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Mortality Statistics for the Oldest-Old: An Evaluation of Canadian Data

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Abstract

The main purposes of this paper is to evaluate the quality of Canadian data among the oldest-old (80+) over the 1951-1995 period, and to compare estimations of Canadian probabilities of death based on the extinct generation method with those of other developed countries in order to ascertain whether Canada experiences a distinct low mortality profile. The evaluation of the data quality suggests that Canadian data are quite good up to the age of 100, and that the main problems concern the centenarians (overstatement of age at death and errors in census age declarations). International comparisons on the basis of two mortality indicators for the 80-99 age-interval lead to the same conclusion: Canadian mortality is lower than in most European countries. The best match is still with the United States.

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1 Background

In Canada, as in many other industrialised countries, half of all female deaths and a third of male deaths occur at advanced ages (80 years and over) [35]. The evolution of this phenomenon thus plays a significant role with respect to increases in life expectancy and the intensity of population aging. Our paper stems from the wider debate regarding the possible limits of human longevity and the evolution of mortality among the oldest-old [36] [37].

For a number of reasons, certain researchers are doubtful that survival probabilities at advanced ages can go on rising and expect life expectancy at birth to reach a ceiling at 85 years. They consider death over the age of eighty to be an inevitable, and natural, consequence of the aging process [4] [13] [14] [31] [32]. More optimistic writers have demonstrated, using simulation techniques, that life expectancy at birth could reach much higher levels; a mortality reduction of 2% at all ages over a long period of time would lead to a life expectancy at birth of 100 years for women and of 95 years for men [1]. This optimism is shared by other researchers who speculate that risk factors could gradually be eliminated by adopting more healthy lifestyles and by advances in medical biotechnology [28] [40].

Their hypotheses were not necessarily based on observed data due to imperfections in mortality statistics at advanced ages. These shortcomings have been partly overcome by researchers at the University of Odense (Denmark), who created a large database of mortality statistics at advanced ages from thirty-one countries known to have reliable data (Kannisto-Thatcher Oldest-Old Database); nonetheless, even in this sample of developed countries with fairly low levels of general mortality, data quality was relatively variable. In their study, still quoted in recent papers (such as [39]), Canadian and American data were classified as being of inferior quality, both in terms of their availability, and because of false declarations of age – in death registration and in census data [20] [21]. We must add that for Canada, the data used in the European study were limited to those published (data with an open age group at 90+, for example), which did not give the real picture in terms of quality of data and measurement of mortality. For this paper, we have obtained more detailed data that will permit a better assessment of data quality.

Other groups of researchers closely examined data on mortality at advanced ages from countries with reliable data sources, though with particular reference to the United States [7] [8] [9] [23] [24] [42]. These researchers established the following results:

- Mortality at advanced ages has decreased since the beginning of the century, and most notably since 1950 [21].

For the majority of countries investigated, i.e. countries with high quality data, mortality rates at 80-99 years fell dramatically between 1960 and 1980. The annual improvement in mortality levels was more pronounced for the female population than for males, between 1 and 2%, and 0.5 and 1.5%, respectively.

- The rate of increase of mortality above age 80 declines with age [7] [18] [19].
- Mortality rates among the oldest-old are often understated in countries where death registration is imprecise and, in general, these age-at-death errors explain a large part of the mortality crossover [7].

In other respects, studies of North American data show that the United States has lower mortality levels than those of most European nations. The reason for this is not obvious, though three possible sources are worthy of mention: the inferior quality of the data [7] [8] [12]; the greater homogeneity of the elderly population in the USA with respect to health status [7] [17]; and a relative advantage for the elderly in terms of income, education and health-care [2] [17].

These studies have led to the introduction of the idea of a “North American profile”, specific to the mortality patterns of the oldest-old. Canada has been assimilated into this profile without any real knowledge of the Canadian situation. However, a study has demonstrated that Canadian data had errors of age declaration similar to those of other English-speaking nations (United Kingdom, Australia and New-Zealand) [9].

In fact, the Canadian life tables are the source of almost all we know about Canadian mortality at advanced ages [3]. But do these life tables reflect accurately the mortality of the oldest-old in Canada? Figure 1 shows the probabilities of dying (q_x) for men and women between age 80 until the end of the life table for each census year from 1951 to 1991 (Canadian Life Tables). First, it is clear that probabilities of dying at advanced ages rise smoothly with age; this is not surprising since they are produced by graduation methods that generate very smooth curves. According to Canadian life tables, mortality seems to have decreased since 1951, although there are some crossovers explained by changes in the method of estimation employed (as in 1980-1982) which may produce fairly surprising results. These probabilities of dying, however, cannot be compared to data from other countries since the methods are not the same. We propose, therefore, to apply the method of extinct generations to Canadian data in order to reconstitute a population that will provide us with a more precise denominator for calculating probabilities of death at old and extreme ages.

FIGURE 1

In this paper, our aim is to assess the Canadian situation, by evaluating the quality of mortality and population statistics, by estimating mortality levels with the aid of methods employed by Kannisto [21] (Kannisto-Thatcher Oldest-Old Database) and by Wilmoth [43] (Berkeley Mortality Database), and by clarifying the debate on the existence or otherwise of a North-American mortality profile [Note 1].

More precisely, we will try to answer the following questions: Are Canadian data really bad in measuring oldest-old mortality? And is Kannisto [20] right about the quality of Canadian data? We will use some indicators suggested by Coale and Kisker [8] and by Kannisto [22] to evaluate the quality of data in Canada, using more detailed data. If the various indicators show the same problems as previously found in other studies, it will confirm the bad quality of Canadian data. If not, we will get a better estimation of Canadian mortality among the oldest-old.

2 Data: Population and Deaths

Quantitative data for our analysis is mainly derived from two sources from Statistics Canada [33]: the Canadian Censuses provide population counts by sex and age and the Annual Vital Statistics provide deaths by sex, age, and year of birth.

2.1 Population

We obtained unpublished population data from the Canadian censuses from 1971 to 1991, with details on population up to 121 years old by single year of age and sex, against which to evaluate and compare our estimated population. On the whole, Statistics Canada's published population counts are of a high quality. When it comes to the elderly and very elderly population, however, certain problems of coverage and of age and birth date declarations emerge. We will broach these problems in detail in the course of our presentation of results.

2.2 Deaths

Data on deaths were obtained from the Health Statistics Division of Statistics Canada for the calendar years 1951 to 1995 by sex, single year of age (up to 119 years old), and year of birth. Deaths are organized by individual triangles of the Lexis diagram. This classification of deaths is essential when applying Vincent's method of extinct generations [38] to the reconstitution of the population at advanced ages. It is generally recognized that the quality of vital statistics declarations of deaths at advanced ages is superior to that of census declarations. Nevertheless, registration of deaths can suffer from the overestimation of age at death, and from age and generation heaping. Moreover, men have a greater tendency than women to overestimate their age [22]. Overestimating age at death leads to an underestimation of mortality at advanced ages. As numbers of individuals decrease rapidly at extreme ages, this overestimation has a more marked effect, exaggerating the size of the denominator used to calculate mortality rates [7].

To give an idea of the importance of the oldest-old in Canada, there were 2.12 millions deaths of persons aged 80 and over, between 1951 and 1995. More women than men died at these old ages: 1 171 707 women (55%) and 947 453 men (45%). Among deaths over the age of 80, 81% of men were aged between 80 and 89 compared to 72 % for women. Deaths of centenarians were 5 471 for men and 16 010 for women and for the super-centenarians (110 +), we count 29 male deaths and 65 female deaths.

3 Method

3.1 Method of Extinct Generations

An important part of our paper thus consists of evaluating the quality of Canadian mortality data for those aged 80 years and over. Drawing on mortality statistics, which generally offer greater coverage, we reconstitute the population with the help of the method of extinct generations [6] [38]. This method has been used by many researchers to study mortality at age 80 and above and is useful to estimate the population at advanced ages using only mortality statistics classified by year of birth and age at death. The principle of the method is very simple; when a cohort has died out, its size for any past year (and, consequently, at any given age) is simply calculated by summing the deaths, beginning with the oldest. Obviously, this method assumes the absence of international migration - a safe assumption at these extreme ages.

Although the extinct generation method can account for the problem of age misreporting in census data, there are still problems of age misreporting at death in vital statistics, mainly net age overstatement in particular at very old ages (100 and over). Depending on the degree of error, this problem may affect estimates of mortality at older ages. In a recent paper, Preston et al. [30] have examined this problem and have shown that the extinct generation method, as well as four other methods, produce the same effect on mortality, a downward bias. However, the degree of error related to the patterns of age misreporting chosen in that study (pattern for African American decedents) was quite extreme, which is not the case for Canada. In fact, the Canadian situation is more comparable to that of white Americans for which the quality of data is sufficiently high that extinct generation methods of estimating mortality produce reliable results [16] [17] [29].

These considerations suggest that the extinct generation method is a sound method to estimate mortality for the oldest-old in Canada. Another consideration is a matter of consistency, since the purpose of our study is to compare mortality of oldest-old in Canada to results from other studies where the extinct generation method has been used.

Graduation methods are not necessary in the context of our study, though they are still very useful. In fact, official life tables (like the Canadian or the U.S. Life Tables) will always require some graduation because of small numbers of deaths at very old ages (above 100 years old).

3.2 Estimating the Deaths of Non Extinct Generations: The Survival Ratio Method

One drawback of the method of extinct generations is the need to wait until all members of the same cohort have died before being able to fully estimate the population at a given age. However, the Survival Ratio method can be used to estimate population figures for non-extinct cohorts at a given moment in time [20] [34] [43]. Depoid [10] claims to obtain very adequate results based on the assumption that the deaths of non-extinct cohorts are distributed by age until extinction in the same way as deaths of earlier, already extinct, cohorts; in other words, it assumes that mortality is invariable. In this study, we have chosen 110 years as the age at which cohorts become extinct; for the cohorts born between 1841 to 1884, very few deaths reportedly occurred at the age of 110 and over (66 for women and 27 for men).

4 Findings

4.1 Data Quality of Deaths and Population

Using a variety of measures of reliability, we first evaluate the quality of mortality data. We then attempt to assess whether or not the censuses provide accurate figures for the population aged eighty and over by comparing these figures with those of populations calculated from deaths.

4.1.1 Age Heaping and Generation Heaping for Deaths

We tested the quality of Canadian data on deaths at advanced ages for the problems of age heaping at ages 80, 85, 90 years and so on, by calculating the Whipple's index used to measure this type of attraction; results revealed no significant signs of age heaping either for the population aged 80 years and above or among centenarians.

It was also possible to verify an attraction for the younger generation at death, often resulting from calculating the year of birth as the difference between the date of the current year and the age at death. For instance, a person dying at 100 years in 1995 was not necessarily born in 1895 (1995-100=1885); he might just as easily have been born in 1884. We would expect deaths to be distributed equally between the younger (1885) and older (1884) cohorts [Note 2]. We used the Generation Heaping Indicator (GHI) - the ratio of deaths attributed to the older cohort to deaths attributed to the younger one - to estimate the accuracy of cohort declaration.

Canadian mortality statistics on deaths of centenarians for the periods 1951-1960 and 1961-1970 are subject to a strong attraction for the younger cohort. The quality of death declarations for the year of birth appears to improve at extreme ages, although the number of deaths attributed to the older cohort are still underestimated. Moreover, an improvement over time meant that for the 1991-1995 period, the GHI was close to unity for octogenarians and is comparable to those of France, Sweden and Japan (countries with high quality data) over the age of 90 years.

4.1.2 Highest Age at Death Comparison

The reliability of mortality statistics in Canada can be estimated by comparing the number of registered deaths at oldest ages to the equivalent figures for other countries known to have high quality data (countries where age at death is carefully scrutinized and accurately recorded). Table 1 shows that the highest age at death reported in Canada exceeds that recorded in all countries except the United States. The highest age at death among the European countries and Japan over a long period of observation rarely exceeded 110 years. There were, in fact, only few cases on record: one woman who died aged 112 in Sweden (1985-1995); two others aged 112 and 111 in Japan (1953 and 1993) and a few who died between age 112 and 116 in France (1970-1995). For men, the highest reported age at death was 114 years old in France during the period 1970-1995 [Note 3]. In Canada, the highest age of registered deaths for the period 1951-1995 was substantially higher, at 118 years for men and 116 years for women.

TABLE 1

In these reference countries, the maximum age at death tended to increase over time, with growing numbers of individuals surviving to old ages. In Canada, this trend is absent, even though, according to the Canadian life tables, 25% more women and 15% more men survived until 80 years in 1991 than in 1951. Moreover, the oldest age at death in Canada was observed in the male population, an unexpected finding given the mortality patterns it shares with other industrialized nations: higher mortality at advanced ages for men than women, and a lower number of male than female centenarians. Finally, this table also shows that the second and third highest ages at death were considerably higher for Canada than for all other countries except the United States, confirming that the highest reported age at death was not a unique case of misstatement of age.

4.1.3 Overstatement of Age at Death among Centenarians

Kannisto [22] has demonstrated the utility of other indicators developed to measure the reliability of data on centenarians. Those pertaining to age overstatement, age heaping and sex selection have been tested in countries with reliable data. In those countries, the rapid depletion of the population at these ages, on the one hand, and the increasing size of successive cohorts of centenarians, on the other, mean that the proportion of those aged 105 and over among all centenarians is expected to be less than 5 %, and to be smaller for men than women (table 2). Reference countries with population registers judged to have a high standard of mortality statistics, such as Sweden, Finland, France, England and Wales, adhere to this norm. The ratio for Canadian data, however, exceeds it, at 7.8 % for men and 8.5 % for women during the 1951-1995 period, indicating overstatement of age at death in Canadian data.

TABLE 2

The second indicator expects that the percentage aged 110 and over among those aged 105 and over will be smaller than the first indicator (105 years + / 100 years +). This condition was respected only among the female populations of Japan, England and Finland. On this point, Canadian data fulfills the assumption, except during the fifties when data reliability was lower. Nonetheless, there is evidence of some overstatement of age in the fact that the first criterion was not respected.

The third indicator is based on the observation that the probability of death at age 101 is higher than at age 100, and thus that the ratio of mortality risks at 100 and 101 years should be below unity ($q_{100} / q_{101} < 1$). An indicator significantly higher than 1 signals an attraction towards declaring death at the exact age of 100 years. This type of error is absent in the majority of reference countries. To verify this indicator for Canadian data, the probabilities from the population estimated by the method of extinct generations were preferred to those published by Statistics Canada. Our tests showed that, at least during the fifties and sixties, Canadian data was subject to this declaration error, particularly for the male population. From 1970 onwards, however, the problem disappears, pointing to a gradual improvement in Canadian mortality statistics at advanced ages over the last half of the twentieth century.

The final indicator is the ratio of women's deaths to those of men. For Canada, this ratio remained stable at around 2 for the decades 1951-1960 and 1961-1970, but had doubled by the period 1991-1995. This provides further evidence of an age overstatement in death declarations among males over 100 years old in earlier decades. The improvement in data quality has raised this ratio to levels that are probably more accurate for Canada and comparable to those of France, Japan and Finland, in recent years.

In summary, Canadian data on deaths do indeed suffer from age overstatement at extreme ages, over 100 or 110 years old, and more so for men than women. The comparison does suggest, however, that Canadian data are more reliable than US mortality statistics that show an even stronger tendency to overestimate age at death. Moreover, since 1951, the quality of death data seems to have improved in Canada.

4.1.4 Overestimation of Centenarians in Canadian Censuses

Table 3 presents the ratio of enumerated population (census population) to population calculated from deaths (population estimates) for Canada by single year of age or age group, sex, and census year. A ratio superior to 1 indicates that the census figures are higher than the estimated population. The accuracy of the figures varies from one census to another but in general, the ratio oscillates around unity between the ages of eighty and one hundred years for women and ninety-five years for men. From then on, however, census counts clearly overestimate the population. Nonetheless, this problem has decreased over the period 1971-1991 by one third for female centenarians (from 1.98 to 1.22) and by half for males (from 2.72 to 1.43).

TABLE 3

The evolution of population estimates at advanced ages, by age group, for Canada and for a group of industrialized countries with high quality data are compared in Table 4. Kannisto's database [20] is the source of information for these reference countries. The proportion of individuals aged 90-99 years to those aged 80 years and over is clearly higher in Canada in 1950 and 1990. In 1991, the proportion of centenarians to the population aged 80 years and over in Canada was five times that in the other industrialized nations: one centenarian for 200, compared with one for 1000 in the reference countries. It is possible that overestimating the age of the oldest-old in Canada may have caused this discrepancy.

TABLE 4

The highest proportion of centenarians in Europe, in 1990, reached between 60-70 per million in the total population, in countries where the demographic transition occurred early and where mortality at advanced ages had been low for some time [20]. According to the estimated populations, Canada had 2884 centenarians in 1991: 106 centenarians per million of the total population [Note 4]. This is twice the average level known in the reference countries, at 45 centenarians per million of population. Thus, although the population estimation has reduced the overestimation of the number of centenarians, the number still appears quite high compared to other industrialized countries.

4.2 Canadian Mortality and International Comparison

4.2.1 Canadian Mortality at Advanced Ages

Figure 2 illustrates the evolution of estimated probabilities of dying (q_x) at advanced ages for Canada, by age and sex, for certain five-year periods in the last half of the twentieth century. These probabilities, rising gradually with age, display a pattern similar to that found in the official life tables; nonetheless, from 100 years onwards, important fluctuations appear, linked to the absence of smoothing, to the small number of deaths at extreme ages, and to the complete absence of deaths at some ages.

FIGURE 2

Figure 3 makes it easier to appreciate the recent development of mortality estimated at advanced ages, by presenting a series of ratios relating probabilities for more recent periods to those for the period 1952-1955, which becomes therefore the point of comparison, and takes the value of 100. Female mortality between 80 and 100 years dropped sharply during the period (35%: 80-89 years, 25 % and less: 90+). For males, it is more difficult to distinguish a clear pattern in mortality decline over time because of great fluctuations from one age to another; but it has clearly declined much less markedly since the fifties than has female mortality. The greatest progress for men has been among octogenarians for whom mortality has declined between 10% and 20% during the period. For each decade, male mortality up to 95 years was substantially higher than that of females, and this difference has increased in magnitude over the last forty years, passing from 20% for octogenarians in the fifties to 40% for the period 1991-94.

FIGURE 3

4.2.2 Canadian Life Tables and estimated probabilities of dying

The ratios of the official life table probabilities of dying (1950-1952 to 1990-1992) to our estimated ones (1952-1955 to 1991-1994), by age and sex, are presented in Figure 4. A ratio inferior to 1 indicates that estimated mortality is higher than that published in the official life tables. With the improved quality of mortality data, we expected our estimated measures for more recent periods to be higher, as Statistics Canada's tables are likely to underestimate mortality at advanced ages. The results were not as obvious as predicted: in 1991 only, the estimated probabilities exceeded those published by Statistics Canada and the difference is not very large, less than 10%.

FIGURE 4

In 1991, for instance, the probability that individuals reaching the age of 80 survive to 100 years is slightly overestimated in the official life tables. For a woman, the estimated probability was 40 ‰ compared with 43 ‰ in the official life tables; the equivalent probabilities for men are 13 ‰ and 15 ‰, respectively.

4.2.3 International comparisons on the basis of estimated probabilities of dying

In this section, estimated probabilities of dying for Canada are compared with other countries for which these probabilities, calculated by the same method, are available in the Berkeley Mortality Database [43]. Figure 5 illustrates the relationship between Canadian probabilities and those of the USA, France, Sweden and Japan, by age (from 80 to 100 years), sex, and time period (1971-1975 and 1991-1995). A ratio inferior to 1 signifies that Canadian mortality is lower than that of the country under comparison.

FIGURE 5

Canadian probabilities of dying resemble those observed in the United States; both countries stand out as having distinctly lower levels than those of Sweden, France and Japan, at all ages over 80 years in 1971-1975 and, more particularly, over 90 years in 1991-1995. During the earlier period, female mortality in Canada was, on average, 15 to 20% lower than that observed in the other countries at that time. For the 1991-1995 period, mortality is lower in France and in Japan from age 80 to 85; then, the gap between Canada and the other countries widens gradually, in Canada's favor, up to 95 years old where, as for the period 1971-75, the mortality of Canadian women is about 10 to 20% lower. For men, the small numbers at each age lead to greater fluctuations in the mortality ratios, making it more difficult to perceive a distinct profile. However, the mortality of American males is still lower than that estimated for Canada. For the first period, Swedish, French and Japanese probabilities of dying are clearly higher than Canadian ones, from 10% to 20%. For the 1991-1995 period, Canada shows a lower mortality above age 85 only. These results hint at the possibility of a profile peculiar to North American mortality.

4.2.4 International comparisons on the basis of age-standardized death rates

Kannisto [20] has suggested using Age-Standardized Death Rates for individuals aged between 80 and 99 years [Note 5]. Out of a pre-selected sample of countries with high quality data, four groups were created according to the level and evolution of mortality: low (Denmark, The Netherlands, Norway and Sweden), medium (Austria, Belgium, England, Finland and West Germany), high (Czechoslovakia, East Germany and Hungary), and rapid decline (France and Switzerland).

In Figure 6, Canadian data indicate a very low level of mortality, inferior to that of the countries categorized as having low mortality. This difference lessens during the period, in particular for the female population. In 1985-1989, for example, Canadian rates stood at 89 ‰ for women and at 133 ‰ for men, compared with only 104 ‰ and 150 ‰, respectively for the low mortality countries. Between 1955-1959 and 1985-89, Canadian mortality at advanced ages declined by 26%: 32% for women, and 16% for men. This reduction is similar to that of countries with low and medium mortality levels and slightly lower than that of countries with sharply declining mortality. For the high mortality nations, grouped geographically in Eastern Europe, the reduction in mortality rates at advanced ages during the period was of - 9%. Mortality decreased at a faster pace from the period 1970-74 onwards for all four groups of countries, and for Canada. On average, the speed of decline for those aged over 80 years was twice as fast for Canada and the reference countries. Female mortality at advanced ages for the low mortality group, for example, declined by 8.9% between 1955 and 1969, and by 19.1% between 1970 and 1989. Advances in Canadian female mortality during the latter period were also higher than during the first, at 11% and 18% respectively.

FIGURE 6

For the period 1985-89, Canada, with an age-standardized death rate for the age range 80-99 of 103.5 ‰, rated before Iceland (105.0 ‰), Japan (111.2 ‰), and before the two countries classed as having rapidly declining mortality, Switzerland (114.0 ‰) and France (115.9 ‰). Iceland, like Japan, has been classified among the countries with excellent data quality, and is even recognized as the country with the most reliable mortality statistics at advanced ages in the world. In the light of these results, therefore, Canada does indeed have exceptionally low mortality levels among the oldest-old.

5 Conclusion

The evaluation of the data quality in Canada suggests that there are some problems concerning deaths and population counts over the age of 80 years, confirming at least in part the conclusions of the study made by Kannisto [20]. However, results in section 4.1 show that Canadian data are quite good up to the age of 100 (generation heaping and age misstatement are at levels similar to those found in comparable countries) and that the main problems concern the centenarians (overstatement of age at death and errors in census age declarations).

International comparisons on the basis of two mortality indicators for the age 80 to 100 lead to the same conclusion: Canadian mortality is lower than most European countries. The best match is still with the United States.

So, we can conclude that, although there are some problems with the data, there is some strong evidence of a lower mortality at older ages in Canada. In fact, the main comparisons shown in section 4.2 concern the 80-99 age interval where Canadian data are quite good.

Can we also conclude that a North American mortality profile exists, as suggested by some authors [2] [17] [29]? This profile is characterised by relatively high mortality rates below age 65 and relatively low mortality rates above age 80, when compared to other low-mortality countries. According to our results, Canadian mortality corresponds to the latter part of this definition; however, mortality below age 65 in Canada is much lower than in the United States and more comparable to many European countries. Although Canada and the United States share the same low mortality level for the oldest-old, their mortality profiles are probably different.

Our results show that Canada and the United States also share the same types of error in their data for the oldest-old. This is not a totally surprising result, because in the two countries it is very difficult to ascertain the date of birth due to the absence of birth registers (before 1921 in Canada). However, recent findings from a record linkage study by Hill et al. [16] show that the American data concerning the age at death of older persons are quite reliable, giving more support to the lower level of U.S. mortality rates above age 80 (at least among native whites).

The same kind of matching study would be useful for Canada. In the meantime, a first step in improving estimation of mortality at advanced ages would be for all Canadian provinces to ameliorate the data on deaths; as there was no civil registration before 1921 in Canada, the task is not easy. However, some reconciliation can be done with administrative files (health records, for example). Another avenue would be to estimate mortality using only data from the Province of Quebec, where death registration is very good and age at death can be verified against baptism register before 1926 [5] [11]. Quebec has the added advantage of a universal health insurance program (Medicare) with a file on all beneficiaries. This would enable us to compare data from vital statistics and from the census to this file. These procedures would lead to a better knowledge of the mortality profile at old ages.

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Notes

1. First results of this research were presented at the 1998 Canadian Population Society Annual Meeting [26]; more detailed results are available in [25].

2. The hypothesis about equal distribution of deaths between the younger and the older cohort is a simplification. In fact, because of rapidly declining numbers of persons with age, combined with a slow increase in the death rate, we would expect more deaths in the younger cohort (lower triangle of the Lexis diagram). However, there is a compensating effect because the upper triangle (older cohort) contains more winter months, and thus deaths at older ages tend to be distributed almost equally between the two cohorts.

3. The exceptional case of Jeanne Calment, a French woman who died in 1997 at the age of 122 years and 5 months is not mentioned in this paper. Other validated cases of exceptional longevity are also omitted: Marie Louise Meilleur, a French Canadian woman who died in 1998 at age 117 and Christian Mortensen, an American man who died in 1998 at age 115.

4. According to the census figures, Canada had 3685 centenarians in 1991: 135 centenarians per million of the total population.

5. To reduce annual fluctuations, death rates were smoothed twice through a moving average, over three and five years, between 1955-59 and 1985-1989. To cancel the effect of structural variations in calculating the rates, Sweden's population distribution by five-year age groups was used for all countries (Sweden: 80-84 years: 0,6360; 85-89 years: 0,2743; 90-94 years: 0,0774 and 95-99 years: 0,0123). Given that fewer men die over the age of 80 years, rates for the total population are composed of two-thirds of female rates and one-third of male rates.

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Table 1:

Highest ages at death by sex, and life expectancy at birth, for differents periods in Canada and other countries

Country and years	Men e_0	Men Highest	Men 2 nd highest	Men 3rd highest	Women e_0	Women Highest	Women 2 nd highest	Women 3rd highest
Canada	***72 years (1981)***				***79 years (1981)***			
1951-60		112	110	110		113	110	110
1961-70		110	110	109		109	109	109
1971-80		114	112	111		114	113	112
1981-90		**118**	116	113		113	111	111
1991-95		112	112	111		**116**	113	113
1951-95		*118*	*116*	*114*		*116*	*114*	*113*
United States	***70.9 years (1982)***				***78.4 years (1982)***			
1980 (Vital Stat.)		122	117	114		122	121	120
1979-81 (Medicare)		124	122	118		124	124	123
Sweden	***73.5 years (1982)***				***79.6 years (1982)***			
1901-14		105	104	103		106	106	105
1914-30		105	105	104		106	105	105
1930-45		106	106	105		106	105	105
1945-67		106	105	105		109	107	107
1983		106	105	105		107	105	105
1985-95		109	107	106		**112**	109	109
Japan	***74.8 years (1984)***				***80.7 years (1984)***			
1953		105	104	104		**112**	108	107
1958		105	104	102		109	108	107
1963		104	102	102		109	108	107
1968		103	102	102		105	105	104
1973		107	105	105		107	107	105
1978		108	107	106		107	107	106
1983		107	106	105		109	107	106
1988		108	107	107		109	109	108
1993		108	107	107		**111**	**111**	110
France	***70.9 years (1981)***				***79.1 years (1981)***			
1920-29		104	104	104		104	104	104
1929-38		104	103	103		104	104	104
1948-69		107	106	106		109	108	108
1970-95		**114**	**114**	109		**116**	**113**	**112**
Netherlands	***73 years (1983)***				***79.8 years (1983)***			
1910-25		104	104	103		104	104	104
1925-45		103	103	103		106	105	103
1945-70		109	107	106		110	109	108
Switzerland	***73.8 years (1984)***				***80.8 years (1984)***			
1876-1914		103	103	103		106	104	102
1914-1948		105	105	103		105	104	104
1948-1970		105	105	105		108	106	105

SOURCES:

Death Data:

Countries other than Canada:
Coale et Kisker, 1990; table 1: Official vital statistics of USA and demographic yearbooks of the individual countries.
Berkeley Mortality Database: Japan, 1988,1993; France, 1970-95; Sweden, 1985-95.
Canada:
Deaths Data, Vital statistics, Statistics Canada

Life Expectancy at Birth Data:

Countries other than Canada:
World Health Organisation from Manton (1992), Mortality and Life Expectancy Changes Among the Oldest Old, table 8-1.
Canada:
Life tables, 1981, Statistics Canada

Table 2:

Indicators of data reliability for deaths of centenarians, by sex, in Canada and other countries

		Deaths 105+/100+ (%)		Deaths 110+/105+ (%)		q_{100} / q_{101}		Death 100+ women/men
		M	W	M	W	M	W	
Canada	1951-60	8,9	8,9	17,6	12,1	1,10	1,04	1,9
Canada	1961-70	10,7	6,7	3,0	-----	1,15	1,00	2,1
Canada	1971-80	7,1	6,6	5,6	4,8	0,98	0,91	2,5
Canada	1981-90	6,7	8,7	6,9	5,5	0,98	0,93	3,0
Canada	1991-95	8,3	9,8	4,6	5,0	0,90	0,94	3,9
Canada	1951-95	7,8	8,5	6,3	5,2			2,9
United-States								
White	1960-69	8,8	7,5	14,6	9,6	1,02	0,97	2,4
	1970-79	7,8	7,4	10,0	6,0	-----	-----	3,0
Non-White	1960-69	30,2	29,8	30,5	29,2	1,25	1,38	1,8
	1970-79	28,9	28,6	22,2	25,8	-----	-----	1,9
Japan	1950-69	5,3	4,4	-----	13,8	1,19	0,99	3,5
	1970-82	3,9	4,2	2,6	3,1	1,13	0,97	3,8
Sweden	1920-83	2,4	3,7	-----	-----	0,88	0,96	2,1
France	1970-83	3,2	4,6	-----	-----	1,07	0,97	4,4
Netherlands	1910-85	2,4	4,4	-----	5,1	0,97	0,96	2,0
England and Wales	1950-83	3,0	5,1	9,4	2,0	0,93	0,94	5,9
Finland	1920-83	1,0	3,5	-----	0,2	0,93	0,90	4,2
New Zeland								
Non-Maoris	1947-84	4,9	5,3	33,3	-----	1,16	0,93	2,8
Maoris	1947-84	30,4	42,1	21,4	35,6	1,40	3,73	2,3

----- Too few cases to calculate rate

SOURCES:

For countries other than Canada: Table 1 from Kannisto (1988)
Canada: Deaths 1951-1995 : Statistics Canada (1997).

Table 3:

Ratio of census population to population estimated from deaths, by age and sex, census years 1971-1991, Canada

AGE	WOMEN 1971	WOMEN 1976	WOMEN 1981	WOMEN 1986	WOMEN 1991	MEN 1971	MEN 1976	MEN 1981	MEN 1986	MEN 1991
80	0,96	0,98	1,02	1,02	1,07	0,97	0,99	1,00	0,99	1,05
81	0,96	0,96	0,99	1,01	1,05	0,97	0,97	1,00	0,98	1,05
82	1,00	0,96	0,99	1,01	1,03	0,99	0,97	1,00	1,00	1,03
83	0,99	0,98	0,98	1,00	1,04	0,99	0,98	0,99	1,00	1,04
84	0,98	0,96	1,00	1,00	1,03	0,98	0,98	0,99	1,01	1,01
85	1,00	0,98	0,99	1,01	1,02	1,01	0,98	1,00	1,00	0,99
86	0,98	0,99	0,99	0,98	1,03	1,00	0,98	0,99	1,00	1,00
87	0,99	1,00	0,98	0,96	1,02	1,00	0,99	0,98	0,96	1,02
88	0,99	0,98	0,98	0,96	1,02	1,01	0,98	0,99	0,97	1,02
89	0,99	0,95	0,97	0,99	1,01	1,03	0,98	0,99	0,96	1,03
90	1,01	1,03	0,99	0,97	1,01	1,01	0,99	0,99	0,99	1,02
91	0,99	0,98	1,00	0,95	0,97	0,97	1,00	0,99	0,97	1,03
92	0,95	1,00	0,97	0,96	0,93	0,98	1,00	1,00	0,95	0,99
93	0,97	1,01	0,99	0,97	0,97	1,05	1,01	0,96	0,98	1,00
94	1,02	0,98	0,94	0,95	1,00	1,10	1,01	1,01	0,97	1,10
95	1,01	1,09	1,03	0,97	1,01	1,09	1,08	1,03	0,95	1,38
96	1,04	0,98	1,01	1,01	1,02	1,19	1,00	0,98	1,00	1,35
97	1,13	1,03	1,00	1,00	1,01	1,14	1,07	1,04	1,05	1,22
98	1,11	1,12	1,02	1,03	1,00	1,52	1,34	1,09	0,95	1,12
99	1,61	1,17	1,08	0,99	1,02	2,25	1,50	1,05	1,12	1,06
100	1,38	1,54	1,28	1,16	1,03	1,64	2,56	1,32	1,18	1,04
101	1,42	***	1,27	1,12	1,19	1,63	***	1,33	1,02	1,28
102	1,54	***	1,13	1,18	1,11	1,90	***	1,55	1,23	1,30
103	1,41	***	1,18	1,23	1,18	2,92	***	1,73	1,22	0,93
104	3,68	***	1,39	1,13	1,26	3,89	***	1,56	1,30	1,25
105	5,00	***	1,39	1,54	1,40	10,00	***	2,14	1,43	1,33
106	8,00	***	1,00	2,11	1,59	8,33	***	3,33	2,86	2,50
107	20,00	***	2,50	2,14	1,82	10,00	***	10,00	2,50	3,33
108	5,00	***	1,67	1,50	1,67	10,00	***	10,00	2,50	10,00
109	30,00	***	5,00	3,33	2,50	---	***	5,00	10,00	5,00
110	----	***	5,00	10,00	6,67	25,00	***	10,00	5,00	5,00
AGE GROUP										
80-84	0,98	0,97	1,00	1,01	1,05	0,98	0,98	1,00	0,99	1,04
85-89	0,99	0,98	0,98	0,98	1,02	1,01	0,98	0,99	0,98	1,01
90-94	0,99	1,00	0,98	0,96	0,98	1,01	1,00	0,99	0,97	1,02
95-99	1,09	1,06	1,02	0,99	1,01	1,24	1,11	1,03	1,00	1,28
100-104	1,55	***	1,25	1,16	1,11	1,93	***	1,39	1,15	1,14
105-109	8,24	***	1,55	1,79	1,58	10,50	***	3,75	2,32	2,42
80+	0,99	0,98	0,99	1,00	1,03	0,99	0,99	1,00	0,99	1,03
90+	1,02	1,07	1,00	0,98	0,99	1,06	1,12	1,01	0,99	1,08
100+	1,98	***	1,37	1,27	1,22	2,72	***	1,74	1,39	1,43
110+	----	***	55,00	125,00	23,13	17,50	***	17,00	90,00	41,67

---- Too few cases to calculate rate

*** Due to sampling procedure in 1976, census population counts over 100 years old are not reliable

SOURCES:

Canadian census population, 1971-1991
Estimated population (Lebel, 1999)

Table 4:

Proportion of the oldest-old and centenarians (estimated), by sex, in Canada and other industrialised countries

Age	Sex	Canada				Other countries (1)			
		1952		1991		1950		1990	
		Number	% 80+	Number	% 80+	Number	% 80+	Number	% 80+
80-89	Men	68.321	92,6%	195.747	89,4%	1.164.309	95,9%	3.633.110	91,7%
	Women	80.436	90,6%	351.981	83,6%	1.850.361	94,2%	7.654.426	88,4%
	Total	148.757	91,5%	547.728	85,6%	3.014.670	94,8%	11.317.736	89,7%
90-99	Men	5.394	7,3%	22.647	10,3%	49.577	4,1%	297.407	7,5%
	Women	8.211	9,3%	66.815	15,9%	113.855	5,8%	988.886	11,4%
	Total	13.605	8,4%	89.462	14,0%	163.432	5,1%	1.286.293	10,2%
100+	Men	63	0,1%	567	0,3%	173	0,0%	2.945	0,1%
	Women	112	0,1%	2.317	0,6%	636	0,0%	14.890	0,2%
	Total	175	0,1%	2.884	0,5%	809	0,0%	17.835	0,1%
80+	Men	73.778	100%	218.961	100%	1.214.059	100%	3.963.662	100%
	Women	88.759	100%	421.113	100%	1.964.852	100%	8.658.202	100%
	Total	162.537	100%	640.074	100%	3.178.911	100%	12.621.864	100%

		Canada				Other countries (2 and 3)			
		1961		1991		1960		1990	
		Number	Proportion	Number	Proportion	Number	Proportion	Number	Proportion
80+ (% Tot. Pop.)	Men	106.980	1,2%	218.961	1,6				
	Women	132.493	1,5%	421.113	3,0				
	Total	239.473	1,3%	640.074	2,3	6.139.172	1,4 (0.92-2.00)	15.783.777	3,0 (2,17-4,19)
100+ (per million inhabitants)	Men	106	11,5	567	42,1				
	Women	150	16,6	2.317	167,4				
	Total	256	14,0	2.884	105,7	1.753	5,3	18.394	45,1 Max (60-70)
Total Pop.	Men	9.218.893	100,0%	13.454.580	100,0%				
	Women	9.019.354	100,0%	13.842.280	100,0%				
	Total	18.238.247	100,0%	27.296.860	100,0%	431 828 000 [2]	100,0%	518 649 000 [2]	100,0%
						330 754 717 [3]	100,0%	407 849 224 [3]	100,0%

Population on January 1st

(1) Austria, Belgium, Denmark, England and Wales, Finland, France, Germany (West), Italy, Japan, Norway, Sweden and Switzerland.

(2) 80+ and Total Population: Austria, Netherlands, New Zealand, Denmark, England and Wales, Finland, France, Germany, Italy, Japan, Norway, Sweden, Switzerland, Belgium, Chili, Czechoslovakia, Estonia, Hungary, Iceland, Latvia, Luxemburg, Portugal, Scotland, Spain.

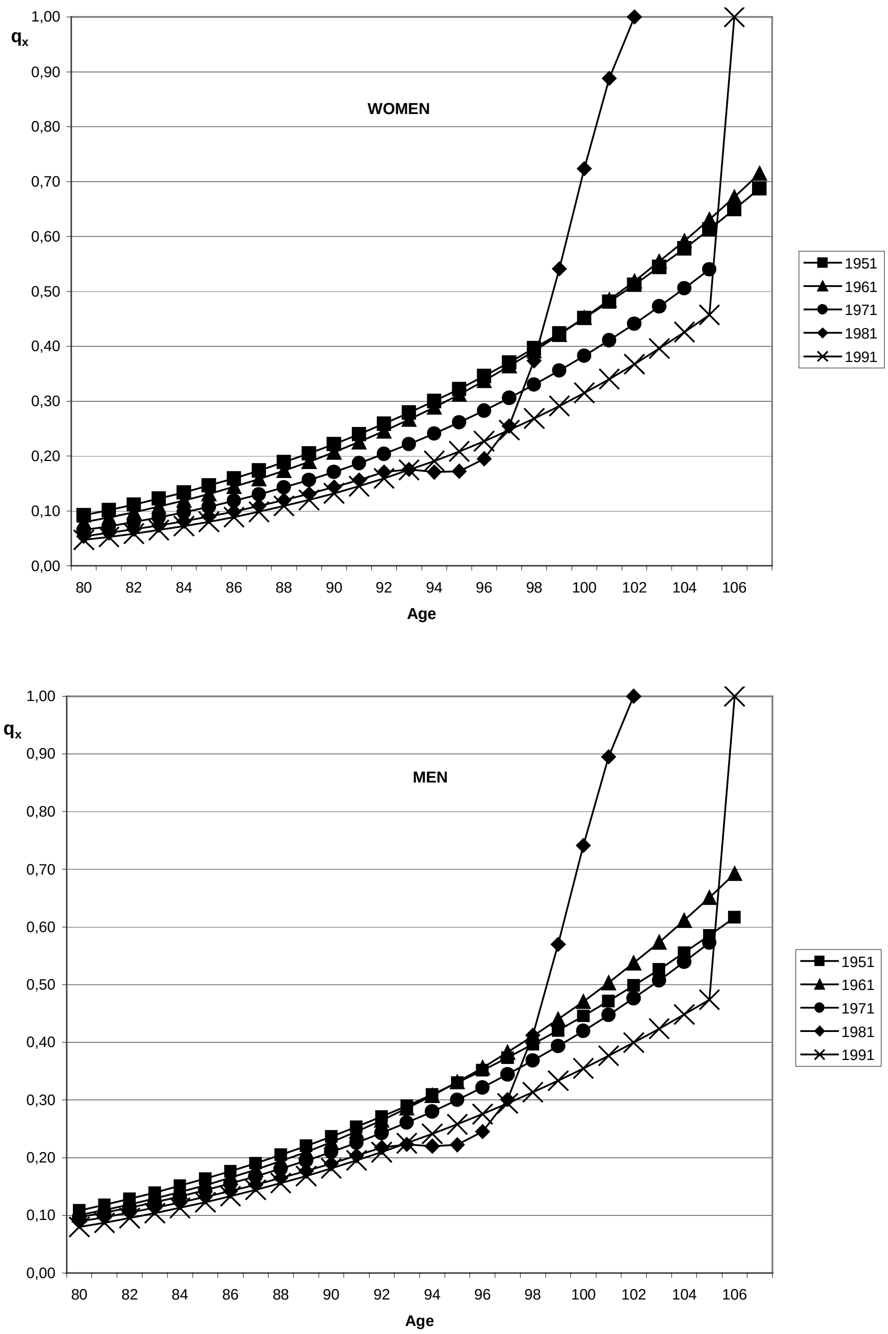
(3) 100+ and Total Population: Austria, Iceland, Netherlands, New Zealand, Denmark, England and Wales, Finland, France, Germany (West), Italy, Japan, Norway, Sweden and Switzerland.

SOURCES:

Industrialised countries: Kannisto, 1994.
Canada: Estimated Population on July 1st
Total Population: Canadian censuses, 1961 and 1991.

Figure 1:

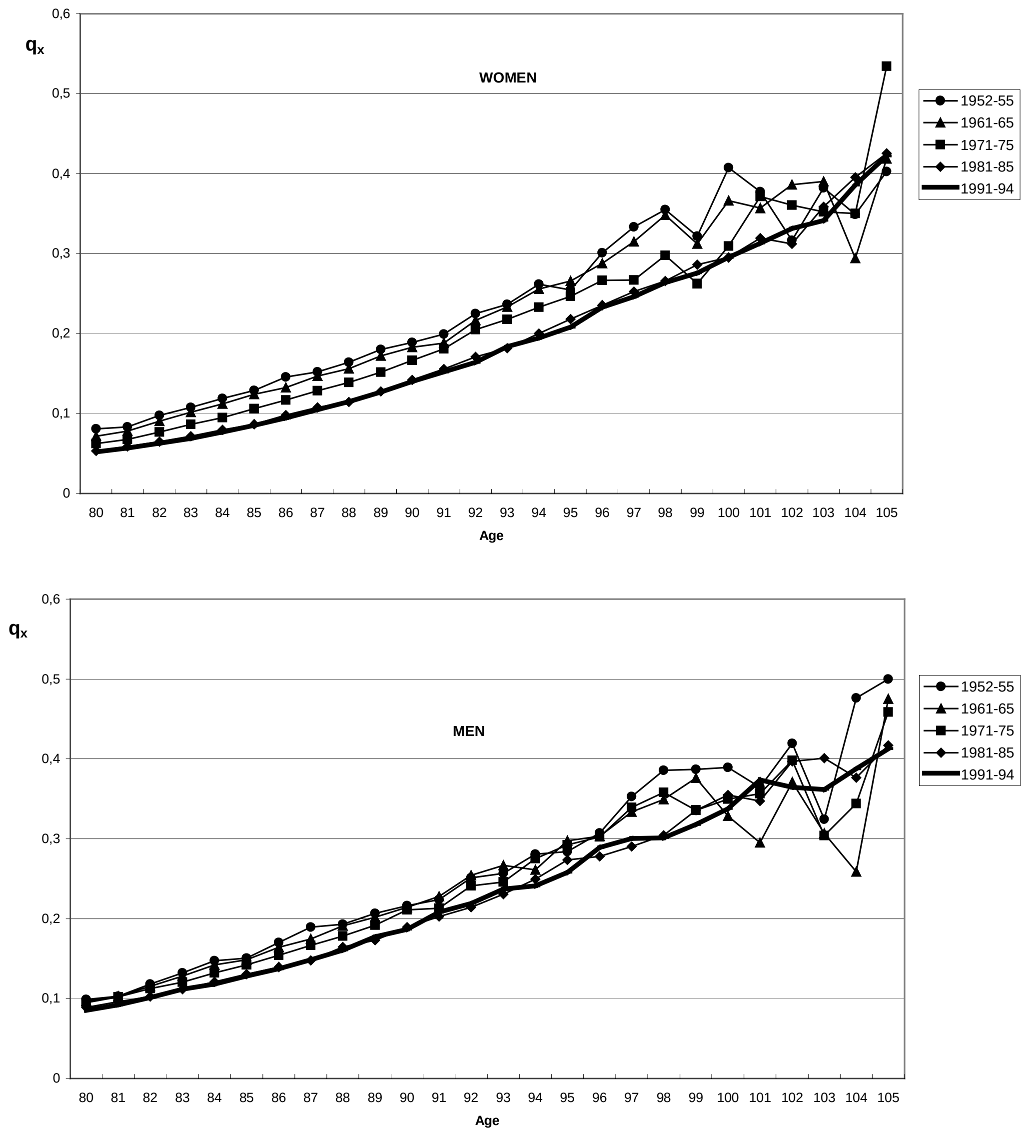
Probabilities of dying by single year of age between ages 80 and 106, and by sex, Canadian Life Tables, 1951-1991.



Source: **Lebel (1999)**

Figure 2:

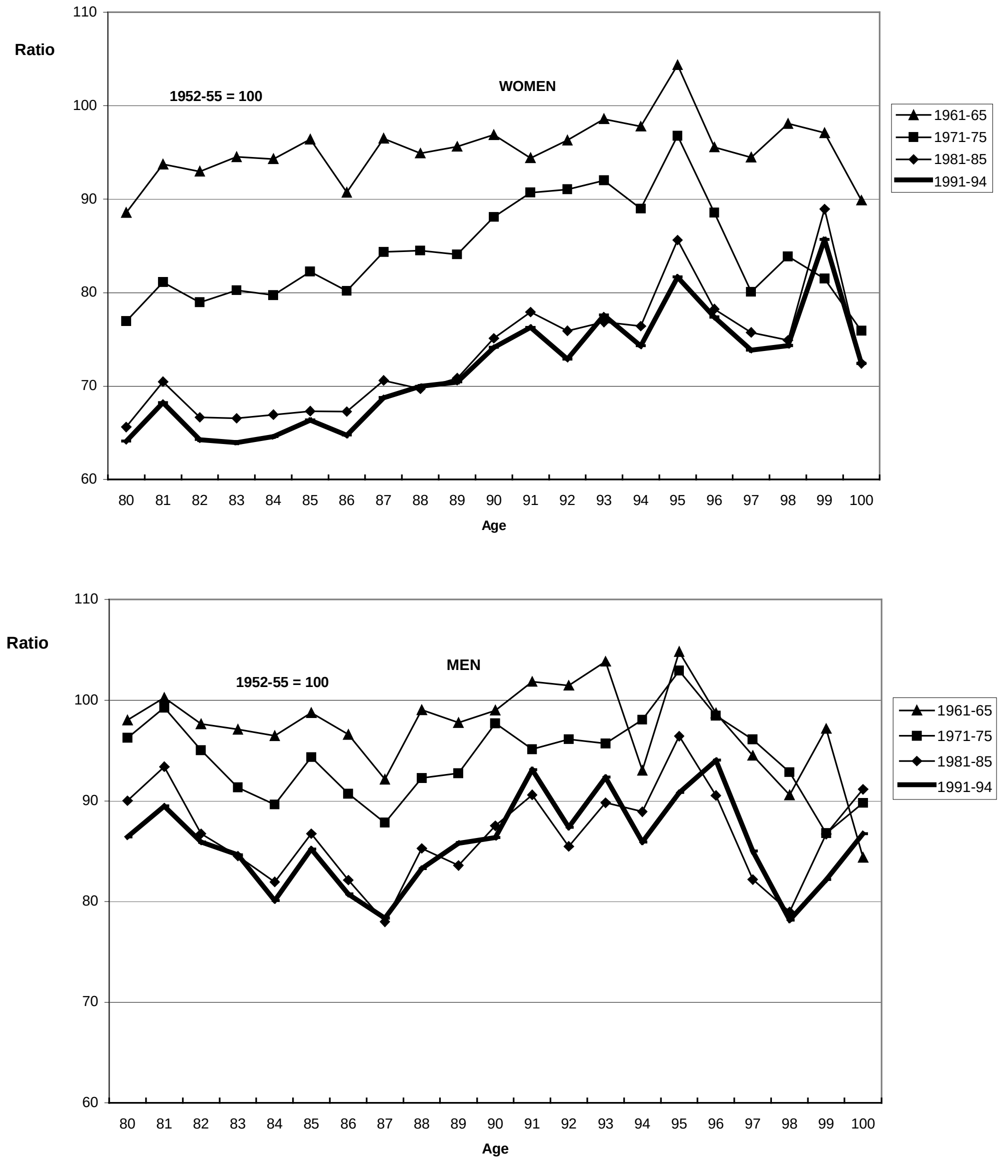
Estimated probabilities of dying by single year of age between 80 and 105, and by sex, periods 1952-1955 to 1991-1994, Canada.



Source: **Lebel (1999)**

Figure 3:

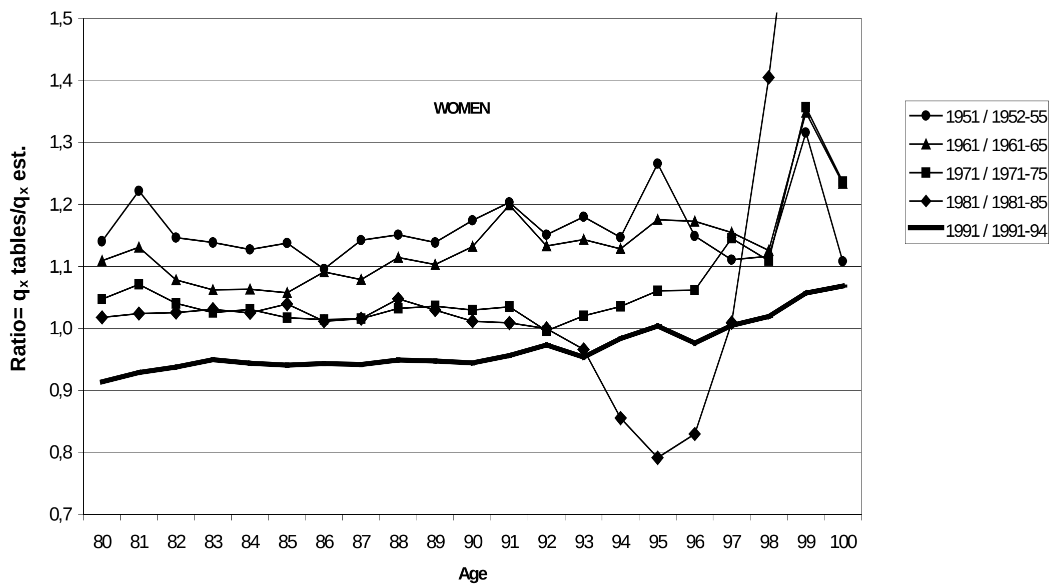
Variation of estimated probabilities of dying at advanced ages by sex and age since period 1952-1955, Canada (Base 100 = 1952-55).

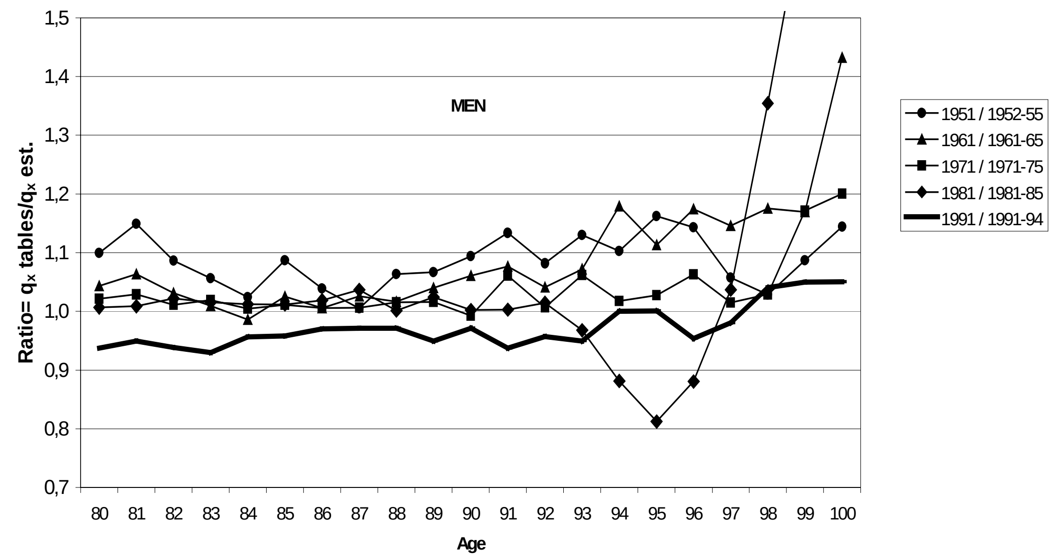


Source: **Lebel (1999)**

Figure 4:

Ratio of Canadian Life Tables probabilities of dying to estimated probabilities of dying, by age and sex, 1952-1955 to 1991-1994 (Ratio = q_x tables / q_x estimated)

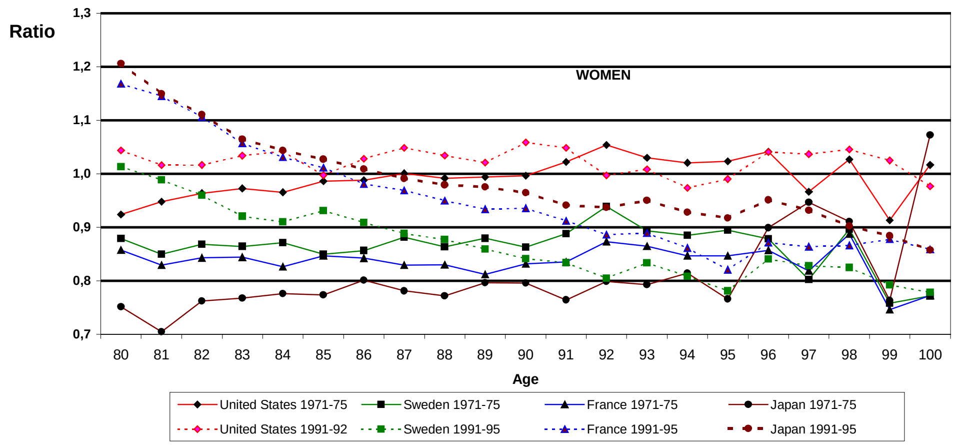


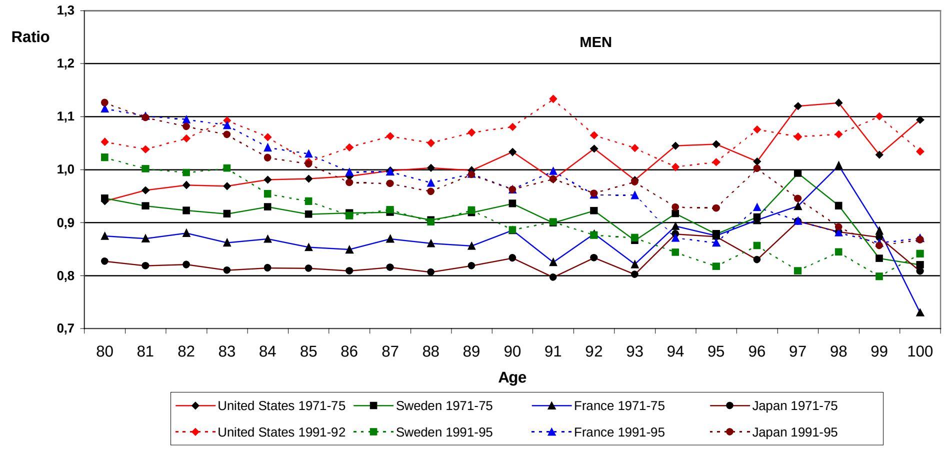


Source: **Lebel (1999)**

Figure 5:

Ratio of estimated probabilities of dying by age and sex, Canada compared to other countries, for periods 1971-1975 and 1991-1995 (Ratio = Canada / Other country)



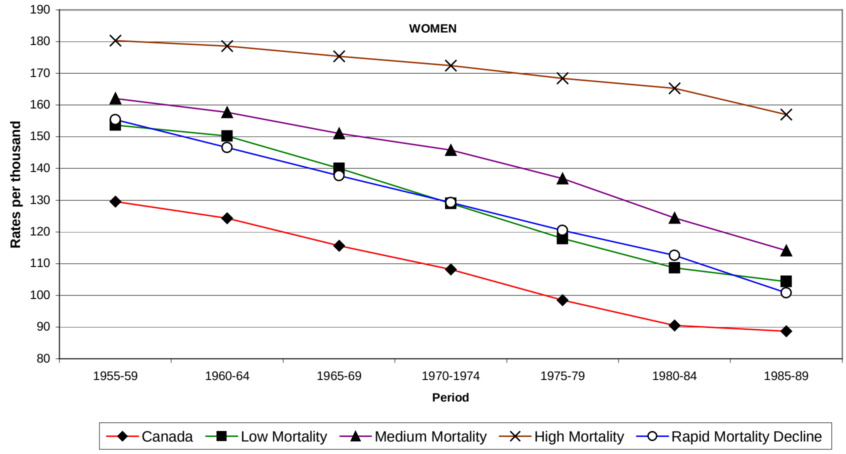


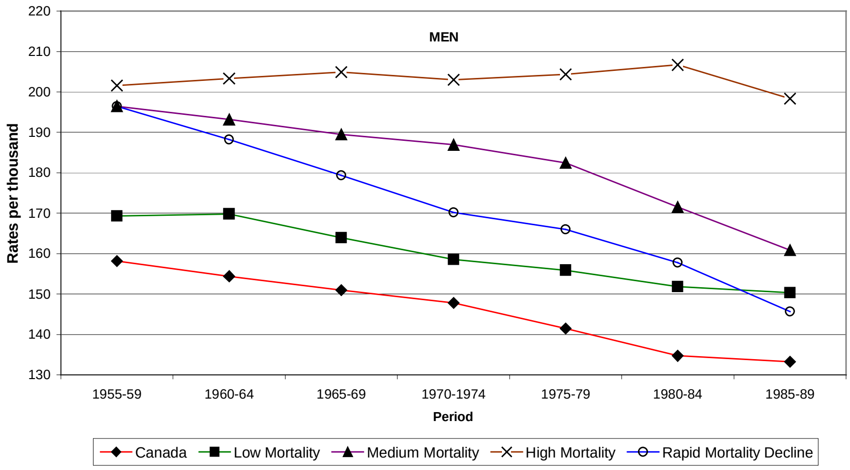
Source: **Lebel (1999)**

Note: Data for Canada are for periods 1971-1975 and 1991-1994
Data for the United States are for periods 1971-1975 and 1991-1992

Figure 6:

Age-standardized death rates at 80-99 years, by sex, for Canada and four groups of countries, 1955-1959 to 1985-1989.





Source: Canada: **Lebel (1999)**

Other countries: **Kannisto, 1994, p. 32**