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Longevity and month of birth
Evidence from Austria and Denmark

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Longevity and month of birth: Evidence from Austria and Denmark.

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Abstract

This article shows that in two European countries, Austria and Denmark, a person's life span correlates with his or her month of birth. It presents evidence that this pattern is not the result of the seasonal distribution of death. It also shows that the seasonal pattern in longevity cannot be explained by the so-called "birthday effect"– the alleged tendency of people to die shortly after their birthday. The article concludes with a discussion of possible social and biological mechanisms related to a person's season of birth that might influence life expectancy.

1 Introduction

One of the first to describe differences in life span according to month of birth was Ellsworth Huntington. In his book "Season of Birth" [10] he presents data on longevity by month of birth based on genealogical memoirs of families from different regions of the United States. For all regions he found that people born in February or March live decidedly longer than those born in July or August.

A study of Japanese males born before 1890 [14] found that those born between May and July have a lower life expectancy after age 70 to 75 than those born in other months of the same year. Recent research on babies born in rural Gambia indicates that those born during the dry season suffer higher mortality later in life than those born during the wet season [15].

Huntington's findings stimulated a long line of research on season of birth and the likelihood of mental disorders, e.g. schizophrenia (for a review of 250 studies, see [12, 16, 19, 21]), Alzheimer's disease [22], and autistic disorder [3]. Most of these studies found significant differences in the risk of developing the respective disease according to season of birth. Findings on cancer patients have also revealed significant seasonality in life span according to month of birth [17, 24].

Up to now studies about the relationship between month of birth and longevity have used comparatively small data samples. For example, Huntington's results are based on genealogical information for about 39,000 persons. Some of the data samples were confined to selected groups: Miura's findings are based on graduates of the Tokyo medical school and on asylum inmates, each group numbering about 400 people.

In this study I use data for total populations to investigate the question of whether or not month of birth and life span are related. I employ two different data sources for two different countries: Austria and Denmark. The Austrian data are based on vital statistics. The exact date of birth and the exact date of death are known for each person who died between 1988 and 1996. Only deaths after age 50 are considered. For the years 1990 to 1997 the cause of death is also reported. The Danish data consist of the total population aged 50+ on 1 April 1968. These people were then followed until their death or until August 1998.

The result of this study suggests that life span and month of birth are in fact related. Having determined this, I then pay particular attention to the question of whether or not this relationship can be explained by factors that become active at the end of one's life. I consider two factors: first, the impact of the seasonal distribution of mortality on life span and, second, the "birthday-effect". The latter refers to the alleged tendency of people to die shortly after their birthday. I show in this study that neither factor can explain the relationship between month of birth and life span. Furthermore, I find cause to question recent results that found a correlation between birthday and the time of death (e.g. [5, 23]).

The article closes with a discussion of possible mechanisms that may explain the relationship between month of birth and longevity.

2 Data & Method

2.1 Data

My analysis of the relationship between month of birth and life expectancy is based on two different sets of data. For Austria the exact dates of birth and death are known for all 302,412 men and 379,265 women who died between 1988 and 1996 at ages 50 and above. Causes of death are given for 460,649 persons for the years 1990 to 1997.

The Danish data consist of a mortality follow-up of all Danes who were at least 50 years old on 1 April 1968; 1,371,003 people were followed until their death or until the end of the observation period (week 32 of 1998). All these people were either born in Denmark (1,304,959 individuals) or their place of birth is unknown (66,044 individuals). The study excludes 1,994 people who were lost to the registry during the observation period. Among those who are included in the study, 85.5% (1,176,494 individuals) died before week 32 of 1998; 14% (192,515 individuals) were still alive.

To test whether the seasonal distribution of births changes with age in Austria I collected data on the number of births per month for the years 1880 to 1907. Only the German-speaking regions of the Austro-Hungarian Empire are included. The data are taken from the annual publications of the Central Bureau of Statistics (Statistisches Jahrbuch 1880 - 1907).

2.2 Methods

For Austria I estimated further life expectancy at age 50 by calculating the average of the exact ages at death; for Denmark further life expectancy at age 50 was calculated on the basis of life tables that were corrected for left truncation. This was achieved by calculating occurrence and exposure matrices which 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. When calculating the life tables, I estimated the central age-specific death rate ${}_2\mu_x$ based on the occurrence-exposure matrix for two-year age-groups. The corresponding life table mortality rate ${}_2q_x$ is derived by the Greville Method [9].

For both countries, results are presented as the difference between the mean age at death of people born in a specific week and the average mean age at death in the study period.

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 [20]. To test this for Austria I compared the monthly distribution of the number of births in the years 1880 to 1907 with the distribution of birthdays among those who died at ages 90–99 in the years 1988 to1996. I also calculated for five-year age-groups the proportion of women in the 1981 census born in winter. For Denmark I compared the distribution of birthdays of the survivors of the cohorts born between 1899 and 1908 at ages 60–69 and 90–99.

To test whether the seasonal distribution of deaths explains the differences in life span, the distribution of deaths was “uniformized” in the Austrian data set. The dates of death were redistributed such that over the year they follow a uniform distribution, while their rank order remains unchanged. In other words, the weeks of death d(t) are sorted that d(1)<=...<=d(t)<=...<= d(n), with n equals the total number of deaths. Under a uniform distribution $i = \frac{n}{52}$ deaths will be observed in each week. Then the k-th death is reassigned to week d(j), with $j = \left[\left(\frac{k-1}{i}\right)+1\right]$, the integer part of the expression inside the brackets (e.g. if the total number of deaths n equals 1040 then in each week i=20 persons should have died. Then the 65th person who has died is reassigned to week 4.) Average age at death according to week of birth is then recalculated based on d(j). This redistribution slightly increases the life span of people who died at the beginning of the year while it reduces the life span of those who died at the end of the year. If the seasonal pattern in life span is in fact caused by the seasonal distribution of deaths alone, the differences in life span should then disappear.

The longitudinal nature of the Danish data set allows me to model $\mu(x)$, the force of mortality at age x, directly. The general mathematical specification of the model is

$$\mu(x) = \mu_0(x)\exp\left\{\sum_i \beta_i y_i(x)\right\} \qquad \{1\}$$

where $\mu(x)$ is a function of the baseline hazard $\mu_0(x)$; the value of the covariate $y_i(x)$ and the regression coefficient β_i that measures the effect of the covariate i on the force of mortality.

In this model the baseline hazard $\mu_0(x)$ is piecewise constant. The model assumes that the age-specific death rate for five-year age groups j follows a step function and that the death rate within the five-year age groups is constant.
Thus,

$$\mu_0(x) = a_j \quad \text{with j = 50-54, 55-59, 60-64, 65-69, 70-74, 75-79, 80-84, 85-89, 90+} \qquad \{2\}$$

All other covariates are sets of binary variables that represent the levels of categorical covariates. The following covariates are included:

- month of birth [MOB]. This variable divides the year into thirteen periods, each consisting of four weeks. Week one starts at day one, week two at day eight, and so forth;
- time lived since the last birthday [TSLB]. This covariate divides the year into three periods: (1) the twelve weeks immediately following an individual's birthday (the week of birthday is defined as week one), (2) week 13 to week 40 (28 intermediary weeks) and (3) the twelve weeks before an individual's next birthday (week 41 to week 52). This variable is defined for each year of an individual's life starting with 1 April 1968;
- current month, which is measured in 13 four-week periods;
- period: the years are divided into the six groups 1968-1974, 1975-1979, 1980-1984, 1985-1989, 1990-1994, 1995-1998.
- birth cohort: 1860-1879, 1880-1889, 1890-1899, 1900-1909, 1910-1918.

The first and the last covariate are independent of time. The other three covariates are time-varying. The second and the third variable account for two factors: first, for the possibility of a 'birthday-effect' and second, for the seasonality in mortality. If they are both included at the same time in one model, the model does not converge; probably this is due to the high correlation between the two variables [Note 1].

Period and cohort effects cannot be included simultaneously in a model that accounts for age effects. Thus, four models were estimated. Model 1a includes sex, period, month of birth and current month; Model 1b uses the same covariates but adjusts for cohort factors instead of period factors. Model 2a includes sex, period and the second-order interaction term "time period since last birthday" x "month of birth"; Model 2b is similar to the latter model but adjusts for cohort factors. The two last models include a full set of second-order interaction terms between "month of birth" and "time period since last birthday" in order to account for the seasonal differences in the risk of mortality. The interaction is modelled by 38 dummy variables, each representing a [MOB, TSLB] pair, with the (born in week 1-4, 1-12 weeks since last birthday) cell omitted as the reference group. The survival models were estimated with the program Rocanova [25].

3 Results

In the Austrian data set, death after age 50 occurred at an average age of 77.7. The mean life span of people born in specific weeks of the year deviates from this average, and the deviations vary periodically in a 12-month cycle (Figure. 1). There was no significant difference in this pattern between men and women. Average age at death is lowest for those born around week 20 and highest for those born around week 46. I found a similar pattern when I considered deaths after age 70.

Dividing the year into four quarters (weeks 1-13, 14-26, 27-39, and 40-52) I found that the deviation in mean age at death is highly significant ($p<0.001$) for those born in the second and the fourth quarters. The life span of people born between weeks 14 and 26 is 0.28 ± 0.03 years below average; the life span of those born between weeks 40 and 52 is 0.32 ± 0.03 years above average. For all major groups of causes of death including accidents and suicides, mean age at death of those born in the second quarter is significantly lower than that of individuals born in the fourth quarter (Table 1). As regards suicides the difference can partly be explained by the seasonal distribution of suicides: in the Austrian data set the number of suicides peaks between March and June and is lowest in December. A similar pattern was found by Avaline et al. [2] for France.

In the Danish data set further life expectancy at age 50 is 27.24 years. The average age at death is lowest around week 18, and it peaks in week 51. As was the case for Austrians, the life span of Danes born in specific weeks varies periodically around the mean (Fig. 1). For those born in the second quarter, life spans are 0.17 years below average; for those born in the fourth quarter they are 0.13 years above average. This difference is statistically significant (Cox-Mantel statistic: $p<0.001$).

To test whether the season of birth affects survival up to the oldest ages, I compared the distribution of birth dates in different age groups. An excess mortality among people born during the first part of the year means that with advancing age the proportion of people born during the second part of the year will increase. In both countries the distribution changes significantly with age: at older ages relatively more people celebrate their birthday in the second part of the year than at younger ages (Figure. 2a, 3).

In principle, the differences in life expectancy by month of birth could be caused either by factors that influence life span at the end of life, or by factors that work at the beginning of life. Two possible factors that may affect life expectancy at the end of life are the seasonal distribution of deaths and the "birthday-effect".

In both Denmark and Austria deaths peak in late winter and are lowest during the summer. In the Austrian data set the exact dates of death were redistributed such that in each week of the year the same number of people died while the rank order of the death-dates remained unchanged. Despite the transformation of the monthly death distribution, the excess mortality of those born in spring remains (see Figure. 4).

Survival models 1a and 1b estimate the effect of the month of birth corrected for the impact of the current month. They reveal that differences according to month of birth remain, even when corrected for seasonally changing mortality risks. Neither the correction for period factors nor for cohort factors changes the result (Table 2a, 2b). A model which included an interaction term between cohort and month of birth showed that the principal pattern of excess mortality for people born in spring is present in all cohorts. In particular, nothing unusual was found for those cohorts born shortly before or during World War I.

If it is the case that people have a higher risk of death shortly after their birthday, the risk of mortality should be highest in the first three months after their birthday and lowest in the three months before their next birthday. This pattern should be observed independently of the month of birth. The results of the models 2a and 2b (Tables 3a and 3b) show that those born in spring do in fact experience the highest mortality risk within the three months after their birthday. However, those born in autumn and winter tend to have an increased likelihood to die between four and twelve months after their birthday. This result leads to the conclusion that there is no “birthday effect” in Denmark. As a consequence the shorter life span of people born in spring is independent of the “birthday effect”.

4 Discussion

This study is the first comparative analysis of the relationship between month of birth and longevity on the basis of data for total populations. The life span of 681,677 Austrians and 1,371,003 Danes was studied. The Austrian data set is cross-sectional and includes only information about those who have died but lacks information about the risk-population. This is due to the fact that in Austria no population register exists. Therefore, for inter-census years it is not possible to sub-divide the Austrian population according to month of birth. Because of the restrictions of the Austrian data set I refrained from estimating an event-history model which would be conditional on the outcome of death and would therefore be biased. The Danish data is based on the population register established in 1968: it is longitudinal and includes both the population at risk and those who have died. Thus, an event-history model is the proper statistical method for the analysis of this data.

Both data sets reveal that the mean age at death of people born in spring is lower than that of those born in winter. The differences in Austria seem to be greater than in Denmark. Neither the seasonal distribution of deaths nor the ‘birthday effect’ can explain the differences in life span.

Following I will discuss the evidence for and against three hypotheses that explain the relationship between month of birth and longevity.

The first hypothesis is that the differences in life expectancy are the result of selective survival in infancy. In the last century it was a well-known fact that the likelihood of infants to survive their first year of life depended to some extent on their month of birth. This knowledge is documented in the extensive data sets on infant mortality in the central statistical offices of many countries (for an overview see [6]). Here, there is data on infant mortality by single month age groups and by month of death. For example, between 1841 and 1850, Belgian infants born in spring experienced lower mortality during their first three months of life than infants born in other seasons but were exposed to a greater mortality risk between their third and sixth months [6, 10].

A recent study on infant mortality by age and season of birth [6] shows that for five countries in the last century, the mortality risk in the first two years of life differed according to the season of birth. The pattern was different in the various countries. The authors explain this by the interaction between climate and socio-cultural behaviour peculiar to the given country, such as breast-feeding and weaning practices. For example, in Italy the summer cohorts were advantaged because they went through the summer with the full protection afforded by breast-feeding and reached winter at an age when they were less vulnerable to viral infections of the respiratory tract. The winter cohorts, on the other hand, were exposed to the impact of the cold season on respiratory diseases in their first months of life. This was then followed by the hot summers and the accompanying viral infections of the digestive tract, at a time when the protection of breast-feeding was diminished. In Switzerland the pattern was just the opposite: the mortality risk was highest for those born in spring and summer; it was lowest for infants born in autumn.

An unpublished analysis of Danish data on infant mortality for the years 1911–1915 conducted by the author reveals that in their first year of life, infants who were born in spring and early summer had a noticeably increased mortality risk. This pattern runs counter to the notion that at older ages the difference in life expectancy according to month of birth is due to selective survival during infancy. Selective survival implies that those cohorts live longer that are born in a season where it is more difficult to survive the first year of life. At older ages these cohorts will then consist of relatively more robust individuals, since frailer members of the cohort already died during infancy. It seems that the opposite is the case: the seasonal pattern in infant death suggests that for those born during the more harmful period of a year, some trait is fixed which makes them more susceptible to diseases later in life.

The explanation of the debilitating effect of early life events, in particular of viral infections early in life, is supported by a large number of studies on seasonality in schizophrenia. A review by Torrey et al. [19] consists of more than 250 studies covering 29 countries in the northern and 5 in the southern hemisphere. For the northern hemisphere most of these studies find a significant excess of births in winter and spring (December to May) for schizophrenia. A study on schizophrenia in Queensland, Australia, suggests for those born in the southern Hemisphere an excess birth in their winter (July to September), while those born in the northern Hemisphere had a March–April birth excess [13]. A recent study in Denmark on the effects of family history and place and season of birth on the risk of schizophrenia [16] found an excess of spring-births. The authors come to the conclusion that, although in most or all cases genetic factors are a necessary cause of schizophrenia, they are modulated by environmental factors such as the season of birth.

The second possible explanation for the differences in life expectancy according to month of birth is prenatal influence. A series of studies by Barker (e.g. [4]) suggest that the susceptibility to circulatory heart diseases later in life may, among other things, also be determined by the nutrition of the mother during pregnancy. At the beginning of this century the food supply in general, and the availability of fresh fruits and vegetables in particular, differed from season to season. Mothers who gave birth in late autumn and early winter had access to fresh fruits and vegetables throughout most of the time of their pregnancy; those who gave birth in spring and early summer may have experienced relatively longer periods of inadequate nutrition. However, a study on the effect of the great famine in Finland in the years 1866-1868 showed that cohorts born shortly before or during the famine did not have a higher mortality risk later in life than those born after the famine [11].

The third hypothesis is that social factors that are closely related to an individual’s birthday could be responsible for the differences in life span. Age at first school attendance is one example. Children who are born after a certain deadline have to wait one more year before they can enrol. In this case they are about a year older than the youngest children in their class. At the turn of the century school started on 1 October in Austria. Those children who had not turned six before this date had to wait another year. Thus, children born in autumn and winter experienced an age advantage over their classmates who were born at the beginning of the year. Research suggests that this age advantage affects scholastic aptitude [1, 7, 8] which may translate into a lifelong advantage in various ways [18]. However, at the turn of the century most schools, especially in rural areas, consisted of only one or two classes. Thus, children of all ages were instructed together. It is questionable whether a one year age advantage would also influence the development of children in a class where the youngest and the oldest pupils are more than four years apart in age.

5 Conclusion

This study provides strong evidence that among people aged 50 and older, those born in winter have a higher life expectancy than those born in summer. This pattern appears not to be the result of factors that shorten one's life span at the end of life. It seems rather to result from factors that affect individuals early in life. I have raised three hypotheses to explain the relationship between month of birth and longevity. I finally came to the conclusion that at present it is not yet known whether the underlying causal mechanisms are of a social or of a biological nature. However, I found evidence that in Denmark selective survival during the first year of life cannot explain the observed phenomenon. More insights into the causal mechanisms will be gained by undertaking comparative studies of populations born in the northern and the southern hemispheres. In addition, the analysis of seasonal patterns in infant mortality and stillbirths may shed more light on the relationship between month of birth and life expectancy at older ages.

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Notes

Note 1.: The following table contains the binary variable sets for the covariates “current month” (v1-v12) and “time lived since last birthday”(p1, p2) for people born in weeks 1-4. It can be seen that for a specific month of birth p1 and p2 are always linear combinations of v1 to v12. Current month and time lived since last birthday are defined for each year of a person’s live after 1 April 1968. This results in the variables p1 and p2 being highly correlated with the variables v1 to v12. Ultimately this may be the reason why a model that includes all fourteen variables simultaneously does not converge.

Current month												time lived since last birthday	
v1	v2	v3	v4	v5	v6	v7	v8	v9	v10	v11	v12	p1	p2
0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0	0	0	0	0	0	0
0	0	1	0	0	0	0	0	0	0	0	0	1	0
0	0	0	1	0	0	0	0	0	0	0	0	1	0
0	0	0	0	1	0	0	0	0	0	0	0	1	0
0	0	0	0	0	1	0	0	0	0	0	0	1	0
0	0	0	0	0	0	1	0	0	0	0	0	1	0
0	0	0	0	0	0	0	1	0	0	0	0	1	0
0	0	0	0	0	0	0	0	1	0	0	0	1	0
0	0	0	0	0	0	0	0	0	1	0	0	0	1
0	0	0	0	0	0	0	0	0	0	1	0	0	1
0	0	0	0	0	0	0	0	0	0	0	1	0	1

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Table 1: Mean age at death by quarter of birth for major groups of causes of death; all deaths above age 50 in Austria between the years 1990 and 1997.

Cause of death	Season of birth 1st Quarter	2nd Quarter	3rd Quarter	4th Quarter	Annual Average	p-value (F-test)
Infectious diseases	71.74	**71.48**	72.39	**72.89**	72.14	0.314
Malignant neoplasm	73.48	**73.37**	73.56	**73.81**	73.55	0.000
Circulatory diseases	80.26	**80.04**	80.36	**80.64**	80.32	0.000
Other natural causes of death	77.21	**76.76**	77.06	**77.58**	77.20	0.000
Accidents & Suicides	72.77	**72.44**	72.82	**73.31**	72.83	0.005

Table 2a: Model 1a: Relative mortality risk estimated by a multivariate survival model which includes simultaneously the four covariates “month of birth”, “current month”, “sex” and “period”.

	Month of birth		Current month	
	RMR	p-value	RMR	p-value
month				
Weeks 1-4 (1 Jan –28 Jan)	0.967	0.000	1 (RG)	
Weeks 5-8 (29 Jan –25 Feb)	0.974	0.000	0.995	0.289
Weeks 9-12 (26 Feb – 25 Mar)	0.997	0.542	0.998	0.631
Weeks 13-16 (26 Mar – 22 Apr)	1 (RG)		0.998	0.638
Weeks 17-20 (23 Apr – 20 May)	1.000	0.836	0.997	0.524
Weeks 21-24 (21 May – 17 Jun)	1.002	0.616	0.991	0.046
Weeks 25-28 (18 Jun – 15 Jul)	0.994	0.221	0.988	0.012
Weeks 29-32 (16 Jul – 12 Aug)	0.981	0.000	0.990	0.026
Weeks 33-36 (13 Aug – 9 Sep)	0.979	0.000	0.991	0.060
Weeks 37-40 (10 Sep – 7 Oct)	0.974	0.000	0.998	0.640
Weeks 41-44 (8 Oct – 4 Nov)	0.971	0.000	0.998	0.683
Weeks 45-48 (5 Nov- 2 Dec)	0.969	0.000	1.001	0.834
Weeks 49-52	0.969	0.000	1.001	0.861

(3 Dec – 31 Dec)		
sex		
males	1(RG)	
females	0.664	0.000
period		
1968-1974	1(RG)	
1975-1979	0.954	0.000
1980-1984	0.943	0.000
1985-1989	0.910	0.000
1990-1994	0.920	0.000
1995-1998	0.916	0.000
age		
50-54	1(RG)	
55-59	1.544	0.000
60-64	2.482	0.000
65-69	3.914	0.000
70-74	6.255	0.000
75-79	9.915	0.000
80-84	15.785	0.000
85-89	25.768	0.000
90+	45.759	0.000

RG...reference group, RMR...Relative mortality risk

Table 2b: Model 1b: Relative mortality risk estimated by a multivariate survival model which includes simultaneously the four covariates "month of birth", "current month", "sex" and "cohort".

	Month of birth		Current month	
	RMR	p-value	RMR	p-value
month				
Weeks 1-4 (1 Jan –28 Jan)	0.969	0.000	1 (RG)	
Weeks 5-8 (29 Jan –25 Feb)	0.976	0.000	0.995	0.289
Weeks 9-12 (26 Feb – 25 Mar)	0.998	0.541	0.998	0.631
Weeks 13-16 (26 Mar – 22 Apr)	1(RG)		0.998	0.638
Weeks 17-20 (23 Apr – 20 May)	1.000	0.865	0.997	0.524
Weeks 21-24 (21 May – 17 Jun)	1.000	0.883	0.991	0.046
Weeks 25-28 (18 Jun – 15 Jul)	0.993	0.096	0.988	0.012
Weeks 29-32 (16 Jul – 12 Aug)	0.980	0.000	0.990	0.026
Weeks 33-36 (13 Aug – 9 Sep)	0.977	0.000	0.991	0.060
Weeks 37-40 (10 Sep – 7 Oct)	0.971	0.000	0.998	0.640
Weeks 41-44 (8 Oct – 4 Nov)	0.968	0.000	0.998	0.683
Weeks 45-48 (5 Nov- 2 Dec)	0.965	0.000	1.001	0.834
Weeks 49-52 (3 Dec – 31 Dec)	0.964	0.000	1.001	0.861
sex				
males	1(RG)			
females	0.646	0.000		
cohort				
1860-1879	1(RG)			
1880-1889	0.911	0.000		
1890-1899	0.839	0.000		
1900-1909	0.782	0.000		
1910-1918	0.729	0.000		
age				
50-54	1(RG)			
55-59	1.530	0.000		
60-64	2.370	0.000		
65-69	3.638	0.000		
70-74	5.637	0.000		
75-79	8.742	0.000		
80-84	13.526	0.000		

85-89	21.408	0.000
90+	36.560	0.000

RG... reference group, RMR...Relative Mortality Risk

Table 3a: Model 2a: Relative mortality risk estimated by a multivariate survival model which includes simultaneously the second-order interactions between "time lived since last birthday" and "month of birth", and the covariates "sex" and "period".

	Time lived since last birthday					
	1-12 weeks		13-40 weeks		41-52 weeks	
Covariates	RMR	*p-value*	RMR	*p-value*	RMR	*p-value*
Month of birth						
Weeks 1-4 (1 Jan –28 Jan)	1.00 (RG)		1.09	*0.000*	0.97	*0.002*
Weeks 5-8 (29 Jan –25 Feb)	1.02	*0.074*	1.10	*0.000*	0.97	*0.001*
Weeks 9-12 (26 Feb – 25 Mar)	1.12	*0.000*	1.10	*0.000*	0.99	*0.452*
Weeks 13-16 (26 Mar – 22 Apr)	1.20	*0.000*	1.06	*0.000*	1.02	*0.025*
Weeks 17-20 (23 Apr – 20 May)	1.22	*0.000*	1.02	*0.075*	1.10	*0.000*
Weeks 21-24 (21 May – 17 Jun)	1.20	*0.000*	1.00	*0.652*	1.17	*0.000*
Weeks 25-28 (18 Jun – 15 Jul)	1.13	*0.000*	1.00	*0.380*	1.16	*0.000*
Weeks 29-32 (16 Jul – 12 Aug)	1.01	*0.280*	1.02	*0.021*	1.18	*0.000*
Weeks 33-36 (13 Aug – 9 Sep)	0.98	*0.060*	1.05	*0.000*	1.14	*0.000*
Weeks 37-40 (10 Sep – 7 Oct)	0.98	*0.074*	1.06	*0.000*	1.08	*0.000*
Weeks 41-44 (8 Oct – 4 Nov)	1.00	*0.802*	1.08	*0.000*	1.01	*0.258*
Weeks 45-48 (5 Nov- 2 Dec)	0.98	*0.095*	1.08	*0.000*	1.02	*0.137*
Weeks 49-52 (3 Dec – 31 Dec)	0.98	*0.015*	1.10	*0.000*	0.98	*0.116*
Sex						
males (RG)	1(RG)					
Females	0.64	0.000				
Period						
1968-1974	1(RG)					
1975-1979	0.95	0.000				
1980-1984	0.94	0.000				
1985-1989	0.91	0.000				
1990-1994	0.92	0.000				
1995+	0.91	0.000				
Age						
50-54	1(RG)					
55-59	1.54	0.000				
60-64	2.48	0.000				

65-69	3.91	0.000
70-74	6.26	0.000
75-79	9.92	0.000
80-84	15.79	0.000
85-89	25.77	0.000
90+	45.76	0.000

RG.......reference group, RMR... Relative Mortality Risk

Table 3b: Model 2b: Relative mortality risk estimated by a multivariate survival model which includes simultaneously the second-order interactions between "time lived since last birthday" and "month of birth", and the covariates "sex" and "cohort".

	Time lived since last birthday					
	1-12 weeks		13-40 weeks		41-52 weeks	
Covariates	RMR	*p-value*	RMR	*p-value*	RMR	*p-value*
Month of birth						
Weeks 1-4 (1 Jan –28 Jan)	1.00 (RG)		1.09	*0.000*	0.97	*0.001*
Weeks 5-8 (29 Jan –25 Feb)	1.02	*0.074*	1.10	*0.000*	0.97	*0.001*
Weeks 9-12 (26 Feb – 25 Mar)	1.12	*0.000*	1.10	*0.000*	0.99	*0.460*
Weeks 13-16 (26 Mar – 22 Apr)	1.19	*0.000*	1.06	*0.000*	1.02	*0.030*
Weeks 17-20 (23 Apr – 20 May)	1.21	*0.000*	1.02	*0.091*	1.10	*0.000*
Weeks 21-24 (21 May – 17 Jun)	1.20	*0.000*	1.00	*0.539*	1.16	*0.000*
Weeks 25-28 (18 Jun – 15 Jul)	1.13	*0.000*	1.00	*0.593*	1.16	*0.000*
Weeks 29-32 (16 Jul – 12 Aug)	1.01	*0.345*	1.02	*0.069*	1.18	*0.000*
Weeks 33-36 (13 Aug – 9 Sep)	0.98	*0.037*	1.04	*0.000*	1.13	*0.000*
Weeks 37-40 (10 Sep – 7 Oct)	0.98	*0.020*	1.06	*0.000*	1.07	*0.000*
Weeks 41-44 (8 Oct – 4 Nov)	0.99	*0.347*	1.08	*0.000*	1.01	*0.454*
Weeks 45-48 (5 Nov- 2 Dec)	0.98	*0.019*	1.08	*0.000*	1.01	*0.458*
Weeks 49-52 (3 Dec – 31 Dec)	0.97	*0.002*	1.09	*0.000*	0.98	*0.019*
Sex						
males (RG)	1(RG)					
females	0.65	0.000				
cohort						
1860-1879	1(RG)					
1880-1889	0.91	0.000				
1890-1899	0.84	0.000				
1900-1909	0.78	0.000				
1910-1918	0.73	0.000				
age						
50-54	1(RG)					
55-59	1.53	0.000				
60-64	2.37	0.000				

65-69	3.64	0.000
70-74	5.63	0.000
75-79	8.73	0.000
80-84	13.54	0.000
85-89	21.37	0.000
90+	36.50	0.000

RG...reference group, RMR... Relative Mortality Risk

Figure 1: Deviation in mean age at death from average annual age at death for people born in a specific week: Austria and Denmark, ages 50+.

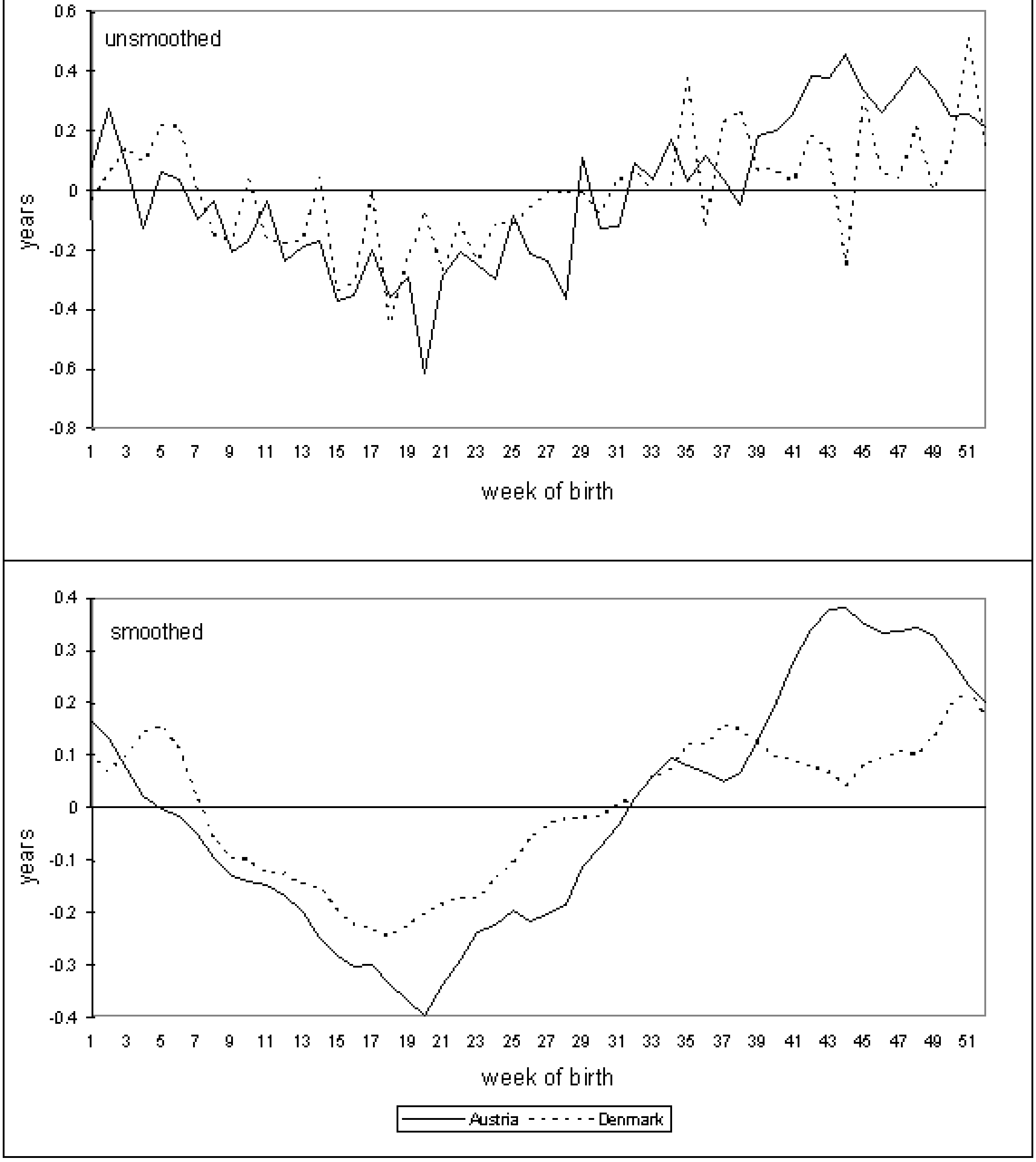

Figure 2: A) Austria: difference between the seasonal distribution of births in the years 1880-1907 and the distribution of birth dates among those who died at ages 90-100 in the years 1988-1996;
B) Denmark: difference between the distribution of birth dates at ages 60-69 and at ages 90-99 for the cohorts born between 1899 and 1908.

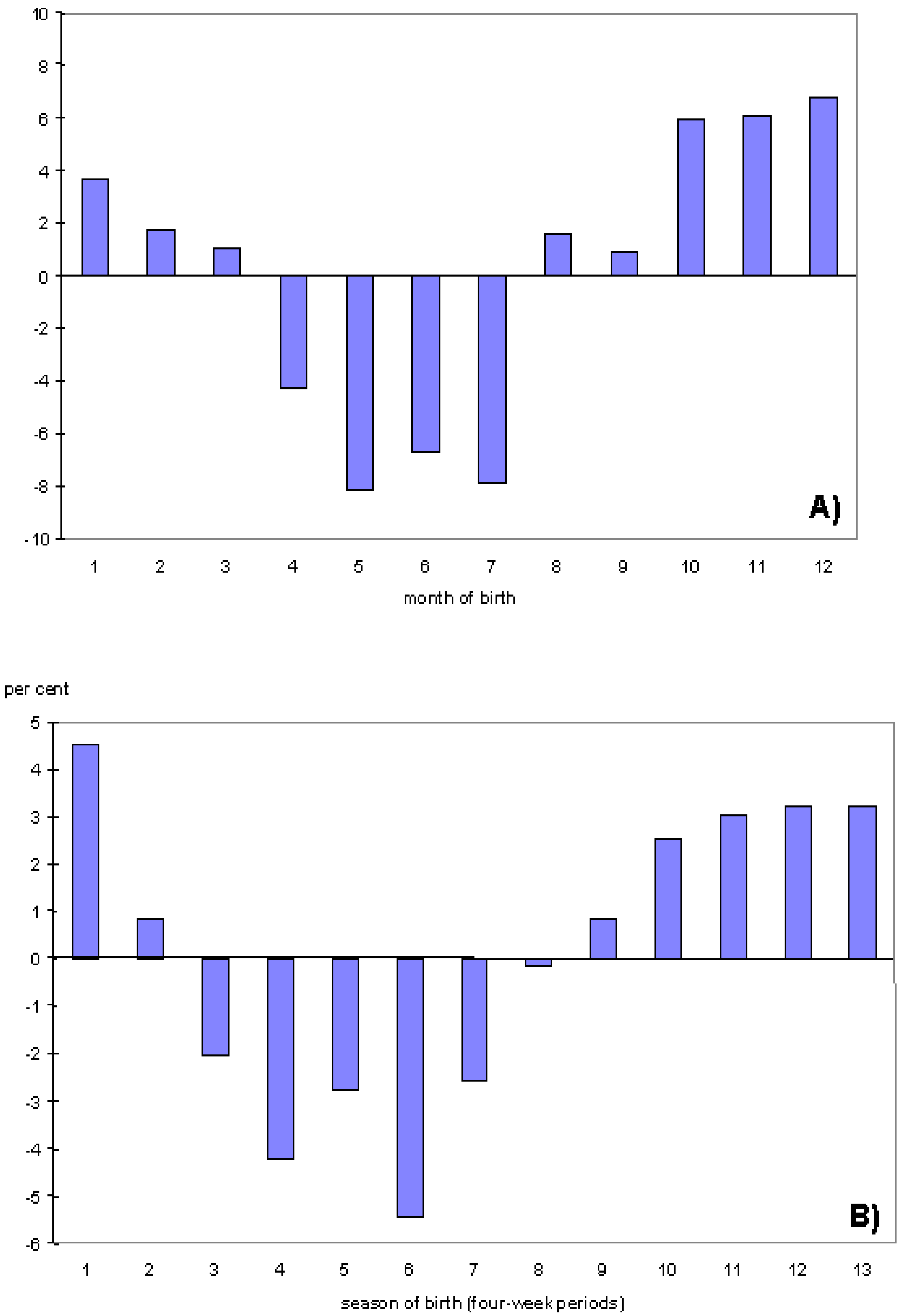

Figure 3: Proportion of women born in the first and fourth quarter of the year by age; Austrian census 1981

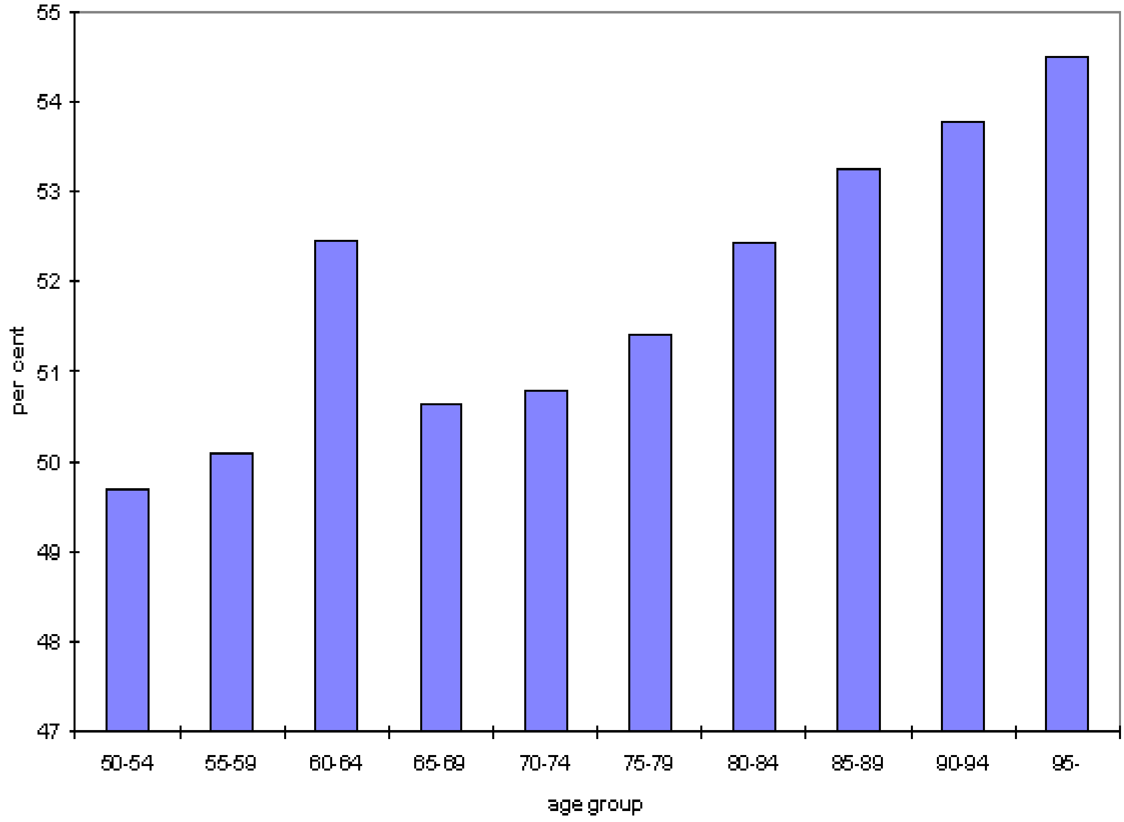

Figure 4: Effect of the "uniformization" of the seasonal distribution of deaths on mean age at death by week of birth: deviation in mean age at death from average age at death for people born in a specific week, Austria 1988-1996, ages 50+.