

**Dealing with Problems in Data Quality for the
Measurement of Mortality at Advanced Ages in Canada**

By

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ABSTRACT

The level and age trajectory of mortality at advanced ages in Canada are not readily and exactly obtained, because of problems with the reliability of data on deaths and on population counts beyond a certain point in the official statistics. There are ways to assure nonetheless the termination of the life tables. One consists in finding ways to validate a sufficient number of unbiased high ages at death to produce an accurate measure with the extinct, or almost extinct, generation method. Another is to establish convincing evidence as to the pattern of survival at the very high ages; mathematical techniques can then be used to generate the rates as an extension of mortality at ages 70 to 90 or 100. Our paper deals with both of these solutions in the Canadian context.

The extinct generation method was used to produce new estimations of Canadian mortality which from our evaluation are quite reliable for ages 80 to 99 but suspect for centenarians. A systematic examination of the quality of age at death information for centenarians in Canada was thus undertaken. In a first stage, a sample of deaths of French-Canadians in the Province of Quebec were verified for accuracy in age declaration by matching birth and death registration on the basis of names; this was possible because of the availability of comprehensive parish registration of vital events in Quebec. Our study showed ages at deaths of the native-born were accurate. Making the reasonable assumption this result will characterise the other provinces of Canada, we present mortality measures based on native-born death registration. A preliminary estimate of the centenarian mortality of cohorts of

Canadian-born individuals seems to lend credence to a leveling off of mortality rates at the highest ages for females.

As for patterns of survival at the very high ages, we tried to get some help from the past. These same parish registers were used in a major research project to establish a computerized data base giving the basic demographic parameters of the French-Canadian population from its origins. From these data was derived a comprehensive longitudinal observation of the adult mortality of an entire population, an exceptional source of information indeed. Specifically, we have at our disposal a reliable measure of the mortality of 3697 men and 4386 women who married hundreds of years ago; notwithstanding the major differences in the mortality regimes of the two periods, the ones who reached very old ages in the past form a selected group which can be assimilated to those who are dying beyond age 90 today. Their experience may then be useful when choosing a pattern for contemporary survival at the highest ages. Contrary to what might have been expected, the progression of mortality remains pretty much exponential until are reached the unavoidable erratic values corresponding to the few extreme observations. This entails that whatever the nature of the selections which would produce a slowing down of the rate of increase of the rates at the highest ages, they did not express themselves conclusively a few centuries ago.

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INTRODUCTION

The difficulty of measuring mortality at the highest ages as the number of observations dwindles is enhanced by frequent problems with the reliability of both the data on deaths and the number of persons at risk in the official statistics. There are basically two ways to assure nonetheless satisfactory termination of the life tables. One consists in working to improve the quality of observation, another is to use mathematical techniques to generate the rates as an extension of mortality at ages 70 to 90 or 100. Our paper deals with both of these aspects in the Canadian context.

CANADIAN MORTALITY AT THE HIGHEST AGES FROM THE OFFICIAL STATISTICS

The most recent period life tables published by Statistics Canada (1995), as well as cohort life tables estimated by Bourbeau and al. (1997), relied on an estimation of mortality from age 90 obtained by graduation and extrapolation methods. The choice of age 90 to replace observation by mathematics certainly has a somewhat arbitrary component but the fact is Canadian statistics have been the object of persistent doubts about the reliability of both population counts and ages at death when they relate to the oldest segments of the population (Kannisto, 1994).

In an earlier study (Bourbeau and Lebel, 2000), it was confirmed these doubts were legitimate for the 1951-1995 period, using indicators suggested by Coale and Kisker (1990), and Kannisto (1988). Compared to countries presumed to have high quality data, the maximum ages at death in Canada were too high, as were also the proportion of centenarians in the population (106 per million compared to an expected 60 to 70) and the ratio of deaths at 105 and over to deaths at 100 and over (near 8% instead of the "usual" 4 or 5%). Although the problem seemed to decrease somewhat from the 1980s, it remained that the censuses might not enumerate the very old correctly and that ages at death in the statistics were suspect from age 100.

The "extinct generation" method, which relies exclusively on death registration (Vincent, 1951), can be used to construct life tables without having to worry about the quality of the census coverage of the very old. It was used to estimate the mortality of the oldest-old (over the 85 to 109 age range), for the 1870-1884 Canadian birth cohorts of each sex.

The oldest-old mortality rates of the 1870-1879 birth cohorts show a slowing down in the age-associated increase in mortality for both sexes, with some evidence, based of course on a limited number of observations, of a leveling-off of the death rate itself at the upper-most ages (Figure 1). The curves can be fitted over the age span both by a logistic and a quadratic function. These results would seem to confirm results observed or suggested from data in other countries (Manton and Vaupel, 1995; Horiuchi and Wilmoth, 1998; Thatcher and al., 1998).

(Figure 1)

However, things are not so conclusive for the 1880-1884 birth cohorts (Figure 2). Indeed, the slowing down in the rate of increase of the rates appears to be less pronounced, to the point the curves are best fitted over the 85 to 109 age range by a simple exponential.

(Figure 2)

These seemingly puzzling results are put in the proper perspective when the curves for the two series of birth cohorts are compared for each sex (Figure 3). Clearly, when reaching age 100, mortality no longer reflects its decline over time, to the point there are some crossovers in the rates. These patterns are consistent with an underestimation, declining through time, of the mortality of the most aged. Most probably, ages at death of the extremely aged contain some proportion that are exaggerated, yielding an underestimation of mortality from around age 100. It must be remembered, although they are free from errors in population counts at old ages, estimations of mortality with the extinct generation method still depend on the quality of age at death declarations in vital statistics, which from our own evaluation are suspect for centenarians.

(Figure 3)

To try to eliminate this stumbling block for the direct observation of Canadian mortality of the oldest-old, it appeared a systematic verification of the accurateness of centenarian age at death data in Canada was in order.

VERIFYING THE QUALITY OF EXTREME AGE AT DEATH INFORMATION IN CANADA

Canada is a federation created in 1867 by an initial group of four provinces to which six others were since added, the last as late as 1949. Under the constitution where are defined the responsibilities of each order of government, all aspects of vital events registration fall to the individual provinces, who handle the initial collecting and processing of data. Although gathered by the central government since the 1920s and the object of standardization efforts as to content and procedures, the information is thus reliant on ten different administrations, each with their own history, traditions, set of rules and methods, varying over time of course.

This has an impact on the quality of extreme age at death information in Canada both through registration of births a century ago and registration of deaths today. In the early days of government registration of births, marriages and deaths, not all events were reported and recorded. Many people and local institutions were often suspicious of why the government wanted such information and refused to comply; in Ontario, Canada's most populous province, for example, it has been estimated that birth registration was only two-thirds complete for the 1875-1895 time period and no more than 85% complete for any of the next 25 years (Emery, 1993). Added

to the pioneer character of many areas of the country at the turn of the XXth century, this entails that a significant number of people born in Canada and dying at very high ages today could be without documentary evidence of their date of birth. This problem is enhanced by the fact Canada having always been a country of immigration, a non negligible part of its population was born outside the country. Conditions of immigration varied greatly over time and space but there is no doubt many were apt to produce situations where exact date of birth might be impossible to assert.

As for contemporary death registration, practices vary greatly across the recent decades and the different provinces. Modern records tend to give quite complete information; but even when a new requirement was made for additional information to be recorded, it often took many years for the new forms to reach all offices and agencies and to be implemented systematically across the country. Provincial data collection agencies were slow to adopt (costly) controls at the time of data entry; as recently as 15 years ago, for example, the death of a 10 year old in Quebec could be registered as the death of a 110 year old by typing his birth date in the 1800s instead of the 1900s, without any further ado.

Unreliable extreme age at death information is thus a clear possibility in the Canadian context. As awareness has finally reached the administrations, some efforts have been made to implement quality control methods and to cross-check information relating to extreme age declarations for example, but a lot remains to be done. And the impact of the relatively late implementation of systematic birth

registration in Canada will go away only as time passes. Church registration of births can be counted on to compensate to a certain degree, but here again quality and coverage vary greatly, according to religious denomination, territory and period.

The Province of Quebec represents here the very fortunate exception. The very first missionaries from France implemented comprehensive registration of baptisms, marriages and burials in the catholic tradition of their home country. Better still, the authorities prescribed in 1679 this registration would be done in two copies, the second one being turned over to the government as civil registration of these events, a system which was maintained without interruption for centuries. Their society being homogeneously catholic, French-Canadians of Quebec have thus benefited from long-standing quality civil registration. These records were never used as such by the authorities to produce statistics of ages at death for example, with the exception of records for the city of Quebec used as a historical sample in the 1871 census of Canada (Census, 1871). But through the linking of the baptism and burial certificates of individuals, they have allowed fascinating advances in data quality evaluation and the exact calculation of the mortality of the historical population of Quebec (Charbonneau et Desjardins, 1990; Desjardins, 1999).

Although their use is much more difficult for more recent times, given the lack of a comprehensive index of births and limits imposed by protection of privacy laws, parish registers still offer a privileged source of information to estimate the quality of age at death declarations in Quebec. Hubert Charbonneau showed the way with a verification of an investigation on centenarianism published along with the results of

the 1871 census of Canada, which reduced a list of 9 deaths of centenarians authenticated by the Chief Statistician of the country to one, most notably invalidating the long standing myth that a man born in 1701 had reached the age of 113 (Charbonneau, 1991). More recently, parish registers were used to verify deaths of super-centenarians - 110 years and over - in Quebec, within an international effort to accumulate validated cases of extreme ages at death ascertained without bias (Bourbeau and Desjardins, 2000). Of 10 such ages at death officially registered for French-Canadians of Quebec since 1975, only four proved to be authentic. Not surprisingly, they were among the most recent declarations, the first real super-centenarian having died in 1983. The data since 1980 contained only one false super-centenarian, probably because of better controls when collecting and processing age information by the Quebec statistical office.

Following this first experience with parish registers to verify the accuracy of official statistics, the study was extended to deaths registered in the 100-109 age group in Quebec as a first step leading towards a comprehensive investigation of extreme age at death registration in Canada.

Verification of the Validity of Reported Centenarian Deaths in Quebec

Age at death is obtained from the difference between date of death and date of birth as written on the person's death certificate. The principle behind using parish registers to validate that age is to find the baptism of the person, that is to perform

a linking of two documents recorded a century apart, basically on the basis of the person's name.

Nominative information in administrative documents is kept out of the public domain for one hundred years in Quebec, but can be obtained for research purposes through a specific permission, given by a commission set up by the government to monitor access to official documents, within a strict protocol governing use and publication of the data. For technical reasons due to differences in computerization protocols through time, it was only possible in this first stage to obtain data from 1985 on, which was ample to establish the feasibility of the project and obtain basic information on data quality.

Of the 754 632 deaths registered in Quebec for the 1985-1999 period, 3031 (0,4%) are of people alleged to be 100 years old or over; they were made available in a file containing for each case: first and family names of the deceased, sex, date of birth, date of death, age at death, place of birth (province in Canada or country), first and last name of the father and of the mother and family name of the spouse for those who were once married. Males form 21% of the total and died 0,2 year younger than females on the average (Table 1); super-centenarians represent 0,46% of deaths of centenarians. Kannisto (1988) suggested a sign of problems in age declarations could be inferred from a ratio of deaths at age 105 and over within deaths of centenarians greater than 5 % ; here the ratio is at 7% for males and 8,4% for females. Preliminary examination of the data thus pointed to some problems for Quebec, in the order of those for the whole of Canada.

(Table 1)

Given the nature of the validation to be performed, it was necessary to distinguish outright within the data set the deaths of persons who were born outside Quebec. They represent about one out of five cases and as can be seen in Table 2, the group shows some slight differences as to average age at death and proportion of deaths at 105+ when compared with the Quebec born; it is also interesting to note they number nine of the 14 super-centenarians in the file.

(Table 2)

Of course, this comes as no surprise. 80% of those born outside Quebec are from another country, and one would expect that for different countries of origin and periods of immigration problems could be present in birth information. If up to the 1970s immigrants predominately originated from European countries - the United Kingdom, southern Italy, France, Greece and Poland for example - , the more recent arrivals are much more diversified, including the West Indies and countries of Asia previously absent, and they already begin to show up in the extremely aged group . This raises the question of heterogeneity in the cases recorded in national statistics, a problem certainly to be addressed in the whole question of quality of age declarations at extreme ages for a given country.

Notwithstanding, the 105+/100+ proportion remains high even for the 2280 cases born in Quebec, meaning quality of the ages could still present a problem. A sample was thus established containing all deaths at ages 107 and over, half of the deaths at age 106, a quarter of the deaths at age 105, 10% of deaths at ages 102 to 104, and 5% of deaths at 100 and 101, for a total of 209 cases, 41 males and 168 females, distributed over the entire 1985-1999 time period. Using the wealth of information available, quite satisfactory results were obtained; the important issue was to make sure the unsolved cases were not selected as to having a greater risk of being incorrect than the others, and great pains were taken in this respect.

Overall, only 4 cases proved to be erroneous . As could be expected, they pertained to very high ages: one super-centenarian and three 107 year olds. Three of them were really 10 years younger but an alleged 107 year old was actually 108 years old! These errors represent 2% of the cases that were examined, but 5% of those at 105+. Thus, after careful examination of the results of the operation, we feel it can safely be said that age at death information for centenarians since 1985 in Quebec is accurate for people born in Quebec, with a caveat to be expressed at the highest ages for which a systematic verification should probably always be performed (Bourbeau and Desjardins, forthcoming).

This positive assessment would seem to be contradicted by the relatively high proportion of deaths at 105 and over among the centenarian deaths. However, this proportion is lower than in Canada as a whole, and is comparable to the proportion among Whites in the United States, for which a recent record linkage study has

concluded age at death on death certificates are of high enough quality to produce a reliable measure of mortality at very old ages (Hill et al. 2000). This higher proportion of deaths at ages 105 + may then be an indication of a lower mortality among centenarians in North America. Furthermore, the ratio of deaths of women to those of men, at 3,7 for people born in Quebec, is similar to the ratio for France, Japan, and England and Wales, another sign of the reliability of the Quebec data. This ratio is lower in the Nordic countries (at about 2), but this could be specific to the region.

If the results found in Quebec can be extended to the other provinces of Canada, ages at death of the very old born in Canada in the later stages of the XIXth century can be considered reliable and used to estimate mortality at the highest ages.

A PRELIMINARY ESTIMATION OF CENTENARIAN MORTALITY IN CANADA

The necessity of knowing the place of birth of the deceased placed an extra burden on the statistical offices, and it was only possible at this time to obtain Canadian-born centenarian death information for the years 1990 to 1997. This limited the scope of the extinct generation method but, accepting some estimations at the most extreme ages, it was possible to make a preliminary estimate of the centenarian mortality of the cohorts of Canadian-born individuals presented in Figure 4, which seems to lend credence to a leveling off of mortality rates at the highest ages for females. As we feel it is most important to bring an observation based measure of mortality to the highest ages possible, we intend to pursue our efforts with the

statistical offices to obtain precisely defined bias free data sets of ages at death in Canada. For the time being, official statistics are not to be counted on to provide a conclusive picture of patterns of mortality at the highest ages in Canada.

(Figure 4)

THE PATTERN OF SURVIVAL AT VERY HIGH AGES IN AN HISTORICAL POPULATION

When using mathematical techniques to generate mortality rates for advanced ages as an extension of earlier mortality, one has to make an assumption about the pattern of survival beyond the last observation point. Because of the lack of reliable observation at the highest ages, there is no consensus as to this pattern: do rates increase exponentially with age, do they increase at a decreasing rate, do they level off or even do they decrease at some point, as some have pleaded? To better our knowledge of these still elusive patterns, we tried to obtain some help from the past.

Given the extraordinary set of conditions we mentioned earlier, Quebec parish registers were used in a major research project to establish a computerized data base giving the basic demographic parameters of the French-Canadian population from its origins (Légaré, 1988). From these data was derived a longitudinal observation of the adult mortality of an entire population, an exceptional source of information indeed. Specifically, we have at our disposal a measure of the mortality of the 3697 men and 4386 women, born between 1680 and 1704 in Quebec, who

married. This measure was established using the extinct generation method; it thus rests on ages at death only, which were established with absolute certainty by matching the date of each death registration with the birth date of the person, identified unambiguously on the basis of its name and the name of its parents and spouse. Migration, usually the major problem for mortality measures of this type, is not a factor in the present case, as the geographical, historical and social context confined the great majority of colonists to the St-Lawrence valley.

Of course, the demographic parameters of the 18th century Quebec population varied greatly from those of today (Charbonneau et al., 2000). Mortality was obviously higher at all ages, but more importantly, it had a much different profile: infant and maternal mortality were very severe, while male mortality in the 20s did not stand out as it does today. Women lived under natural fertility conditions, meaning they accumulated a high number of pregnancies which could be expected to have effects in the later stages of life, either through selection or depletion. Notwithstanding, those who reached the highest ages formed a selected group of survivors whose mortality pattern could very well furnish an insight on the mortality of the longer lived of today. In the historical context, it seems appropriate here to focus on the period from age 50, which marks the end of the childbearing period. Life expectancy at that point was 19,3 years for the men and 20,6 years for the women, with maximum age at death at 95 and 97 respectively. The q_x values for each sex are given in Figure 5.

(Figure 5)

More interesting for us here is the mortality of the very old. Using the 1891 birth cohort life table (Bourbeau et al., 1997), it is possible to relate the historical population to the very old in the Canadian death statistics of the 1980s and 1990s. The life expectancy at age 50 is 24,3 years for males and 28,6 years for females of the 1891 birth cohort, reflecting both the fall of mortality and the emergence of a large mortality gap between the sexes in the 20th century. The 85+ represent about 25% of those who reached their fifties from the 1891 birth cohort; this proportion is found in the 75-79 age group in the historical population, so we considered the mortality from age 75 as relating to that selected proportion of people from the past who constitute the very old (Figure 6).

(Figure 6)

Contrary to what might have been expected, the progression of mortality remains pretty much exponential, until are reached the unavoidable erratic values corresponding to the few extreme observations. This entails that whatever the nature of the selections which would produce a slowing down of the rate of increase of the rates at the highest ages, they did not express themselves conclusively a few centuries ago. The lesson of the past, if it is in any way applicable to the contemporary, is that the forces of mortality continue to increase exponentially with age until the most extreme ages; there are no clear signs of deceleration in the progression of mortality. In the table calculated here on rigorously exact ages, the

highest probability of dying before the next anniversary which rests on a minimum of 10 survivors is in the 0.5 – 0.6 range for each sex.

CONCLUSION

Whatever the method used to generate mortality rates for advanced ages as extensions of patterns of mortality rates at younger ages, it is clearly advisable to extend to the highest ages possible the exact measure of mortality based on bias free observations. Of course this is easier said than done, as problems in official statistics are always present and their effects are compounded as one approaches the higher limits of human life. The Canadian situation is a case in point, and the patterns of mortality of the very old have proven to be very elusive. Another problem for Canada is the fact that a fraction of deaths at very old ages belong to foreign-born, whose ages are impossible to verify. Nevertheless, we are committed to pursuing our efforts to establish secure measurements up into the domain of the centenarians and reduce the uncertainty and the arbitrary in the production of the rates of the very old.

Of course, there will always remain a number of very high ages where the small number of observations will preclude a direct measure of mortality. Our efforts, including a look into the past, have not permitted to this day to affirm conclusively that a plateau is necessarily reached before these ages where observations are too few to be used statistically. In fact, one is brought to wonder if it does not become meaningless to establish yearly probabilities of dying which would relate to a handful

of survivors to a given age. Does it really make any sense to say that Jeanne Calment had the same or a higher or a lower risk of dying at age 121 than at age 118? Maybe the time has come to seriously discuss the principles themselves used in "closing" the life table...

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Table 1. Recorded deaths of centenarians by sex and year of age, Quebec, 1985-1999

Age	Males	Females	Total
100	253	838	1091
101	168	586	754
102	97	367	464
103	53	227	280
104	30	167	197
105	17	100	117
106	14	42	56
107	7	29	36
108	2	10	12
109	1	9	10
110	3	4	7
111	0	5	5
112	0	0	0
113	1	1	2
Total	646	2385	3031
Avg. age	101,9	102,1	102,1
D(105+)/ D(100+)	7.0%	8.4%	8.1%

Table 2. Average age at death of centenarians and proportion of deaths at 105+ according to place of birth and sex, Quebec, 1985-1999

Place of birth	Sex	N	Avg. age at death (in years)	D(105+)/D(100+) (in %)
Born in Quebec	M	480	101,88	6,7%
	F	1800	102,08	7,8%
	T	2280	102,03	7,5%
Born outside Quebec	M	139	102,19	10,5%
	F	487	102,32	9,4%
	T	626	102,27	10,2%

Note: for 125 cases, it was not possible to ascertain if the person was born in Quebec or not. Their average age at death and proportion of 105+ is in between the two above groups in every category.