Survival advantage of siblings and spouses of centenarians in 20th century Quebec

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ABSTRACT

We studied the old age mortality of a group of siblings and spouses of 808 centenarians born in Quebec between 1885 and 1900. Using Quebec Civil Registration, as well as the 1901 and 1911Canadian censuses, we show that after age 40, siblings of centenarians lived on average 3-4 years than their contemporary, who were drawn from the 5% random sample of the 1901 Census (Canadian Family Project). Spouses of centenarians also lived longer than the general population, although the survival benefit was less pronounced for wives of centenarians than for husbands of centenarians. Men benefited more from being married to a centenarian than to having a centenarian sibling until the age of 75. After that age, a cross-over occurs, suggesting that early life or genetic factors become more important than socioeconomic factors at older ages.

INTRODUCTION

The dramatic increase in life expectancy from about 45 to 77 years during the last century is unprecedented in human history. Decisive victories against childhood infectious diseases were the primary force behind these changes, and account for about two third of the improvements during that period. In the second part of the 20th century, gains shifted to chronic diseases that essentially affect the elderly. Reduction of death rates above age 65 played a larger role, accounting for 30% of the improvements (Bourbeau and Smuga 2003). Overall, data from various countries indicate that progress has been greater for females than for males, and more rapid in recent than in earlier decades (Vaupel et al. 1998).

As mortality rates began to plunge at older ages, centenarians became the fastest growing segments of many industrialized populations. In Canada, 151 death certificates indicated an age over 100 in 1959, which is two times the 1921 count. In 2003, 1,597 deaths of centenarians were recorded, ten times the 1959 count (Desjardins and Bourbeau 2006). Validated data from the Canadian Human Mortality Database show a similar trend for Québec, with 50 centenarian deaths in 1975, and 425 in 2005 (CHMD 2006). As elsewhere, the elderly now benefit from a deceleration in mortality (Thatcher et al. 1998; Vaupel et al. 1998), and recent cohorts of centenarians are surfing on a mortality plateau. A fascinating phenomenon itself, the emergence of centenarians also holds major implications for our society. It is therefore important to understand the conditions predisposing individuals to exceptional survival.

Despite spectacular advances, we still have limited knowledge of old age survival (Christensen and Vaupel 1996). In addition to genes and biological robustness, lifestyle (e.g. smoking or diet), physical and mental activity, exposure to pathogens or chemicals, and access to medical care and social support are all important determinants of longevity. The general presumption is that adult lifestyle and socioeconomic positions give rise to chronic health conditions, which develop over the life course (Elo and Preston 1996). However, as the family of origin generally sets the stage for adult life achievement, research on aging and health is increasingly turning to childhood, where the earliest gains in life expectancy were achieved.

An important part of longevity thus comes from family influences. Parents can influence the longevity of their children by transmitting a genetic endowment in favor of a long life as well as providing them with favourable resources. Longevity could thus be the attributed in part to a familial component, whether genetic or environmental. Studies have indicated that a modest amount of about 25% of the variation in human lifespan can be attributed to genetic factors (Christensen and Vaupel, 1996). However, one of the strongest concepts remains one of a similar longevity between relatives, especially between parents and children, between siblings and between spouses. In the belief of a familial component of longevity, the likelihood of reaching old ages would be significantly higher if a parent or sibling has lived long, or if the spouse has reached the older ages.

The survival advantage of siblings of long lived individuals

The familial component in longevity has been mainly analyzed in the context of research on survival of siblings and parents of individuals who reached advanced ages. A study of Mormon genealogies, based on individuals who lived at least to age 65 years, showed that siblings of probands who have reached the 97th percentile of their cohort in terms of age have a longer life expectancy of 14.8 years compared to 5,000 randomly selected individuals within the same population (Gerber et al., 2001). These findings closely agree with a study of the Icelandic genealogies in which first-degree relatives of probands living to the 95th percentile were almost twice as likely of achieving this age (Gudmundsson et al., 2000). A study conducted on a sample of 1655 Pennsylvania Amish born prior to 1890 also showed that parental and sibling's ages at death were significantly correlated, meaning that parents and siblings of long-lived individuals had a higher probability of surviving to very old age than the relatives of those with average life spans (Mitchell, 2001). Schoenmaker and colleagues (2006) analyzed the survival experience in Dutch families with at least two long-living siblings. Standardized mortality ratio for siblings of the long-living participants was 0.66 whereas that of the parents was 0.76.

In Quebec, the study conducted by Blackburn, Bourbeau and Desjardins (2004) recognized a significant association between the ages at death of siblings, which provides evidence for a familial component of longevity. This study also revealed greater lifespan variability for sisters than for brothers, corroborating the observations of Desjardins and Charbonneau (1990) of a higher correlation in ages at death among brothers than among sisters. Mazan and Gagnon (2007) explored the relationship for individuals born between 1625 and 1704 and also found high dependency among siblings, with reduction in risks of death of 2.1% and 1.6% respectively for males and females for each additional years of increase in the average age at death among their siblings. This study also established stronger associations between siblings living in the same region, especially for brothers.

A number of studies have analyzed the familial component of longevity through the pedigrees of centenarians. Perls and al. (2000) compared the siblings of 102 centenarians with the general population and found that the relative risk of survival for siblings of centenarians increases with age, to such an extent that they were about 4 times as likely to live to 91 as the siblings of people who died at age 73. Perls and his colleagues (2002) conducted a second study in which they compared the survival of siblings of 444 centenarians from the New England centenarians Study (NECS) with the U.S. 1900 cohort. This study reveals that, starting from age 20, brothers of centenarians were 16.95 as likely to live to age 100 compared to their birth cohort, while sisters were 8.22 times as likely. In addition, the death rates of siblings of centenarians were about one-half those of the general population at most ages. In an article published in 2006, Willcox BJ et al. compared the survival of siblings of 348 centenarians with that of the 1890 Okinawan general population cohort. A survival advantage for the siblings of centenarians was again reported, with approximately half the mortality of their birth cohort–matched counterparts.

Survival advantage of spouses of long lived individuals

The above studies provide valuable information on the familial correlates of longevity, but they do not provide a mean to account for the impact of shared environment in adulthood, which can be proxied by the age at death of spouses (Mazan and Gagnon, 2007; Drefahl, 2010). Only a few have examined such influences. Gudmundsson and al. (2000) found a positive correlation of death rates between spouses, although relationship was very week. Blackburn et al. (2004) found a mean age at death of 66.3 years for men whose wife died between 50 and 54 years and of 69 years for men whose wife died after 85 years, a difference of 2.7 years. The relationship was even stronger for women, with a corresponding difference of 4.3 years. For men, each additional year of life of their spouse reduced the risk of death by 0.6% (5.8% for 10 years), while the corresponding figure was 0.5% for women (4.9% for 10 years) (Mazan and Gagnon 2007).

The aim of this paper is to examine the mechanisms that influence the familial transmission of longevity in families including at least one centenarian. We compare the survival experience of siblings of centenarians as well as of spouse of centenarians to that of their respective birth cohorts.

DATA AND METHODS

Centenarians' information was obtained from a list of registered deaths provided by the Institute of Statistics of Quebec, which contains the records on centenarians who died between 1985-2005 in the Province. To ensure the reliability of ages at death, systematic validation of these ages was done by retaining only the French Canadian Catholic who were born and who died in Quebec.

Our sample includes 808 centenarians. Families were reconstituted by linking these centenarians to their family members through the 1901 and 1911 Canadian censuses, which are available on the Internet through Ancestry.ca and automated Genealogy. A total of 5,338 siblings of centenarians have been identified, as well as 596 spouses. Once the database was completed, we searched for the date of death of each of these individuals through the Quebec Consolidated Deaths Index from the Société de généalogie du Québec. This database allows users to find dates of death and of birth, maiden names, etc. of persons who died in Quebec between 1926 and 1996. For deaths occurring beyond 1996, we used a list of registered deaths over 85 years old for the years 1997-2004 provided by l'Institut de la Statistique du Québec. Linkage was made on the basis of information contained in both the censuses and death registers, particularly through the name(s) of the subject, his date and place of birth and the name(s) of his parents.

We could find 3,120 dates of death for the initial 5,338 siblings of centenarians. The spouses of centenarians were found in the parish registers, which were made available for the years 1800-1940 through the Projet BALSAC. We found 396 dates of death for the original 596 spouses, which represents 67% of our total sample or. Since our focus is on old age mortality, only individuals who survived to age 40 were included in our sample. Thus, the final sample is based on 2961 siblings of centenarians, 1546 brothers and 1415 sisters as well as 77 wives and 319 husbands, for which are analyzed survival from age 40.

To compare the survival of siblings and of spouses of centenarians to that of their birth cohort, we used a control sample extracted from the Canadian Families Project five-percent 1901 Canadian Census sample. We chose from this random sample, families with at least one child born between 1885 and 1901 (at least one child less than 15 years old). Only French-Canadian who went on to live at least to age forty were selected, i.e., 7,784 individuals, for whom we found 3784 deaths (1906 females and 1878 males).

We do not find all deaths in our sample. The missing death records may be due to deaths occurring before 1926, year of the establishment of the Québec death register records. It may also be due to difficulties in identifying individuals, such as errors in the first name or date of birth. In addition, the frequency of several names made the identification process complex. It is also possible that some individuals born in Quebec have died outside of Quebec. Finally, it is possible that a few individuals were still alive in 2004.

Estimating the survival function: the non-parametric approach

We first calculated the mean age at death of the siblings and spouses of centenarians, conditional on survival to age 40. Second, we estimated their survival probabilities from the age 40 to older ages, as well as their confidence intervals. These results were then compared to the corresponding estimates obtained for the individuals of our control sample.

We used the Product estimator (Kaplan and Meier, 1958), a nonparametric approach that allowed us to test the differences in survival between siblings and spouses of centenarians and their respective birth cohort.

The survival probabilities between x and x + a were computed as follow

$$ {}_{a}p_{x} = 1 - \frac{\mathrm{d}\,(\mathrm{x}, \mathrm{x}+\mathrm{a})}{\mathrm{Y}_{\mathrm{x}}} \tag{1} $$

where d (x, x + a) represents deaths between age x and x + x and Y, the number of individuals surviving to age x.

Survival probabilities to age 40 until age x, based on the equations given by Klein and Möschberg (2003.83-84), were estimated by

$$ S_{x} = \prod_{i \leq x} \left(1 - \frac{d(i, i+a)}{Y_{i}} \right) \tag{2} $$

S is based on the probability that an individual survives to the end of an interval of time, knowing that the individual was present at the beginning of the interval.

Then, the 95% confidence interval were calculated as

$$ {}_{a}p_{x} \pm 1{,}96 \cdot S_{x} \sqrt{\sum_{i \leq x} \frac{d(i, i+a)}{Y_{i}\,(Y_{i} - d(i, i+a))}} \tag{3} $$

RESULTS

Table 1 compares the mean ages at death of the siblings and spouses of the centenarians with the corresponding estimates for their respective birth cohort conditional on survival to age 40. For brothers, the mean age at death is 75,4 years whereas it is 79.3 years for their female counterparts. As for the control group, the mean ages at death are 71.8 and 75.4 years respectively for males and females. The survival advantage was thus about 4 years.

A survival advantage was also observed for the spouses of centenarians. Conditional on survival to age 40, the mean ages at death of wives and husbands were respectively 75.0 and 77 years. Husbands of centenarians lived 3 years longer than their contemporaries while the corresponding figure was about 2 years for their female counterparts. Contrarily to men, women benefited more from having a centenarian among their sibling than being married to a centenarian. A t test was performed and allowed us to conclude that the difference was statistically significant at the $p<0.05$ level.

Table 1. Mean Ages at Death, conditional on Survival to Age 40, of siblings and spouse of centenarians

	Mean Age at Death Conditional on Survival to Age 40	Siblings of respective birth cohort	Excess Years
Siblings of centenarians			
Women	79,3	75,4	3,9
Men	75,4	71,8	3,6
Spouse of centenarians			
Women	77,3	75,4	1,9
Men	75,0	71,8	3,2

Table 2. Comparison of Survival Probabilities of Centenarians' Siblings from Age 40 to Higher Ages With their respective Birth Cohort

	Women			Men		
Probability of Survival From Age 40 to Age…	Siblings of Centenarians (95% CI)	Siblings of respective birth cohort	Relative Survival Probability	Siblings of Centenarians (95% CI)	Siblings of respective birth cohort	Relative Survival Probability
50	0,96 (0,94-0,97)	0,94	1,02	0,96 (0,95-0,97)	0,94	1,019
60	0,89 (0,88-0,91)	0,84	1,06	0,88 (0,87-0,89)	0,83	1,057
70	0,78 (0,77-0,80)	0,69	1,13	0,71 (0,69-0,73)	0,60	1,176
80	0,57 (0,55-0,59)	0,44	1,29	0,41 (0,39-0,43)	0,29	1,422
90	0,25 (0,23-0,27)	0,16	1,55	0,11 (0,10-0,13)	0,06	1,916
100	0,02 (0,01-0,03)	0,01	1,83	0,0032 (0,00-0,01)	0,0027	1,219
N	1415	1908		1546	1881	

Table 2 shows the survival probabilities, including their 95% CI values, from age 40 to older ages for the siblings of centenarians compared with their respective birth cohorts. As shown in this table, siblings of centenarians experienced a survival advantage throughout their lives relative to their birth cohort and their relative survival probabilities from age 40 increased at older ages. Sisters of centenarians were 1.5 times more likely to survive from age 40 to age 90 and more than twice as likely to survive from age 40 to age 100. As for the brothers, they were found to be approximately 1.5 times more likely to survive from age 40 to age 80 and nearly twice more likely to reach 90 when compared with men from their birth cohort. The number of men who lived pass 90 years is too small to warrant statistical significance.

Siblings of centenarians are also compared with their respective birth cohorts in Figure 1. The survival probabilities demonstrate that siblings of centenarians experienced greater longevity than the general population and kept this advantage through old ages. As revealed by a log-rank test, a statistically significant difference in survival times exists between survival probability of centenarians' siblings and the general population birth cohort at the 1% level of significance ($p < 0.001$). For sisters of centenarians, the median life expectancy was about 4 years higher (82 years) when compared with females from their birth cohort (78 years). As for brothers of centenarians, the survival advantage was also considerable, their median age at death being of 77 years compared to 73 years for male in the general population.

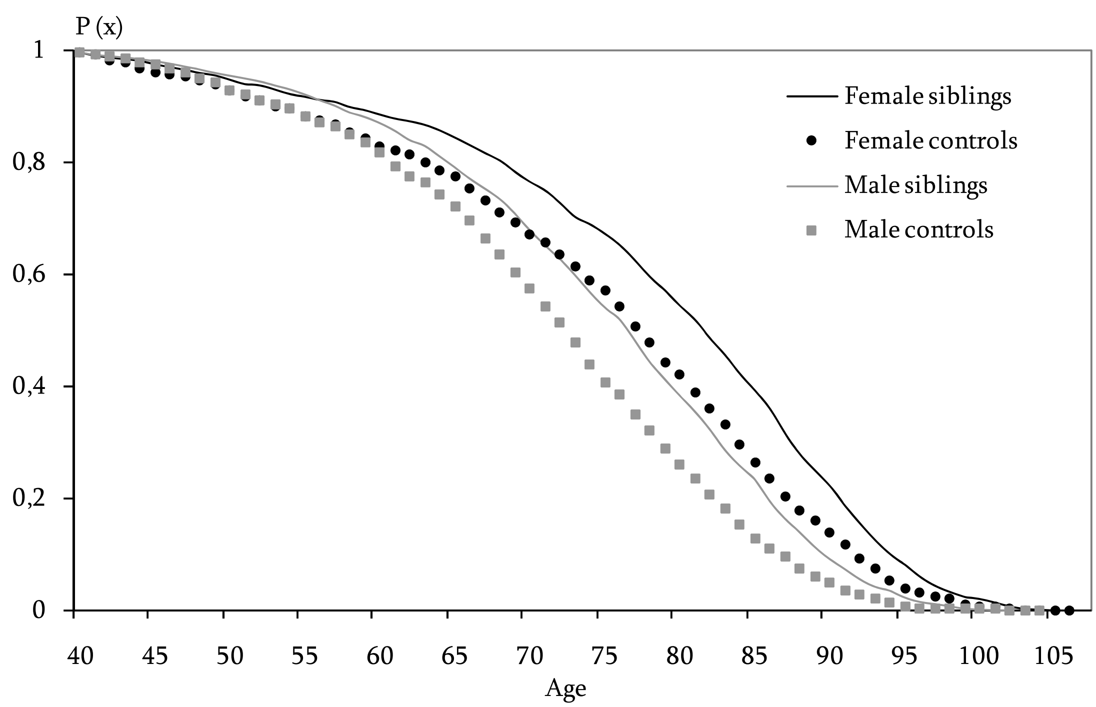
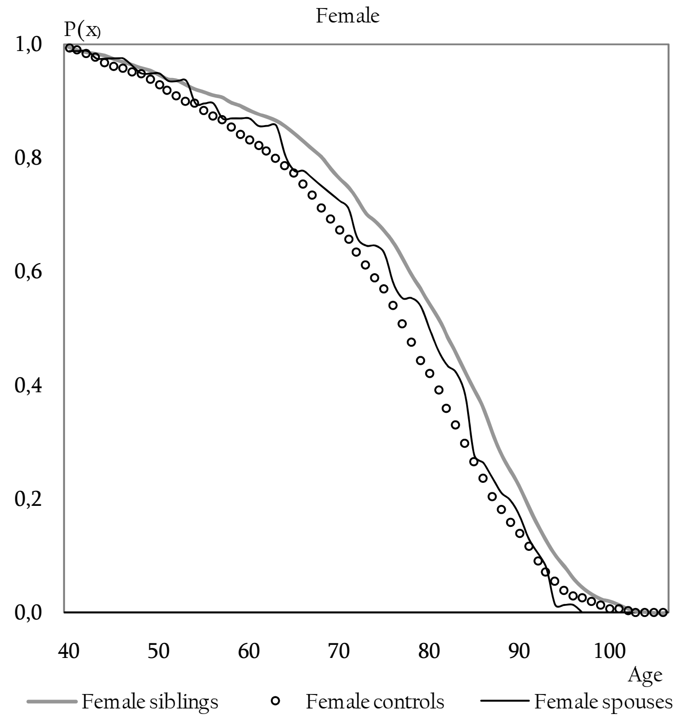


Figure 1. Comparison of Survival Curves of Centenarians' Siblings from Age 40 to Higher Ages With their respective Birth Cohort



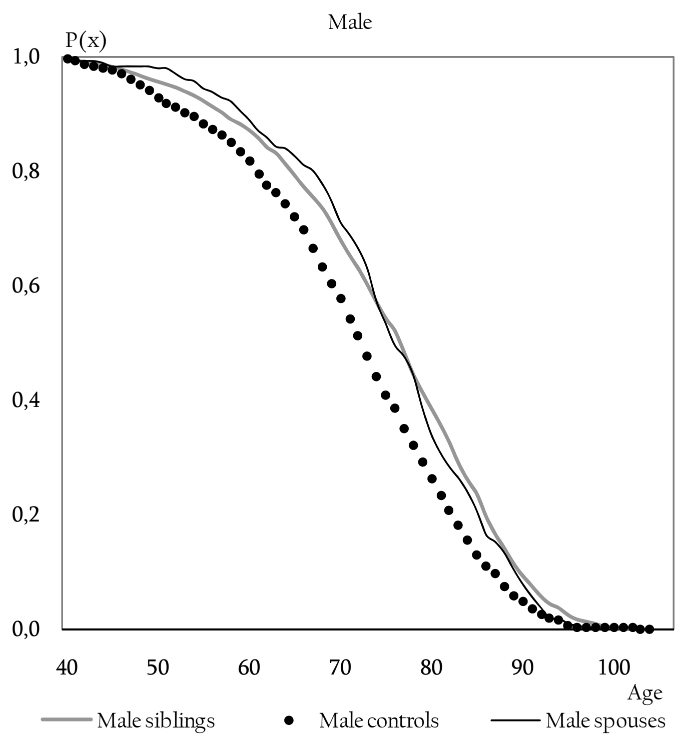


Figure 2. Comparison of Survival Curves of Husbands of Centenarians from Age 40 to Higher with those of their respective Birth Cohort and those of Centenarians' Siblings

Figure 2 displays survival curves for spouses of centenarians from age 40 compared with their respective birth cohorts, as well as with siblings of centenarians. Wives of centenarians experienced a survival advantage throughout life compared to their birth cohort. Nonetheless, sisters of centenarians appear to have the greatest survival experience among all three groups. The small number of male centenarians, however, did not yield reliable statistical results.

For husbands of centenarian, survival curves show a significant survival advantage at the 0.001 level compared to the control population. We can also observe that before age of 75, husbands of centenarian had lower mortality than siblings of centenarians. However, after that age, a cross-over occurs and the advantage in survival belongs to the siblings of centenarians.

We further decomposed the effect of sex in order to see whether having a centenarian brother offered better chances of surviving than having a centenarian sister. In other words, we wanted to know if males enjoyed a higher survival advantage if one of their brothers managed to reach 100 years rather than one of their sisters and vice versa. As shown in Figure 3, it is very clear that for women, the sex of the centenarian sibling does not matter. On the other hand, for a man, having a centenarian brother is associated with better survival chances than having a centenarian sister, the difference being statistically significant.

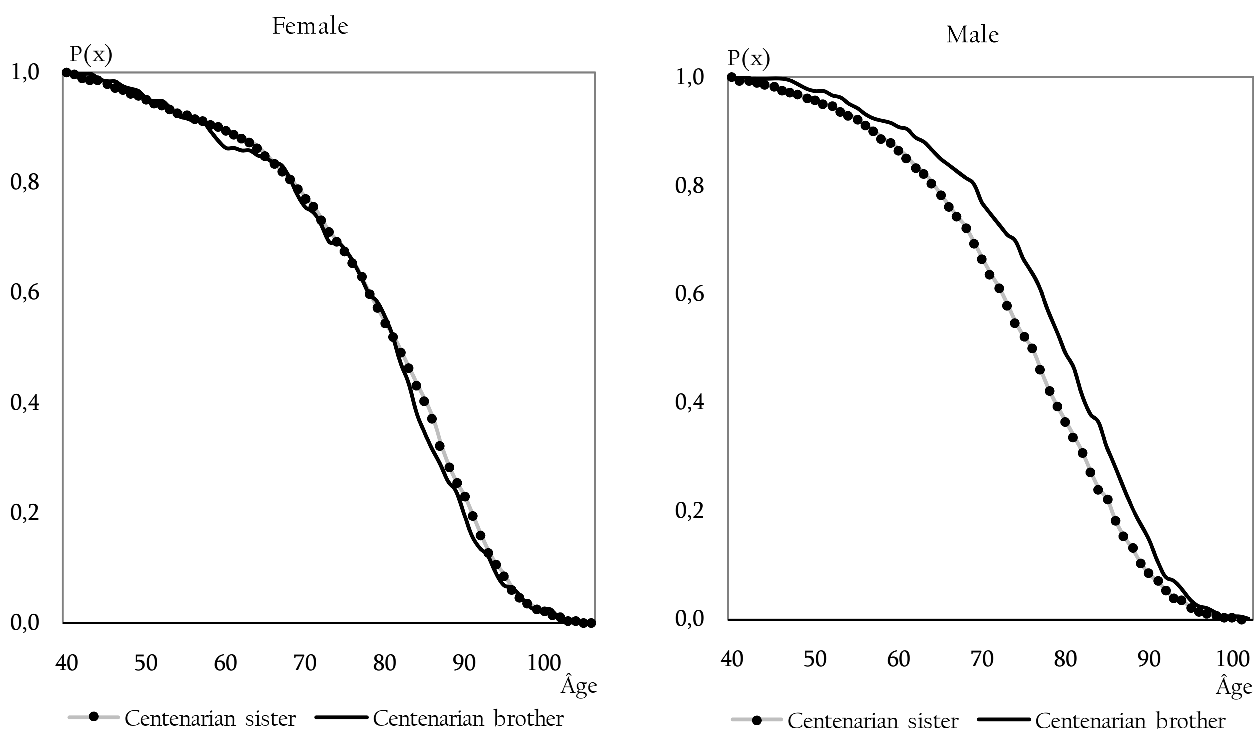


Figure 3. Comparison of Survival Curves of Sisters and of Centenarians according to the sex of centenarian

DISCUSSION

To be continued

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