Data Validation and Measurement of Cohort Mortality among Centenarians in Quebec (Canada) According to Ethnic Origin

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Abstract

Recent trends in mortality suggest that future gains in life expectancy will occur after age 80. This fact stresses the need and the importance to obtain precise measures of mortality at the highest ages, which are always subject to uncertainty due to misreporting of age at death. In Quebec, the available data on deaths of centenarians according to ethnic origin allows the differentiation of mortality based on this characteristic. For French-Canadians, data on the ages at death of centenarians can be validated using parish registers, leading to an improvement in the extreme age mortality measurement. A comparison between validated and nonvalidated data can also be performed.

First results indicate there is a slowing down in the rise of mortality rates with age. Mortality estimates according to ethnic origin among Quebec-born centenarians suggest a lower mortality for French-Canadians from age 100 to 104.

1. Introduction

The rise in the number and the proportion of centenarians within low mortality societies has led to multiple studies conducted on the trajectories of mortality at the highest ages and the biological limits of human life. However, the study of mortality at the highest ages is confronted with a problem that has to do with the age group under observation. Indeed, the misreporting of ages at death, highly present in this age group, lowers the reliability of the mortality rates obtained beyond the age of 100. A way to eliminate this problem is to use a sample of individuals whose age at death has been validated. This allows a precise measure of mortality at the highest ages.

In the province of Quebec, the Catholic parish registers include all the baptism, marriage and burial certificates produced since the beginning of the 17th century and therefore allow the matching of the data. As French-Canadians were virtually all Catholic, the declared age at death of French-Canadian centenarians can thus be validated by finding their actual baptism certificates. In this article, we first present the database we used to measure the mortality of centenarians. Secondly, we compare the estimations of mortality at age 100 and beyond with the type of data used: validated and nonvalidated. Finally, we analyze mortality according to ethnic origin of the centenarians under observation.

2. Materials and Methods

Our study of the mortality at the highest ages is based on the deaths of centenarians of the 1870-1894 generations[†] who died in Quebec between 1970 and 2004.[‡] They pertain to 2,840 individuals, among which 1,891 are French-Canadian Catholics born and deceased in the province of Quebec, and 949 are Anglophones born in Quebec or individuals born outside the province.

[†] Grouping such a number of generations is necessary to provide a sufficient number of cases for measuring rates. It has the disadvantage, however, of bringing together generations which might have known different mortality levels given the decrease in overall mortality over the last 25 years.

[‡] We have included two deaths that occurred in 2006 and 2007 to complete to extinction the observation of the generations.

TABLE 1
Recorded Deaths of French-Canadian Centenarians
By Sex and Year of Age, Quebec, 1870-1894 Birth Cohorts

	Sex		
Age at death	**Females**	**Males**	**Total**
100	454	179	633
101	337	114	451
102	220	53	273
103	147	36	183
104	121	25	146
105	75	13	88
106	37	12	49
107	29	10	39
108	10	2	12
109	5	2	7
110	4	1	5
111	2		2
112	2		2
113	0		0
114	0		0
115	1		1
Total	1444	447	1891
Average age	102,39	102,01	102,30
D(105+) / D(100+)	11,4%	8,9%	10,8%

If we take a closer look at the distribution of the ages at death for the French-Canadian centenarians born and deceased in Quebec, we first notice that 76 percent of deaths belong to women. We also note that the distribution of the deaths by age varies greatly according to gender: deaths of supercentenarians (110 years and older) are almost exclusively those of females; conversely, a higher proportion of male deaths, 65.5 percent, occurred at the earlier ages, 100 and 101, against a proportion of 54.8 percent for females. The mean age at death for centenarians is 102.01 years for men as opposed to 102.39 years for women. The proportion of deaths at ages 105 or older for men is 8.9 percent and 11.4 percent for women. These proportions are relatively high if we compare them to the 5 percent obtained for the 15 countries with the best quality data at the highest ages (Kannisto, 1994). According to Kannisto, a ratio higher than 5 percent shows the presence of false age declarations: we shall discuss this issue later in the paper.

The validation of the ages at death was undertaken for the 1,891 deaths of French-Canadians. We focused on this group because of its homogeneity and because the parish registers and the index of all marriages of French-Canadians between 1799 and 1939 helps in

the validation process. This process was accomplished by linking the baptism certificate to the burial certificate of each individual. For certain cases, age at death was validated with the ages and birth dates registered on the census returns of 1881, 1901 and 1911, all of which are readily available on the Internet.

TABLE 2
Validity of Reported Centenarians Deaths in Quebec, 1870-1894 Birth Cohorts

		F	M	Total
VALIDATED	Reported birth date confirmed	1117	322	1439
	Erroneous reported birth date	240	95	335
	Probable	34	9	43
Subtotal		**1391**	**426**	**1817**
NOT VALIDATED (reported birth date not confirmed or proven wrong)		**53**	**21**	**74**
TOTAL		**1444**	**447**	**1891**

The age at death has been validated or considered probable for 1,817 French-Canadian centenarians, which represent 96.1 percent of the total deaths of French-Canadian centenarians deceased in Quebec. Among these 1,817 validated cases, 1,439 are associated with centenarians for whom the official birth date was confirmed by the baptism certificate or the birth date found on the census return. We identified 335 (18.4 percent) misreported birth dates for centenarians for whom the baptism certificate was found. We classified as "probable" 43 centenarians for whom the reported birth date was different by a year from the one given in the census return or was indirectly confirmed by the date of their marriage or the date of their parents' marriage.

Within the centenarians under study, we identified as "not validated" (74) the ones which we could not find in the census returns, the ones whose identities were uncertain, and the ones for which the birth date registered in the census returns was too different from the one found on their death certificate. The majority of these cases have to do with individuals about to turn 100 years old, especially for men. Among women, the deaths that could not be

validated are spread between 100 and 107 years old, although 53 percent were declared as being 100 or 101 years of age.

TABLE 3
Distribution of the Erroneous Birth Dates According to the Difference between the Reported Birth Dates and the Real Birth Dates

Difference in days, months or years	N
3 days or less	200
Between 4 and 30 days	38
Between 1 and 11 months	23
Between 1 and 4 years	38
Between 5 and 9 years	12
10 years or more	24
Total	**335**

The validation process has shed some light on the inconsistencies in the birth dates found on the death certificates. We identified 335 misreported birth dates for centenarians among which age at death has been ascertained. 59.7 percent of these errors are of three days or less, probably due to confusion between baptism date and birth date. The differences of less than one month are of minor importance, since their corrections will not change the age at death nor will it affect the measure of the mortality of centenarians. 7.2 percent of the mistakes are associated with differences of at least 10 years between the official birth date and the real birth date.

3. Results

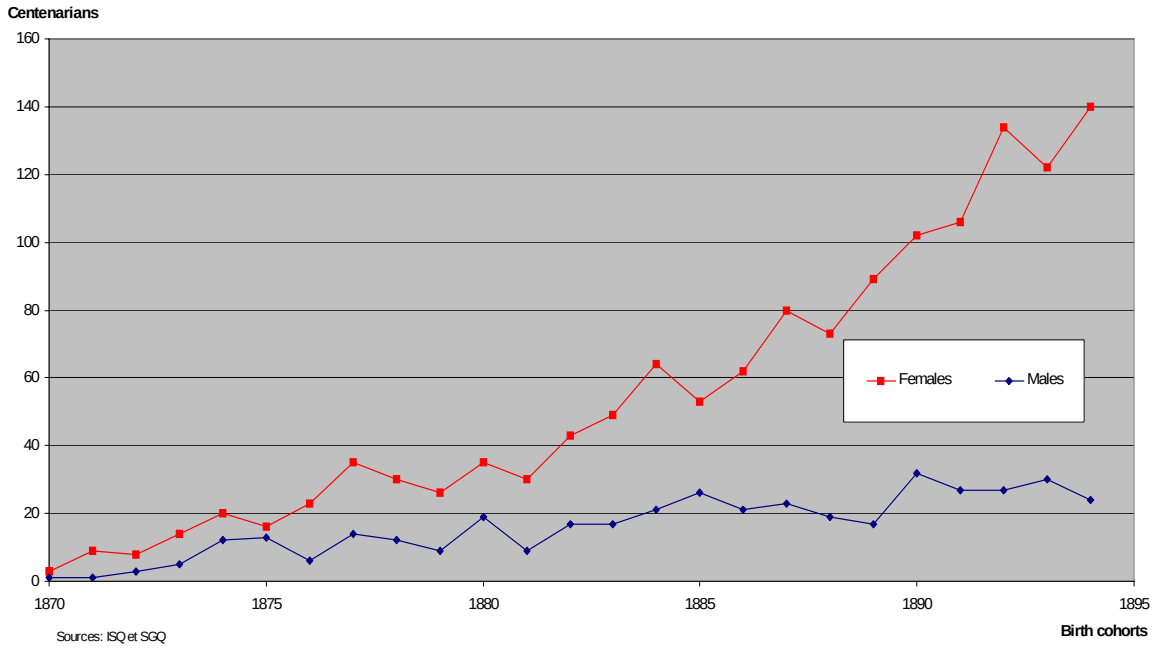
3.1 Measure of the Mortality of Centenarians Based on the Validated Data

Among the 1,817 validated cases, 44 were false centenarians and two persons were born outside the group of generations under study. The measure of centenarian mortality then relies on the 1,771 deaths of true French-Canadian centenarians born between 1870 and 1894; 1,366 (77.1 percent) are women and 405 (22.9 percent) are men. The proportion of female deaths for each age is 73 percent higher than the one for men. However, among men, the proportions of deaths at 100, 101, 106 and 107 years of age are higher than the ones found in

women, especially at the age of 100. These results might lead us to think that the ages of 100 and 105 years represent key ages for men, mortality rising at subsequent ages.

Our sample includes 188 deaths of semi-supercentenarians (105 years and older), of which 81 percent are women, and nine deaths of supercentenarians (110 years and older) that are all women. The woman who has lived the longest belongs to the 1891 generation and died in 2007 at the age of 115 years. She was considered to be the oldest person on earth during the months before her death.

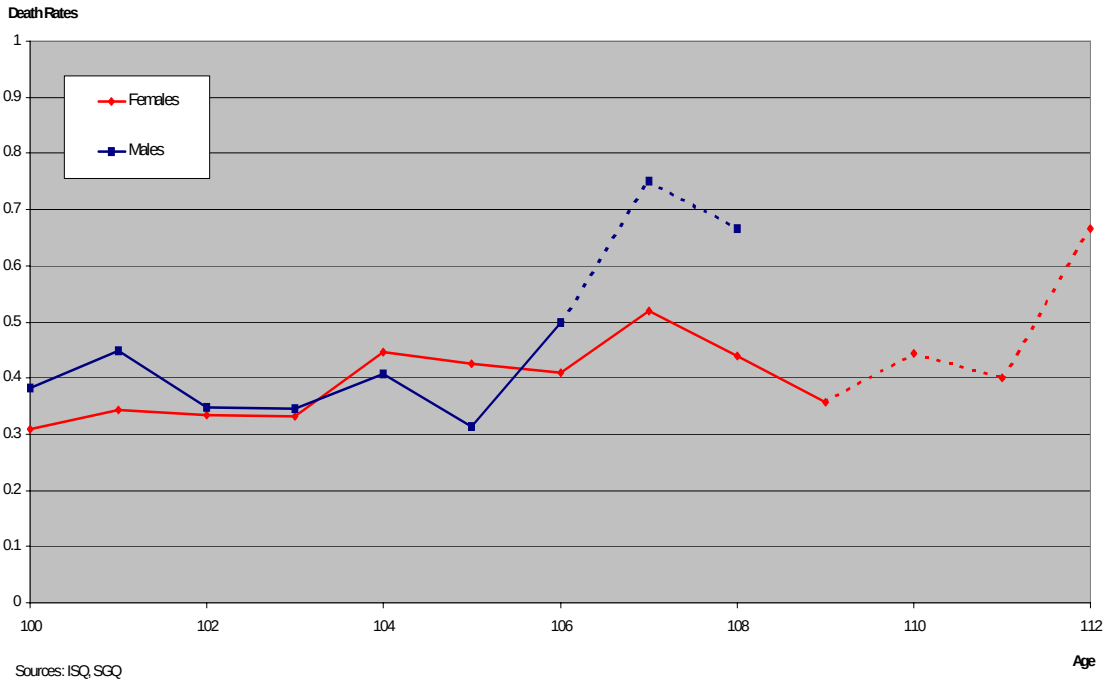
FIGURE 1
Deaths of Centenarians by Year of Birth, 1870-1894 Birth Cohorts, Quebec, Validated Data



Among women, the absolute number of deaths of centenarians has increased exponentially from generation to generation. Within the 1870 generation, only four women reached the age of 100 years; 25 generations later, more than 140 have done so. The number of centenarians has been multiplied by about 35 in 25 generations. This exponential rise is not found for men. On the contrary, the number of deaths of centenarians has risen very slightly within the 25 generations under study here. We even notice a stabilization of the number of centenarian deaths observed in the generations 1885-1894. In other words, the number of

deaths of male centenarians hasn't varied much since the 1885 cohort. Knowing that the number of births increased by 5 percent over the 1885-1894 period, these results are somewhat surprising. This could indicate a decline in male survival probabilities at advanced ages in the 10 last generations under study.

FIGURE 2
Age-Specific Life Table Death Rates at ages 100+ by Sex, 1870-1894 French-Canadian Birth Cohorts, Validated Data



Recent studies (Bourbeau and Desjardins, 2002, 2006; Yi and Vaupel, 2003; Horiuchi and Wilmoth, 1998; Thatcher, Kannisto and Vaupel, 1998) have shown that the trajectory of mortality at the highest ages does not follow an exponential distribution as the Gompertz model suggests, but rather a logistic distribution; the rates rise, but at a decelerating pace with age. The evolution of the mortality rates starting at 100 years old obtained for the 1870-1894 generations confirms the decline in the force of mortality at the highest ages. This trend is more important for women—the rates rising from 30.8 percent to 42.5 percent between the ages of 100 and 105. In this age group, the population under observation is greater than 100 individuals. Among men, the small number of individuals does not allow us to define the evolution of mortality beyond 103 years old. Up to this age, we observe a ceiling of the

mortality rates at around 40 percent. As indicated by the dotted lines, the population at risk of dying is less than 25 persons beyond 106 and 109 years old for men and women respectively.

3.2 Comparing the Measure of Mortality of the Centenarians According to the Type of Data Used: All Deaths vs. Validated Deaths Only

One of the goals of our study is the evaluation of the quality of the data from Quebec and, more precisely, of the ages at death registered in the vital statistics and the potential effect of age misreporting on the measure of mortality at the highest ages. Three elements must be considered here: the proportion of ages at death qualified as ”not validated,” the proportion of erroneous birth dates and the proportion of erroneous birth dates that lead to a change in the age at death.

Within the 1,891 deaths of French-Canadian centenarians belonging to the 1870-1894 generations, only 3.9 percent were not validated and were therefore rejected from the analysis. We must specify that the rejection of these cases does not mean that the ages at death were inaccurate. These are deaths of centenarians for whom the birth date could not be confirmed by either one of the sources of information available. Therefore, it is entirely possible that the ages at death for some of these individuals are accurate. A religion other than Catholic, migration, a birth outside Quebec or missing registers are all reasons that could possibly account for the uncertainty which led to the rejection of these cases. Perhaps their exclusion can have an impact on the measure of mortality at the highest ages. Nevertheless, considering that the age distribution of these deaths is very similar to the one of the validated deaths, we are confident that their rejection has little effect on the evolution of mortality beyond the age of 100 years.

The centenarians for which the age at death found on the death certificate is erroneous represent 18.4 percent of the total of deaths of French-Canadian centenarians. As we previously mentioned, this proportion might be slightly underestimated considering certain ages at death could not be validated by the baptism certificates and that others were rejected from our sample. Seventy-one percent of the identified errors yielded a difference of 30 days or less, which does not influence the measure of mortality at the highest ages as the age at death is not affected.

There are 84 erroneous birth dates for which the correction leads to a change in the age at death; this represents 25.1 percent of the entire birth dates that were misreported and 4.6 percent of all the validated ages at death. In other words, in the majority of the cases (74.9 percent), the correction of the erroneous birth date had no impact on the ages at death and, accordingly, no effect on the measure of mortality. When we examine the distribution of the ages at death of the centenarians for which the correction of the birth date led to a change in the age at death, we do not find a trend that could bias the measure of mortality beyond age 100. In fact, the majority of the changes in the age at death are related to deaths of centenarians that occurred at the age of 100. The proportion of corrections at ages where the number of survivors is limited is very low. We note only seven errors beyond the age of 105 that involved a change in the age at death, and two of these individuals gained a year. Within the six errors that led to a reduction of the life span, four cases were rejected from our analysis.

A comparison of some indicators shows no significant differences between validated data and all data records in terms of the level of mortality (see Table 4). Life expectancy at the age of 100 years (average age at death over age 100) and the proportion of deaths at age 105+ among deaths at age 100+ give the same picture in terms of survival experience at age 100 and beyond. As shown by these indicators and the results of the validation process based on the experience of the province of Quebec, we can say that validation is no longer necessary to obtain a relatively good measure of mortality among centenarians, at least for French-Canadians born in Quebec.

TABLE 4
Life Expectancy at 100 Years Old and Proportion of Deaths at 105+, All Records and Validated Data Records

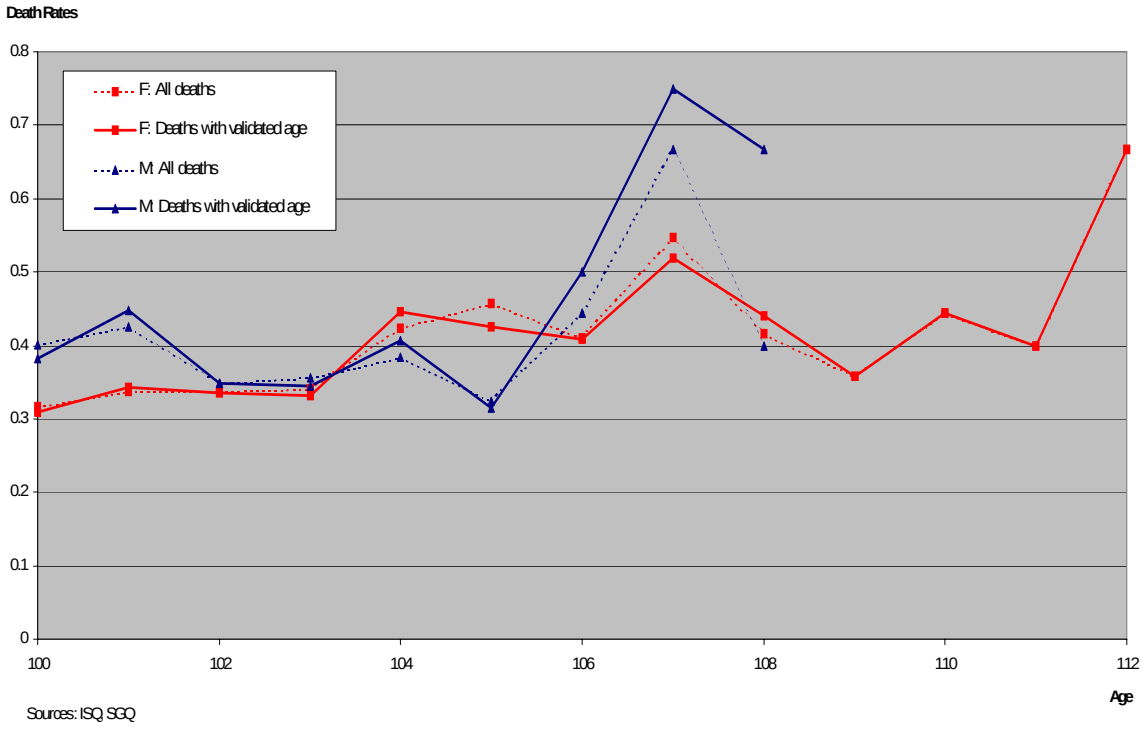
		Only validated data records (n=1,771)	**All records (n=1,891)**
e_{100}	M	2.01	2.01
	F	2.41	2.38
	T	**2.32**	**2.30**
D(105+)/D(100+)	M	8.6%	8.9%
	F	11.2%	11.4%
	T	**10.6%**	**10.8%**

The impact of the corrections and rejections from the original sample can be seen in Figure 3, where the death rates calculated using the validated data are compared with the ones obtained with all the data. On the whole, the type of data used has little impact on the trajectory of the mortality observed at 100 years old and beyond. Up to 105 and 112 years old, for men and women respectively, the curves are similar.

In the case of men, the use of all death records induces an underestimation of mortality. The death rates calculated with all the records are inferior to those obtained with validated data, except at the ages of 100, 103 and 105—ages at which we count a majority of false centenarians and of ages at death that could not be validated. After 105 years old, the distance between the two curves deepens. Overall, in the case of men, the impact of the erroneous declarations seems stronger as age rises, leading to a slight underestimation of the mortality at the highest ages, but this may be caused by the small number of observations.

FIGURE 3

Age-Specific Life Table Death Rates at ages 100+ by Sex, 1870-1894 French-Canadian Birth Cohorts, All Deaths and Deaths with a Validated Age



Among women, the trend is less obvious. The curves merge up to age 103 years and then separate slightly at certain specific ages. Therefore, the use of all records does not lead to an underestimation of the mortality at the highest ages for women.

3.3 Measure of the Mortality of Centenarians According to Ethnic Origin

The following analyses are based on reported centenarians born in the 1885-1894 period for which the birthplace is known. Using the first names and the family names of the centenarians and their parents, along with the census information about the origin, it is possible to conduct analyses according to this characteristic. Even though interesting, this path of research is nevertheless challenged by the small number of Anglo-Canadian centenarians born in Quebec between 1885 and 1894. For this matter, we were forced to conduct analyses for both sexes together. We hope that the upcoming inclusion of the 1870-1884 generations will allow us to develop analyses according to the sex.

TABLE 5
Recorded Deaths of Centenarians, Average Age at Death of Centenarians and Proportion of Deaths at 105+ According to Ethnic Origin and Sex, 1885-1894 Birth Cohorts

		Born in Quebec		
		French-Canadian	***English-Canadian***	***Total***
N	M	263	41	**304**
	F	1001	119	**1120**
	Total	**1264**	**160**	**1424**
Average age at death	M	102.01	101.79	**101.98**
	F	102.43	102.17	**102.40**
	Total	**102.34**	**102.09**	**102.31**
D(105+) / D(100+) in %	M	8.75%	2.44%	**7.89%**
	F	11.29%	6.72%	**10.80%**
	Total	**10.76%**	**5.67%**	**10.18%**

There are 1 929 centenarians of the 1885-1894 generations who died in Quebec. 1 424 of them were born in Quebec of which 88.8% are of French-Canadian origin. Among the

people born in the province, we notice that the mean age at death of French-Canadian centenarians is greater than the one for Anglo-Canadians by 2.5 tenths of a year.

The ratio between the number of deaths that occurred at the ages of 105 and over and the ones that occurred beyond the age of 100 (105+/100+) is often used to judge the quality of age reporting at the highest ages. Kannisto (1994) suggested that a ratio higher than 5 percent shows the presence of errors in the age declarations. This indicator rises to 5.67 percent for the English-Canadian centenarians and to 10.76 percent for the French-Canadian centenarians. According to these results, we would be tempted to believe that the data from Quebec are of poor quality, in particular in the case of French-Canadians. However, when we compare the proportion of deaths at the age of 105 and over for the French-Canadian centenarians for whom the age at death has been validated (1,771 cases) with the proportion for all the records of centenarians of French-Canadian origin (1,891 cases), we must reconsider that conclusion. The proportion goes from 10.76 percent for the French-Canadian centenarians to 10.62 percent for the ones that have been validated (see Table 4). The ratio obtained using validated data remained higher than 5 percent, so we have no choice but to question the quality of this indicator to identify the presence of errors in the age declarations at the highest ages. Since this indicator was developed with what is observed in low mortality countries displaying good quality data (all the European countries but one), it is possible that it does not suit the situation in Quebec, or the Canadian situation for that matter, if the mortality patterns at the highest ages are different from the ones displayed in the countries used by Kannisto. A higher ratio does not necessarily equate with the presence of erroneous age declarations; it can simply be caused by a mortality profile characterized by better surviving probabilities at the very high ages.

TABLE 6

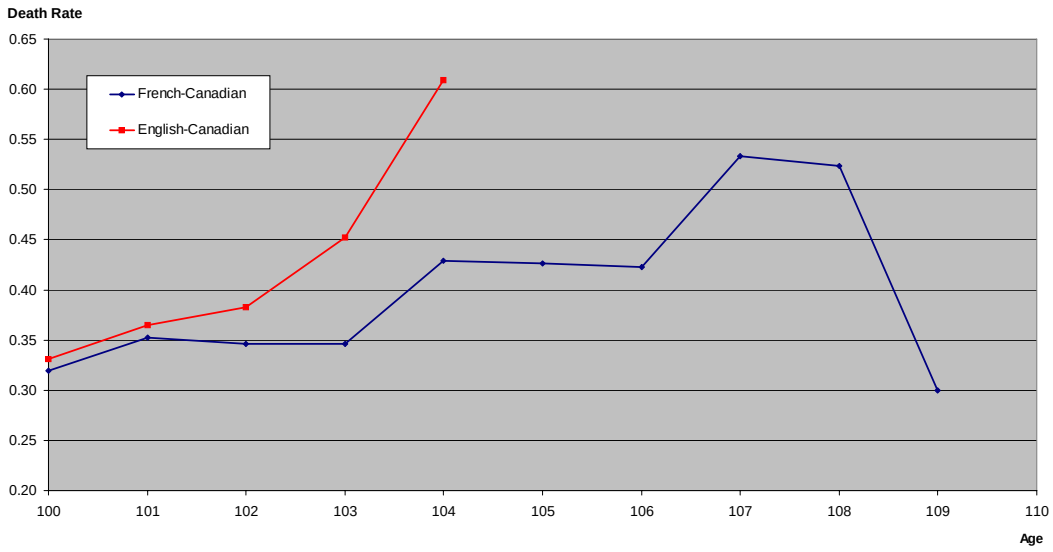
Age-Specific Life Table Death Rates by Birthplace for Centenarians, Quebec, 1885-1894 Birth Cohorts

Age	*Born in Quebec*		
	French-Canadian	***English-Canadian***	***Total***
100	**0.31962**	**0.33125**	**0.32093**
101	**0.35233**	**0.36449**	**0.35367**
102	**0.34650**	0.38235	**0.35040**
103	**0.34615**	0.45238	**0.35714**
104	**0.42857**	*0.60870*	**0.44444**
105	**0.42647**		**0.44828**
106	0.42308		0.42500
107	0.53333		0.54348
108	*0.52381*		*0.52381*
109	*0.30000*		*0.30000*

Note: Numbers in bold refer to a population under observation of more than 100 individuals. Those in italic refer to a population at risk of less than 25 individuals. Age-specific death rates based on a population at risk of less than 10 individuals were not considered.

FIGURE 5

Age-Specific Life Table Death Rates of Centenarians Born in Quebec According to Ethnic Origin, Quebec, 1885-1894 Birth Cohorts



As can be seen in Table 6, the population under observation is lower than 100 surviving individuals beyond the age of 102. When we eliminate the ages for which the population at risk is inferior to 10, our analyses are limited to ages 100 to 104. The impact of small numbers is also apparent in Figure 5. The evolution of the death rates of the centenarians of English origin stands out from the evolution of the death rates of centenarians

of French origin. While the evolution of the mortality rates of the French-Canadian centenarians follows a logistic distribution, the evolution of the mortality rates of English-Canadian centenarians seems to follow an exponential increase. At this stage of our analysis, it is difficult to identify the reasons potentially responsible for such a trajectory; it could be that the English-Canadians have a specific mortality profile or could simply be the result of the small number of survivors of English origin at these ages. We hope that adding the 1870-1884 generations will allow us, on the one hand, to define the trajectory of the mortality of the English-Canadian centenarians born in Quebec and, on the other hand, to reach some conclusions about the evolution of the death rates beyond the age of 104.

4. Conclusion

The validation of the ages at death of centenarians born between 1870 and 1894 allowed us to evaluate the quality of age at death registration in the vital statistics relating to French-Canadian centenarians. Of the 1,891 deaths of French-Canadians reported as centenarians for which age validation was attempted, 74 could not be validated (3.9 percent), and 335 were found to be inexact (18.4 percent), of which only 84 (4.6 percent) led to a correction of the age at death. Of these 84, 44 turned out to be people who were not centenarians. These results confirm that Quebec data on the highest ages at death are of very good quality, especially considering that some of those which could not be validated could be exact notwithstanding.

The measure of centenarian mortality is affected by the elimination of the non-validated cases and by the dates of birth which correspond to a change in the age found in the death registration. But considering that, within the French-Canadian centenarian population, only 4.6 percent of ages at death were found inexact and only 3.9 percent could not be validated, it is clear that globally these errors can alter but slightly the measure of mortality. Providing these proportions can be considered to hold for Anglophones born in Quebec, and then the measure of high age mortality obtained from vital registration without correction is, globally, true to reality.

TABLE 7
Age-Specific Life Table Death Rates of Centenarians, Both Sexes, Quebec, 1621-1739 and 1870-1894 Birth Cohorts, Validated Data

Generations 1621-1739		***Generations 1870-1894***	
Age	$_1q_x$	Age	$_1q_x$
92	0.29	103	0.33
93	0.41	104	0.44
94	0.40	105	0.40
95	0.45	106	0.43
96	0.45	107	0.56
97	0.45	108	0.46

Another important finding of our study concerns the mortality rate ceiling at around 40–50 percent at the highest ages. This result has also been found in another study based on historical data for French-Canadians born between 1621 and 1739 (Desjardins, 2006). Allowing the plateau is observed at lower ages (between ages of 92 and 97) because of the much higher mortality of the past, the level is strikingly similar: 40–50 percent. This result is in line with the phenomenon of mortality deceleration induced by a selection process among survivors at very old ages.

Acknowledgments

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