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Mortality and Longevity

Updating the Canadian Mortality Data in the Human Mortality Database and in the Canadian Human Mortality Database

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CONTENTS

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Thanks to a contribution from the Society of Actuaries Research Institute as part of a partnership with the Canadian Institute of Actuaries, the Canadian mortality series in the Human Mortality Database (HMD, www.mortality.org) has been updated to include revised data for 2017-2021 and new data for 2022 and 2023. The same data is used for on-going work to update the Canadian Human Mortality Database (CHMD, http://www.bdlc.umontreal.ca/CHMD/). The work is carried out by the University of California, Berkeley team of the HMD project under the leadership of Magali Barbieri and with support from the two Directors of the CHMD, Dr. Nadine Ouellette and Pr. Robert Bourbeau from the *Université de Montréal* in Canada.

Section 1 Background

First published in 2002 and continuously updated since then, the Human Mortality Database (HMD, www.mortality.org) is a unique open-access collection of detailed mortality and population data for 41 countries with complete and reliable vital registration and census data, which includes Canada. The project is a collaboration between the Department of Demography at the University of California, Berkeley, the Max Planck Institute for Demographic Research (MPIDR) in Rostock, Germany, and the French Institute for Demographic Studies (INED) in Paris. It is led by Dr. Magali Barbieri at the University of California and Dr. Dmitri Jdanov at the MPIDR. The HMD contains calculations of death rates and life tables for national populations, as well as the original input data used for constructing those tables and extensive documentation. Regarded as a gold standard for mortality information, it is a major source of data for the actuarial profession, researchers, journalists, policy analysts, and international organizations such as the United Nations and World Health Organization. More than 75,000 users have registered to access the HMD series and over 7,000 publications (including over 5,500 scientific articles in peer-reviewed journals) cite the HMD as one of their primary data sources.

Building from the experience of the HMD, researchers in the Department of Demography at the *Université de Montréal*, namely Pr. Robert Bourbeau and Dr. Nadine Ouellette, have developed a similar repository of mortality indicators for the 10 Canadian provinces and three territories. This database is called the Canadian Human Mortality Database (or *Base de données sur la longévité canadienne*, http://www.bdlc.umontreal.ca). It was constructed in close collaboration with the HMD team at the University of California, Berkeley (UCB) as it strictly follows the HMD methodological protocol. The CHMD was first published in 2004 and has been updated periodically up to 2014 by Pr. Bourbeau and Dr. Ouellette. Given new constraints at the *Université de Montréal*, the HMD team at UCB was asked to take over the data extraction, computational work, and verification of results to further update the CHMD. A contribution from the Canadian Institute of Actuaries in 2018, renewed in 2020 and again in 2021 and in 2023, has enabled the collaboration to go through to update both the Canadian series in the HMD and the Canadian Mortality Database. Using revised data for 2011 and new data for 2012-2016, the UCB team carried out a first update of the CHMD in 2018, and then additional ones the following years to extend the data series up to the year 2021 for the last update. The latest contribution, through a joint partnership between the Canadian Institute of Actuaries and the Society of Actuaries Research Institute, has allowed the Canadian series of the HMD and the CHMD to further include the years 2022 and 2023 (as well as revised data for 2017-2021).

The Canadian mortality series in the HMD and in the CHMD rely on the same sources of data, namely vital statistics and annual population estimates from Statistics Canada, and they involve the same methods protocol (as described here: https://mortality.org/File/GetDocument/Public/Docs/MethodsProtocolV6.pdf). An agreement between each province and territory registrar and the *Université de Montréal* had allowed Pr. Bourbeau and Ouellette to obtain from Statistics Canada the detailed data necessary to construct the initial mortality series (i.e., death counts by province/territory, calendar year, sex, age at last birthday, and birth cohort), which was renewed in the Spring of 2025 for an additional five years.

Section 2 Updating the Canadian Series in the HMD

The life table series available in both the HMD and the CHMD are constructed following the HMD Methods Protocol through a highly standardized process which is briefly summarized here. Work has been completed to extend the HMD mortality series for Canada to the year 2023 and the series has been published on the HMD website (www.mortality.org) on May 19, 2025 (https://mortality.org/Country/Country?cntr=CAN).

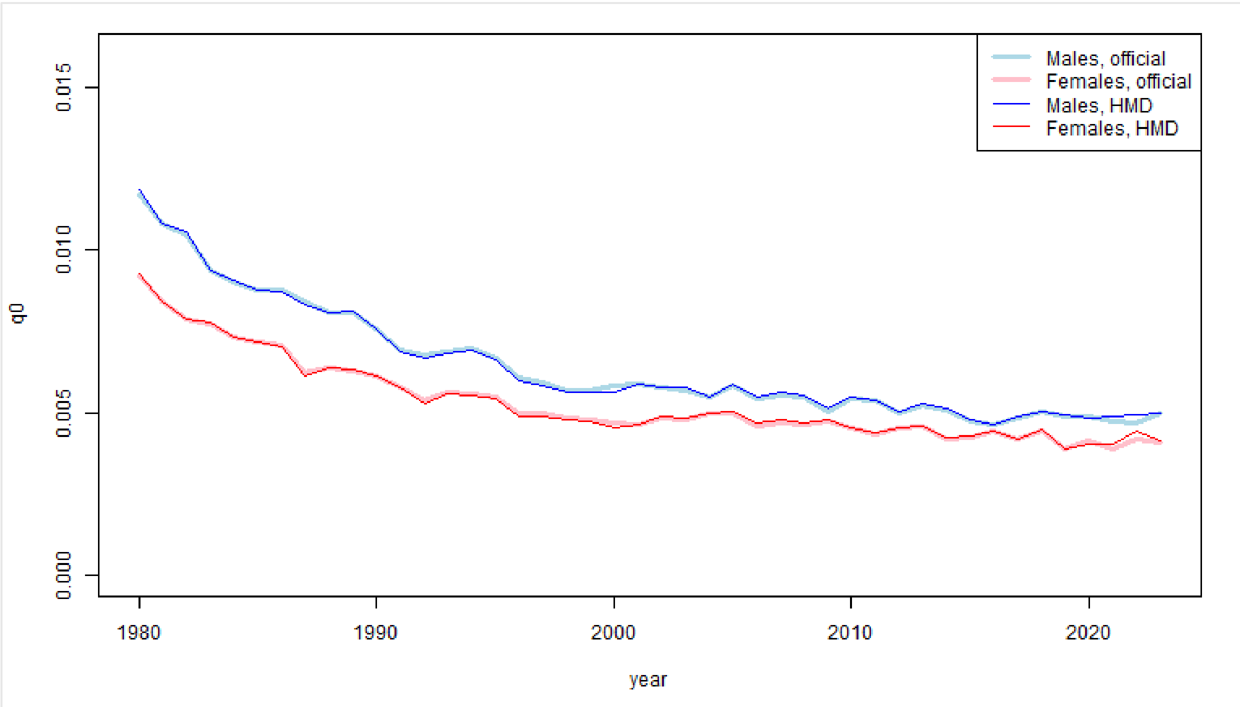
First, the necessary data were collected and carefully checked, namely: 1) births by sex and births by month for every calendar year; 2) deaths by sex, single year of age, and birth cohort; and 3) annual population estimates by sex and single year of age. The data collected were those for years not yet included in the HMD series (2022 and 2023) as well as those for previous years (2017-2021) that have been updated by the national statistics office as is typically the case from one year to the next.

Birth counts were used to derive and to check population estimates at younger ages. Annual estimates of population size by age and sex were converted into exposures to risk by correcting for the timing of deaths within each age-time interval using the births-by-month distribution corresponding to each cohort. To account for the lack of age detail in the early data and to avoid biases associated with age overstatement for those born in the early 20th century, exposures-to-risk were indirectly estimated at ages 80+ years from the death counts within each cohort by implementing a combination of the extinct cohort method and the survival ratio method. Next, sex-specific death rates were calculated as the ratio of death counts for a given age-time interval divided by exposures-to-risk in the same interval. Rates at very high ages were subsequently smoothed using the Kannisto method to reduce large year-to-year variations due to small numbers. Probabilities of death were calculated from the smoothed death rates to construct life tables for each year, including life expectancies at birth and at other ages. The single year of age single calendar year life tables (from ages zero to 110+) were used to construct life tables in other formats (five-year age groups and five- and 10-year periods).

The resulting life tables were checked for internal and external inconsistencies. The former was carried out following the standard HMD process (see Appendix A for a list of all checks). The latter was done by comparing the age structure of mortality to the mortality patterns in the HMD universe as well as by comparing the HMD lifetable values with those published by Statistics Canada (see Figure 1 for a comparison of the probability of dying below age one and Figure 2 for a comparison of the life expectancies at birth and at age 65 years). The background and documentation files (both internal and public) were updated and published on the HMD website with the input data and the lifetables. Note that for all three indicators (and all others that have been checked), there is good agreement between the HMD estimates and the official estimates from Statistics Canada.

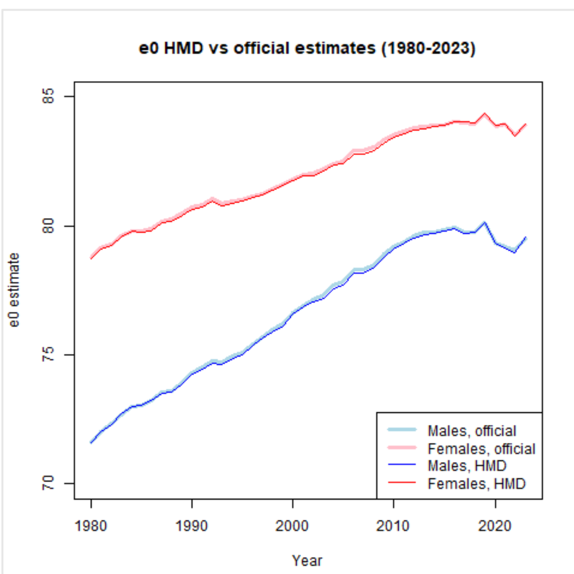
Figure 1

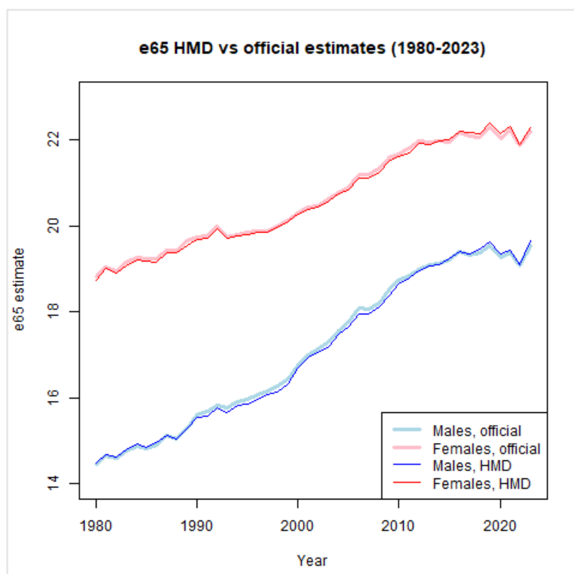
A COMPARISON OF THE HMD ESTIMATES WITH THE OFFICIAL ESTIMATES FROM STATISTICS CANADA FOR THE PROBABILITY OF DYING BELOW AGE ONE BY SEX (1980-2023)



Figures 2a and 2b

A COMPARISON OF THE HMD ESTIMATES WITH THE OFFICIAL ESTIMATES FROM STATISTICS CANADA FOR THE EXPECTATIONS OF LIFE AT BIRTH AND AT AGE 65 BY SEX (1980-2023)





Section 3 Updating the CHMD Series

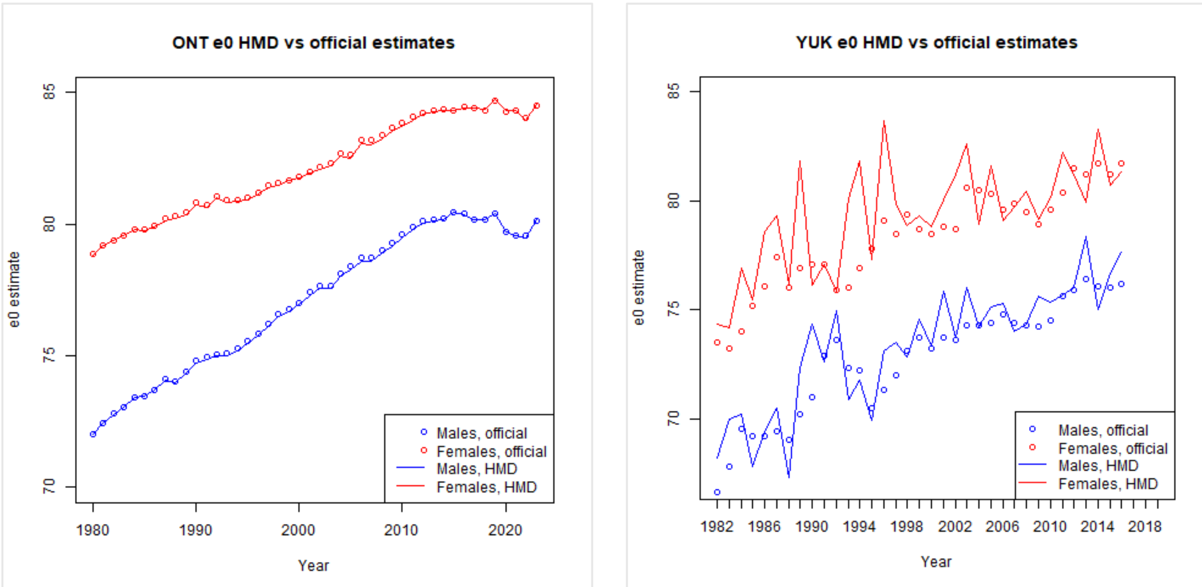
Individual-level mortality data were provided by Statistics Canada to Pr. Nadine Ouellette and Robert Bourbeau and tabulated by sex, single year of age, birth cohort, and for the CHMD, province/territory for the researchers' own purpose. The birth and population data were downloaded from the website of Statistics Canada. The data were tabulated for each calendar year 2018-2023 as the 2018-2020 data previously used had been revised by Statistics Canada to take delayed registration (of births and deaths) into account. All the input files for the CHMD were prepared and formatted according to the HMD standard. The HMD code was run to produce tabulations of death counts and exposure counts by Lexis triangle for every calendar year and age separately for each sex and for both sexes combined. The HMD Methods Protocol involves implementing two methods to estimate mortality at ages 80 and above (the extinct cohort method and the survival ratio method). These methods require the recalculation of mortality estimates at all ages 80 and above for all calendar years back to the earliest cohort with surviving members at the last data point (2023).

The lifetables are calculated for each province and territory from the Lexis triangle counts of deaths and exposures, starting with the death rates, first for single years of age and single calendar years, and then for five- and 10-year age groups. Note that because of issues with very small numbers, the life tables by single year of age and single calendar year and the life tables by five-year age group and single calendar year are not published for Yukon nor for the Northwest Territories on the CHMD website. In addition, because of delays at the local Registrar's Office, no data are available for Yukon for years since 2016 as previously mentioned, so the update does not include this territory.

In addition to standard internal consistency checks (described in Appendix A), the final lifetable values were compared with those published by Statistics Canada. Note that though the CHMD series starts in 1921 (1950 for Yukon and the Northwestern Territories), Statistics Canada only started publishing official lifetables at the province/territory level in 1980. This analysis shows that the degree of consistency between lifetable values in the HMD and CHMD and those prepared by Statistics Canada varies inversely with the size of the populations. There were hardly any differences in the expectation of life at various ages between the two data sources for the provinces of Alberta, British Columbia, New Brunswick, Nova Scotia, Ontario, Quebec, and Saskatchewan, especially over the past 10 calendar years. However, there were some in Newfoundland Prince Edward Island, and quite a lot in the Northwest Territories and Yukon (see Figures 3a and 3b for illustration, where a large and a small province were chosen for contrast). Note that Statistics Canada publishes lifetables at the regional level for three-year periods only for low-populated provinces (i.e., Yukon, Prince Edward Island, and Northwest Territories and Nunavut), while the CHMD series provides data for each calendar year for all provinces. Some of the discrepancies in the mortality estimates for the smaller provinces may thus be attributable to the difference in the reference periods between the official three-year averages and the single-year CHMD estimates.

Figures 3a and 3b

A COMPARISON OF LIFE EXPECTANCY AT BIRTH IN ONTARIO AND IN YUKON IN THE HMD LIFETABLES AND IN THE LIFETABLES PUBLISHED BY STATISTICS CANADA,[1] 1982 THROUGH 2019-2023 (ONTARIO) AND 1980-1982 THROUGH 2014-2016 (YUKON)

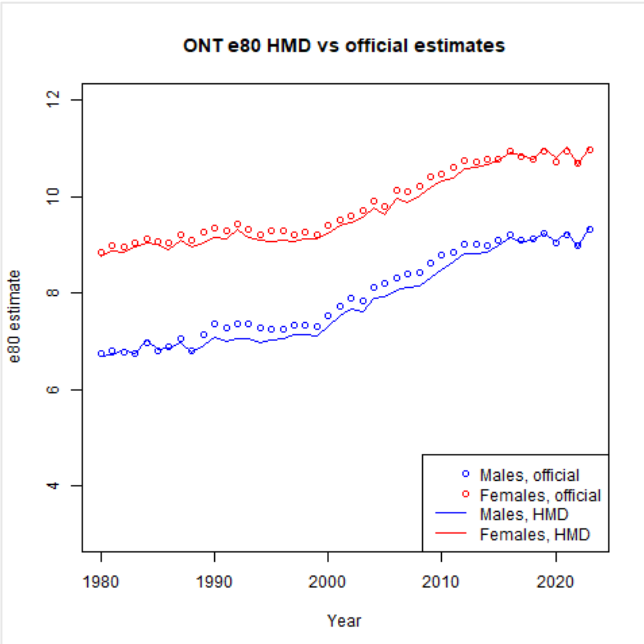


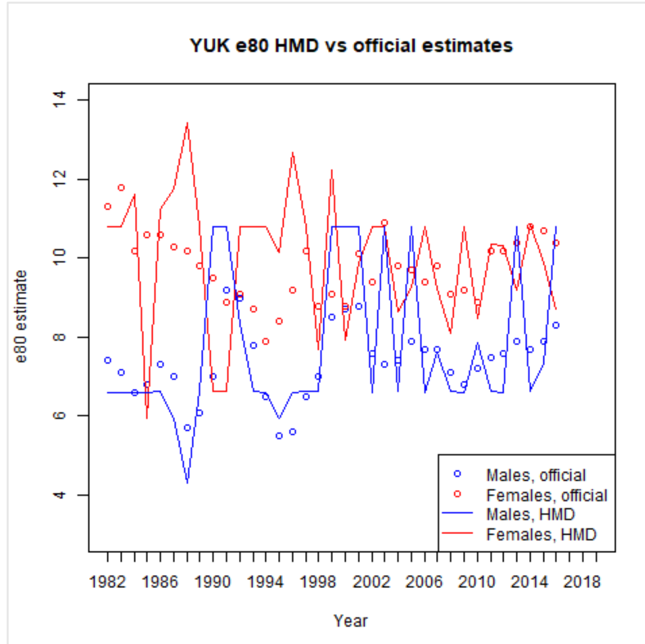
The pattern is very similar for the expectation of life at age 60 but there are some differences at age 80, even in the most populated provinces for past calendar years, that is between approximately 1990 and 2012-2013 (Figures 4a and 4b). For this earlier time period, the estimates for the remaining length of life at age 80 tend to be higher in the lifetables prepared by Statistics Canada than in the HMD, which is likely due to differences in the methods used to estimate mortality at ages 80 and above. As previously explained, the HMD implements the extinct cohort method to remedy the issue of age overstatement in older generations. As age reporting improves over time, the gap between the two sources closed progressively, as has been the case for recent years.

[1] Sources: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1310083701 and https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1310014001 [accessed June 10, 2025].

Figures 4a and 4b

A COMPARISON OF LIFE EXPECTANCY AT AGE 80 IN ONTARIO AND IN YUKON IN THE HMD LIFETABLES AND IN THE LIFETABLES PUBLISHED BY STATISTICS CANADA,[1] 1982 THROUGH 2019-2023 (ONTARIO) AND 1980-1982 THROUGH 2014-2016 (YUKON)





Section 4 Publication of the Updated Canadian HMD and CHMD Series

The updated Canadian series was published on the HMD website on May 19, 2025. The updated CHMD series was published on the CHMD website (at http://www.bdlc.umontreal.ca/chmd/index.htm) on July 31, 2025. Support from the Society of Actuaries Research Institute and the Canadian Institute of Actuaries for this work has been acknowledged on the HMD and CHMD websites (see https://www.mortality.org/Project/InstitutionalAndFinancialSupport and http://www.bdlc.umontreal.ca/CHMD/acknowledgements.htm).

Appendix A: Internal Consistency Checks

- Verify that raw death and population data cover the expected age and calendar range
- Comparison of raw population data with exposure counts (after various adjustments are carried out)
- Check that the procedure for smoothing deaths before fitting the model to redistribute deaths into the open age interval (if any) produces a reasonable output
- Compare male and female mortality to identify suspicious patterns
- Compare single year of age mortality rates with adjacent ages (for instance to identify age attractions)
- Compare the implied migration patterns with those reported by the national statistics office (i.e., implementation of a growth balance method that compares January 1 population with births for a given calendar year added and deaths during the same year removed with population on January 1 of the following year)
- Evaluate the consistency of the age patterns of implied migration (for instance there should be very little migration during the first year of life and at old ages except when and where retirement migrations are expected)
- Compare trends in life expectancy values with Sweden (HMD gold standard for data quality)
- Compare age pattern of mortality with that in other HMD populations at the same level of life expectancy at birth
- Verify that all discrepancies between the updated death rates and the previous death rates are attributable to known changes in the HMD methods or to new death or population data

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