2 Month-of-Birth Patterns in the Northern and Southern Hemisphere

One of the first scholars to be interested in the effect of month of birth on longevity was Ellsworth Huntington. In his book “Seasonality” (1938) he described the relationship between the seasons of the year and social, psychological, and demographic phenomena.

On the basis of 10,890 persons in the Dictionary of American Biography who died at an average age of 68.9 years, he found that those born in February died at age 69.7, whereas those born in June at an average age of 67.8. He observed a secondary maximum in September and October. He obtained similar results for 13,891 New Englanders from genealogical memoirs of 80 families; 3,019 New Englanders and New Yorkers; 12,173 people from New York, New Jersey and Pennsylvania and 9,921 people from Maryland, Virginia, North and South Carolina, a few from states farther south or west; and 7,517 people in the British “Who Was Who”.

Huntington comes to the conclusion that, in all populations (with the exception of the British population), people born in February or March live longer than those born in July or August. Huntington’s finding stimulated extensive research in the area of psychology. Since the 1930s more than 200 studies have been conducted about the prevalence of schizophrenia and month of birth (for a review see Torrey 1997). More recently, researchers attempted to attribute the differences in the prevalence of schizophrenia by month of birth to maternal virus infections such as measles or flu during pregnancy. The results, however, are not conclusive.

Eysenck took up the topic of the impact of month of birth on life span in his book “Astrology. Science or Superstition?” in 1982 (Eysenck & Nias 1982) and Miura edited a series of epidemiological studies in his book entitled “*Seasonality*” (Miura 1987). In the 1980s and 1990s quite a few epidemiological studies were conducted that found a relationship between month of birth and specific diseases such as allergies, insulin-dependent diabetes, congenital malformations, Parkinson’s and Alzheimer’s disease, breast cancer, etc. (see Chapter 5). In all these studies month of birth is used as an indicator for the environment early in life.

This chapter takes up the topic and provides evidence from population data that month of birth and life span are indeed related. In contrast to earlier research, this study is not based on sample data but on complete population data for countries of the Northern and Southern Hemisphere.

Huntington conjectured that the month of birth is an indicator for environmental factors that are linked to the seasons of the year. If this is true, then the patterns of two geographically close populations should resemble each other, and the pattern in the Northern Hemisphere should be mirrored in the Southern Hemisphere. Furthermore, life spans of people who were born in the Northern Hemisphere but who died in the Southern Hemisphere should resemble the pattern of the Northern Hemisphere.

The first step, therefore, was to obtain data on the populations of Denmark, Austria, and Australia to test this conjecture. Statistics Denmark provided longitudinal data based on the Danish population register that follows every person living in Denmark from 1968 to the present. Statistics Austria and Statistics Australia provided death certificates for all deaths that occurred between 1988 and 1996 in Austria, and between 1993 and 1997 in Australia. In addition to these three countries, data were also obtained for Hawaii. Hawaii is of particular interest for the study of differences in life span by month of birth because it is located close to the equator. The data for Hawaii are based on US death records for the years 1989 to 1997; these records include place of birth.

The optimal data to test for differences in life span by season of birth are longitudinal data. Birth cohorts born in a specific season are followed from birth to death and life expectancy can be calculated using simple life-table methods. Such data rarely exist however. The data that are closest to this requirement are register data from the Scandinavian countries. The Danish data used in this study consist of a mortality follow-up of all Danes who were at least 50 years old on 1 April 1968. This is a total of 1,371,003 people, who were followed up to week 32 of 1998. The study excludes 1,994 people who were lost to the registry during the observation period. Among those who are included in the study, 86% (1,176,383 individuals) died before week 32 of 1998; 14% (192,626 individuals) were still alive at the end of the follow-up.

Thus, for Denmark both the risk population and the number of deaths are known, which means that it is possible to estimate remaining life expectancy at age 50 on the basis of life tables that were corrected for left truncation. This was achieved by calculating occurrence and exposure matrices that take into account an individual's age on 1 April 1968. For example, a person who was 70 at the beginning of the study and who died at age 80 enters the exposures for ages 70 to 80 but is not included in the exposures for ages 50 to 69. The central age-specific death rate is based on the occurrence-exposure matrix. The corresponding life-table death rate is derived by means of the Greville Method (Greville 1943).

Population registers do not exist for Austria, Hawaii, and Australia, where only individual death records are available. Exact dates of birth and death are known for a total of 681,677 Austrians who died between 1988 and 1996 and for 219,820 native-born Australians who died between 1993 and 1997 at ages 50+. 42,969 decedents of similar age were born in Hawaii and died between 1989 and 1997. The population at risk, however, is unknown, which means that life span by month of birth cannot be estimated on the basis of simple life-table techniques. For Austria, Australia, and Hawaii remaining life span at age 50 was therefore estimated by calculating the average of the exact ages at death.

Mean age at death is not equivalent to life expectancy when cohorts are not extinct. Gavrilov and Gavrilova (2003) pointed out that mean age at death is influenced by changes in the seasonal distribution of births. In Northern Europe the number of births generally peaks in February and March and reaches a minimum in December. Suppose that in younger cohorts the seasonality in births has become smaller as compared to older cohorts. This would imply that in younger populations there are proportianally less people born in winter and more born in fall. In death data this shift in the birth distribution will be reflected in a higher mean age at death for those born in winter and a lower mean age at death for those born in fall.

The usual procedure to account for the effect of possible shifts in the seasonal distribution of births is to compare the seasonal birth distribution at the time of birth of a cohort with the birth dates of the deceased or the survivors of the birth cohort at a given age. Unfortunately, for Australia and Hawaii this information is not available. For Austria the seasonal distribution of births is recorded in statistical yearbooks for the years 1881-1912 and it will be compared with the birth dates of the survivors in the 1981 census. The resulting pattern is compared with the month-of-birth pattern on the basis of the mean age at death.

Furthermore, the Danish twin registry is drawn on for the calculation of remaining life expectancy using the information about the population at risk and the number of deaths. The month-of-birth pattern is then compared with the pattern on the basis of the death counts alone.

In all these analyses the age range is generally restricted to ages 50 and above so as to exclude the possibility that the differences in life span simply reflect differences in survival during the first part of life by month of birth rather than at old age.

2.1 Life Span by Season of Birth

A similar relationship between month of birth and life span exists in both of the Northern Hemisphere countries. Adults born in the autumn (October–December) live longer than those born in the spring (April–June). The difference in life span between the spring- and autumn-born is twice as large in Austria (0.6 years) as in Denmark (0.3 years).

In Denmark remaining life expectancy at age 50 is 27.52 years. The average age at death is lowest among those born around week 18, and it peaks at week 51. The life span of Danes born in specific months varies periodically around the mean (Fig. 2.1.C). For those born in the second quarter, life spans are 0.19 ± 0.05 years shorter than average; for those born in the fourth quarter they are 0.12 ± 0.04 years longer than average. This difference is statistically significant (Cox-Mantel statistic: $p<0.001$).

In Austria deaths occurred at an average age of 77.7. The mean life span of people born in specific months of the year deviates from this average (Fig. 2.1.A). The average age at death is lowest for those born around week 20 and highest for those born around week 46. The deviation in mean age at death is highly significant (Bonferroni test: $p<0.001$) for those born in the second and the fourth quarters. The life spans of people born between weeks 14 and 26 are 0.28 ± 0.03 years below average; life spans of those born between weeks 40 and 52 are 0.32 ± 0.03 years above average.

The pattern in the Northern Hemisphere is mirrored in the Southern Hemisphere. The mean age at death of people born in Australia in the second quarter of the year is 78.0; those born in the fourth quarter die at a mean age of 77.65. The difference of 0.35 years is statistically significant (Bonferroni test: $p<0.001$) (Fig. 2.1.B).

Significant differences in the life span by month of birth exist for Hawaii (Fig. 2.1.D). The mean age at death of people born in Hawaii is 74.5. The mean age at death of the March-born is 0.53 years above the average; that of the October-born is 0.29 years below the average. The difference between the two months is statistically significant at $p=0.004$ (Bonferroni test).

Based on the results reported above one can conclude that the pattern in the Southern Hemisphere is a reversed mirror image of the Northern Hemisphere pattern. This can be clearly seen from the correlations of the mont-of-birth patterns. The correlation of the deviations in life span by month of birth between Austria and Denmark is 0.83 (Pearson correlation, one sided test: $p<0.0001$). Between Austria and Australia it is -0.79 ($p<0.001$) and between Denmark and Australia -0.80 ($p<0.001$).

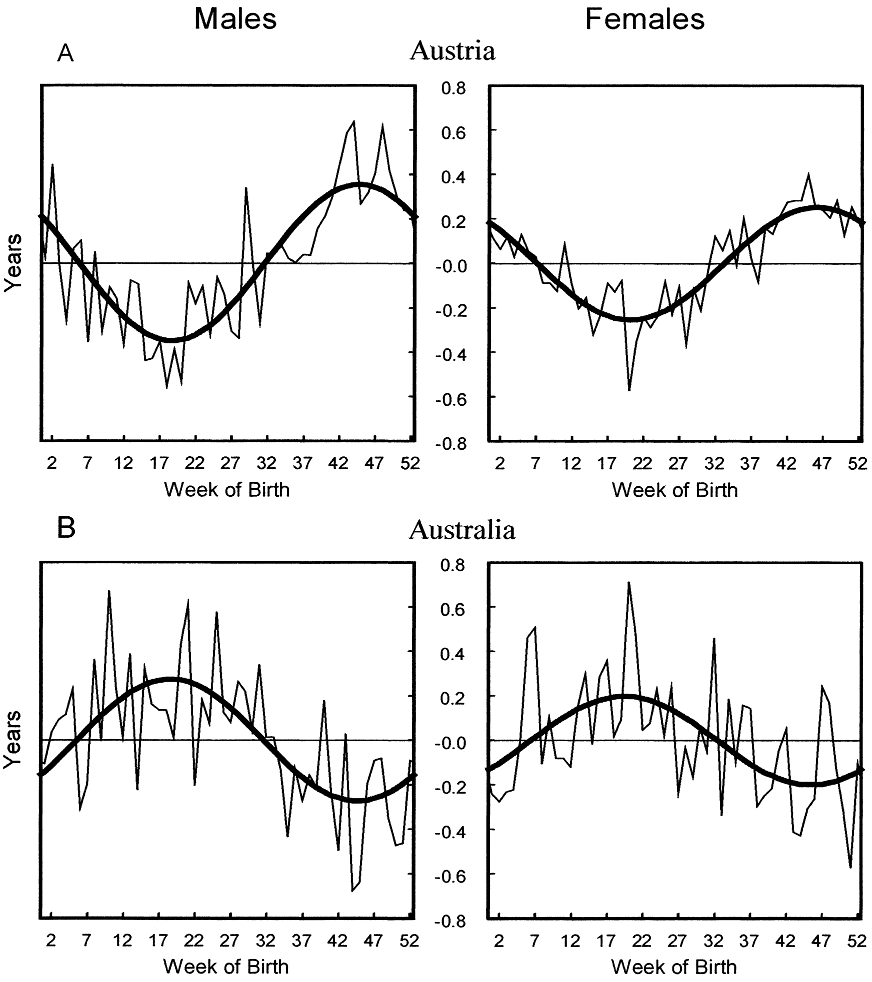

Figure 2.1. Austria (A) and Australia (B): Mean ages at death by week of birth. The fitted line is estimated by a cosine term with a period of 52 weeks.

Single cosinor analysis with a period of 52 weeks (or 12 months) shows that in all four populations the differences in lifespan follow a seasonal pattern. For each of the four populations, ages at death (Austria, Australia and Hawaii) and remaining life expectancy at age 50 (Denmark) are fitted

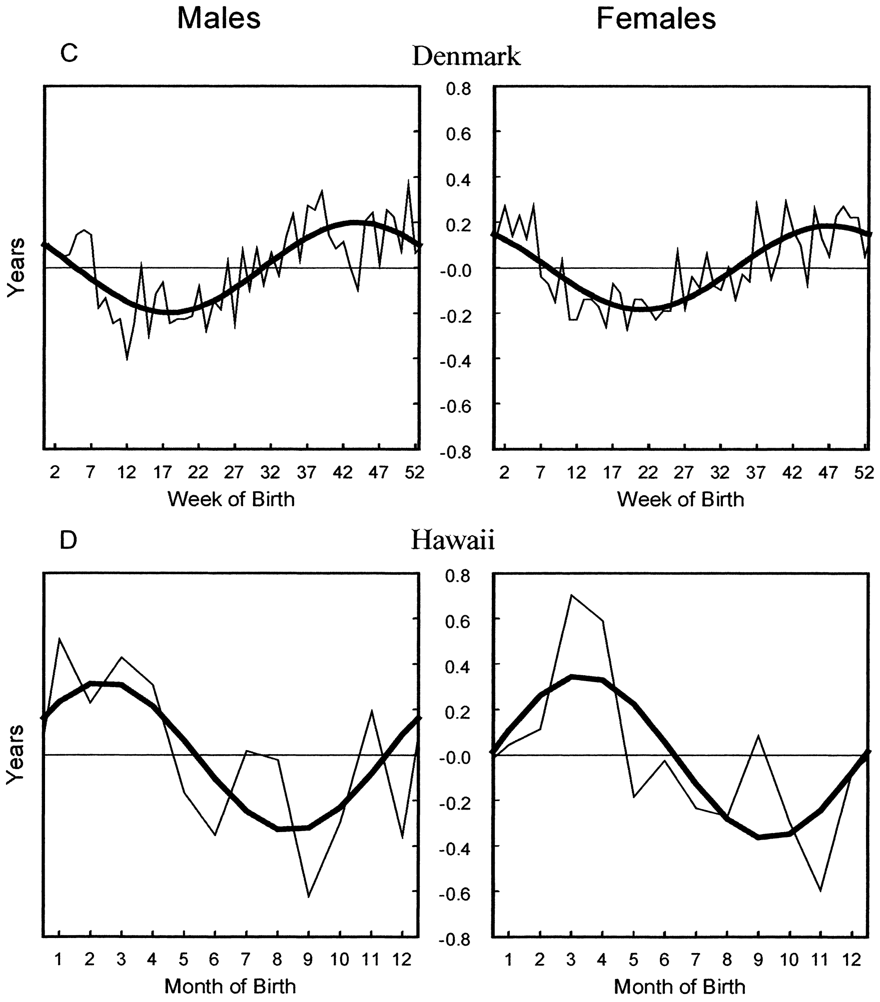

Figure 2.1. (continued) Denmark (C) and Hawaii (D): Mean ages at death by month of birth. The fitted line is estimated by a cosine term with a period of 12 months (Hawaii) and 52 weeks (Denmark).

by a cosine term $age = a_0 * cos(t - a_1)$, where a_0 is the amplitude, a_1 the acrophase (maximum), and $t = week\ of\ birth / 52 * 2\pi$ (Hawaii: $t = month\ of\ birth / 12 * 2\pi$). The parameters are estimated using the least squares estimation procedure. Figures 2.1.A–D show the weekly means together with the fit-

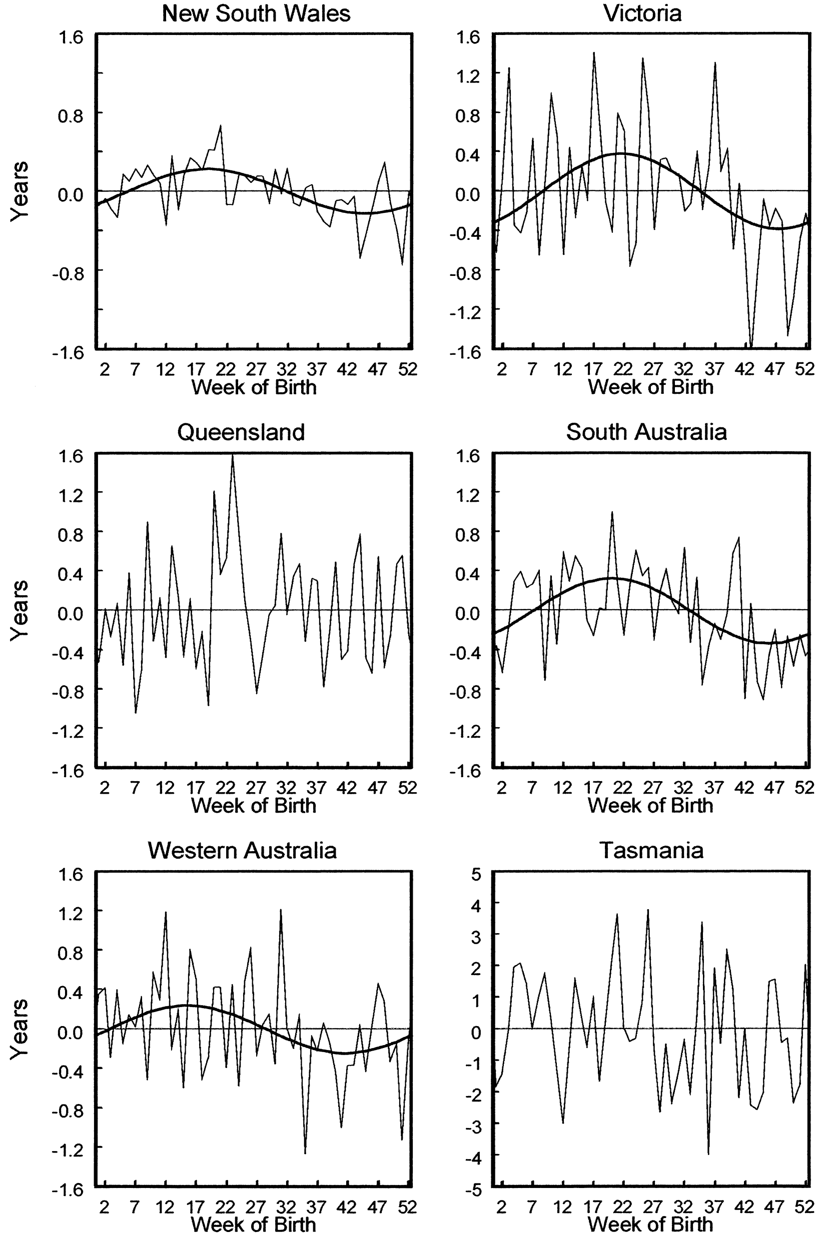

Figure 2.2. Australia: Mean age at death by week of birth and region of birth. The fitted line is estimated by a cosine term with a period of 52 weeks. The cosine term is significant for all regions with the exception of Queensland and Tasmania.

ted cosine terms. The fit of the sinusoidal functions is highly significant, with $p<0.001$.

For Austria the data allow us to analyse causes of death for the years 1990-1997 (Table 2.1). There is a general tendency for people born in the first half of the year, especially in the second quarter, to die at younger ages than those born in the second half of the year, especially in the fourth quarter. The differences between people born in the second and fourth quarters are significant for both heart disease and cerebrovascular disease. In the group of malignant neoplasms, significant differences exist for stomach cancer and the residual group 'other neoplasms'. Differences for lung cancer, cancer of the urinary system, and diabetes mellitus are of borderline significance ($p=0.06$). Significant differences exist for chronic respiratory diseases, pneumonia and influenza, digestive diseases, the residual group 'other natural causes of death', and for violent causes of death. Although the Austrian death data consist of more than 600,000 decedents, the number of deaths from a particular cause of death can become quite small, especially when the data are further distinguished by month of birth. Some of the non-significant results may thus be caused by insufficient numbers of observations. Chapter 5 reports the cause-specific results from the analysis of about 16 million death certificates from the United States.

Since Australia is a whole continent, the analysis of the month-of-pattern for different birth regions may provide evidence concerning the underlying causal mechanisms. It appears that the reversal of the pattern seen in the Northern Hemisphere exists in almost all Australian states and territories: the mean age at death in the first half-year is generally higher than in the second half-year (Table 2.2, Fig. 2.2).

The peak-to-trough difference between those born in the second and the fourth quarter is significant for New South Wales (0.39 years), Victoria (0.89 years), and South Australia (0.61 years). It is of borderline significance ($p<0.1$) for Western Australia (0.49 years). The largest difference ($p=0.157$), which is however not significant, exists for Tasmania, with 1.6 years. The cosine analysis supports these results. The cosine functions are generally highly significant with the exception of Tasmania and Queensland. The regional differences in the pattern of life span by month of birth are not significant (ANOVA F-test for the interaction effect between month of birth and region: $p=0.585$).

The most interesting result of the regional analysis is that the peak-to-trough difference for Queensland is not significant. The non-significant result is not due to small numbers of observations. There are more observations for Queensland than, for example, Victoria, where the difference is highly significant. Figure 2.3 reveals that in Queensland, like in the other

Table 2.1. Difference in mean age at death for people born in a specific season from average age at death by major causes of death; Austria 1990-1997.

Causes of death (ICD Number)	Season of birth					Number of deaths
	Winter (Jan-Mar)	Spring (Apr-Jun)	Summer (Jul-Sep)	Autumn (Oct-Dec)	p*	
Heart disease (390-429, 440-458)	-0.08	**-0.30**	0.06	**0.33**	0.00	257,167
CVD (430-438)	-0.01	**-0.23**	-0.03	**0.27**	0.00	80,367
Malignant neoplasms						
Breast (174)	0.12	**-0.25**	0.00	**0.14**	0.53	12,201
Uterus & female genital organs (179-184)	0.05	**-0.08**	**0.10**	-0.07	0.92	9,530
Prostate & male genital organs (185-187)	**-0.18**	-0.05	0.01	**0.24**	0.40	9,401
Urinary system (188-189)	-0.09	0.07	**-0.39**	**0.42**	0.06	8,508
Haemoblastoses (201-208)	**-0.19**	-0.07	-0.02	**0.28**	0.44	9,147
Lungs (162)	-0.14	**-0.18**	0.06	**0.26**	0.06	24,178
Stomach (151)	-0.10	**-0.44**	0.03	**0.50**	0.00	12,689
Intestines (152-154)	-0.02	**-0.12**	**0.12**	0.02	0.70	21,233
Other	-0.07	**-0.24**	-0.01	**0.33**	0.00	39,359
Respiratory system (460-479, 488-519)	0.04	**-0.18**	-0.16	**0.33**	0.05	18,018
Pneumonia and influenza (480-487)	-0.01	-0.10	**-0.35**	**0.45**	0.02	10,807
Digestive system (520-579)	0.23	-0.20	**-0.28**	**0.24**	0.01	27,384
Diabetes mellitus (250)	-0.06	**-0.33**	0.19	**0.20**	0.06	13,537
Other natural	**-0.26**	-0.22	-0.08	**0.58**	0.00	27,197
Violent (E800-E999)	-0.04	**-0.41**	-0.01	**0.49**	0.00	21,998

Bold figures: maximum and minimum difference from average age at death

* p value: Anova F-Test for all seasons

Table 2.2. Mean age at death by state of birth and quarter of birth, amplitude, and peak estimated by cosinor analysis based on Australian death records for the years 1993 to 1997.

	Quarter of Birth				Max. Dif.+	Cosinor Analysis		Deaths
	1	2	3	4		Amplitude	Maximum Week	
New South Wales	77.1	**77.2**	**77.0**	76.9	0.39**	0.23 0.14-0.31	19 16-22	126,308
Victoria	**77.1**	**78.2**	78.1	77.3	0.89**	0.38 0.13-0.96	22 16-27	14,130
Queensland	**77.4**	**77.7**	77.5	77.6	0.31	n.s.	n.s.	20,686
South Australia	78.3	**78.5**	78.2	**77.9**	0.61**	0.33 0.17-0.49	20 16-24	32,260
Western Australia	**77.5**	77.4	77.2	**77.0**	0.49**	0.24 0.05-0.43	16 9-22	23,395
Tasmania	78.6	**79.5**	78.3	**77.9**	1.60	n.s.	n.s.	1,843

** Bonferroni test: $p<0.01$, * Bonferroni test: $p<0.1$, bold figures indicate the minimum and the maximum mean age at death

\+ Maximum difference in mean age at death between quarters

n.s. cosinor term not significant

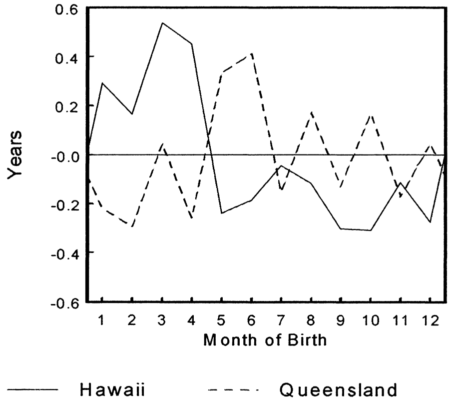

Figure 2.3. Queensland and Hawaii: Deviation in life span for people born in a specific month from the average remaining life span at age 50.

Australian states, mean age at death is highest for those born in May or June. It is lowest, however, for those born in January and February. The two major cities of Queensland are Brisbane (27.39 South Latitude, 153.12 East Longitude) and Townsville (19.25 South Latitude, 146.77 East Longitude). Queensland is geographically almost a mirror image of Hawaii, whose capital, Honolulu, is situated at 21:18 North Latitude and 157:51 West Longitude. Comparing the month-of-birth patterns for these two countries one finds that they are reversed: in Hawaii mean age at death is highest for those born during the first four months, in Queensland it is lowest; from May on mean age at death is generally lower in Hawaii and generally higher in Queensland. The correlation between Hawaii and Queensland is -0.594 and significant at p=0.021.

Comparing the seasons of the year in both Hawaii and Queensland, those born at the beginning of the winter season, which is characterized by lower temperatures, live longer. In tropical northern Australia the wet season corresponds with summer and lasts from November through April. The dry season corresponds with winter and lasts from May through October. In Hawaii the wet season coincides with moderate temperatures and lasts from October to May, while the hot and dry summer lasts from June to September.

The Australian data distinguish between native-born Australians of foreign heritage and aborigines and contains the death records of 2,254 Aborigines and 218,279 native-born non-indigenous Australians. These figures exclude records with birth dates 1 January and 1 July because of a heaping of birth dates on these two days. It is highly likely that unknown birth dates were assigned randomly to one of these two dates. The mean age at death of aborigines is almost 10 years lower (67.9 years) than that of the non-indigenous Australian population (77.8 years). The week-of-birth pattern is similar (Fig. 2.4), but the amplitude is much larger among aborigines (1.17 years, 95% CI: 0.40-1.94). The cosine function peaks in week 20 (95 % CI: 15-25). The amplitude among the native-born non-indigenous Australian population is 0.24 years (95% CI: 0.18-0.30), mean age at death peaks for decedents born in week 19 (95% CI:17-22). The fit of the cosine functions is highly significant at $p<=0.001$.

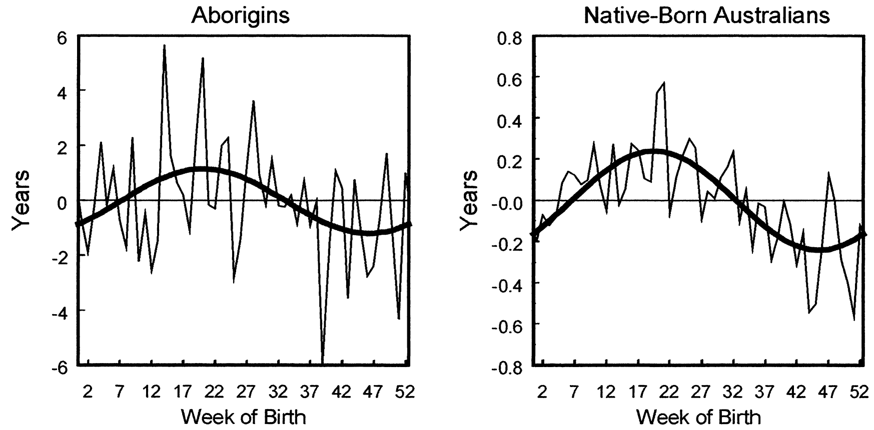

Figure 2.4. Aborigines and native-born Australians of foreign heritage: Deviation in mean age at death for people born in a specific week from the average age at death (ages 50+) estimated by a cosine function with a period of 52 weeks.

2.2 A Different Approach

If people born in a specific month experience a higher mortality risk than others, the distribution of birth dates of the total population changes with age (Vaupel & Yashin 1985). This can be easily tested on the basis of population censuses. A simple tabulation of the Austrian 1981 census gives the proportion of those born in the first and fourth quarters for five-year age-groups. A lower mean age at death for people born in the second and third quarters implies that, with advancing age, the proportion of people born in the first and fourth quarters of the year will increase. This is exactly what is to be observed in the Austrian 1981 census, where the proportion increases by almost 5 percentage points from 49.7 per cent at ages 50-54 to 54.5 per cent at ages 95+. The change in the proportion is statistically significant at $p=0.0001$ (χ^2 test).

This change could also be due, however, to a change in the seasonal distribution of births. For example, it has been shown that, in Austria, the seasonal fluctuations in the number of births changes between the periods 1881-1912 and 1947-1959 (Doblhammer et al. 2000). A better approach, therefore, is to compare the seasonal distribution of births of a cohort with the seasonal distribution of birth dates among survivors fifty or more years later. For Austria the seasonal distribution of births is available for almost all years between 1881 and 1912. The statistical yearbooks, which were published annually by the Central Bureau of Statistics of the Austro-Hungarian Empire, contain the number of births by month of the year. It is therefore possible to compare the seasonal birth distribution of the years 1881 to 1911 in the German-speaking regions of the Austro-Hungarian Empire with the distribution of the survivors in the 1981 Austrian census. At the time of the census the survivors were between the ages of 70 and 100 (Table 2.3). The distribution of birth dates is clearly different at the time of birth and in the 1981 census. For all birth cohorts the proportion of the fall-born increases with age. The increase is 1.1 percentage point for the youngest cohort (1907-1911) and 4.4 percentage points for the oldest cohort (1881-1886).

Table 2.3. Percent of winter births at the time of birth and in the Austrian 1981 census for different birth cohorts.

Birth cohort	Age of the cohort in the 1981 census	% winter births at the time of birth	% winter birth dates in the 1981 census	% Difference
1881-1886	95-100	50.1	54.5	4.4
1887-1891	90-94	50.2	53.8	3.6
1892-1896	85-89	49.9	53.3	3.3
1897-1901	80-84	49.8	52.4	2.6
1902-1906	75-79	49.9	51.4	1.5
1907-1911	70-74	49.7	50.8	1.1

2.3 Bias in the Month-of-Birth Pattern

In the case of extinct cohorts, mean age at death is similar to life expectancy estimated by the life-table method. The data that exist for Austria, Australia, and Hawaii, however, do not come from extinct cohorts and mean age at death is therefore a biased estimate of life expectancy.

One unobserved factor that causes bias in the month-of-birth pattern is a change in the seasonal distribution of births over time. In Northern Europe the number of births usually peaks in February and March, declines thereafter, reaches a secondary peak in September and a trough in December. In the United States the pattern is reversed with a trough in spring and a peak in late summer and fall (Lam & Miron 1996). The basic seasonal pattern has not changed over time but in some countries such as the United States the fluctuations became smaller between 1947 and 1976 (Seiver 1985), in other countries such as Austria they became larger (Doblhammer et al. 2000).

Take the case of Austria, where information about the monthly number of births exists for the years 1881 to 1912 and 1945 onwards. No information is available starting from World War I, which led to the collapse of the Austrian Hungarian Monarchy and the destruction of most administrative structures, until the end of World War II.

The seaonal pattern develops as follows: the peak in February decreases from 8.83% for birth cohorts 1881-1890 to 8.73% for birth cohorts 1891-1900. It remains stable for birth cohort 1901-1912 and considerably increases (9.15%) for birth cohorts 1947 to 1959. The intermediary September peak sharply increases between 1881-1990 (8.08%) and 1891-1900 (8.33%) and remains stable thereafter, while the December trough remains almost unchanged between 1881-1890 and 1947-1959. These changes in the seasonal distribution of births result in proportionally more younger decedents among the February-born, and mean age at death will therefore underestimate true life expectancy.

In the following an attempt is presented for assessing the bias by using the information about the seasonal birth distribution for the years available. In the Austrian death records of the years 1988 to 1996 decedents aged 50 and above were born between 1881 and 1946. The frequency distribution of birth years is: 1881-1890: 0.14%, 1891-1900: 7.2%, 1901-1912: 44.3%, 1913-1922: 25.4%, 1923-1932: 16% and 1933-1946: 7.1%. To calculate the number of expected decedents by month of birth, one needs the average seasonal birth distribution for the time period 1881-1946. This average is derived by weighting the seasonal birth distributions for the respective time period with the according frequencies of birth years observed in the death records. Since no seasonal birth distribution is available for the time periods 1913-1922, 1923-1932 and 1933-1946, it is assumed that the seasonal distribution of the period 1901-1912 holds true for the period 1913-1922, while from 1923 onwards the seasonal distribution of births follows the pattern observed in 1947-1959. The distribution of birth months in the death records is then compared with the distribution of birth months in the average seasonal birth distribution. A similar calculation is performed for all decedents aged 80+. In the death records they were born between 1881 and 1916 and the seasonal distribution of the number of births is known with the exception of the last 4 years. Again a weighted seasonal birth distribution is calculated and compared with the distribution of birth months in the death records.

Figure 2.5 shows the month-of-birth pattern based on mean age at death, together with the percentage deviation of the birth months in the death records for ages 50+ and 80+ as compared to the average seasonal birth distribution for the time period 1881-1946 (ages 50+) and 1881-1916 (ages 80+). For example, the value -0.06 indicates that for ages 80+ the proportion of the February-born is 0.06 percentage points lower in the death records than in the corresponding seasonal birth distribution of the years 1881-1916.

Comparing the two trajectories in Figure 2.5.A it appears that the pattern based on mean age at death is shifted to the left for those born in the first half-year. In other words, excess mortality, particularly of those born in the first three months, is overestimated. This is especially true for ages 50+. For ages 80+ the patterns based on mean age at death and on the frequency distribution of birth dates are close, and no serious bias is introduced by using mean age at death as a measure of life expectancy.

The seasonal birth distribution for the period 1881-1912 is based on the

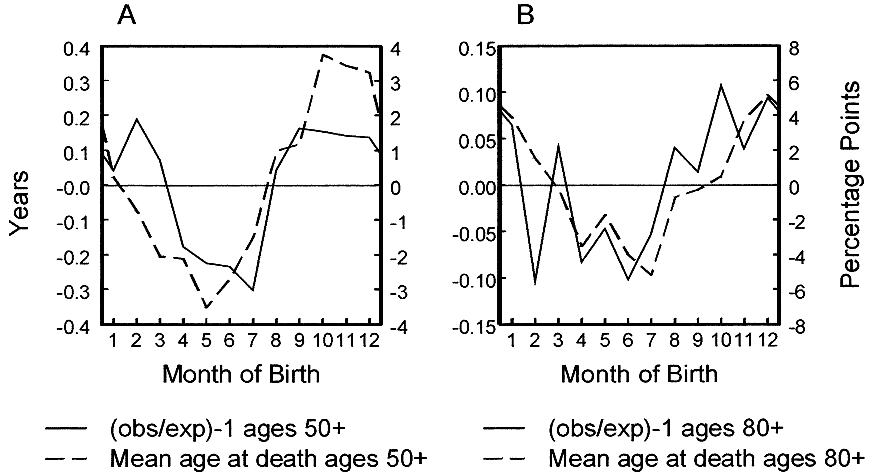

Figure 2.5. Deviation of mean ages at death from average mean age at death for ages 50+ (A) and 80+ (B) and percent deviation of the observed seasonal birth distribution for ages 50+ and 80+ from the expected distributions. Austrian death records 1988-1996 and seasonal distribution of births for the years 1881-1912 and 1947-1959.

German speaking core of the Austrian Hungarian Empire, which is largely identical with the area which constituted the Austrian Republic from 1918 onwards. A considerable proportion of the decedents that were born before 1918, however, was born outside of this core-region.

The Austrian death records do not include the place of birth, they only distingiush between Austrians and foreign nationality. Decedents born before 1918 in regions of the Monarchy that were outside the German speaking core are considered Austrians. An unpublished review of the seasonal birth distributions in the different regions of the Monarchy shows that the distributions differ enormously. It is therefore impossible to determine the exact seasonal birth distribution that should be used for the comparison with the death records.

The second data source that can be used for assessing the difference in the month-of-birth pattern in life span on the basis of mean age at death and on life expectancy is the Danish twin registry. The Danish twin registry was established in 1954 and contains all twin pairs born between 1870 and 1910 and all same-sex pairs born between 1911 and 1930.

Twin pairs were included when both partners survived their 6th birthday. Birthdates of 28,102 twins are included in the registry. Of these, 4323 twins are of unknown survival status, 7,368 twins are censored due to emi-

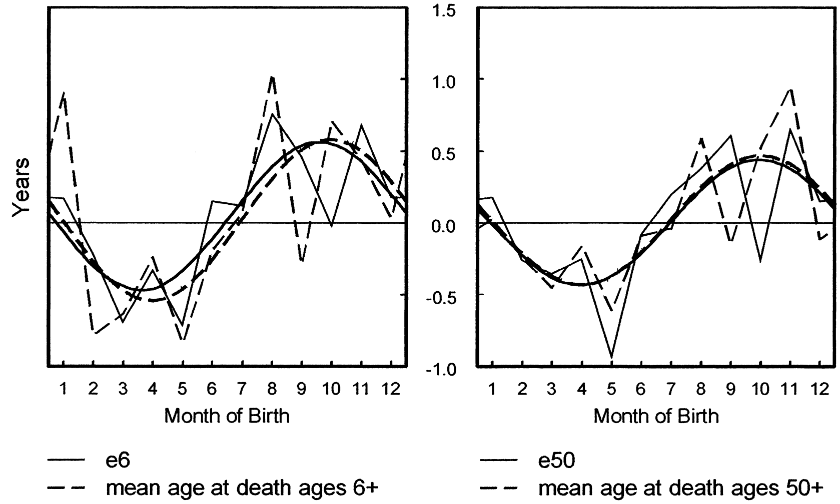

Figure 2.6. Deviation in mean age at death (ages 6+ and 50+) from average mean age at death and deviations in life expectancy (e^6 and e^{50}) from average life expectancy by month of birth. The bold sinusoidal functions are fitted cosine terms.

gration or survival at the end of the observation period (September 1995), 16,411 twins have died.

The frequency distribution of birth cohorts is shifted towards the more recent cohort and is as follows: 1870-1879: 8.5%; 1880-1889: 11.7%; 1890-1899: 13.8%; 1900-1909: 17.9%; 1910-1919: 22.0%; 1920-1930: 26.1%. As expected, life expectancy and mean age at death differ widely: remaining life expectancy at age 6 is 76.87 years, mean age at death 67.24 years. The difference remains for ages 50+ with a remaining life expectancy of 78.52 years and a mean age at death of 73.74 years. The month of birth pattern, however, is almost unchanged (Figure 2.6) and neither the peak to trough difference nor the pattern itself depends on whether life expectancy or mean age at death is used in the calculation.

The two examples show that using mean age at death from death records of not extinct cohorts results into a minor bias concerning the month-of-birth pattern in the case of Austria and into no bias at all in the case of Denmark. For populations without information about the seasonal distribution of births and without population registries mean age at death therefore gives a reasonable approximation of the month-of-birth pattern.