

Chapter 12

Extreme Longevity in Quebec: Factors and Characteristics



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12.1 Introduction

Rising life expectancy at birth, and in particular lower mortality at advanced ages, has led to a marked increase in the number and the proportion of centenarians, and to new records in longevity in low mortality countries. This explosion in the numbers of centenarians has been studied in the United States (Krach and Velkoff 1999), France (Meslé et al. 2000; Vallin and Meslé 2001), England and Wales (Thatcher 2001; Dini and Goldring 2008), Belgium (Poulain et al. 2001), Denmark (Jeune and Skytthe 2001), Switzerland (Robine and Paccaud 2004), Italy (Poulain et al. 2004), Japan (Robine and Saito 2003; Robine et al. 2003), Australia (Terblanche and Wilson 2014), as well as in Europe (Robine and Saito 2009) and the industrialised countries (Rau et al. 2008; Herm et al. 2012). These studies all document the rapidity of the increase of this population, starting in the mid-twentieth century, and they also highlight its absolute numbers and its proportional share of the general population. The rate of decline in mortality at advanced ages has not slowed in recent years, so this phenomenon can be expected to grow in scale over the coming century, with new records being set in terms of survival into extreme old age.

On 1 January 2015, the USA and Japan had the largest number of centenarians among the selected countries in Table 12.1. However, in view of the relative size of their populations, the situation in Japan is quite exceptional, with 5.1 centenarians per 10,000 inhabitants. This country is known for the values associated with its long life expectancy at birth, for the prevalence of centenarians, and especially for the speed of growth of this particular population group – in the space of 20 years from

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Table 12.1 Number of centenarians and sex ratios of centenarians in selected countries, 1 January 2015

Countries	Numbers			Centenarian rate (Number of centenarians per 10 000 persons)	Sex ratio (Number of women per men)
	Women	Men	Total		
USA	54,525	10,253	64,778	2.0	5.3
Japan	56,187	7,923	64,110	5.1	7.1
France	20,681	3145	23,825	3.7	6.6
United Kingdom	12,330	2240	14,570	2.2	5.5
Canada^a	6116	835	6951	1.9	7.3
<i>Quebec^a</i>	1478	145	1623	2.0	10.2
Belgium	1833	249	2082	1.8	7.4
Switzerland	1349	273	1622	2.0	4.9

Source: Human Mortality Database and Statistics Canada (population estimates)

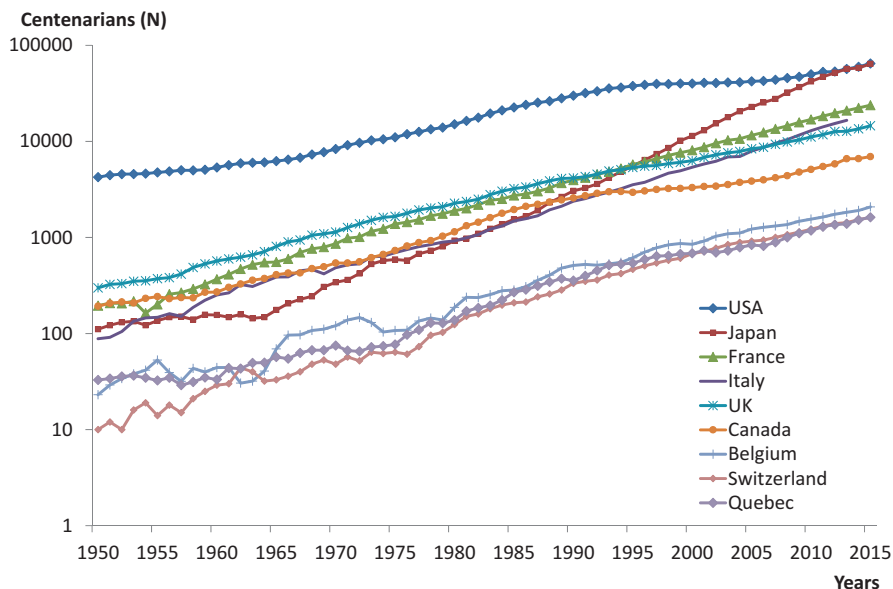
^aPopulation on 1 July

1996 to 2015, the number of centenarians multiplied by 10. France is also outstanding with 3.7 centenarians per 10,000 persons. Canada and Quebec, with 1.9 and 2.0 centenarians per 10,000 persons respectively, show prevalences similar to the USA, United Kingdom, Switzerland and Belgium.

Sex ratios reflect the lower mortality of women. These ratios also vary between the selected countries. There are between 4.9 and 5.5 females for every male centenarian in Switzerland, the USA and the United Kingdom, while France, Japan, Canada and Belgium have ratios higher than 6.6. The very high ratio observed in Quebec in 2015 may be explained by the small size of the population, leading to important annual fluctuations.

The speed of growth in the numbers of centenarians has also varied from one country to another. Whereas growth rates have been relatively steady in France, Belgium, Switzerland and the United Kingdom, there has been some slowing of the growth in numbers in Canada (including Quebec) and the USA from the 1990s onwards (Fig. 12.1). In the case of Japan, the centenarian population has been growing at a much more rapid pace since the 1960s, and the growth curve even shows an acceleration in the last 20 years, so that by 2015 Japan's growth curve is as high as that of the USA and will probably cross the USA in the years to come.

In this study we analyse the evolution of the number of centenarians in Quebec. We chose to focus on Quebec because its mortality data offer the best possibilities for analysis in Canada, in terms of availability and quality. Census data and population estimates as well as civil registration statistics are available to enable the study of this relatively new and rapidly expanding phenomenon, although imperfections in the data mean that hypotheses have to be formulated and corrections introduced to make them representative of the reality. The aim of the study is to analyse the levels and trends in the numbers of centenarians in Quebec and to make comparisons with that observed in other low mortality countries. To this extent, we use the



Source : For Quebec: Canadian Human Mortality Database (CHMD); for other countries: Human Mortality Database

Fig. 12.1 Evolution of numbers of centenarians (Those aged 100 and over), selected countries, 1950–2015

best demographic indicators such as the centenarian ratio, the probabilities of surviving and maximum age at death to give an account of the evolution of this population over the course of the last century, and to measure its place in today’s society. As a result, we will be able to identify the factors responsible for the increase in the numbers of centenarians, and to quantify their relative contributions. Projection of the centenarian population for Quebec until 2061 is also presented.

12.2 Sources and Data

12.2.1 Censuses and Civil Registration

The first census was carried out in 1666 by the Intendant Jean-Talon. It was conducted *de jure*, covering French settlements in New France. By 1851, when the first national census took place, 98 colonial and regional censuses had been taken at more or less regular intervals, but none after 1681 were complete, being limited to heads of households and statistics of the household. From 1851 to 1951 “official” censuses took place every 10 years, and thereafter every 5 years, in years ending with 1 or 6. Two different kinds of problem compromise the use of census data to study changes in the numbers of centenarians. The first has to do with publication

Table 12.2 Oldest available age groups showing population numbers in Canadian censuses, 1881–2011

Census year	Age group	
	95 and +	100 and +
1881		x
1891	x	
1901	x	
1911		x
1921		x
1931		x
1941	x	
1951	x	
1956	x	
1961	x	
1966	x	
1971		x
1976		x
1981		x
1986		x
1991		x
1996		x
2001		x
2006		x
2011		x

and treatment of information on the population of persons aged 100 and over. For some census years there are no population numbers for those aged over 100, because the oldest recorded age group is that of persons aged 95 and over (Table 12.2). In addition, where these data are available (since 1971), they are rounded up to multiples of five, to ensure the confidentiality of respondents. This procedure, established by Statistics Canada, creates a problem because the numbers of the population aged 100 and over are very low. Rounding these numbers up therefore causes a loss of precision which impedes the study of mortality at advanced ages.

The second major problem with the census data is the quality of the information on the numbers of centenarians. In a study carried out in Canada on the quality of data on people at advanced ages, Bourbeau and Lebel (2000) showed that while the Canadian data are reliable up to the age of 100, misreporting from age 100 is responsible for false estimates of mortality (Bourbeau and Desjardins 2002; Bourbeau and Lebel 2000). Fortunately the problem can be alleviated using civil registration data which provides information on all events such as births, marriages and deaths taking place each year. Unlike censuses which are time-specific events, civil registration is a system of continuous recording. This system was established in Canada in 1921, but only in 1926 in Quebec. Registration of births, marriages and deaths is the responsibility of the ten Provinces and of the northern Territories; the data are sent to Statistics Canada where they are aggregated and standardised. Nevertheless, as

pointed out by Bourbeau and Desjardins (2006) and Desjardins and Bourbeau (2010), methods and procedures for registration and data entry vary from one Province to another, with the result that biases may be introduced into the published results.

The registration of age at death in the civil register is recognised as being of superior quality compared to the population data in the census (Bourbeau and Lebel 2000; Bourbeau and Desjardins 2002; Desjardins 1999; Manton and Yashin 2000; Beaudry-Godin 2010). Over the course of the past century, procedures for checking age at time of death have been improved and standardised. In Quebec, data have been subject to systematic control measures since 1986, involving the checking of the reported age at time of death against the recorded year of birth of the individual concerned. Since 1992, the death certificate has been checked in this way for all deaths reported as taking place at over 103 years of age. And finally, the Institut de la Statistique du Québec has carried out more exhaustive checks since 1997, matching health insurance numbers and dates of birth.

For the purposes of this study we used data on deaths at age 100 and over in Quebec and Canada. We worked with a file obtained from Statistics Canada, which includes a classification of deaths by age and cohort from 1950 onwards and a death count up to the last recorded age (unpublished data). The civil register data can be consulted via the *Canadian Human Mortality Database*, which is available online.¹ However, until 1950 all deaths after age 100 were recorded as simply 100 or over; from 1950, the open ended age group became 110 years and over. The double classification of deaths is also available for the entire period, although before 1950 they are estimates obtained by redistributing the deaths uniformly by age within the generations concerned.

12.2.2 Reconstituted Populations

A number of different methods have been proposed to remedy the problem of misreporting at advanced ages in the census; these include the method of extinct generations and the survivor ratio method. These enable us to estimate population sizes on January 1st of each year and survivors of a cohort at exact age x . These methods are among those used to construct the life tables of the *Human Mortality Database*,² the *Kannisto-Thatcher Database*³ and the *Canadian Human Mortality Database*. The basic principle of the extinct generations method is that in a closed population, the population size of a cohort at age x is equal to the sum of the deaths after this age until the complete extinction of the cohort. This method, developed by Vincent (1951) is only applicable to age groups in which migration is negligible (such as

¹ <http://www.bdlc.umontreal.ca/bdlc/index.htm>

² Available on line at: <http://www.mortality.org/>

³ Available on line at: <http://www.demogr.mpg.de/databases/ktddb/>

those aged over 80). A cohort is considered extinct when it attains the maximal age beyond which the probability of a death is virtually nil. This method enables estimates to be derived of population sizes of the extinct generations i.e. those having attained the maximal age in the most recent registration year. For subsequent generations, the survivor ratio method is used; this assumes that deaths by year of age of a generation X are distributed in the same proportions as those of the 5 or 10 preceding generations.

12.2.3 *Data Comparison*

A quick and simple way of judging the quality of official population data is to compare the census data with population estimates published by the CHMD⁴ (based on the extinct generations and survivor ratio methods). To make the comparison with census data easier we decided to present the CHMD population estimates on July 1st of each year (Table 12.3). The results for the age group composed of those aged 90 and over are shown in Appendix.⁵ Note that since 1971 the census data have been corrected for undercoverage of the population. The Statistics Canada estimates (in column 2) show the corrected numbers of nonagenarians. Over the period as a whole, this correction is about 1% for both men and women. Although there are differences, which are sometimes significant, between the number of people aged over 90 according to these two sources, they are not as large as those we find for the centenarian population (Table 12.3). While the maximum difference between sources for the population over 90 is 20.0% for men and 16.8% for women, for those over 100 we find differences in size estimates of 94.0% and 86.9% respectively for men and women in the census year 1976. If we exclude this particular year, which is evidently especially problematic, the census results overestimate the male population aged over 100 by between 5% (1996) and 78% (1971) compared with the results derived from reconstitution methods, while for the female population the census results under-estimate by 1.9% (2011) and over-estimate by 66.7% (1941) using the same comparison. Sampling and data entry errors and over-reporting of ages are among the reasons which may explain these divergences. However, it is worth noting that the differences are considerably reduced in the period since the 1990s (except for a notable difference in 2006).

Comparing census data with population estimates based on the extinct generations method clearly shows the deficiencies of the census results for the population aged 100 and over. For the purposes of this study, to ensure greater accuracy and reliability of the indicators we present, we base our calculations on population estimates derived using the extinct generations and survival ratio methods published by the CHMD.

⁴Canadian Human Mortality Database (CHMD).

⁵See p. 22.

Table 12.3 Comparison of population numbers of those aged 100 and over, according to two sources of data, Quebec, 1921–2011

Years	Males			Females		
	Census data	CHMD estimations ^a	Relative difference (%)	Census data	CHMD estimations ^a	Relative difference (%)
1921	11	5	54,4	18	9	52,4
1931	8	3	65,9	14	10	30,3
1941	13	4	67,8	23	8	66,7
1951	19	6	66,8	35	29	17,9
1956	22	9	58,3	40	23	42,8
1961	26	15	41,3	47	28	39,6
1966	28	16	44,3	61	43	28,7
1971	65	14	78,0	125	52	58,5
1976	510	31	94,0	560	74	86,9
1981	110	47	57,3	260	131	49,6
1986	130	82	37,2	310	220	29,1
1991	150	80	47,0	485	353	27,2
1996	110	105	5,0	500	513	-2,6
2001	120	102	15,3	645	613	5,0
2006	135	95	29,9	865	761	12,0
2011	180	152	15,8	1160	1182	-1,9

In **bold**: data obtained by applying mean ratio of population aged 100 and over to population aged 95 and over (100+/95+)

^aEstimates on July 1st, based on extinct generations and survivor ratio methods

Sources: Census data: Statistics Canada (1996); CHMD estimates: Canadian Human Mortality Database (CHMD) and Statistics Canada (1998)

12.3 Choice of a Longevity Indicator

One of the aims of this study is to compare survival at advanced ages in Quebec with that observed in other low mortality countries. Because population size varies so much from one country to another, we cannot compare mortality in extreme old age using recorded numbers of centenarians or numbers of recorded deaths of centenarians. A comparison must rely on a longevity indicator which is not affected by population size. The most commonly used indicators in comparative analyses of survival to extreme old age are life expectancy, prevalence of centenarians, the extreme longevity index, the ratio of centenarians per 10,000 births and per 10,000 persons aged 60.

Although life expectancy and prevalence of centenarians are measures found widely in the literature, they are not particularly suitable for this type of analysis. Low numbers mean that the values attached to life expectancy at 100 years are imprecise. In addition, life expectancy is not a real measure of the mean number of years an individual can expect to live, because its calculation rests on the hypothesis that mortality rates at different ages remain unchanged over time. As an indicator, life expectancy fails to capture the real conditions of mortality which have affected

the many cohorts it is based on. The prevalence of centenarians, which relates the number of centenarians to the total population, is influenced significantly by migration and by a range of phenomena and events which may have affected its age structure. For this reason, it is not a suitable indicator for international comparisons.

The ratio of centenarians per 10,000 births has been used in several studies of centenarians (Poulain et al. 2001; Robine et al. 2003; Robine and Saito 2003; Robine and Paccaud 2004; Robine et al. 2006). This index is obtained by dividing the number of persons aged 100 at a given date (January 1st for example) by the number of births that took place between January 1st and December 31st one century earlier. In mathematical terms:

$$RC_{[0]} = \frac{P^{01.01.y}}{N^{y-100}},$$

Where y refers to any given year.

The major difficulty with this index is that because of migratory flows, the numbers making up the numerator and the denominator are not derived from the same populations. On the one hand, the index over-estimates the prevalence of centenarians because the numerator includes individuals born outside the population being studied. On the other hand, it under-estimates the prevalence of centenarians because it does not consider centenarians born in the study population but who have emigrated and celebrated their 100th birthday outside the territory of the country in question. The extreme longevity index (ILE) proposed by Poulain et al. (2004) is an improved version of the ratio of centenarians per 10,000 births. This relates the number of survivors to age 100 in a given generation to the number of births in the same generation. In mathematical terms:

$$ILE = \frac{S_{100}}{S_0} \cdot 100,$$

where S_{100} = Survivors to age 100 and S_0 = Survivors at age 0 (number of births).

As the authors point out, this index is not affected by over-estimation because it considers only individuals born in the country of study. In addition, it includes centenarians born in the generation in question who may have emigrated and reached the age of 100 outside the country, in cases where their existence is known. As an example, Poulain and Naito (2004) could trace centenarians belonging to the generations studied who originated in Okinawa and died in Hawaii, and to include them in the calculation of the index of longevity. In the context of Quebec, however, there are two problems of a very different kind which undermine the use of this index. The first has to do with the type of data available. Not only is there no accurate information on the numbers of births in Quebec in the late nineteenth century, but it is difficult to identify the immigrants within the centenarian population. We could

of course estimate the numbers of births and of immigrants,⁶ but this would severely reduce the level of reliability and comparability of the indices of extreme longevity. The second problem arises when this indicator is used for international comparisons. If we compare countries based on probabilities of survival from birth to the age of 100, we are bringing together cohorts which have not been subject to the same mortality regime. Wars and epidemics are among the disruptive factors which have had impacts on child and adult mortality rates and consequently on the numbers of centenarians.

The ratio of centenarians per 10,000 persons aged 60 forty years before (Robine and Paccaud 2004; Robine et al. 2006) seems better suited for the study of survival to extreme old age. This type of indicator enables the influence of disruptive effects to be avoided – not only effects caused by migration but also those associated with infant mortality – while preserving the essential element of adult mortality. This indicator is based on the hypothesis that “the number of centenarians in a country is essentially dependent on the number of individuals aged 60 forty years earlier, and on mortality trajectories after that age”.⁷

$$RC_{[60]} = \frac{P(100)^t}{P(60)^{t-40}} \cdot 10000$$

The use of this kind of indicator is particularly appropriate given the migration context of Quebec in the nineteenth and twentieth centuries. If we accept the estimations of Lavoie (1972), which the author herself admits are conservative, 1,550,000 Canadians including 510,000 Québécois crossed the frontier into the USA in the period from 1860 to 1900. This corresponds to an annual migration rate of about 10.3%. This massive emigration from Quebec to the United States was followed by a return to Quebec by some of them, but also importantly by the start of a major international immigration into Quebec. By relating the size of the population aged 100 to the size of the same population at age 60, we considerably reduce the impact of migration movements which may have affected the denominator population.

This centenarian ratio was proposed by Caselli et al. (2003) to compare the distribution of centenarians in certain regions of Italy. Their choice of the denominator was mainly influenced by the type of migrations associated with Italian age cohorts at the end of the nineteenth century. Here the generations from 1870 to 1890 were particularly affected by labour migration, which generally takes place before the age of 60. Furthermore, as the authors emphasise, return migrations after the age of 60 were exceptional, with most of such returns taking place a short time after the period of emigration (Robine et al. 2006).

In this chapter, we are interested in the survival at old ages of the generations from 1860 to 1905, which reached the age of 60 between 1920 and 1965 and the age

⁶On this see page 11.

⁷Robine, J.-M. et Paccaud, F. 2004. « La démographie des nonagénaires et des centenaires en Suisse », *Cahiers québécois de démographie*, 33(1), p.63.

of 100 between 1960 and 2005. Although it is generally accepted that migration after the age of 80 is negligible, it is worth pausing here to explore the prevalence of migrations between the ages of 60 and 80 in Quebec. Immigration statistics⁸ and the 2006 census⁹ show that the proportion of immigrants entering Quebec who were aged over 60 was 0.31% before 1961 and 1.6% in the period from 1966 to 1975. In terms of Québécois leaving the province after the age of 60, Yolande Lavoie (1972) has estimated that more than 98.5% of emigrants in the period from 1900 to 1930 were aged under 50. As Desrosiers et al. (1976) show, Québécois of this period emigrated mainly for economic reasons. These findings taken together lead us to believe that migration movements after the age of 60 were quite rare in Quebec before the mid-1970s (by which time the generations under study were either extinct or already in old age).

In view of the objective of making international comparisons, and considering the nature of the data to be used, as well as the nature of the migration profile prevailing in Quebec in the first half of the twentieth century, our measure of longevity in Quebec is therefore based on the ratio of centenarians per 10,000 individuals of the same generation at age 60. If we accept that there is a very low level of migration after age 60, the populations making up the numerator and the denominator are relatively similar. In other words, we are assuming that migration flows are negligible between age 60 and age 100. However, it is worth pointing out that the population numbers on January 1st of each year do include immigrants, and that this may have some effect on the ratios of centenarians. In particular, lower ratios could be partly explained by the “healthy immigrant effect”. However, as argued by Bourbeau (2002), the size of this immigrant group is not great enough at advanced ages to account for a Québécois survival advantage, so we can claim that a finding of lower centenarian ratios would reflect a real survival advantage at advanced ages.

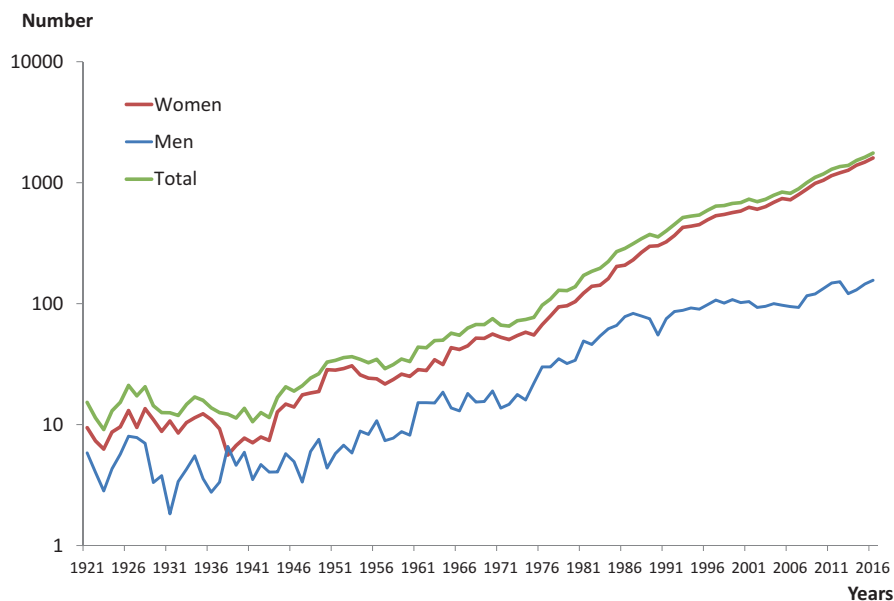
12.4 Results

12.4.1 *Evolution of the Number of Centenarians in Quebec*

The evolution of the number of centenarians in Quebec in the period 1921–2016 is illustrated in Fig. 12.2. The number of centenarians rose only slightly during the two first decades of the study period, both for men and women. The population aged 100 and over amounted to just 15 individuals at the beginning of the 1920s. It took 30 years for this population to double in size. However, from the 1950s onwards, and especially at the beginning of the 1970s, it grew more or less exponentially; in the space of 20 years, between 1971 and 1991, it increased six-fold, from 66 to 399

⁸ *Immigration statistics*, Ministry of Labour and Immigration, Immigration Division, Canada, Ottawa, 1966 to 1996.

⁹ Statistics Canada, 2006 Census, Catalogue No. 97-557-XCB2006023.



Sources: 1921–2012 : Canadian Human Mortality Database (CHMD); 2013–2016: Statistics Canada, population estimates

Fig. 12.2 Evolution in numbers of centenarians (Individuals aged 100 and over) by sex, Quebec, 1921–2016

individuals. At the end of the period, on January 1st 2016, the total number of centenarians stood at 1757. The population aged 100 and over has always been composed of more women than men. In 1921 just under two thirds of centenarians were women, while in 2016 the proportion of women was nearly 90%. Thus, in the course of the twentieth century the growth rate of the numbers of centenarians was higher for women than for men. Until the mid-1990s there was a time lag of about 20 years between the growth curves for the two sexes, with total numbers for male centenarians reaching 10 and 100 approximately 20 years later than for females. Since the beginning of the 1990s, the number of male centenarians appears to be stabilising at around one hundred individuals, although there has been a small increase in this figure in the last years of the study period. Over the period as a whole, the female and the male centenarian populations have multiplied by 170 and by 27 respectively.

The last century has seen not only an explosion in the number of centenarians in Quebec, but also the appearance and growth in the number of semi-supercentenarians (individuals reaching the age of 105) and supercentenarians (those reaching the age of 110). The first semi-supercentenarians are found in the mid-1940s (Fig. 12.3). Their numbers remain relatively stable during the succeeding decades, at around 5 individuals, until the end of the 1970s. This period marks a break in the rate of growth of this particular population; thereafter it multiplies seven-fold in the space of 25 years, to reach 68 individuals in 2012. The number of supercentenarians is,

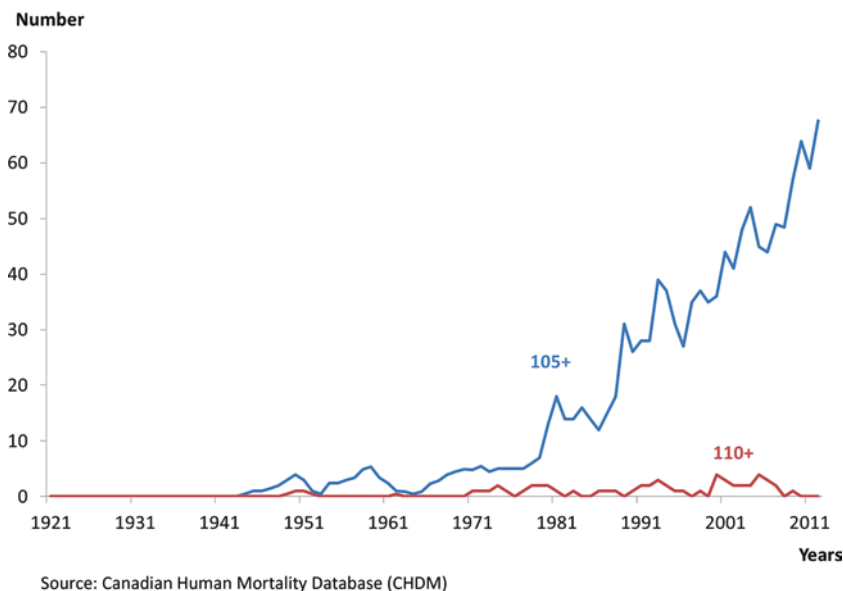


Fig. 12.3 Evolution of numbers of semi-supercentenarians and supercentenarians, Quebec, 1921–2012

naturally, very small throughout the observation period. On the basis of the CHMD population estimates, the 110-year mark was reached for the first time in the 1950s. Although the statistics we have analysed show no increase in numbers, the existence of supercentenarians becomes less exceptional from the 1990s.

12.4.2 Centenarian Ratio

From 1961 to 2011, the ratio of male centenarians rose from 11.6 to 34.7 per 10,000 individuals aged 60 forty years earlier (Table 12.4). This is quite a small increase considering that the ratio of female centenarians multiplied 10 times in 50 years. In 2011 there were 196 women aged 100 per 10,000 women aged 60 forty years earlier. These results are consistent with the probabilities of surviving from 60 to 100 calculated from the *New birth cohort life tables for Canada and Québec, 1801–1991* (Bourbeau et al. 1997).

Our objective was to compare the survival profile at advanced ages in Quebec with those found in other low mortality countries. We therefore estimated the centenarian ratio for seven countries including Canada, using population figures published by the CHMD and HMD (Table 12.5).¹⁰

The centenarian ratio has increased in all the countries considered. But over the period as a whole the increase has been highest in Switzerland, where the ratio has

¹⁰Human Mortality Database.

Table 12.4 Ratio of centenarians per 10,000 individuals aged 60 Forty Years earlier, Quebec, 1961–2011

Year	Men	Women	Total
1961	11.6	19.4	15.5
1971	6.3	29.0	17.4
1981	21.5	55.4	37.9
1991	29.4	104.7	66.6
2001	31.2	147.7	90.3
2011	34.7	196.4	118.3

Source: Canadian Human Mortality Database (CHMD)

Table 12.5 Comparison of centenarian ratio (RC_{60}), selected countries, 1961 to 2011

	Japan	France	Canada	Quebec	USA	Switzerland	UK	Belgium
1961		5.4	24.0	15.5		3.1	8.0 ^a	3.7
1971		11.4	34.0	17.4		7.3	14.7	9.3
1981		22.6	62.8	37.9	59.8	19.9	21.6	13.8
1991	29.2	43.4	99.4	66.6	91.3	35.9	34.6	25.6
2001	81.8	72.0	105.2	90.3	103.8	57.9	48.9	37.7
2011	227.9	135.3	135.0	118.3	111.0	87.4	72.8	63.2

Sources: Human Mortality Database (HMD) and Canadian Human Mortality Database

^aPopulation numbers aged 60 in 1922

multiplied almost 29-fold in the space of 50 years. Although Switzerland is the country which has had the biggest increase over time, it is in Japan, France and Canada that we find the highest centenarian ratios. In the case of Canada, it is possible that the quality of the data at advanced ages may partly explain these results up until 2001. Since 2001, data on centenarians are verified more closely by Statistics Canada.

Until 2001, the centenarian ratio in Quebec was notably higher than in European countries. But in 2011 it was below that of France, at 118 centenarians per 10,000 individuals aged 60 forty years earlier. As shown by Beaudry-Godin (2010), data quality cannot be held responsible for the reduced gap between the indices for Quebec and for countries in Europe. But despite this convergence, the population of Quebec still has a profile which displays certain advantages compared with the majority of European countries.

12.4.3 *Factors Responsible for the Increase in Numbers of Centenarians*

The growth in numbers of centenarians in successive cohorts may be attributed to several main factors such as the increasing size of birth cohorts, migration, and the rising probability of survival from birth to age 100 (Vaupel and Jeune 1995; Thatcher

2001; Robine and Paccaud 2004). To isolate the impact of improved probability of survival to advanced old age on the increase in numbers of centenarians, we distinguished the probability of surviving from birth to age 80 from the probability of surviving from age 80 to age 100. Since Quebec experienced significant migratory movements in the early twentieth century, it is important to take into account this factor that is however difficult to quantify exactly. It is therefore estimated as a residual (Vaupel and Jeune 1995; Thatcher 2001). Thus, the increase in the number of centenarians is decomposed into five multiplicative factors:

- Increase in the size of birth cohorts
- increase in the probability of survival from birth to age 80 for specific cohorts,
- increase in the probability of survival from age 80 to age 100 years for specific cohorts,
- change in the number of persons aged 100 and over relative to the number of persons reaching exact age 100,
- net change due to migration and other factors (errors).

We studied the relative contribution of each of these five factors to the increase in numbers of centenarians for the cohorts from 1881 to 1911.

12.4.4 Increased Cohort Size

The numbers of births by sex were taken from the Canadian census for the 1881 cohort. For the births of the 1911 cohort, we used the estimate proposed by the Institut de la Statistique du Québec. The number of births has increased by about 46% between the two cohorts.

12.4.5 Increase in the Probability of Survival from Birth to Age 100

We calculated the probabilities of survival from birth to age 80 and from age 80 to 100 from the Cohort Life Tables published by Bourbeau et al. (1997) for Canada and Quebec. Mortality during the nineteenth century in Canada and Quebec is poorly known, since the system for registering vital statistics did not begin until 1921 in Canada and 1926 in Quebec. It has been necessary to make up for the lack of data by indirect methods of estimating mortality. Through the “method of lag”, which is original at least in its application (Bourbeau and Légaré 1982), and the use of model life tables, it has been possible to reconstruct a badly known reality.

Between 1881 and 1911, the probability of survival from birth to age 80 for men rose from 0.16 to 0.24, an increase of 48%. For women, the improvement was even more striking, with the probability of surviving from 0 to 80 almost doubling in the

same 30 year period from 0.21 to 0.41. The growth rate in the probability of surviving from age 80 to age 100 is notably higher than for the probability of surviving to age 80, doubling for men and multiplying by 6.7 for women over the space of 30 years.

12.4.6 Population at Age 100 and Over in 1981 and 2011

The number of centenarians in the years 1981 and 2011 were taken from the estimates produced by the CHMD on January 1st. These population estimates are based on the method of extinct generations. Numbers of survivors at the exact age of 100 were obtained by adding the population aged 100 in year x (total numbers on January 1st)¹¹ to the deaths taking place at 100 years of age in the lower Lexis triangle of the year $x-1$. As an example, the survivors aged 100 of the 1881 cohort are the numbers aged 100 on January 1st 1982 with the addition of the deaths of members of this generation taking place at age 100 in 1981.

Table 12.6 shows the respective contribution of each of the factors discussed above to the increase in the number of centenarians. The number of male centenarians has been multiplied by 3.08 and that of females by 9.38 between 1981 and 2011. For men, this increase is due to the increased size of the birth cohorts by a factor of 1.45, of the probability of surviving from birth to age 80 by a factor of 1.48, of the probability of surviving from age 80 to age 100 by a factor of 2.20, and to a small decrease in ratio of the number of centenarians to the number of persons aged 100 (0.89). A residual factor 0.73 corresponds to the net effect of migration and to possible errors in the components. For women, the corresponding growth coefficients are 1.47, 1.95, 6.68, and 1.08. The residual factor is more important in the case of women (0.45). The increase in the numbers of centenarians in Quebec is

Table 12.6 Breakdown of factors responsible for the rise in numbers of centenarians 1981 and 2011, Quebec

Factors	Men	Women	Total
Increase in the number of births between 1881 and 1911	1.45	1.47	1.46
Increase in survival from birth to age 80 in cohorts 1881 to 1911	1.48	1.95	1.75
Increase in survival from age 80 to age 100 in cohorts 1881 to 1911	2.20	6.68	6.25
Variation in the ratio of the number of centenarians (100 and over) to the numbers of persons aged 100 in 1981 and 2011	0.89	1.08	1.07
Net variation due to migration and to other factors	0.73	0.45	0.45
Increase in the number of centenarians between 1981 and 2011	3.08	9.38	7.60

Source: Canadian Human Mortality Database (CHMD); Institut de la statistique du Québec; Cohort Life Tables for Quebec (Bourbeau et al. 1997)

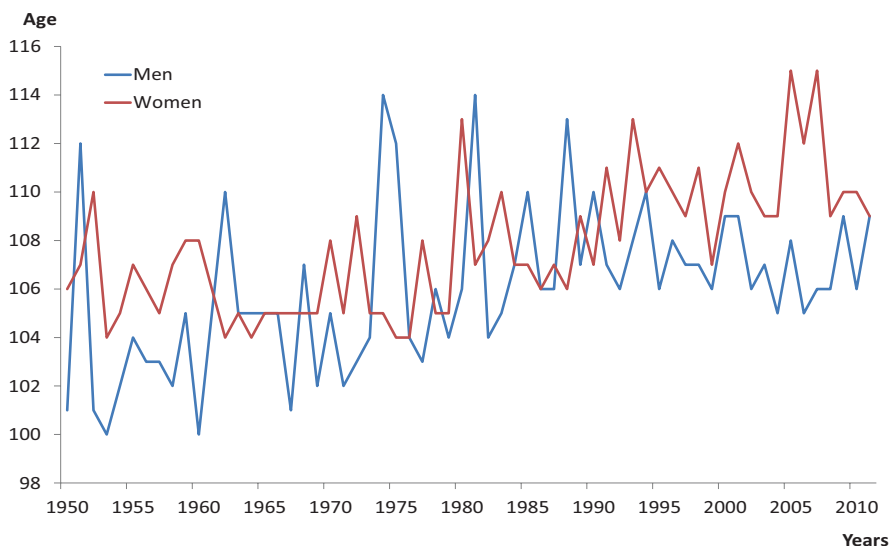
¹¹These population estimates on January 1st published by the CHMD are based on the method of extinct generations.

therefore principally attributable to a higher probability of survival at advanced ages, and this applies both to women and to men.

So far, we have focused on indicators of population longevity. However, it is relevant to extend the analysis to the level of the individual, making use of the maximum age recorded at death, which also provides an insight into progress in survival to advanced ages.

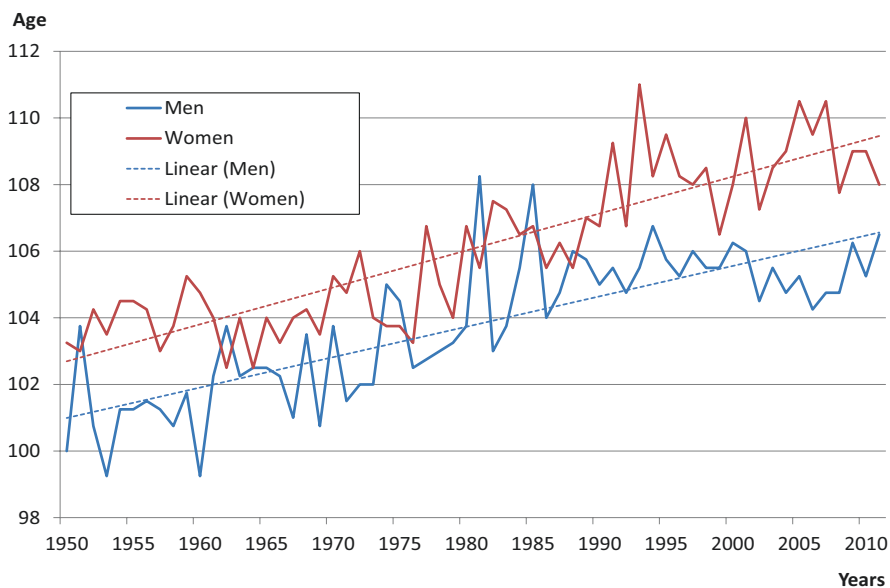
12.4.7 *Maximum Age at Death*

In the case of Quebec, it is difficult to determine a rising trend in the maximum age at death because of significant annual fluctuations (Fig. 12.4). At the most these data enable us to identify supercentenarians, and at the same time to judge the quality of data at advanced ages. Mean highest four ages at death, calculated on the basis of the four highest recorded ages at death, is an indicator which is more representative of the evolution of maximum age at death in the course of the second half of the twentieth century (Fig. 12.5). In Quebec, the increase in mean highest four ages at death has been as great for men as for women. For women, the indicator has been above 106 since the 1980s; for men this level did not become established until the 2000s. Overall there is difference of 2 years between maximum age and mean highest four ages at death.



Source: Canadian Human Mortality Database (CHMD) and Institut de la statistique du Québec (unpublished data)

Fig. 12.4 Evolution of Maximum Age at Death, Quebec, 1950–2011



Source: Canadian Human Mortality Database (CHMD) and Institut de la statistique du Québec (unpublished data)

Fig. 12.5 Evolution of Mean Highest Four Ages at Death, Quebec, 1950–2011

The trends in and the values of maximum age at death recorded in Quebec since the 1950s are comparable to those observed in Japan (Wilmoth and Lundström 1996; Robine and Saito 2003) and in Switzerland (Robine and Paccaud 2004). Robine and Saito (2003) studied the evolution of the maximum age at death and of the 10th highest age at death, to eliminate the distortions caused by age misreporting. In the second half of the twentieth century, the tenth highest age at death rose from 100 to 107 for men and from 102 to 110 for women. The gap between maximum age at death and the tenth highest age at death was 3 years for men and 4 years for women. Instead of analysing the mean maximal age at death or the tenth highest age at death, Robine and Paccaud (2004) made a quadratic adjustment of the values associated with maximum age at death to identify clear trends. In these terms, the “adjusted” maximum age at death rose from 101 to 107 for men and from 103 to 109 for women between 1950 and 2011. In the same way as we observe in the case of Quebec, the maximum age at death in Japan and Switzerland also rose steadily throughout the second half of the twentieth century.

12.4.8 *Projection of the Centenarian Population*

According to the population projections of the Institut de la Statistique du Québec (2014), the growth of the population of centenarians which has been observed since the 1950s is set to continue through the first half of the twenty-first century (Fig.

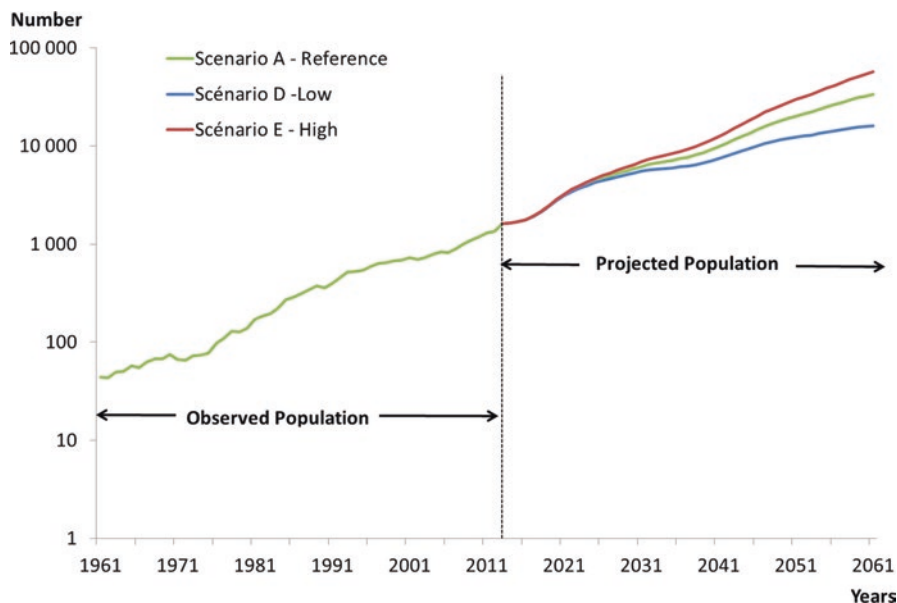


Fig. 12.6 Observed and projected centenarian population, three forecast scenarios, Quebec, 1961–2061. (Source: Canadian Human Mortality Database (CHMD) et Institut de la statistique du Québec, Perspectives démographiques du Québec et des régions. 2011-2061.)

12.6). The scale of this increase in numbers is however mainly attributable to future trends in mortality, because the centenarians of 2061 are those aged 50 and over in 2011. According to the baseline scenario, life expectancy for men will rise from 79.7 to 87.8, and for women from 83.8 to 90.1 by 2061. In the lower and higher scenarios, life expectancy for men in 2061 will be 83.9 and 91.0 respectively. For women, the equivalent values will be 86.7 and 92.6 years. Considering all the hypotheses relating to the baseline scenario, the population of centenarians will multiply by 26 by 2061, rising from 1292 to over 33,600 between 2011 and 2061. In the low and high scenarios, the number of centenarians will multiply by 12 and by 44 respectively. So, the centenarian population is predicted to increase very strongly in the first half of the twenty-first century in all the projection scenarios.

12.5 Conclusion

All the indicators analysed in this study concur in showing clearly a major increase in the numbers of centenarians during the twentieth century, and especially since the 1950s. The total numbers of centenarians, the centenarian ratio, the probabilities of surviving and the maximum age at death have all seen significant growth during this period. However, it is important to note the differences in the trends for the two sexes. While the numbers of women centenarians have increased constantly over the second half of the twentieth century, the numbers of men increased at first and then

stabilised during the 1990s. The rising trend for men does however seem to have been re-established since 2000, according to the most recent figures available.

As a conclusion to our analysis we can state that the increase in the probabilities of survival at advanced ages, particularly between 80 and 100, has been the main determinant of the rising numbers of centenarians since the 1970s. In view of medical and technological advances in recent decades, this factor can be expected to continue to play a preponderant role in the future increase in numbers of individuals aged 100 or more.

The findings relating to the ratio of centenarians per 10,000 individuals aged 60 forty years earlier do not justify us in concluding that populations in North America enjoy a survival advantage. On the one hand, Japan has centenarian ratios which are markedly higher than those recorded for Canada and the USA. On the other hand, there is also room to question the quality of the data on advanced ages in these two countries. Our analysis may, at the most, support a suggestion that there is a survival advantage for the North American countries compared with European countries – an advantage which, in the light of recent trends, may be expected to diminish over the coming decades.

Projections of the centenarian population demonstrate the importance of engaging in research targeting those aged 100 and over. Given that this population will occupy an increasingly large place in our societies, it is becoming correspondingly more important to understand their socio-demographic characteristics and behaviours. The information we currently have about their health, marital status, economic situation, level of education etc. is fragmentary, but such knowledge is vital to be able to develop social and economic measures which are appropriate and effective in the context of an aging society.

The growth in the number of centenarians will also have an impact on the maximum reported ages at death. The more centenarians there are, the greater the probability of new records being established in terms of survival to extreme ages. It would not be a surprise if the 115-year lifespan of Julie Winnifred Bertrand was to be surpassed in the records of longevity in Quebec during the twenty-first century.

Appendix

Comparison of Population Numbers of Individuals Aged 90 and Over According to 3 Data Sources, Quebec, 1881 à 2011

Years	Males		Females			
	Census data	Statistics Canada estimates	CHMD estimates ¹	Census data	Statistics Canada estimates	CHMD estimates ¹
1881	467			517		
1891	562			617		
1901	502			594		
1911	540			674		

(continued)

Years	Males		Females			
	Census data	Statistics Canada estimates	CHMD estimates ¹	Census data	Statistics Canada estimates	CHMD estimates ¹
1921	565		461	699		704
1931	616		589	811		829
1941	704		767	1088		1148
1951	1041		1010	1614		1617
1956	1202		1131	1879		1927
1961	1371		1359	2209		2332
1966	1829		1823	2895		3007
1971	2375	2428	2158	4005	4091	3709
1976	3055	3163	2488	5665	5773	4863
1981	3255	3296	3150	7295	7417	7077
1986	3975	4017	3893	10,235	10,470	10,027
1991	5055	5155	4424	14,250	14,515	13,616
1996	5450	5587	5424	18,305	18,601	18,214
2001	6845	6325	6545	23,435	22,635	23,153
2006	9480	7598	8434	30,950	27,968	29,466
2011	12,055	11,744 ^a	11,915	38,570	38,232 ^a	38,381

¹Estimates at July 1st based on extinct generations method and survival rates method

^aDefinitive post-census estimate

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