific population counts to calculate population life tables, and health survey data on proportions of the population in specific health states at specific ages (Lamb and Siegel, 2003). For this paper we will be estimating LE and ALE for different years during the twentieth century, and projections into the early twenty-first century using the Sullivan method of ALE estimation based on period life tables and period-specific disability prevalence estimates (Sullivan, 1971). Use of national life tables in calculating ALE has the advantage of providing survival estimates with relatively little sampling variability. Calculation of disability prevalence among survivors to a given age is typically done using data from large national health surveys. A comparison of life tables based on national data with life tables calculated from health surveys is useful to check the representativness of the health and mortality experience of the survey samples.

III. Data

The 1982 to 1999 NLTCS. The National Long Term Care Survey has been conducted in 1982, 1984, 1989, 1994, 1999, and most recently, 2004-2005, which has just been completed. It is a longitudinal survey of the Medicare enrolled U.S. population aged 65+. In each survey year approximately 20,000 persons are screened for chronic limitations in Activities of Daily Living (ADLs) (Katz, 1963) and Instrumental Activities of Daily Living (IADLs) (Lawton and Brody, 1969).

The roughly 20,000 person sampled in each survey is comprised of 15,000 persons who were surveyed in the prior round of the NLTCS and 5,000 persons who passed age 65 between the close of the prior survey and the selection of the supplementary sample drawn for the new survey. The 5,000 persons in the 65-69 supplemental sample approximately compensate for the mortality experienced over the five years between surveys. Within the 15,000 persons who survive to the next survey, persons who had chronic disability in the prior survey are not only included in the sample but are automatically scheduled for a detailed interview to assess the conditions surrounding changes, both positive and negative, in functional and health status between surveys. In 1994, 1999, and 2004 the disabled sample receiving a detailed interview was enhanced with a supplementary sample of persons who were screened "out" as not disabled to increase the precision of trait estimates for non-disabled persons.

To further enhance the sample, persons aged 95+ were oversampled in 1994 (N ~ 540), 1999 (N ~600) and, in the new 2004-2005 NLTCS (N ~1584) to improve the precision of estimates for the extremely elderly population. The 95+ oversample was included because a) the prevalence of chronic disability had been declining at younger ages to relatively low levels (e.g., for persons 65 to 69; Manton and Gu, 2005) so oversampling the very old was necessary to more precisely characterize a large proportion of the future disability burden, and b) while disability changes in the young old might be explained by existing models of chronic disease risk, and resulting disability, changes at ages 95+ will require more in depth investigation of the physiology of aging processes because it brings us closer to the current biological limits of longevity and, consequently, of physiological change in function (Walston, 2004; Manton et al., 2005a, 2005b).

Mortality at extreme ages. Projecting mortality trends, and life expectancy, to late ages is a difficult exercise because there has been relatively little reliable data for mortality at later ages (e.g., 95+). One source of good quality data is annuitant life tables prepared by the Society of Actuaries (SoA; 2000). Those tables, which are based on the longitudinal observation of persons in private insurance programs, suggest a plateau in mortality hazard rates exists at extreme ages with no credible evidence of hazard rates over 40% per annum at extreme ages. Social Security Administration (SSA) life tables do not provide insight into mortality at these late ages since a Gompertz-type function with a predetermined shape parameter ($\theta = 0.05$ or 0.06) is used to describe mortality at ages 95+. This is highly problematic when future long range projections of life expectancy begin to approach age 90, i.e., the majority of survival experience over age 65 in these smoothed tables is artifactual (NCHS, 1999).

We have been conducting detailed analyses of mortality at ages 95 to 110 using the enhanced NLTCS data and linked Medicare mortality data to characterize the slope of the survival curve at those advanced ages and found it to be very different than the Gompertz function with evidence of a mortality rate plateau (as found by SoA), and possibly of a decline in mortality rates at very extreme ages (Manton et al., 2005a, 2005b). A more general model for heterogeneity hazard models has been created that provide a better fit to mortality above age 95. After employing a number of tests to evaluate the quality of the Medicare mortality data for older ages the data were found to be consistent with a plateau effect (i.e., a leveling off), and with declines in the per annum hazard rate among survivors to ages 100+. Figures 1 and 2 present the mortality hazard rates calculated for males and females, respectively, using the SSA, SoA, and NLTCS mortality data to demonstrate these trends. This trace of a mortality plateau is also evident in predicted and observed incidence rates for 5 diseases, as shown in Figures 3 and 4 for males and females respectively, using NLTCS/Medicare data for 1992-2001.

Disability prevalence. For this study disability prevalence is measured in the NLTCS as the proportion of persons aged 65 years and over that has any health-related difficulty in performing at least one IADL or ADL, or resides in an institution (Manton and Gu 2001). In other NLTCS analyses we have used multivariate indices constructed using a multivariate procedure (Grade of Membership [GoM] analysis, Manton et al., 1994) applied to 27 ADL, IADL, Nagi, and sensory measures (Manton and Gu, 2005). These multivariate analyses provide more detail on underlying disablement processes but are still broadly consistent with analyses of the trends using simpler indices.

Earlier 20th century trends of LE and ALE. For comparative purposes we will include U.S. estimates of life expectancy and active life expectancy for 1935 and 1965 as estimated in an earlier paper (Manton et al., 2005c). For the 1935 mortality estimates we used modifications of SSA calculated life tables. The 1965 mortality estimates are from National Center for Health Statistics (NCHS) life tables. The effects of the Gompertz style smoothing at advanced ages would be less important for the early SSA life tables (i.e., pre-1950) because relatively few persons survived to such late ages at that time.

The early disability estimates are based upon the trends of declines in disability and chronic conditions as reported by analyses by Robert Fogel and Dora Costa (Costa 2002, 2004; Fogel 1994, 2004; Fogel and Costa 1997) of Civil War Union veterans and more recent NHIS data for WW II veterans in 1985-1988 and noninstitutionalized white men assessed in the 1988-1994 NHANES and the 1994-1995 NHIS. The available disability measures used by Fogel and Costa focus primarily on mobility problems.

IV. Results

For the period 1910 to the late 1980s-early 1990s, the Fogel and Costa estimates of the rate of decline in chronic disease and disability average about 0.6% per year, with different measures declining 0.3 to 0.9% per annum (Fogel 1994; Costa 2002). From 1982 to 1999, we have age detailed rates of decline in chronic disability in the U.S. elderly population from the NLTCS. From 1982 to 1999 the seventeen year rate of decline averages about 1.7%. From 1994 to 1999 the rate of decline in chronic disability and institutional use increased to about 2.6% per annum (Manton and Gu, 2001). We estimate life expectancy and active life expectancy at select critical dates (i.e., 1935, 1965, 1982, 1999, and projections made for 2015, and 2022). The date 1935 was selected because it was the date of inception of the Social Security program. The date 1965 refers to the start of the Medicare program. The dates 1982 and 1999 refer to the period for which we have direct national data on individual disability changes. The year 2015 reflects the date at which the first several baby boom cohorts become SSA eligible. The year 2022 reflects the date to which Costa (2002) projects rapid increases in life expectancy due to improvements in social and economic factors would continue.

Table 1 presents estimates of life expectancy and active life expectancy at age 85 for the total U.S. population. We see total LE grew at a slightly greater rate than ALE from 1935 to 1982 for ages 85+ as there is some increase in the number of disabled years (column 3). This is because disability prevalence, according to Fogel and Costa's estimates, declined at a relatively slow 0.6% per year.

In contrast, because of the acceleration of the rate of decline in disability 1982 to 1999, ALE grew much faster than total LE, i.e., the percent ALE of total LE jumped from 33.9% to 46.9%. This trend is projected to further increase from 1999 to 2015, i.e., from 46.9% to 64.6%. Our mortality and disability analyses suggest relative rates of improvement might be even faster at ages 95+ (Manton et al., 2005a, 2005b).

These results for 1935 to 2022 might be better appreciated graphically. As shown in Figure 5, 65 year olds in 1935 experienced an ALE of 8.8 years comprising 74% of a total LE estimated to be 11.9 years. In the figure we see that there were expected to be relatively few survivors to age 90 in 1935.

The second time point we examine was 1965, the date at which the Medicare program was initiated. All changes 1935 to 1965 were generated without the benefits of the Medicare program or, in general, without the benefit of modern biomedical research. The survival and ALE curves for 1965 are in Figure 6.

In Figure 6 we see that there was relatively good progress, despite the great depression and WW II, in ALE in the 30 year period 1935 to 1965. In 1965 ALE was 10.9 years and LE was 15 years. Life expectancy to ages 90+ increased significantly. However, in this period the ALE/LE ratio actually declined modestly. The ALE/LE ratio at ages 85+ is less – about a quarter of LE is in an active state though, in contrast to age 65, there was an improvement in the ratio.

The next time period we examined was the date at which the NLTCS was initiated, 1982, which corresponded to the recognition that LE, especially for males, was moving more rapidly than had been anticipated by SSA actuaries in the period immediately preceding 1982. Prior to 1982, SSA actuaries argued that LE had reached a biological maximum in 1977 (Myers, 1981). The net improvement in LE, 1969 to 1982, was associated with rapid declines in heart disease that began for males in 1969.

A 65 year old in 1982 experienced an ALE of 12.3 years (an increase of 2.4 years since 1935) comprising 73% of the total LE of 16.9 years, as shown in Figure 7 Again the survival to later ages showed considerable increase. The percent of LE at age 85 that is expected to be active increased 6.1% to 33.9%

The situation in 1999 is different in that chronic disability declined almost 1.7% per annum from 1982 to 1999 (Manton and Gu, 2001) as shown in Figure 8. ALE increased 1.6 years from 1982 to 1999 (from 12.3 to 13.9 years) while total LE increased only 0.8 years. Thus quality of survival above age 65 increased more rapidly than survival quantity over the 1982 to 1999 period, i.e., the ALE/LE ratio increased from 72.8 to 78.5%. Active life expectancy over ages 85+ increased more rapidly, from 33.9% to 46.9%, or 0.9 years.

It is important, for Medicare and Social Security program evaluation, to determine how these changes will occur in the relatively near future. One set of projections, based on changes in education at ages 85+, suggested that a 2.1% per annum decline in chronic disability could be supported to 2022 (Manton et al., 2002). Alternate analyses by Costa (2004) of changes in BMI and other biometric measures also suggest mortality declines, and health improvement, would also continue to 2022. A pessimistic approach based on recent obesity trends in younger population suggested that disability declines will continue to only 2015 or 2020 (Bhattacharya et al., 2004). Olshansky et al (2005) actually suggested total U.S. life expectancy might drop 2 to 5 or more years. These pessimistic perspectives were based on an evaluation of the obesity "epidemic" and have recently been discredited on both methodological and substantive grounds (Flegal et al., 2004; Flegal et al., 2005; Gregg et al., 2005; Couzin, 2005). As a consequence we calculated projections assuming a continuation of the 17 year disability declines to 2015 and 2022.

Extrapolating to 2015 the ALE increase is 3.1 years while LE increased 2.7 years, as shown in Figure 9. The proportion expected to be spent in an active state at age 65 grew from 78.5% to 83.3%. At age 85 the increase was from 46.9 to 61.5%. Overall, ALE increased 5.1 years from 1935 to 1999 – and 8.2 years to 2015 based on the short term extrapolation to 2015 of the more rapid recent NLTCS disability declines.

Figure 10 shows that by 2022 the increases at age 65 were 8.9 years of ALE and 10.0 years of LE compared to 1935. At age 85 ALE grew 4.6 years and LE increased 5.2 years. However, the LE increases were "front end" loaded from 1935 to 1982. After 1982 the relative proportion of the growing LE that is expected to be active increased steadily from 72.8 to 83.9%. The parallel increases at age 85 were 5.2 years gain in LE and 4.6 years gain in ALE with the proportion expected to be spent non-disabled growing continuously from 23.3% to 64.6%. We would expect improvements in function to more advanced ages (e.g., 95+) to also show rapid increases because this is where much of the remaining disability is to be decreased if progress at this rate is to continue.

Male and female differences in LE and ALE. Tables 2 and 3 show age 85 total LE and ALE estimates between 1965 and 2022 for males and females, respectively. Table 2 shows the continuous increase in male LE and ALE over the study. In 1965 85 year old males were estimated to have 5.0 years of total LE of which 1.8 years would be active. This yielded an ALE/LE ratio of 36%. By 1982 male LE had modestly increased to 5.4 years, and ALE to 2.2 years. ALE for males at age 85 increases a year 1982 to 1999, and 2.5 years 1982 to 2022. Between 1965 and 2022 the ALE/LE ratio almost doubles to 70.1%. The number of disability years declined from 3.2 in 1965 to 2.0 in 2022. Figure 11 shows the increase in LE and ALE for males and demonstrates the relative increase in ALE compared to total LE.

For females the trends are more modest but still demonstrate the remarkable LE increases evident over the second half of the twentieth century and forecast to continue to 2022. Table 3 shows ALE increase from 1.4 years to 3.7 years (+2.3 years) 1965 to 2022. Years of total LE for 85 year old females increased 2.6 years over the same period. Figure 12 shows these trends graphically.

VI. Discussion

One major question raised by this analysis is how certain one can be that disability decline will continue after 1999 to say 2025. We will have important evidence soon with the analysis of the new 2004 NLTCS results. A recent criticism of the continuation of the disability declines was due to Bhattacharya et al. (2004), who argued the obesity epidemic would end disability declines in roughly 2015. Olshansky et al (2005) suggested large declines in U.S. life expectancy of up to six years could occur. Unfortunately these analyses used faulty methods and largely obsolescent data as shown in a series of recent peer reviewed articles from CDC staff. Flegal et al. (2004) analyzed the results of recent CDC analyses and found that errors in the forecasting methodology could induce errors of 17 to 100% in the estimate of excess deaths due to obesity. Flegal et al. (2005) using more recent data that better reflected recent improvements in the management of major risk factors (i.e., hypertension, hypercholesterolemia, smoking, diabetes) had greatly reduced the risks of overweight and obesity (as they had been defined by CDC). Indeed, the effect of producing 114,000 excess deaths due to inappropriate weight, which included under weight, was largely counter balanced by the 86,000 fewer than expected deaths found for over weight persons with a body mass index (BMI) of 25-29.9. In a series of auxiliary studies (Flegal, 2005) these analyses were redone with exclusions for smoking, unstable weight, ill-health, and with the first years of follow-up, to control for reverse causation and to test for residual confounding. The higher risks for low BMI persons were confirmed as were the results for all of the BMI levels (Flegal, 2005). These results were confirmed in other studies such as Gregg et al (2005) who found the risk of death had decreased within specific BMI levels, and of Fox et al. (2004) who found improvements in CVD risk of diabetes was faster than that for non-diabetics – though the absolute risk for diabetics was still higher than that for non-diabetics.

These later studies strongly suggest that obesity was less of a risk factor in 2005 than in the 1970s and 1980s, especially for the elderly, due to better identification and management of major risk factors. In addition to better therapy and health care delivery there is the change in implications of various levels of BMI due to changes in social environmental factors that allow more health potential of individuals to be realized due to improved nutrition, sanitation and hygiene reducing, not only infectious disease risks, but also many chronic disease risks. This perspective is embedded in Fogel’s (1994) theory of techno physiological evolution that predicted that the optimal level of BMI should have increased from the time of the Civil War relative to the current time. The current optimal BMI calculated by Fogel (2004) is now, for males, roughly 26.5 – well into what CDC had labeled as overweight – though in an age range they later found to have the lowest level of mortality risks (Flegal et al., 2005). Analyses by Costa (2002) suggest that such factors should continue to cause declines in mortality (and, additionally, improvements in health before death) up to the U.S. birth cohort of 1955 (aged 65 in 2020). The health improvement due to increased education levels at ages 80+ are anticipated to occur up to 2015.

Thus, a continuation of known improvements in therapy, education, and in general public health and nutrition should support disability decline up to 2020 to 2025. After that time biomedical and other innovations to reduce chronic disability will have to occur at advanced age (e.g., over age 85) and involves interventions in more basic parameters of aging.

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Table 1. Life expectancy and active life expectancy at age 85

Year	LE	ALE	Difference (Disabled years)	ALE ratio to LE (%)
1935	3.0	0.7	2.3	23.3
1965	5.4	1.5	3.9	27.8
1982	6.2	2.1	4.1	33.9
1999	6.4	3.0	3.4	46.9
2015	7.8	4.8	3.0	61.5
2022	8.2	5.3	2.9	64.6

Table 2. Male life expectancy and active life expectancy at age 85

Year	LE	ALE	Difference (Disabled years)	ALE ratio to LE (%)
1965	5	1.8	3.2	36.0
1982	5.4	2.2	3.2	40.7
1999	5.7	3.2	2.5	56.1
2015	6.5	4.3	2.2	66.2
2022	6.7	4.7	2.0	70.1

Table 3. Female life expectancy and active life expectancy at age 85

Year	LE	ALE	Difference (Disabled years)	ALE ratio to LE (%)
1965	5.7	1.4	4.3	24.6
1982	6.6	2.0	4.6	30.3
1999	6.8	2.6	4.2	38.2
2015	7.9	3.4	4.5	43.0
2022	8.3	3.7	4.6	44.6

Figure 1. Estimated Male Mortality Hazard Rates

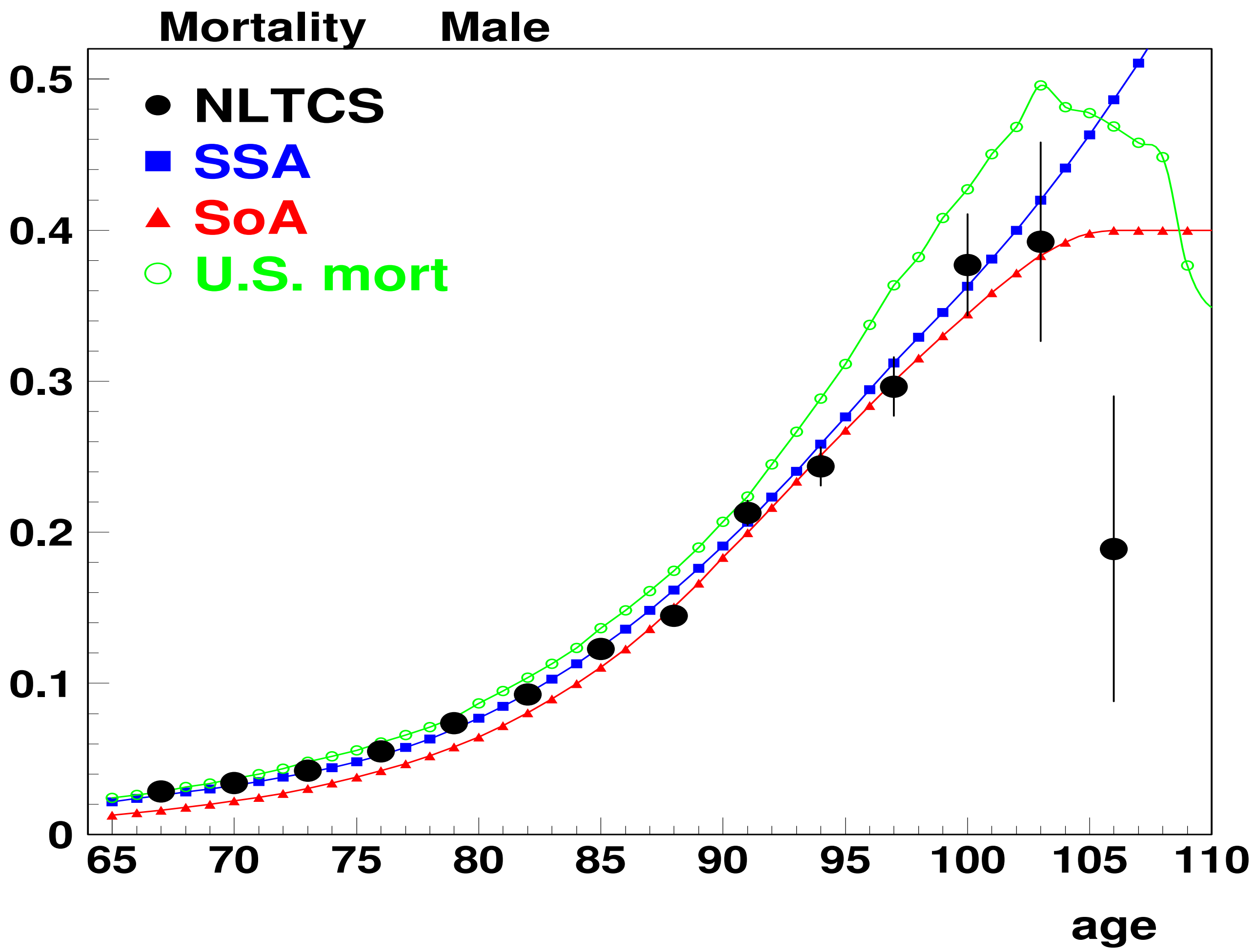


Figure 2. Estimated Female Mortality Hazard Rates

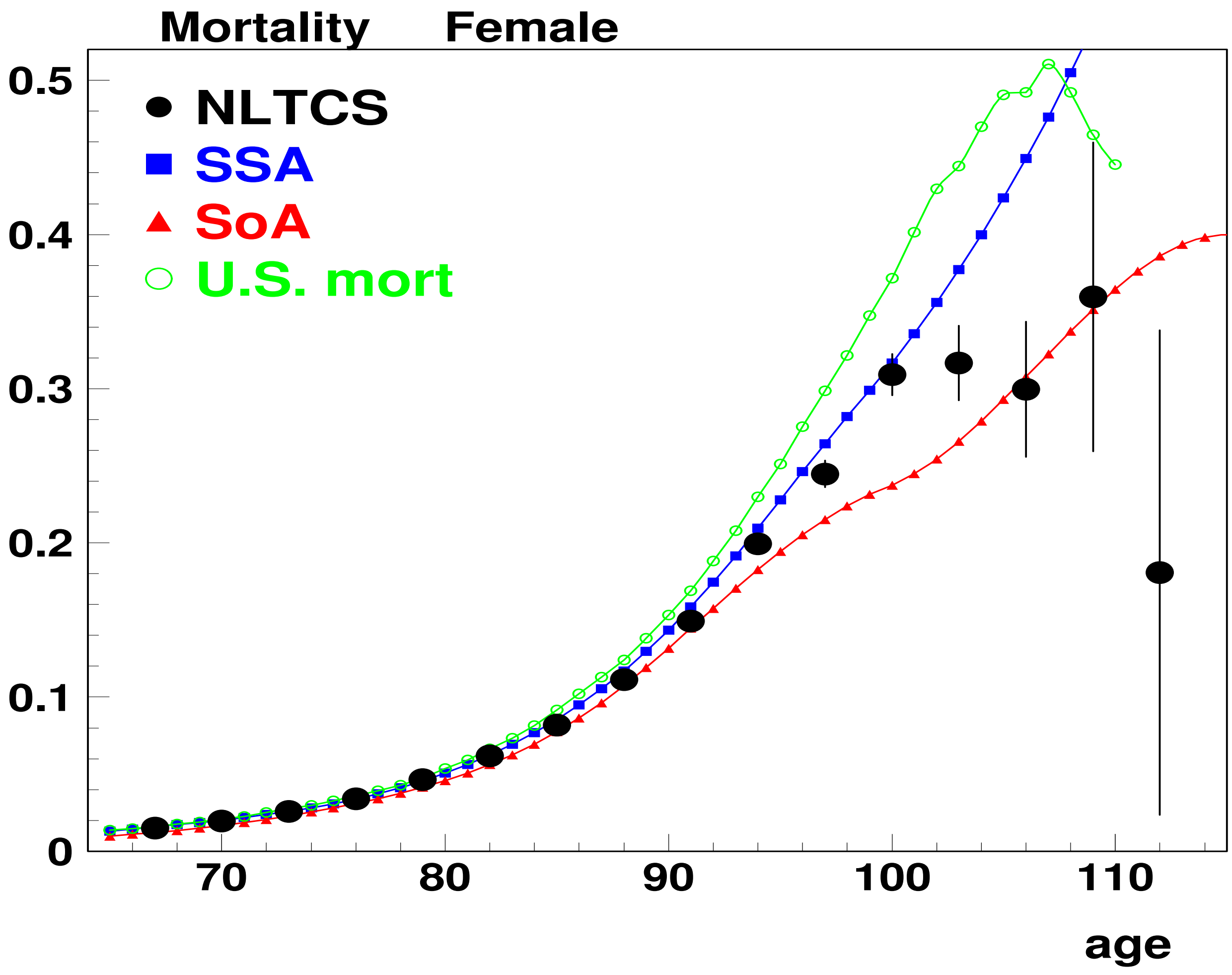


Figure 3. Predicted and Observed Incidence Rates for 5 Disease Categories, Males

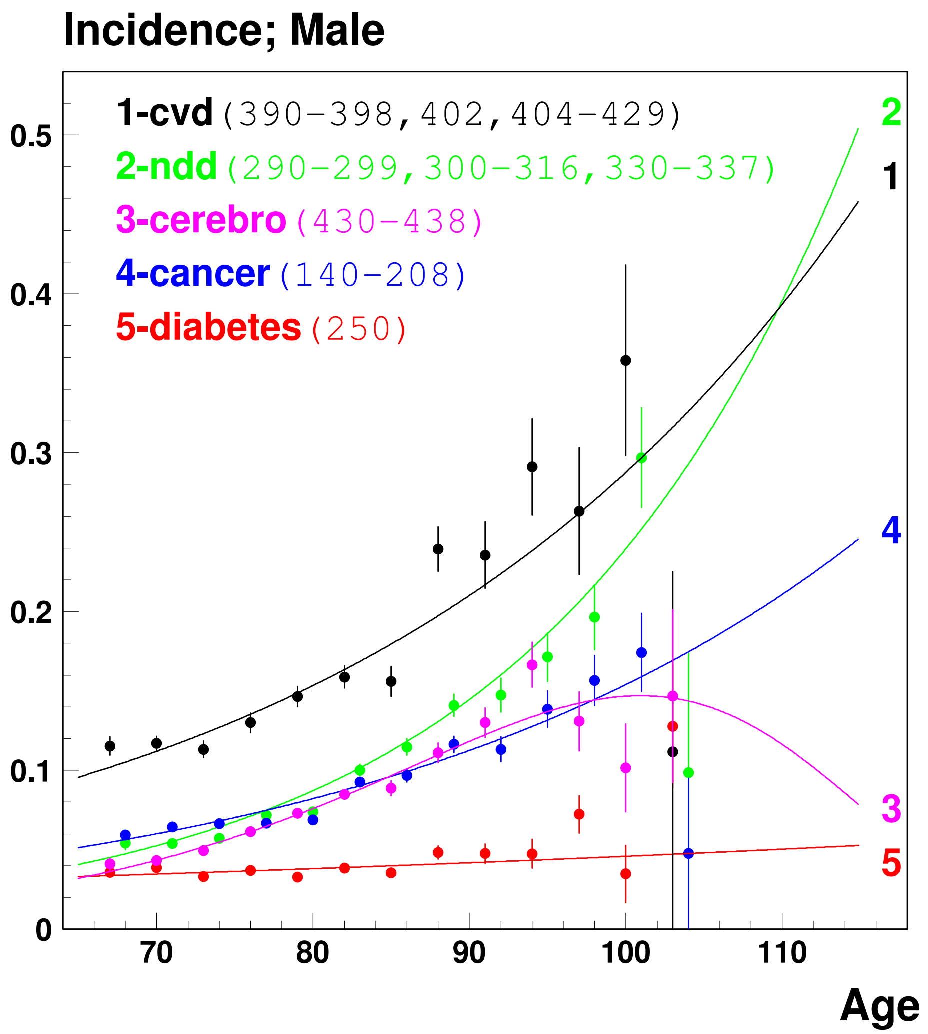
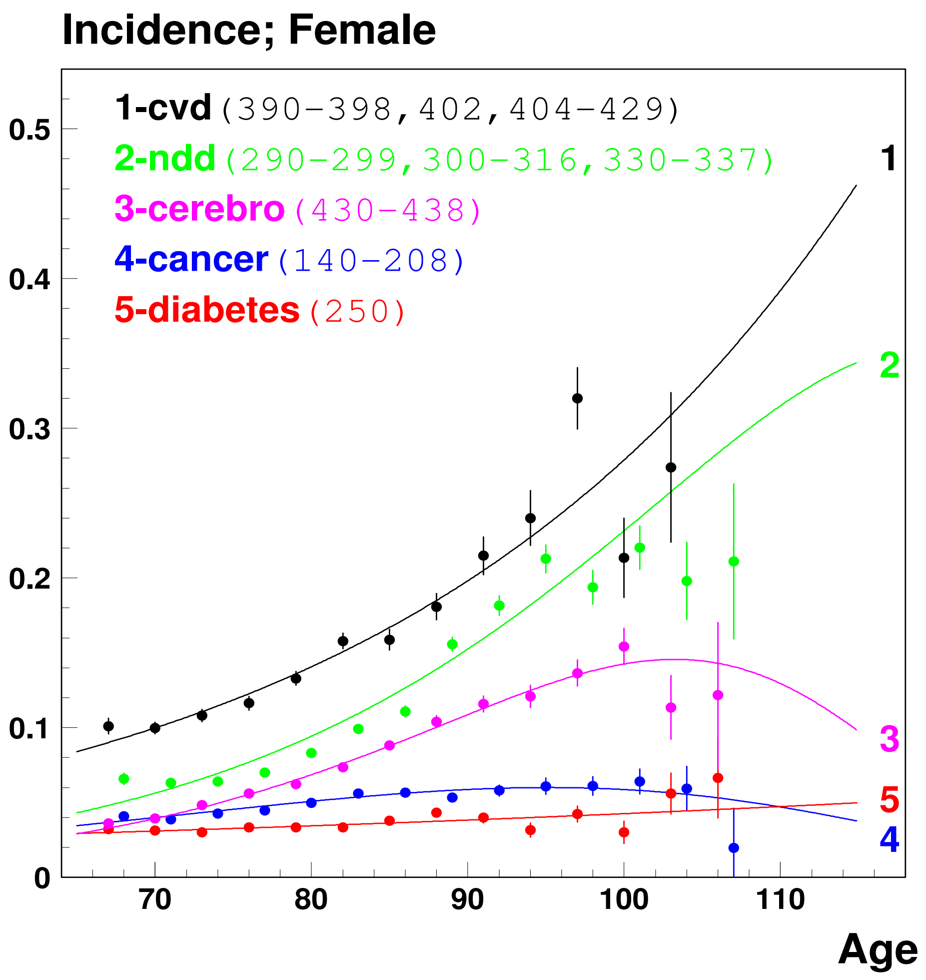

Incidence; Male

Figure 4. Predicted and Observed Incidence Rates for 5 Disease Categories, Females



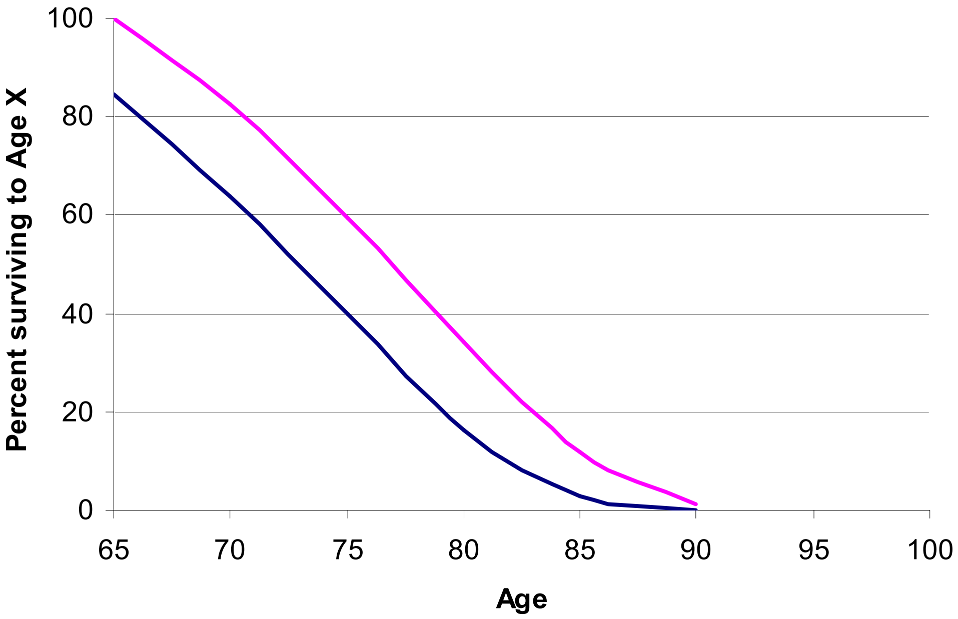


Fig 5. Life Expectancy & Active Life Expectancy in 1935

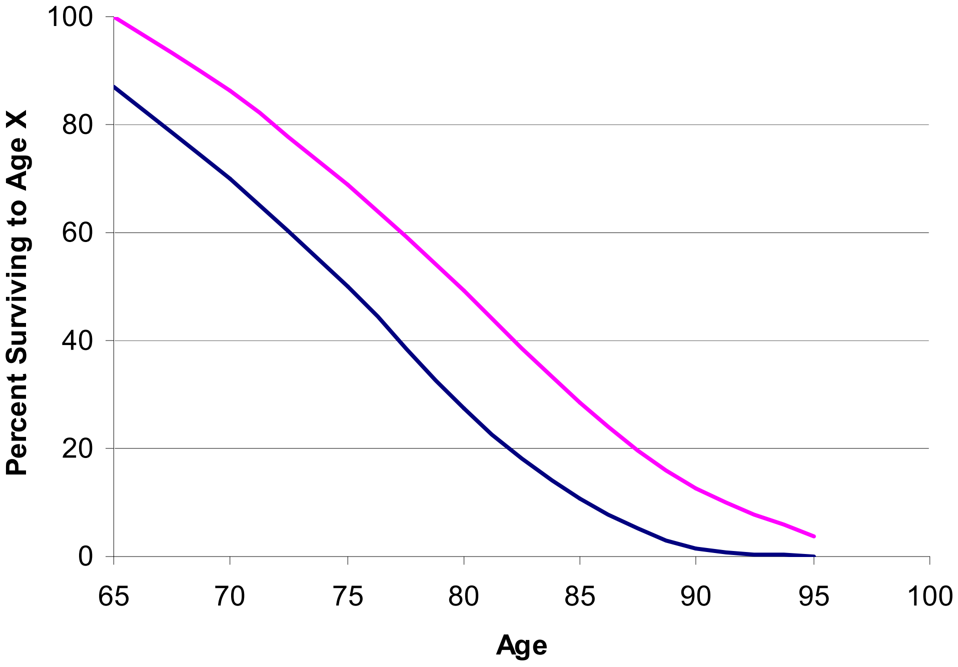


Fig 6. Life Expectancy & Active Life Expectancy in 1965

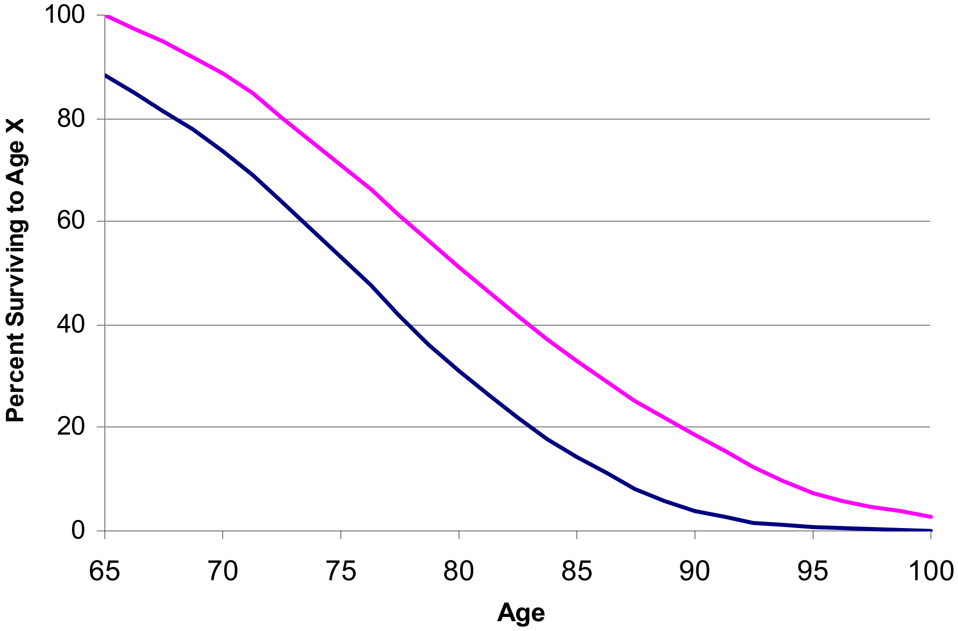


Fig 7. Life Expectancy & Active Life Expectancy in 1982

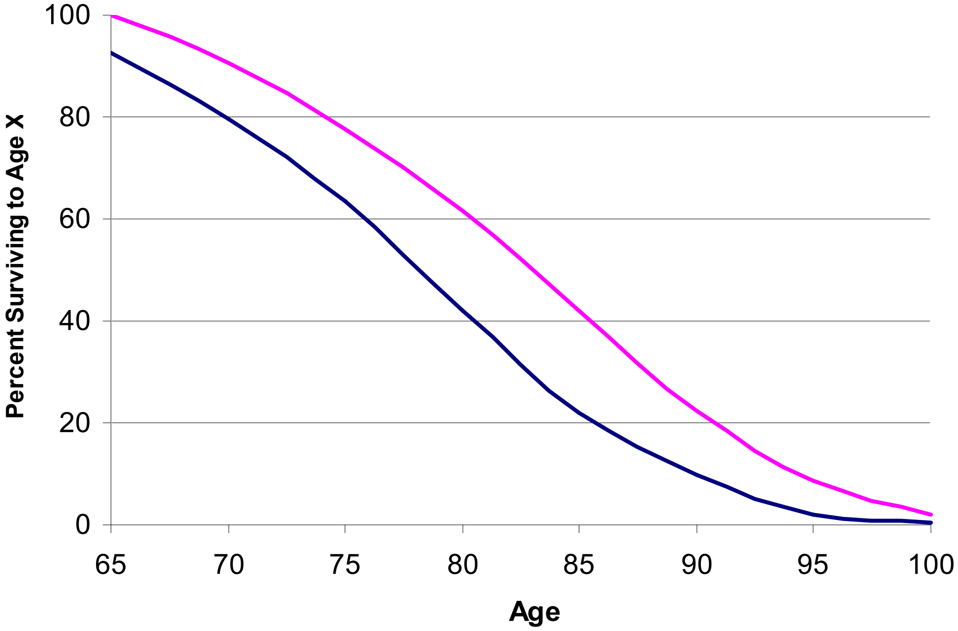


Fig 8. Life Expectancy & Active Life Expactancy in 1999

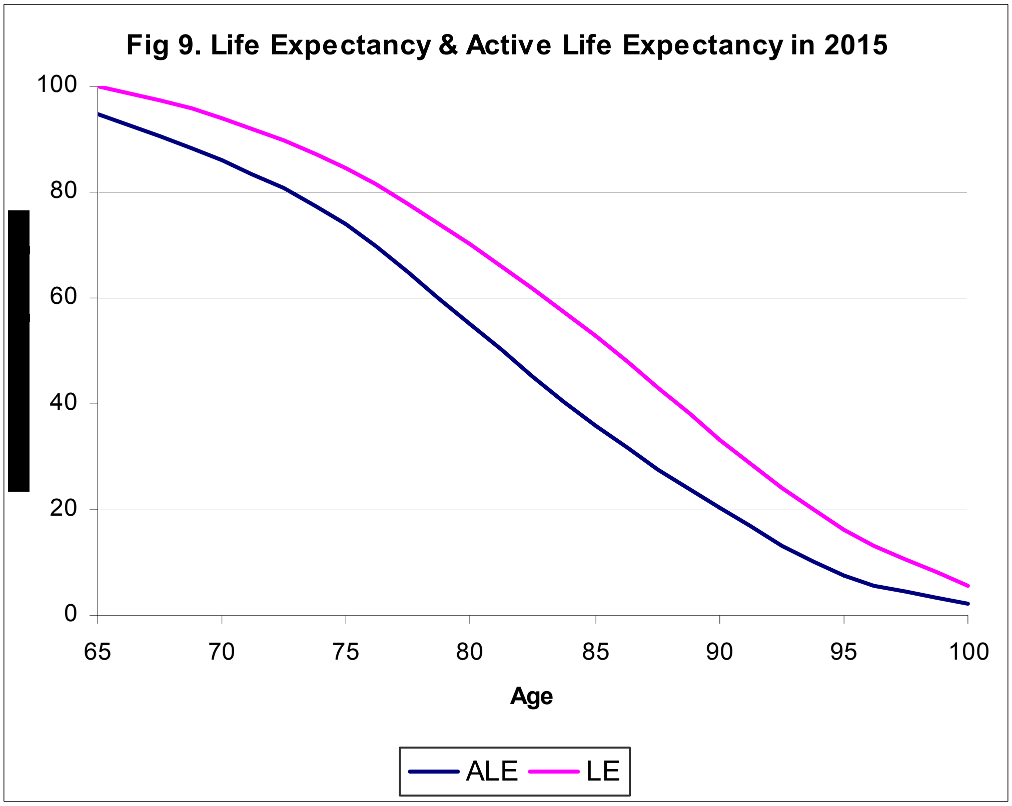


Fig 9. Life Expectancy & Active Life Expectancy in 2015

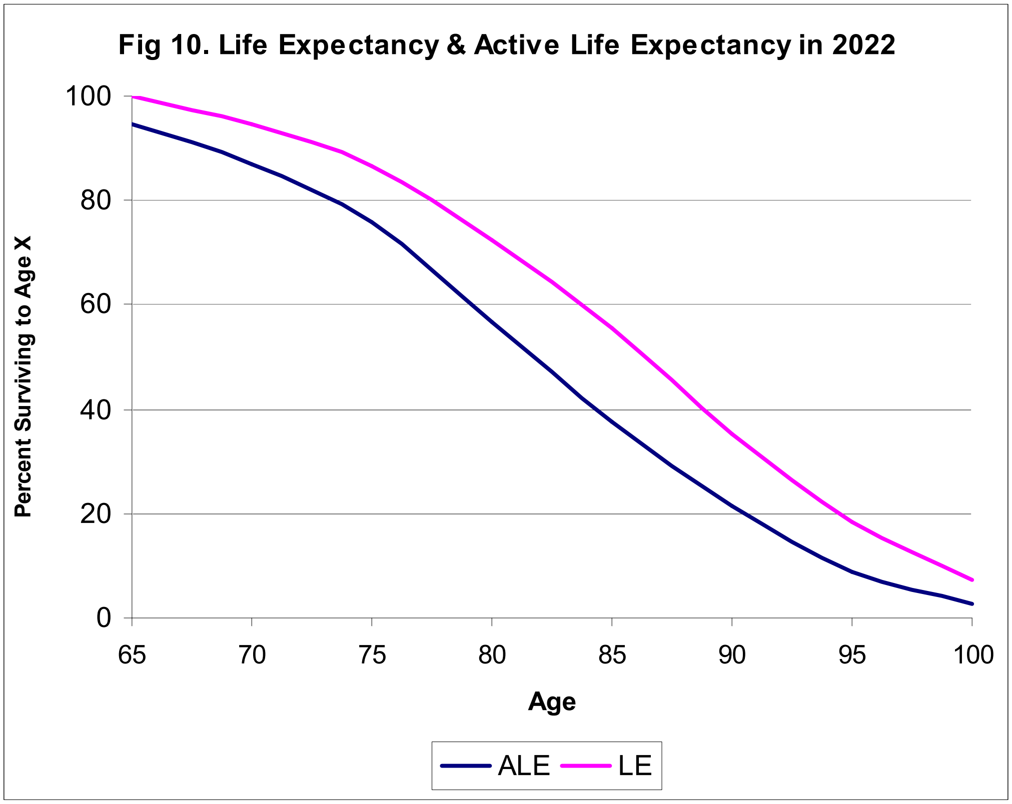


Fig 10. Life Expectancy & Active Life Expectancy in 2022

Figure 11. Male Life Expectancy and Active Life Expectancy at Age 85, 1965-2022

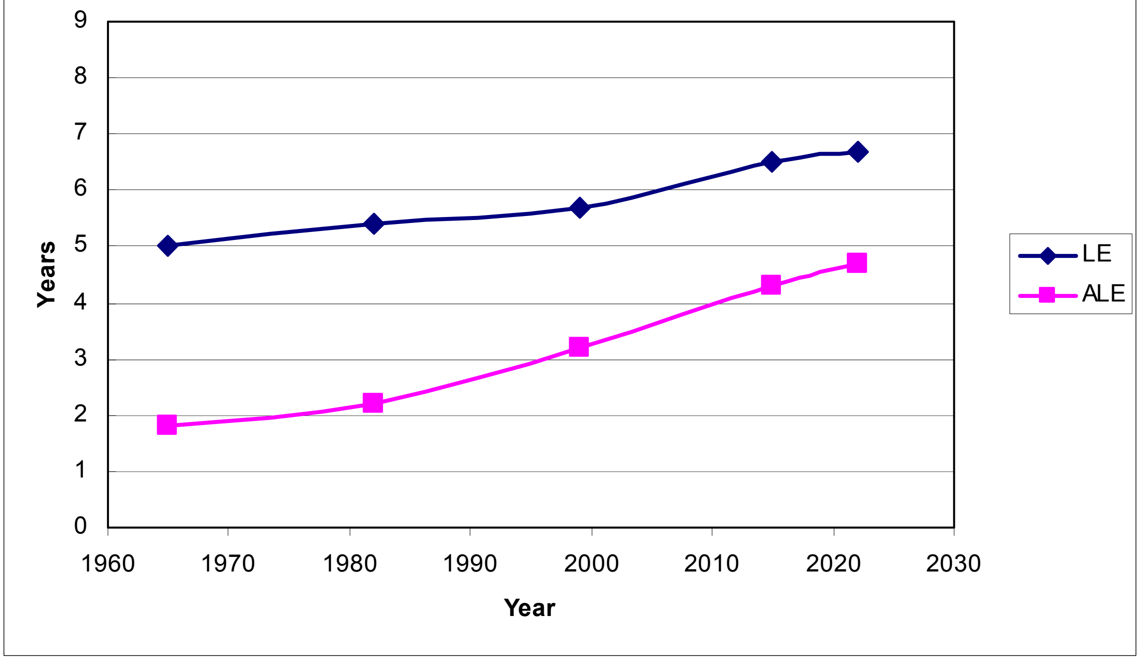


Figure 12. Female Life Expectancy and Active Life Expectancy at Age 85, 1965-2022