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Mortality of Centenarians: A Study Based on the Social Security Administration Death Master File

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Abstract
SSA Death Master File (DMF) covers deaths that occurred in the period 1937-2003 and is considered by some researchers superior in quality to the official U.S. vital statistics. Some birth cohorts in DMF may be considered as extinct or almost extinct. Detailed information about birth and death dates of decedents allowed us to estimate hazard rates of older persons at each month of age. Study of three birth cohorts (1885, 1889 and 1891) showed that mortality grows steadily without deceleration from 80 to 102-105 years of age. Then statistical noise rapidly increases and mortality tends to decelerate. Life expectancy at age 80 depends on month of birth: persons born in April-June live shorter than persons born in October-November and this periodicity repeats in every birth cohort. However, by age 100 this dependence of survival on month of birth disappears indicating that centenarians indeed represent a selected population.

Introduction
It is now considered as an established fact that mortality at advanced ages has a tendency to deviate from the Gompertz law, so that the logistic model often is used to fit human mortality (Horiuchi, Wilmoth, 1998). The estimates of mortality force at extreme ages are difficult because of small numbers of survivors to these ages in most countries. Data for extremely long-lived individuals are scarce and subjected to age exaggeration. Traditional demographic estimates of mortality based on period data encounter well known denominator problem. More accurate estimates are obtained using the method of extinct generations (Vincent, 1951). In order to obtain good quality estimates of mortality at advanced ages researches are forced to pool data for the several calendar periods. In the Kannisto-Thatcher Database on Old Age Mortality data are aggregated for ten-year calendar periods to accumulate enough cases of survivors to older ages. Single-year life tables for many countries have very small numbers of survivors to age 100 that makes estimates of mortality at advanced ages unreliable. The aggregation of deaths for several calendar periods however creates a heterogeneous mixture of cases from different birth cohorts. Mortality deceleration observed in these data might be a result of data heterogeneity. In addition to that, many assumptions about distribution of deaths in the age/time interval used in mortality estimation are not valid for extreme old ages when mortality is particularly high and grows rapidly. Thus, we need more research efforts to obtain reliable estimates of mortality at advanced ages.

Mortality at advanced ages: A historical review

The history of mortality studies at extreme ages is very rich in ideas and findings. Early studies starting with Gompertz (1825) himself suggested that the Gompertz law of mortality is not applicable to extreme old ages, and that mortality deceleration and leveling-off takes place at advanced ages (for an excellent historical review of studies on mortality deceleration at extreme old ages, see Olshansky, 1998). In 1939 the British researchers, Greenwood and Irwin published a research article "Biostatistics of Senility," with an intriguing finding that mortality force stops increasing with age at extreme old ages and becomes constant (Greenwood, Irwin, 1939). Their study and findings were considered to be so important that they were featured at the front page of academic journal "Human Biology", where their study was published. This study, accomplished by the famous British statistician and epidemiologist, Major Greenwood, may be interesting to discuss here because it correctly describes the mortality pattern at advanced ages for humans.

The first important finding was formulated by Greenwood and Irwin in the following way: "***…the increase of mortality rate with age advances at a slackening rate, that nearly all, perhaps all, methods of graduation of the type of Gompertz's formula over-state senile mortality***" (Greenwood, Irwin, 1939, p.14). This observation was confirmed later by many authors (see review in Gavrilov, Gavrilova, 1991), and it is known as the "late-life mortality deceleration."

The authors also suggested "***the possibility that with advancing age the rate of mortality asymptotes to a finite value***" (Greenwood, Irwin, 1939, p.14). Their conclusion that mortality at exceptionally high ages follows a first order kinetics (also known as the law of radioactive decay with exponential decline in survival probabilities) was confirmed later by other researchers, including A.C. Economos (1979; 1980), who demonstrated the correctness of this law for humans and laboratory animals (linear decrease for the logarithm of the numbers of survivors). This observation is known now as the "mortality leveling-off" at advanced ages, and as the "late-life mortality plateau."

Moreover, Greenwood and Irwin made the first estimates for the asymptotic value of human mortality (one-year probability of death, q_x) at extreme ages using data from the life insurance company. According to their estimates, "***… the limiting values of*** q_x ***are 0.439 for women and 0.544 for men***" (Greenwood and Irwin, 1939, p.21). It is interesting that these first estimates are very close to estimates obtained later using more numerous and accurate human data including recent data on supercentenarians (Robine, Vaupel, 2001). The authors also proposed an explanation of this phenomenon. According to Greenwood and Irwin (1939), centenarians live in more protected environment than younger age groups and hence have lower risk of death than it is predicted by the Gompertz formula.

The actuaries including Gompertz himself first noted this phenomenon of mortality deceleration. They also proposed a logistic formula for fitting mortality growth with age in order to account for mortality fall-off at advanced ages (Perks, 1932; Beard, 1959, 1971). Robert Eric Beard (1959) introduced a model of population heterogeneity with gamma distributed individual risk in order to explain mortality deceleration at older ages. This explanation is the most common explanation of mortality deceleration now.

The same phenomenon of 'almost non-aging' survival dynamics at extreme old ages is detected in many other biological species. In some species mortality plateau can occupy a sizable part of their life (Carey et al., 1992).

Biologists were well aware of mortality leveling-off since the 1960s. For example, Lindop (1961) applied Perks formula in order to account for mortality deceleration at older ages in mice. George Sacher believed that the observed mortality deceleration in mice and rats can be explained by population heterogeneity: “one effect of such residual heterogeneity is to bring about a decreased slope of the Gompertzian at advanced ages. This occurs because sub-populations with the higher injury levels die out more rapidly, resulting in progressive selection for vigour in the surviving populations” (Sacher, 1966, p.435). Strehler and Mildvan (1960) considered mortality deceleration at advanced ages as a prerequisite for all mathematical models of aging to explain.

Later Economos published a series of articles claiming a priority in the discovery of a “non-Gompertzian paradigm of mortality” (Economos, 1979, 1980, 1983, 1985). He found that mortality leveling-off is observed in rodents (guinea pigs, rats, mice) and invertebrates (nematodes, shrimps, bdelloid rotifers, fruit flies, degenerate medusae *Campanularia Flexuosa*). In the 1990s the phenomenon of mortality deceleration and leveling-off became widely known after publications, which demonstrated mortality leveling-off in large samples of *Drosophila melanogaster* (Curtsinger et al., 1992) and medflies *Ceratitis capitata* (Carey et al., 1992), including isogenic strains of Drosophila (Curtsinger et al., 1992; Fukui et al., 1993, 1996). Mortality plateaus at advanced ages are observed for some other insects: house fly *Musca vicina*, blowfly *Calliphora erythrocephala* (Gavrilov, 1980), fruit flies *Anastrepha ludens*, *Anastrepha obliqua*, *Anastrepha serpentine*, parasitoid wasp *Diachasmimorpha longiacaudtis* (Vaupel et al., 1998), and bruchid beetle *Callosobruchus maculates* (Tatar et al., 1993). Interestingly, the failure kinetics of manufactured products (steel samples, industrial relays, and motor heat insulators) also demonstrates the same 'non-aging' pattern at the end of their 'lifespan' (Economos, 1979).

The existence of mortality plateaus is well established for a number of lower organisms, mostly insects. In the case of mammals data are much more controversial. Although Lindop (1961) and Sacher (1966) reported short-term periods of mortality deceleration in mice at advanced ages and even used Perks formula in their analyses, Austad (2001) recently argued that rodents do not demonstrate mortality deceleration even in the case of large samples. Study of baboons found no mortality deceleration at advanced ages (Bronikowski et al., 2002). In the case of humans this problem is not yet resolved completely, because of scarceness of data and/or their low reliability. Thus, more studies on larger human birth cohorts are required to establish with certainty the true mortality trajectory at advanced ages.

The phenomenon of late-life mortality leveling-off presents a theoretical challenge to many models and theories of aging. One interesting corollary from these intriguing observations is that there seems to be no fixed upper limit for individual lifespan (Gavrilov, 1984; Gavrilov & Gavrilova, 1991; Wilmoth, 1997).

Hazard rate estimation at advanced ages

A conventional way to obtain estimates of mortality at advanced ages is a construction of demographic life table with probability of death (q_x) as one of important life table functions. Although probability of death is a useful indicator for mortality studies, it may be not the most convenient one for studies of mortality at advanced ages. First, the values of q_x depend on the length of the age interval Δx for which it is calculated, which hampers both analyses and interpretation. For example, if one-day probability of death follows the Gompertz law of mortality, probability of death calculated for other age interval does not follow this law (see Gavrilov and Gavrilova, 1991 and Le Bras, 1976). Thus it turns out that the shape of age-dependence for q_x depends on the arbitrary choice of age interval. Also, by definition q_x is bounded by unity, which makes difficult the studies of mortality at advanced ages.

It seems that more useful indicator for mortality studies at advanced age is instantaneous mortality rate or hazard rate, m_x which is defined as follows:

$$\mu_x = -\frac{dN_x}{N_x dx}$$

where N_x is a number of living individuals at age x.

Hazard rate does not depend on the length of the age interval (it is measured at the instant of time x), has no upper boundary and has a dimension of rate ($time^{-1}$). It should also be noted that the famous law of mortality, the Gompertz law, was proposed for fitting the hazard rate rather than probability of death (Gompertz, 1825).

The empirical estimates of hazard rates are often based on suggestion that age-specific mortality rate or death rate (number of deaths divided by exposure) is a good estimate of theoretical hazard rate. One of the first empirical estimates of hazard rate was proposed by George Sacher (Sacher, 1956; 1966):

$$\mu_x = \frac{1}{\Delta x}\left(ln\ l_{x-\frac{\Delta x}{2}} - ln\ l_{x+\frac{\Delta x}{2}}\right) = \frac{1}{2\Delta x}\ ln\frac{l_{x-\Delta x}}{l_{x+\Delta x}}$$

This estimate is unbiased for slow changes in hazard rate if $\Delta x \Delta \mu_x << 1$ (Sacher, 1966). A simplified version of Sacher estimate (for small age intervals equal to unity) often is used in biological studies of mortality: $m_x = -\ln(1-q_x)$. This estimate is based on the assumption that hazard rate is constant over age interval.

At advanced ages when death rates are very high, the assumptions about small changes in hazard rate or a constant hazard rate within the age interval becomes questionable. Violation of these assumptions may lead to biased estimates of hazard rates calculated on annual basis.

Fortunately the narrowing the age interval from one-year to one-month period for estimation of hazard rates might help to resolve this problem.

Hazard rate estimates at advanced ages using data from the Social Security Death Master File

Social Security Administration Death Master File (DMF) is a publicly available data source that allows a search for individuals using various search criteria: birth date, death date, first and last names, social security number, place of last residence, etc. This resource covers individual deaths that occurred in the period 1937-2003 (see Faig, 2002 for more details). Many researchers suggest that the quality of SSA/Medicare data is superior to vital statistics records because of strict evidentiary requirements in application for Medicare while age reporting in death certificates is made by proxy informant (Kestenbaum, 1992; Kestenbaum, Ferguson, 2002; Rosenwaike et al., 1998; Rosenwaike, Stone, 2003).

In this study we collected information from the DMF on persons who lived 80 years and over and died before 2004. Total number of records collected is 9,014,591 including 924,222 records for persons lived 100 years and over. The information contained in this file is interesting not only for verification purposes but also for mortality estimates at advanced ages. Several birth cohorts (born in 1882-1891) may be considered as extinct or almost extinct, so it is possible to estimate mortality kinetics at very advanced ages up to 115-120 years. DMF database is unique in this regard because it represents mortality experience for one of the largest cohort of the oldest-old persons, which is readily available for survival analysis. Although the National Center for Health Statistics' National Death Index (NDI) provides superior coverage of deaths, its use is restricted and expensive, so for many researchers the DMF may be an appropriate choice (Hill, Rosenwaike, 2001).

Using DMF data we obtained monthly hazard rate estimates for single-year birth cohorts using data taken from the Social Security Administration's Death Master File, which collects deaths for persons received SSA benefits and covers over 90% of deaths occurred in the United States (Faig, 2002) and 93 percent to 96 percent of deaths of individuals aged 65 or older (Hill, Rosenwaike, 2001). Despite certain limitations, this data source allows researchers to obtain detailed estimates of mortality at advanced ages. We already used this data resource for centenarians' age validation in the study of centenarian genealogies (Gavrilova, Gavrilov, 2005). This data resource is also useful in mortality estimates for several extinct or almost extinct birth cohorts in the United States.

The last deaths in the DMF available at the Rootsweb website occurred in January 2004. We obtained data for persons died before 2004, because only two individuals born in 1885-1891 (birth cohorts that we studied) died in 2004. Thus, 1885-1891 birth cohorts in this sample may be considered as extinct or almost extinct. Assuming that the number of living persons belonging to these birth cohorts in 2004 is close to zero, it is possible to construct a cohort survivorship curve. In the first stage of our analyses we calculated an individual life span in completed months:

Lifespan in months = (death year – birth year) x 12 + death month – birth month

Then it is possible to estimate hazard rate for each month of age using standard methods of survival analysis (using Nelson-Aalen estimator of hazard rate). All calculations were done using Stata statistical package (procedures stset and sts). This program provides estimates of hazard rate per month's period. In order to obtain more common annual rates we multiplied these estimates by 12. We estimated hazard rates for three single-year birth cohorts: 1885, 1889 and 1891.

Results of the hazard rate estimates for three birth cohorts (1885, 1889 and 1891) are presented in Figures 1-4.

Figure 1 About Here

Recent study of age validation among supercentenarians (Rosenwaike, Stone, 2003) showed that age reporting among supercentenarians in SSA database is rather accurate with exception of persons born in the Southern states. In order to improve the quality of our dataset when estimating mortality rates, we excluded records for those persons who applied for social security number in the Southeast (AR, AL, GA, MS, LA, TN, FL, KY, SC, NC, VA, WV)and Southwest (AZ, NM, TX, OK) regions, Puerto Rico and Hawaii. This step of data cleaning however did not change significantly the overall trajectory of mortality at advanced ages, but decreased the number of too low mortality estimates and increased the number of higher mortality estimates after age 105 years (see Figures 1-2).

Figure 2 About Here

Note that from ages 85-89 up to ages 102-105 years mortality grows steadily without obvious deceleration. Only after age 105 years mortality tends to decelerate, although high statistical noise makes mortality estimates beyond age 105 years less reliable. Also for cohorts born after 1890, mortality over age 110 years is affected by data truncation. These figures demonstrate that for single-year birth cohort mortality agrees well with the Gompertz law up to very advanced ages. Previous studies of mortality at advanced ages used aggregated data combining several birth cohorts with different mortality and this aggregation apparently resulted in early mortality deceleration and subsequent leveling-off as it was demonstrated by heterogeneity model (Beard, 1971). Mortality deceleration and even decline of mortality often is observed for data with low quality. On the other hand, improvement of data quality results in straighter mortality trajectory in semi-log scale (Kestenbaum, Ferguson, 2002). In our study more recent 1891 birth cohort demonstrates straighter trajectory and lower statistical noise after age 105 than older 1885 one (see Figures 2 and 4). Thus, we may expect that cohorts born after 1891 would demonstrate even better fit by the Gompertz model than the older ones because of improved quality of age reporting. Testing this hypothesis now is hampered by the problem of data truncation for non-extinct birth cohorts.

Figure 3 About Here

Figure 4 About Here

We already noted that the period of mortality deceleration in mammals is very short compared to lower organisms. It appears to be relatively short in humans too. This observation agrees well with the prediction of reliability theory of aging according to which more complex living systems/organisms with many vital subsystems (like mammals) may experience very short or no period of mortality plateau at advance ages in contrast to more simple living organisms (Gavrilov, Gavrilova, 1991; 2001; 2003a; 2004).

Gender-specific differences in mortality after age 100

The Social Security Administration Death Master File does not provide information about the sex of deceased. To avoid this limitation of the data sample, we conducted a procedure of sex identification using information provided by the Social Security Administration about 1000 most common first names for males and females born in 1900. From these two lists of male and female names we removed names consisting of initials and names with unclear sex (like Jessie or Lonnie). It is interesting that SSA male list contains some obviously female names (Mary, Elizabeth) and the same problem was observed for the female list, which indicates that the SSA data apparently contain many sex misidentifications. These female names were removed from the male list and the same procedure was done for the female list. Using final lists of male and female first names we identified sex in the 89.5 percent cases of the 1886 birth cohort of persons aged 90 years and over. The remaining 10.5 percent of persons with unknown sex had the same mean lifespan as the remaining 89.5 percent of individuals with identified sex, so the existence of possible sex bias after sex identification looks unlikely. This data sample of 190,696 individuals with known sex out of 213,174 individuals was used for more detailed study of gender-specific mortality at advanced ages.

The result of hazard rate estimation for males and females is presented in Figure 5. Note that male mortality continues to exceed female mortality up to very advanced ages and this difference narrows very slowly with age. At age 110 years the number of remaining males (9 persons) and females (44 persons) is too small for accurate estimates of hazard rate after this age.

Figure 5 About Here

Interestingly, the hazard rate estimates made using crude estimates of lifespan in whole years (like in common demographic life tables) create an of more pronounced mortality deceleration (Figure 6) than estimates obtained for every month of life (Figure 5).

Figure 6 About Here

Another way to check the leveling-off of mortality at advanced ages is to draw a plot of survival curve in semilog coordinates. This plot is presented in Figure 7 and shows a good linear dependence suggesting that mortality trajectory at advanced ages may be constant.

Figure 7 About Here

Higher male mortality after age 100 results in rapid increase in the proportion of females among the extremely old (see Figure 8).

Figure 8 About Here

Visual inspection may be sometimes misleading so we used nonparametric measures of mortality leveling-off. One such measure is a coefficient of variation for life expectancy at different ages. For non-aging systems with constant mortality over age or radioactive decay mortality kinetics the coefficient of variation is equal to 100% while for aging systems it is significantly lower. On the opposite, "rejuvenating" systems with declining mortality have coefficient of variation for lifespan higher than 100%. We estimated coefficient of variation for life expectancy separately for males and females at different ages after age 100 years. The results of our estimations are presented in Figure 9. Note that males demonstrate a nonaging mortality kinetics rather early – after age 102 years while females continue to demonstrate an aging kinetics up to age 106 years.

Figure 9 About Here

These results do not show an increase of the coefficient of variation for life expectancy over 100% at advanced ages, so the decline of mortality at extremely high ages seems unlikely.

Month of birth and mortality at advanced ages

The Social Security Administration Death Master File data allow us to explore another interesting problem: the effects of early-life conditionss and month-of-birth in particular on mortality at advanced ages. It was shown that month of birth has a significant effect on later-life mortality and lifespan (Gavrilov, Gavrilova, 1999; Doblhammer, Vaupel, 2001; Costa, Lahey, 2003). For example, Costa and Lahey (2003) used data on month of birth and mortality for the Union Army veterans at age 60-79 in 1900 and Americans of the same age in 1960-1980. They found that persons born in the second quarter had higher mortality than persons born in the fourth quarter (Costa, Lahey, 2003). Another study of month-of-birth effects on mortality in the United States (Doblhammer, 2003) was based on the analyses of cross-sectional death certificates, that do not take into account the underlying structure of population exposed to risk. This approach could be justified only for stationary population with population structure constant over time. In real life this assumption usually is not valid, and the mean age at death (calculated from death certificates) is affected by temporal trends in population characteristics as well as temporal changes in seasonality of births and infant mortality. Because of these problems, using mean age at death as a proxy for life expectancy may lead to incorrect conclusions about better survival for low educated or widowed persons (Doblhammer, 2003). More reliable estimates of mortality by month of birth could be obtained either by using death certificates in conjunction with population denominator data taken from censuses or by analyzing cohort mortality. In this regard DMF containing cohort data may provide more accurate estimates of month-of-birth effects on mortality.

The Social Security Administration Death Master File contains data on month of birth for each person (in the overwhelming majority of cases), so it is possible to estimates life expectancy at age 80 years for each month of birth. In a cohort life table mean lifespan (mean age at death in a cohort) is equivalent to the life expectancy, while this is not the case for period life tables. We use the term life expectancy here instead of mean age at death in order to avoid confusion with mean age at death calculated on the basis of cross-sectional (death certificates) data. In order to avoid possible truncation biases we estimated life expectancy in the age range 80-110 years.

Figure 10 shows the effects of month of birth on life expectancy at age 80 for two birth cohorts: 1885 and 1891. Note that persons born in January have higher life expectancy at age 80 than persons born in April-June. Figure 11 confirms this observation for longer time period: practically all single-year birth cohorts born from 1885 to 1899 demonstrate the same monthly pattern in life expectancy. It is interesting that monthly pattern does not change for this relatively long 14-year calendar period. Thus, life expectancy at age 80 depends on month of birth: persons born in January (or December) live longer than persons born in other months and in April-June in particular. This seasonal pattern repeats in every birth cohort from 1885 to 1899.

Figure 10 About Here

Figure 11 About Here

These seasonal patterns are consistent with earlier reports that persons born in the second quarter live shorter than persons born in the fourth quarter (Costa, Lahey, 2003). These monthly patterns also partially agree with previous study based on aggregated death certificates, which found peak of mean age at death in September/October and trough in June/July (Doblhammer, 2003). Agreement with results obtained on the basis of cross-sectional data might indicate that effects of month of birth are indeed rather stable over time. This stability is evident at least for the 1885-1899 birth cohorts (Figure 11).

The fact that such an early circumstance of human life as the month of birth may have a significant effect 80 years later on the chances of human survival is quite remarkable. It indicates that there may be critical periods early in human life particularly sensitive to seasonal variation in living conditions in the past (e.g., vitamin supply, seasonal exposure to infectious diseases, etc.).

However, by age 100 this monthly pattern in life expectancy apparently disappears indicating that centenarians indeed represent a selected population (Figures 12-13). We already found in our previous studies that month-of-birth pattern of survival depends on age, so that the overall monthly patterns might be different in different periods of life. For example, in the study of 1800-1880 birth cohorts of European aristocracy we found that lifespan at age 30 is particularly low for February-born women and higher for December-born ones (Gavrilov, Gavrilova, 1999). However this monthly pattern changed when life span at age 50 and over was analyzed (Gavrilov, Gavrilova, 2002).

Figure 12 About Here

Figure 13 About Here

In our previous study we found that month-of-birth effects may be different for males and females in the case of life expectancy at age 30 years (Gavrilov, Gavrilova, 1999). In this study we tried to estimate month-of-birth effects using the 1886 birth cohorts of males and females described above. The obtained monthly patterns of life expectancy for males and females are presented in Figure 14.

Figure 14 About Here

These results suggest that male and female monthly patterns of life expectancy at age 90 are similar: low mortality in the middle of the year and slight increase by December-January. The strength of month-of-birth effects is weaker for life expectancy at age 90 than for life expectancy at age 80 years, but the monthly effects still exist in contrast to no effects at age 100 years.

What may be the cause of these month-of-birth effects? We already mentioned studies, which demonstrated month-of-birth effects on lifespan of middle and older individuals. These effects are usually explained by possible early-life factors (like vitamin or nutrient deficiency or seasonal infections). There may be an alternative explanation through the effects of seasonal mortality later in life with high mortality usually observed in winter (Laake, Sverre, 1996; Wilkinson et al., 2004). It is suggested that persons who had their last birthday in January face longer period of mild and good weather compared to persons born in the middle of year. If both persons die in November-December (when weather is bad) then persons born in January would live longer than persons born in June. In order to test this hypothesis, we conducted a survival analysis using Cox proportional hazards model with months of birth and death as covariates using mortality after age 80 for the 1885 birth cohort. The results of this analysis are presented in Table 1 and demonstrate that the effect of month of birth remains statistically significant after controlling for the month of death. Also it is known that seasonality of deaths is increasing with age, so we may expect larger effects of month of birth on mortality after age 100 if the hypothesis is correct and this is not the case (see Figure 13).

The results obtained in this study are interesting but yet should be regarded with some caution. The Social Security Administration Death Master File provides no information about sex and race of decedents. Also quality of data for earlier birth cohorts is lower than for more recent birth cohorts. Thus, we may expect that 5-10 years from now the quality of the SSA DMF data would be sufficient enough to obtain more accurate estimates of mortality at advanced ages.

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Table 1. Results of the proportional hazard analysis for mortality after age 80 of the 1885 birth cohort (446,528 observations).

Variable	Hazard ratio	Std. Err.	p-value	95% Conf. Interval	
Month of Birth:					
January	1.000000	Reference level			
February	1.007261	0.007429	0.327	0.992806	1.021927
March	1.013964	0.007236	0.052	0.999881	1.028246
April	1.026251	0.007599	0.000	1.011465	1.041252
May	1.031297	0.007631	0.000	1.016450	1.046362
June	1.033714	0.007840	0.000	1.018406	1.049195
July	1.024147	0.007507	0.001	1.009539	1.038966
August	1.014002	0.007323	0.054	0.999752	1.028456
September	1.019335	0.007316	0.008	1.005096	1.033775
October	1.024171	0.007411	0.001	1.009749	1.038799
November	1.010036	0.007491	0.178	0.995459	1.024826
December	1.017989	0.007307	0.014	1.003646	1.032538
Month of Death:					
January	1.000000	Reference level			
February	0.996444	0.006957	0.610	0.982902	1.010174
March	1.010668	0.006957	0.123	0.997123	1.024396
April	1.034676	0.007311	0.000	1.020445	1.049105
May	1.056972	0.007504	0.000	1.042366	1.071782
June	1.066079	0.007677	0.000	1.051139	1.081231
July	1.061146	0.007562	0.000	1.046428	1.076072
August	1.053948	0.007597	0.000	1.039164	1.068943
September	1.033857	0.007500	0.000	1.019262	1.048660
October	1.024935	0.007254	0.001	1.010816	1.039252
November	1.026247	0.007261	0.000	1.012114	1.040577
December	1.015266	0.006978	0.027	1.001681	1.029036
Southern states	1.000000	Reference level			
Non-Southern states	1.019258	0.003537	0.000	1.01235	1.026214

Figures

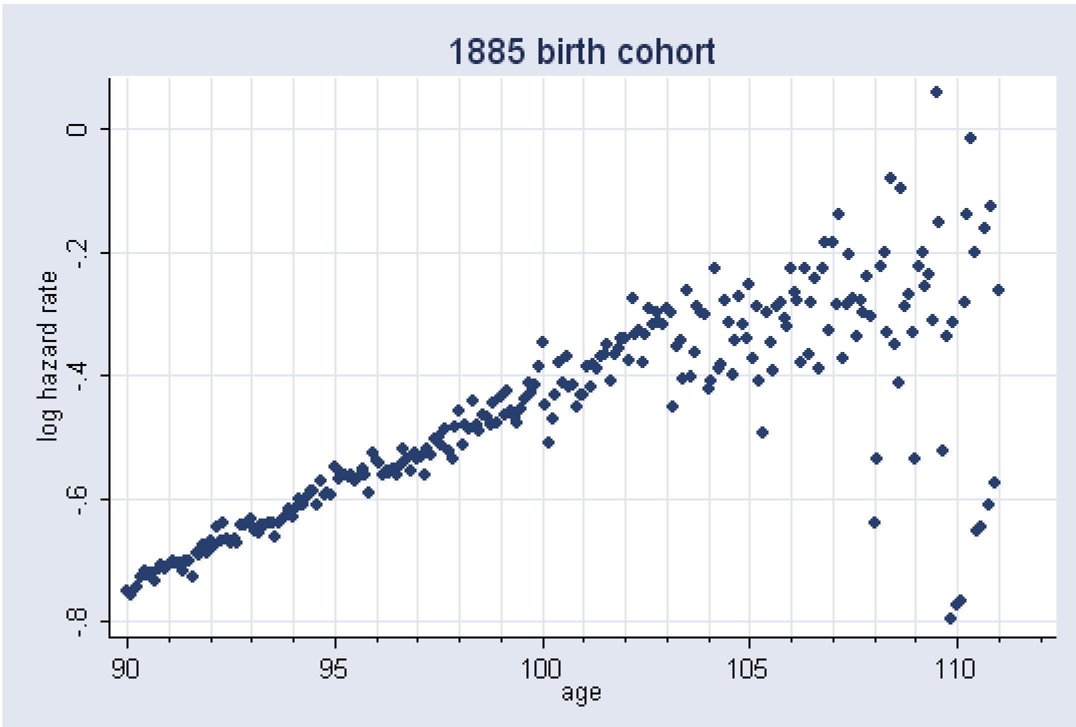

Figure 1.
Hazard rate (per year) for 1885 birth cohort.
Data from the Social Security Administration Death Master File.

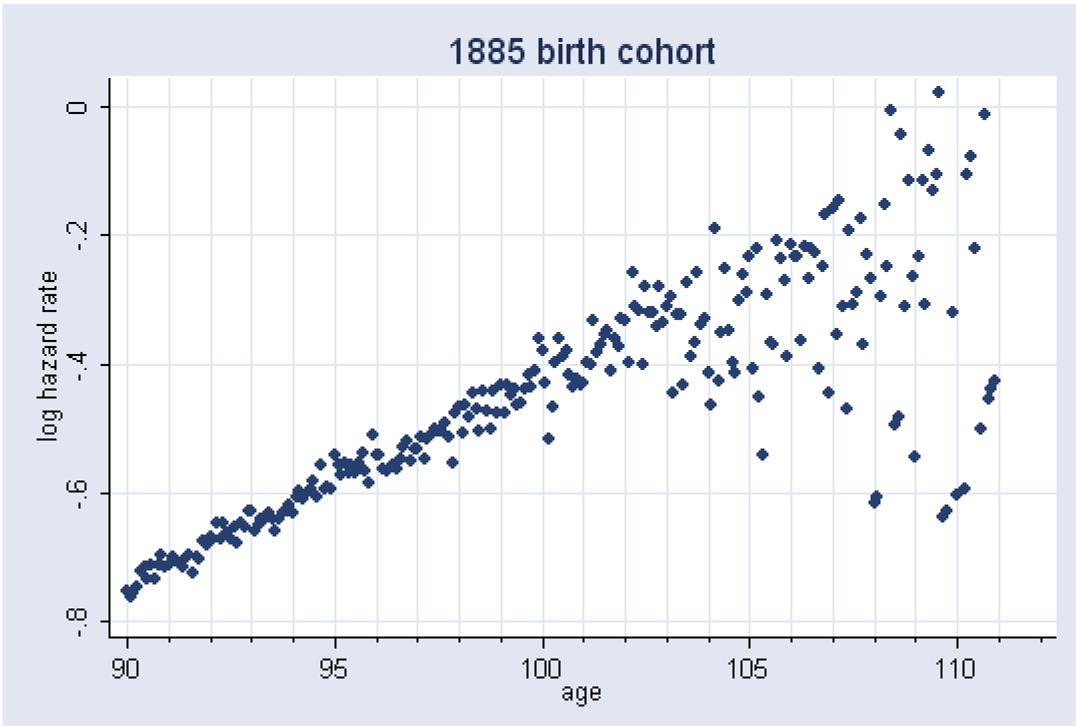

Figure 2.
Hazard rate (per year) for 1885 birth cohort.
Less reliable data for Southern states, Puerto Rico and Hawaii are excluded.
Data from the Social Security Administration Death Master File.

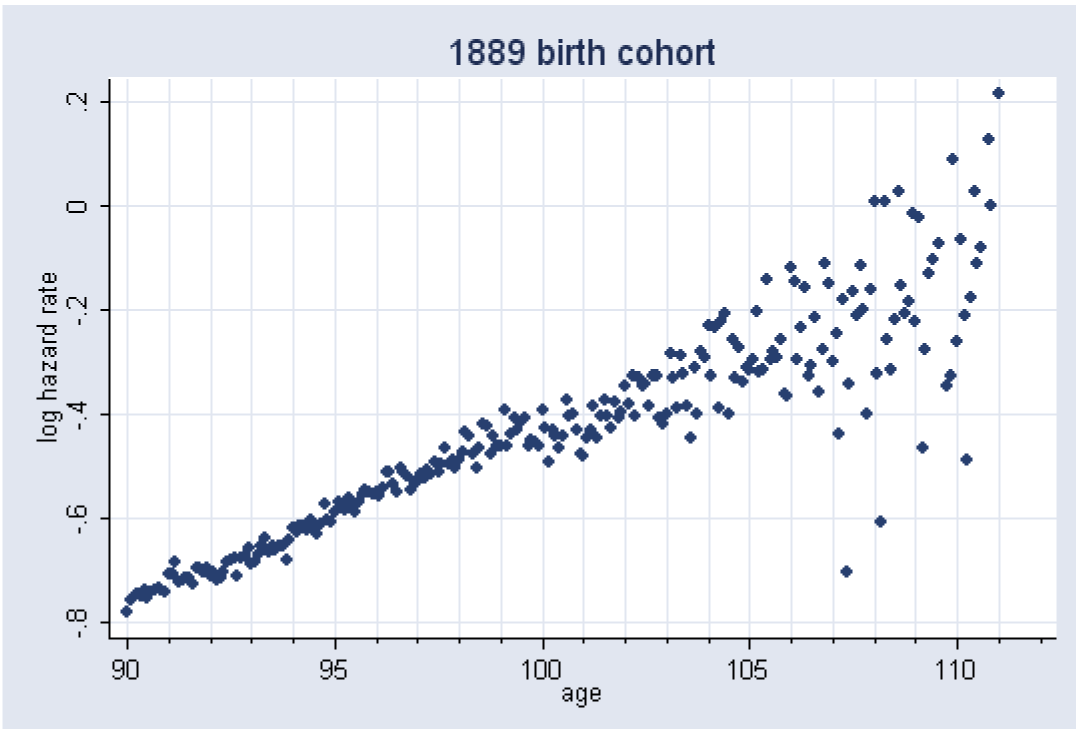

Figure 3.
Hazard rate (per year) for 1889 birth cohort.
Less reliable data for Southern states, Puerto Rico and Hawaii are excluded.
Data from the Social Security Administration Death Master File.

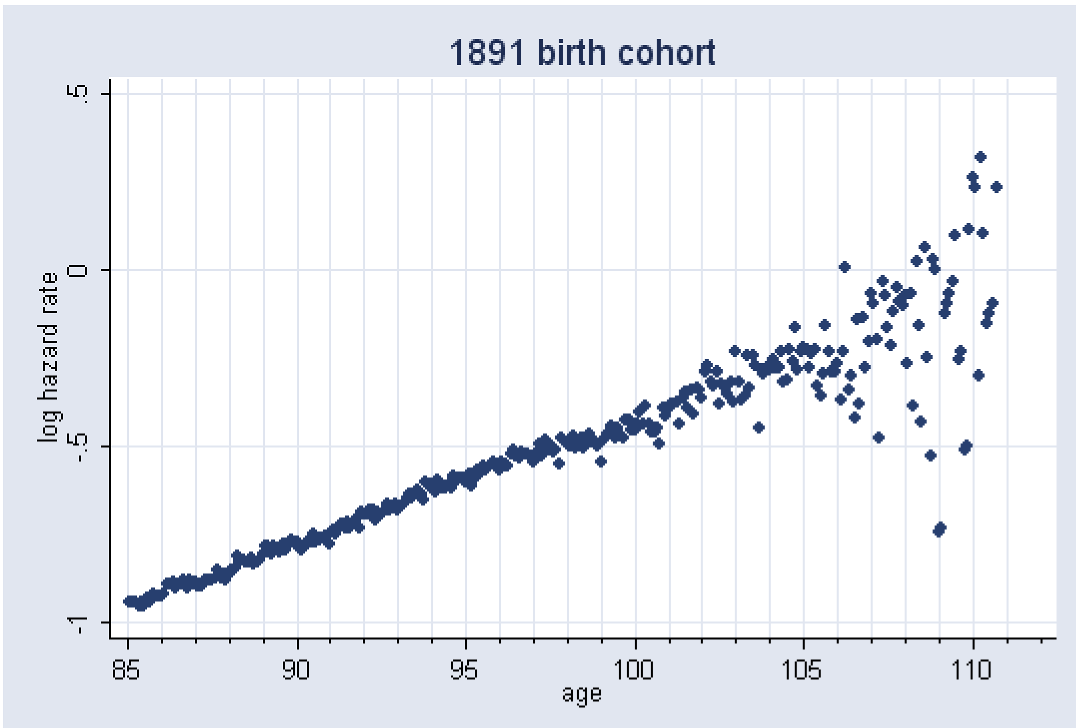

Figure 4.
Hazard rate (per year) for 1891 birth cohort.
Less reliable data for Southern states, Puerto Rico and Hawaii are excluded.
Data from the Social Security Administration Death Master File.

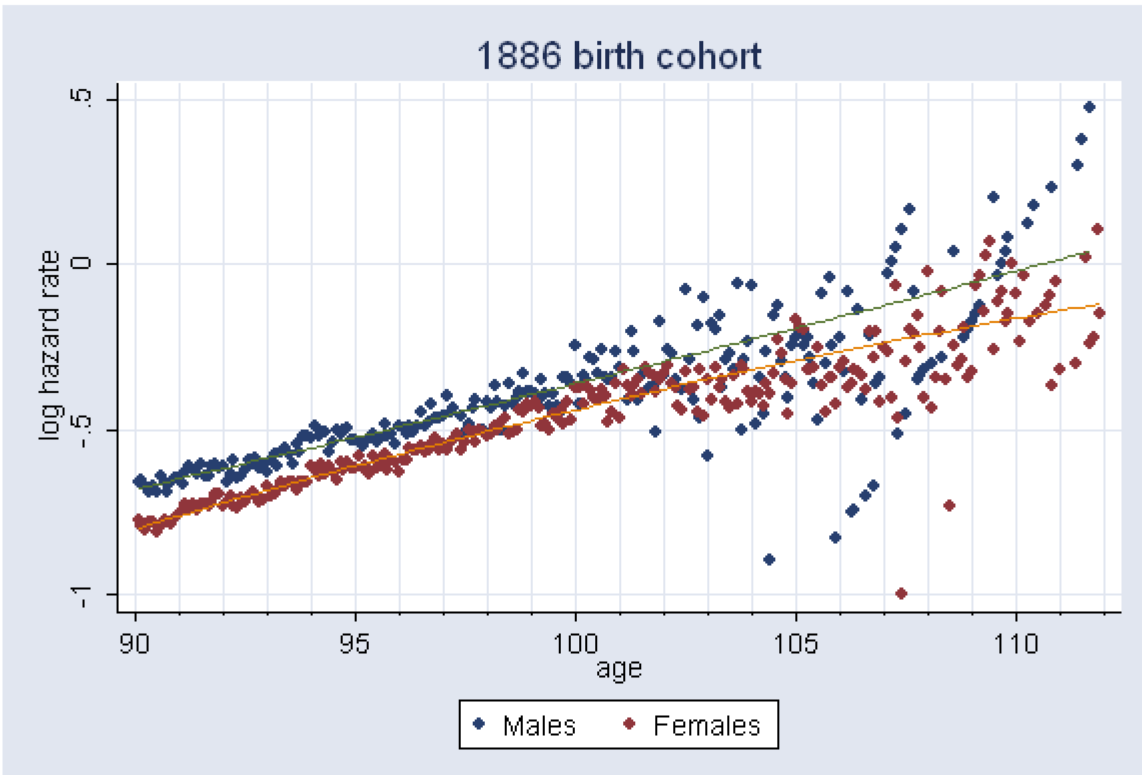

Figure 5.
Hazard rate (per year) for males and females from 1886 birth cohort. Data are fitted using quadratic regression.
Data from the Social Security Administration Death Master File.

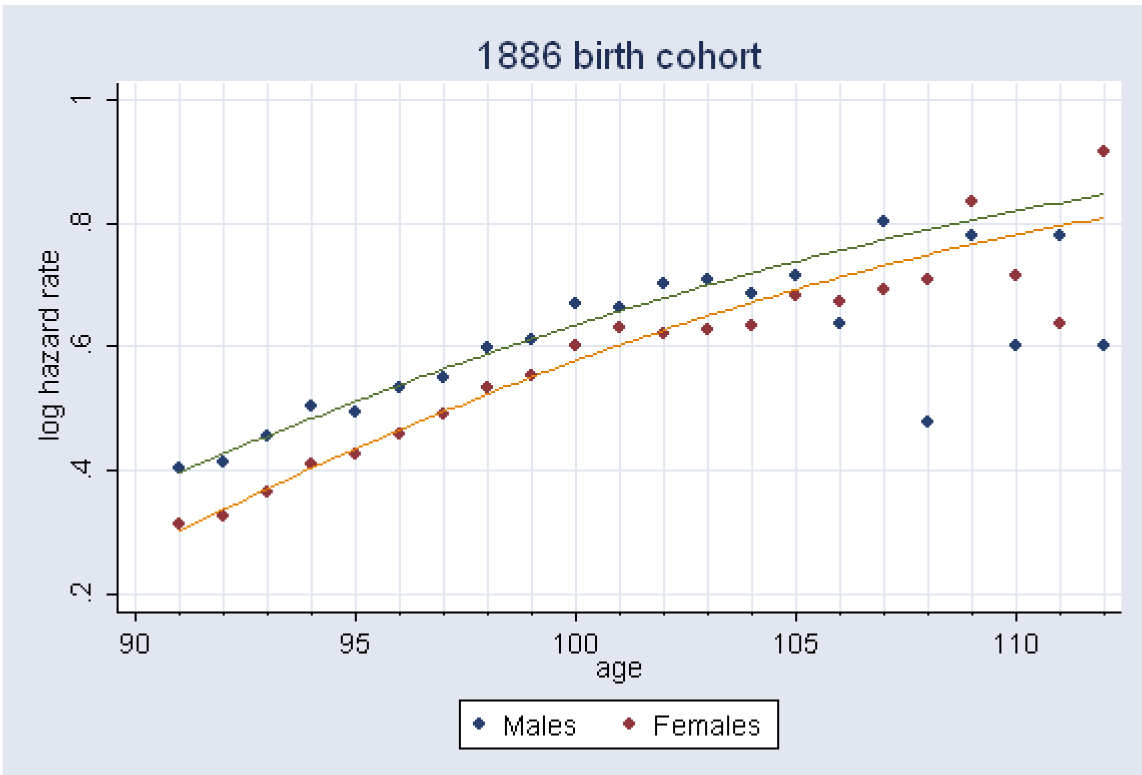

Figure 6.
Hazard rate (per year) for males and females from 1886 birth cohort. Lifespan is estimated in whole years. Data are fitted using quadratic regression.
Data from the Social Security Administration Death Master File.

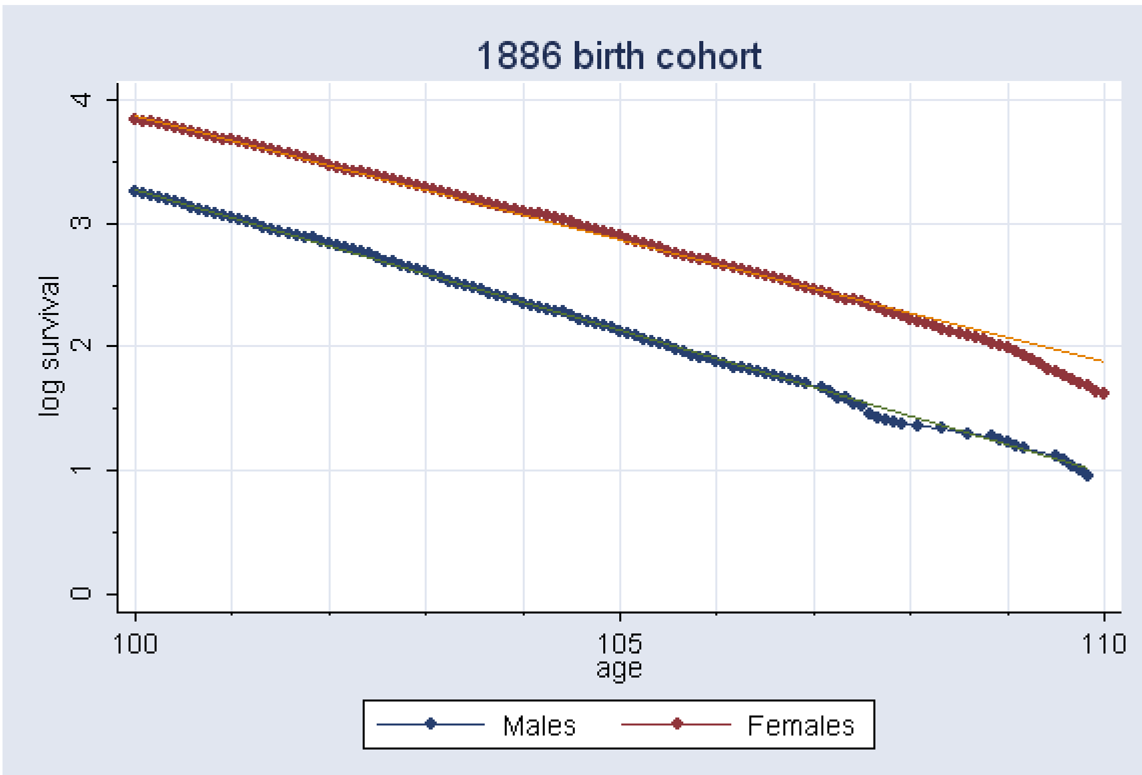

Figure 7.
Logarithm of survival as a function of age for males and females from 1886 birth cohort. Data are fitted using liner regression.
Data from the Social Security Administration Death Master File.

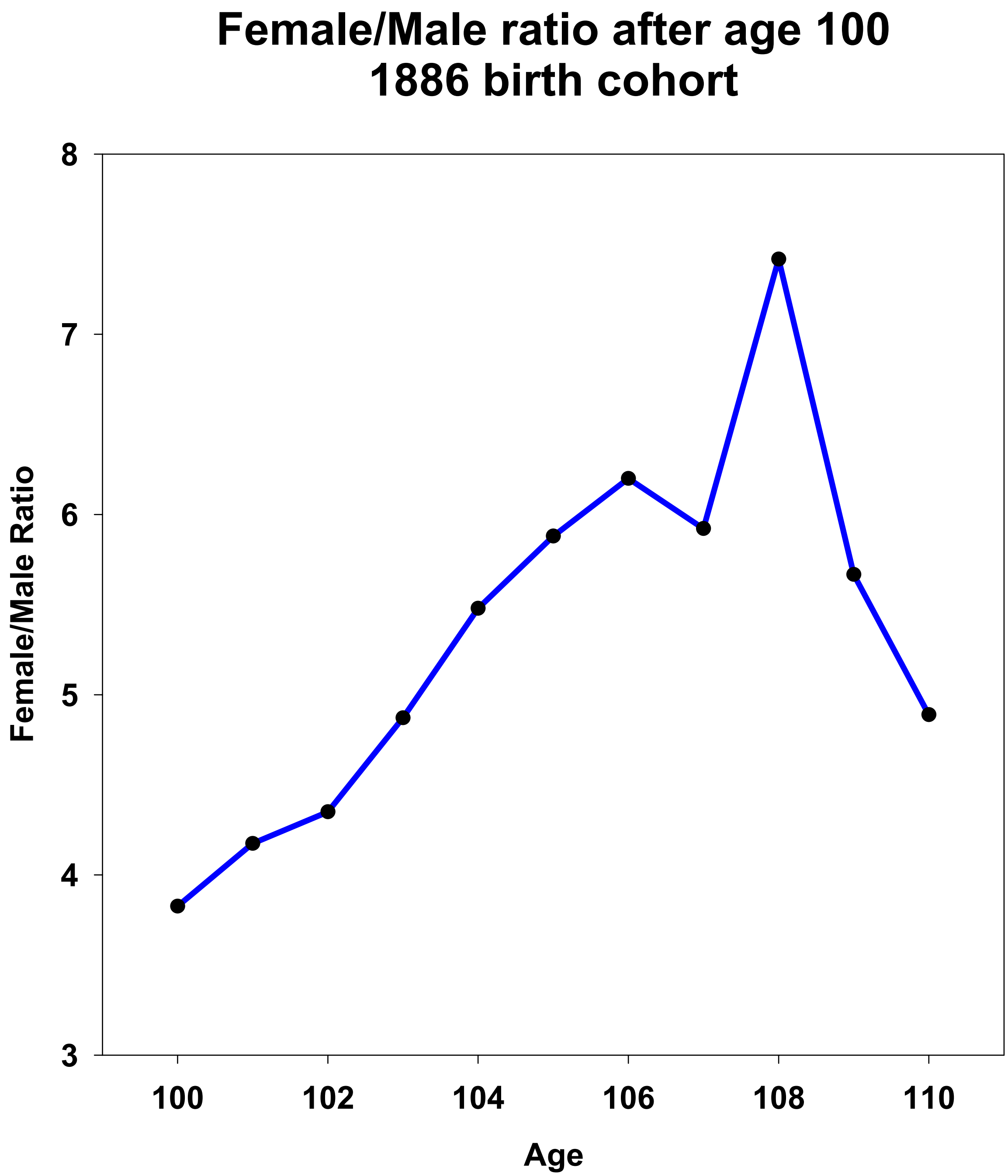

Figure 8.
Female/male ratio as a function of age for the 1886 birth cohort.
Data from the Social Security Administration Death Master File.

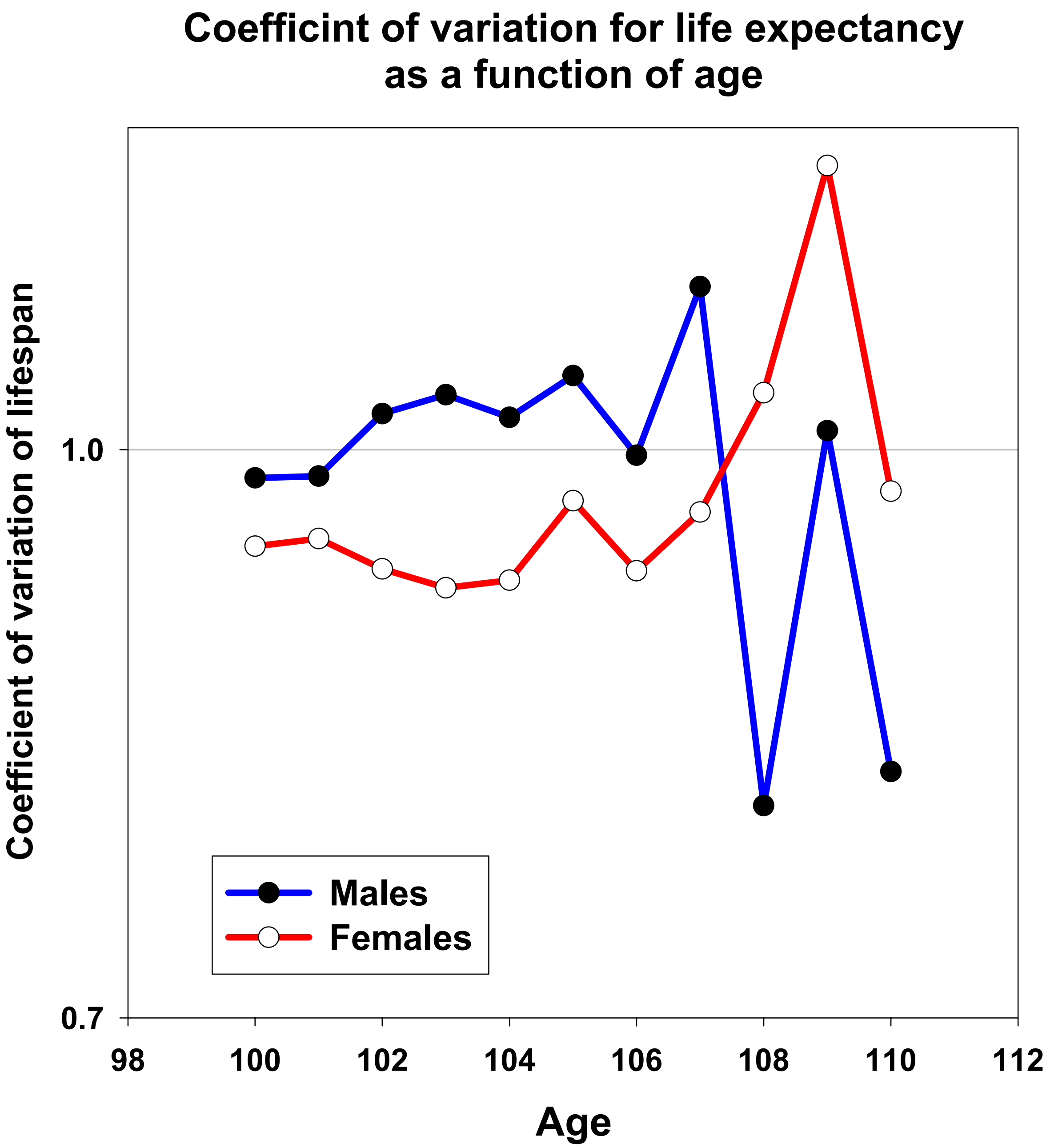

Figure 9.
Coefficient of variation for life expectancy as a function of age for the 1886 birth cohort. Data from the Social Security Administration Death Master File.

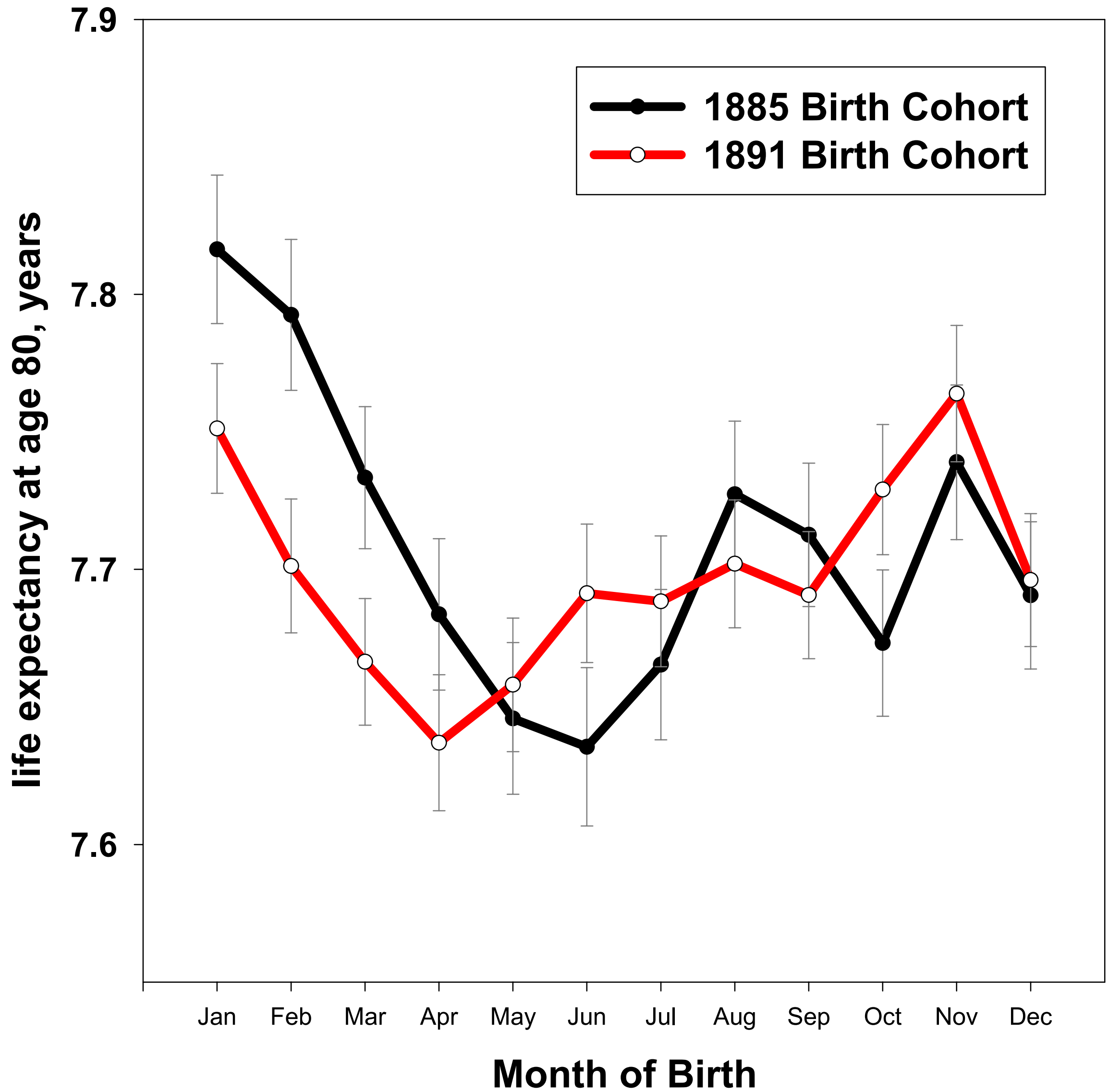

Figure 10. The dependence of life expectancy at age 80 on person's month of birth. Comparison of 1885 and 1891 birth cohorts.
Data on extinct birth cohorts obtained from the Social Security Administration Death Master File.

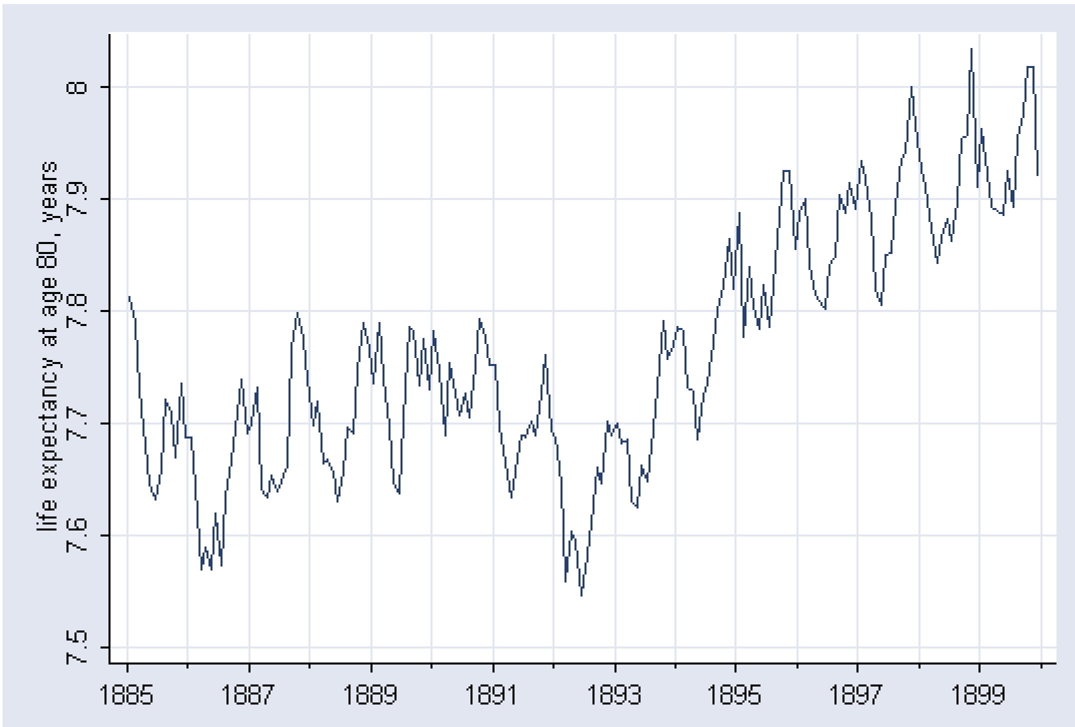

Figure 11. Periodic seasonal changes in life expectancy at age 80 for 1885-1899 birth cohorts depending on month of birth.

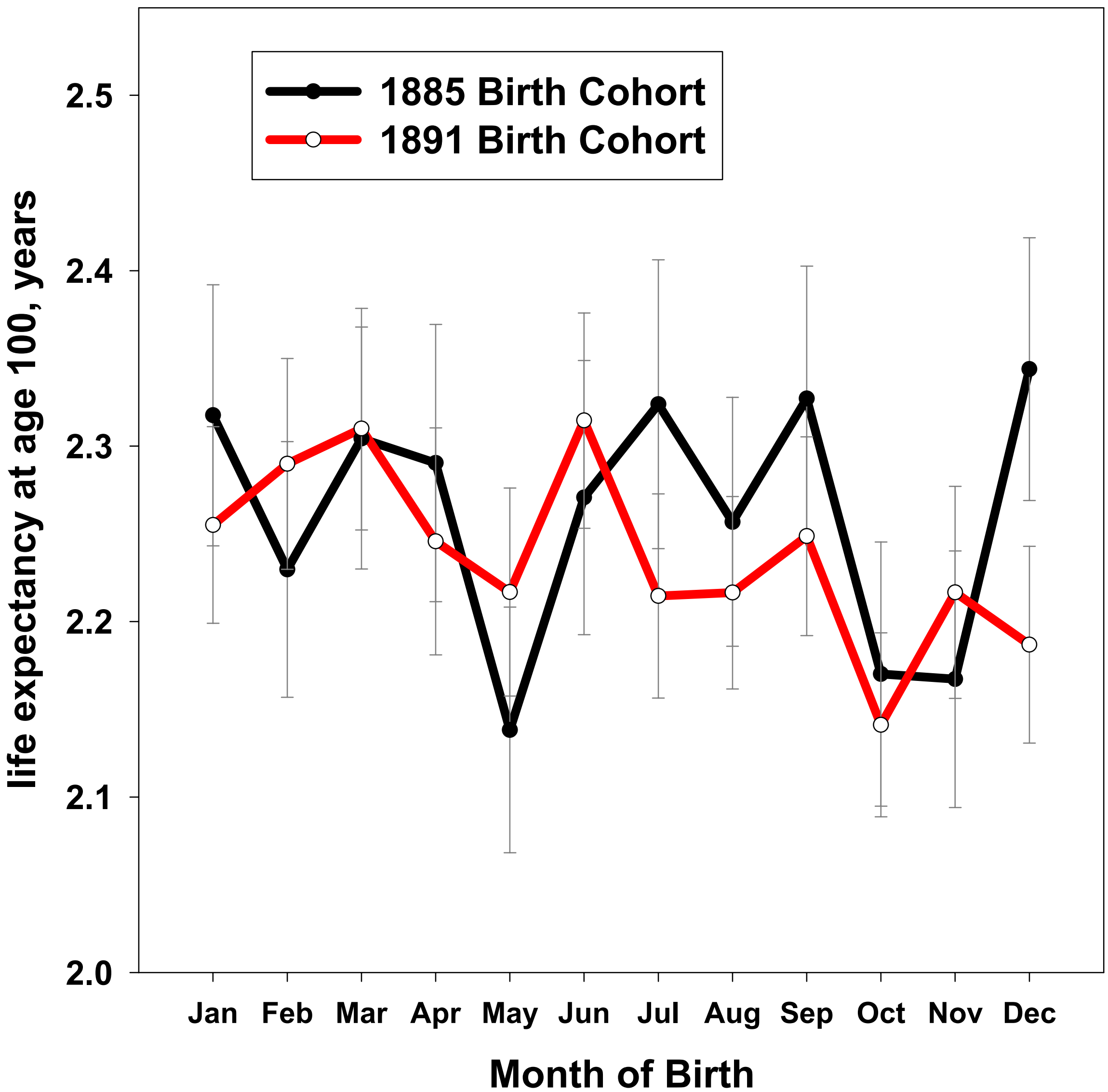

Figure 12. The dependence of life expectancy at age 100 on person's month of birth. Comparison of 1885 and 1891 birth cohorts.

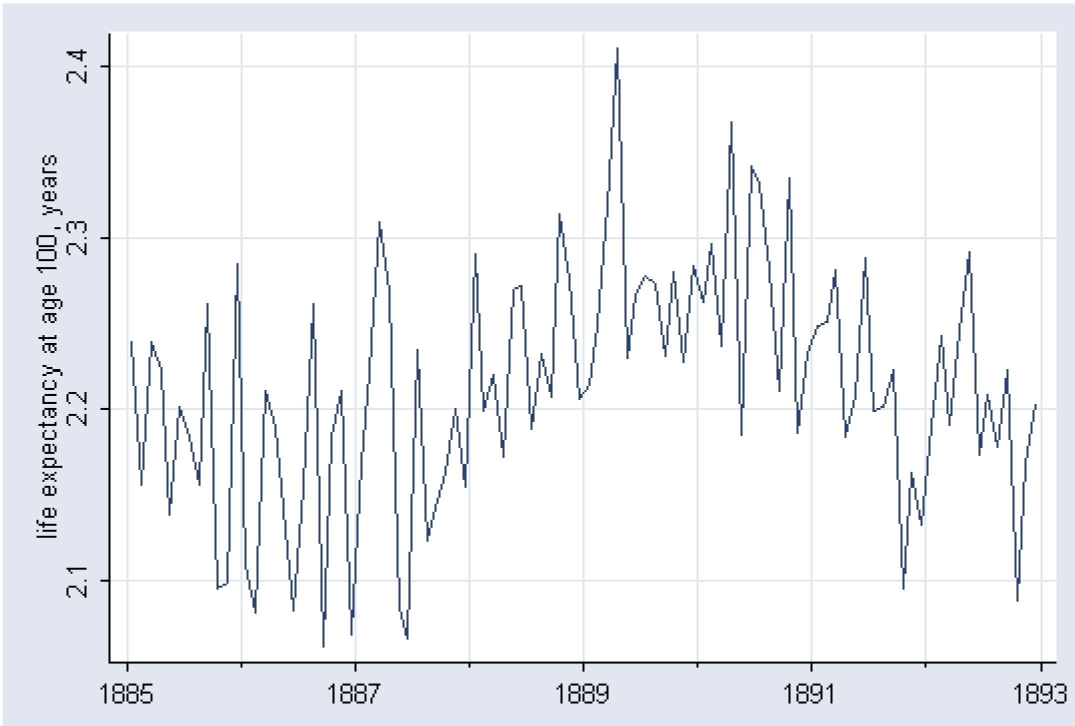

Figure 13. Life expectancy at age 100 for 1885-1893 birth cohorts.

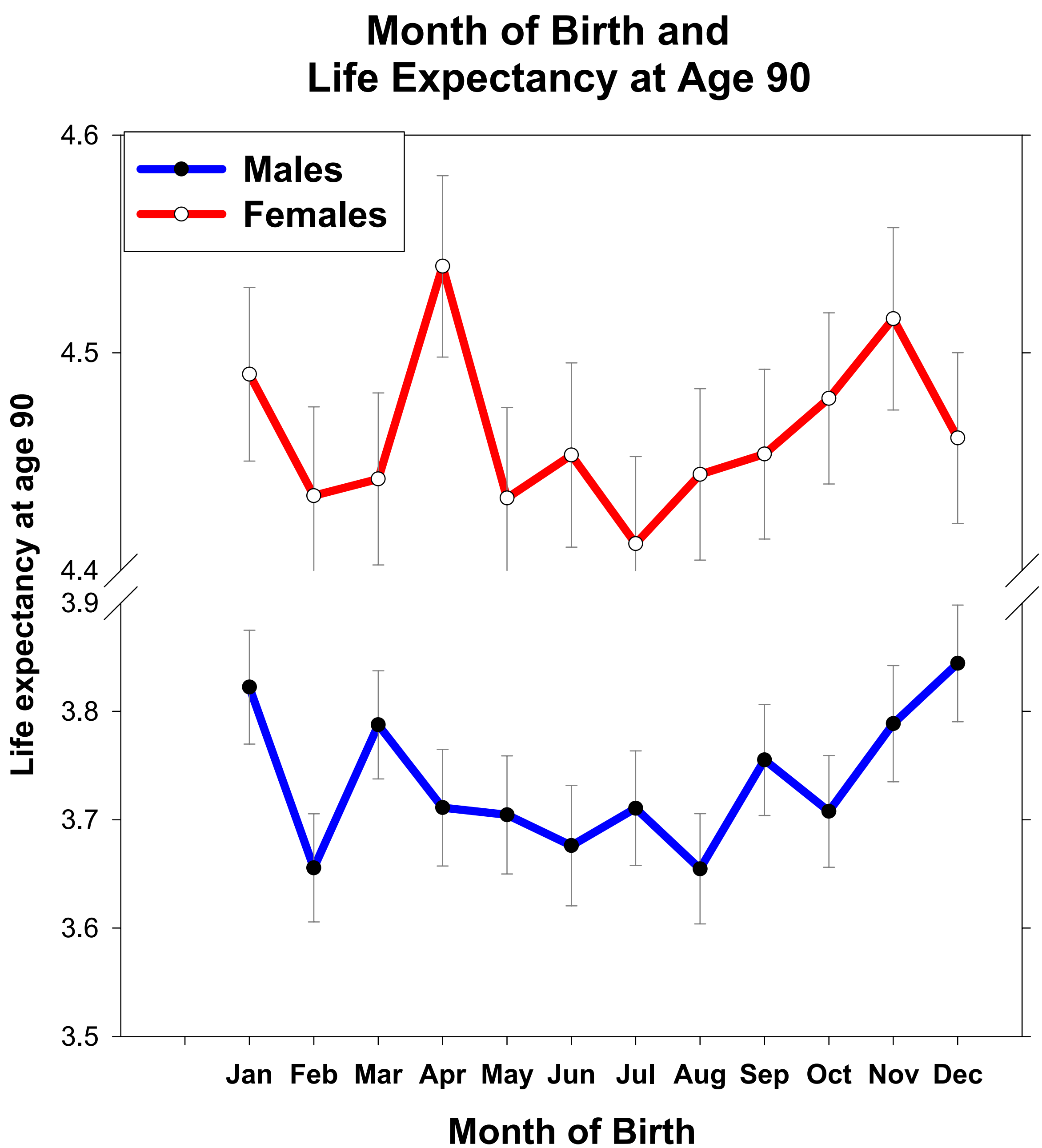

Figure 14. Month of birth and life expectancy at age 90 for males and females from 1886 birth cohort.