Updating the Canadian Mortality Data through 2021 in the Human Mortality Database and the Canadian Human Mortality Database

APRIL | 2024

Mortality and Longevity

SOA Research INSTITUTE

Updating the Canadian Mortality Data through 2021 in the Human Mortality Database and the Canadian Human Mortality Database

AUTHOR Magali Barbieri, Ph.D.
Co-Director, Human Mortality Database
Director, U.S. Mortality Database
University of California, Berkeley

SPONSORS Mortality and Longevity Strategic Research Program

Canadian Institute of Actuaries

Society of Actuaries Product Development Section

Society of Actuaries Reinsurance Section

CONTENTS

Updating the Canadian Mortality Data through 2021 in the Human Mortality Database and the Canadian Human Mortality Database

Through a financial contribution from the Canadian Institute of Actuaries and the Society of Actuaries, the Canadian mortality series in the Human Mortality Database (HMD, www.mortality.org) has been updated to include revised data for 2017-2019 and new data for 2020 and 2021. The same data was used to update the Canadian Human Mortality Database (CHMD, http://www.bdlc.umontreal.ca/CHMD/). This report presents the background and processes for extending the data series in each of the databases.

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 relatively 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 deaths 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 the World Health Organization. More than 70,000 users have registered to access the HMD series and over 7,000 publications (including nearly 5,500 scientific peer-reviewed articles, books, and book chapters) 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 Nadine Ouellette, have developed a similar repository of mortality indicators for the ten Canadian provinces and the three territories. This database is called the Canadian Human Mortality Database (or *Base de données sur la longévité canadienne*, http://www.bdlc.umontreal.ca) (CHMD). It was constructed in close collaboration with the HMD team at the University of California, Berkeley (UCB). The CHMD was first published in 2004 and has been updated periodically up to 2014 by Pr. Bourbeau and Ouellette. Given new constraints at the *Université de Montréal*, the HMD team at UCB was asked to take over the computational and verification work to further update the CHMD. A contribution from the Canadian Institute of Actuaries in 2018, renewed in 2020, 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 a second one in 2020 to extend the data series to 2019 (except for Yukon for which data are missing for years since 2017). The current SOA-CIA grant has allowed the project to carry out yet another update, with revised data for 2017, 2018 and 2019 and new data for 2020 and 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 involve the same methods protocol (as described here: https://www.mortality.org/File/GetDocument/Public/Docs/MethodsProtocolV6.pdf). An agreement between each province and territory registry 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, which was renewed for another ten years in 2018.

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 2021.

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 (2020 and 2021) as well as those for previous years (2017-2019) that have been updated by the national statistics office as is typically the case from one year to the next. Note that, because data for Yukon have not been provided by the territorial registrar's office to Statistics Canada since 2017, the calculations exclude this Territory and the data available through the CHMD for this territory is interrupted (though still provided up to 2016). The impact on national mortality estimates is however negligible because the number of deaths in Yukon (a mere 218 in 2016, the last year when it was available) represents only a fraction of a percent (less than 0.1%) of the total death count for Canada.

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 0 to 110+ years) were used to construct life tables in other formats (5-year age groups and 5- 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 1 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 life table 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 life tables. Note that for all three indicators (and all others that we have checked), there is excellent 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 (1980-2021)

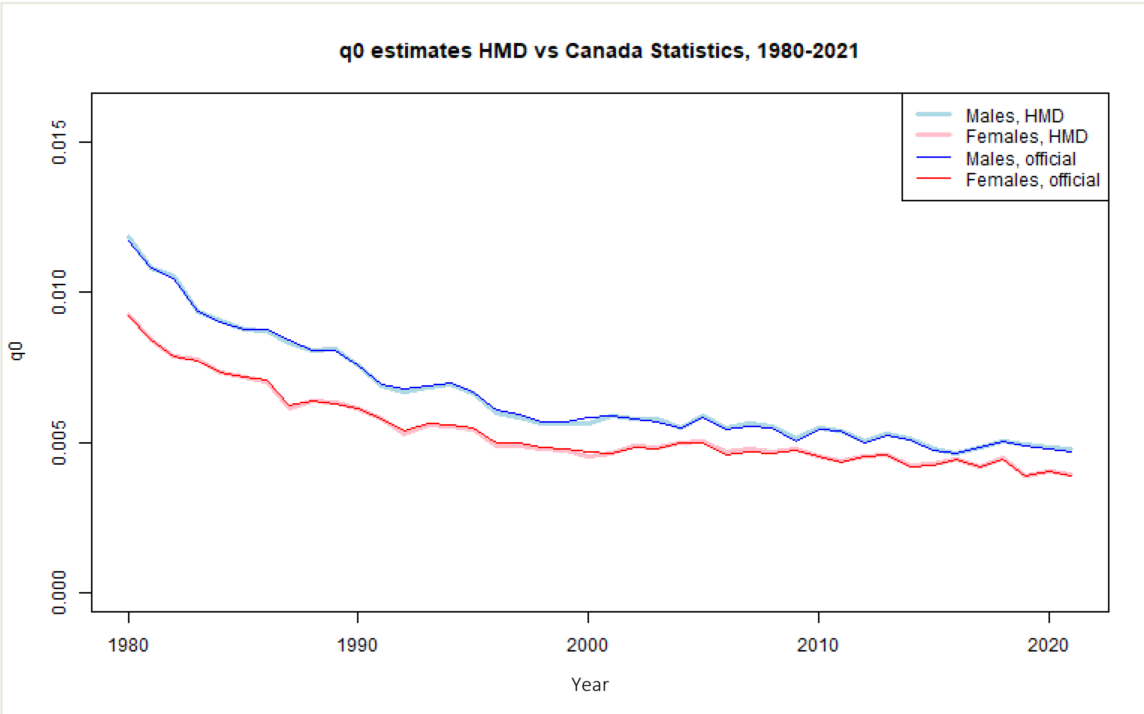
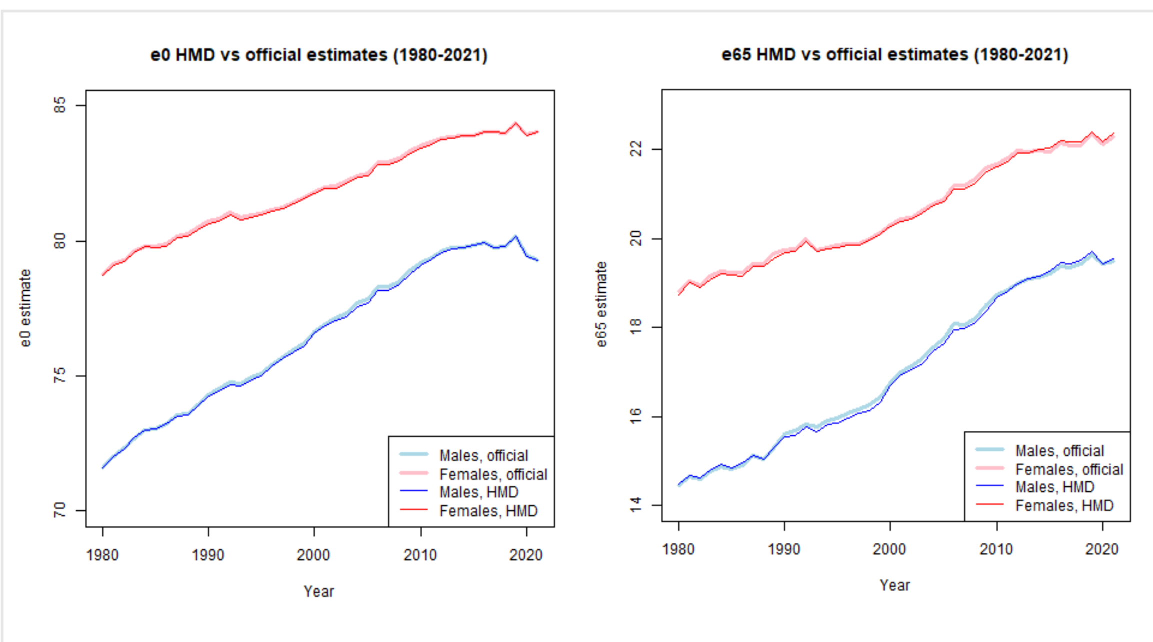


Figure 2

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 (1980-2021)



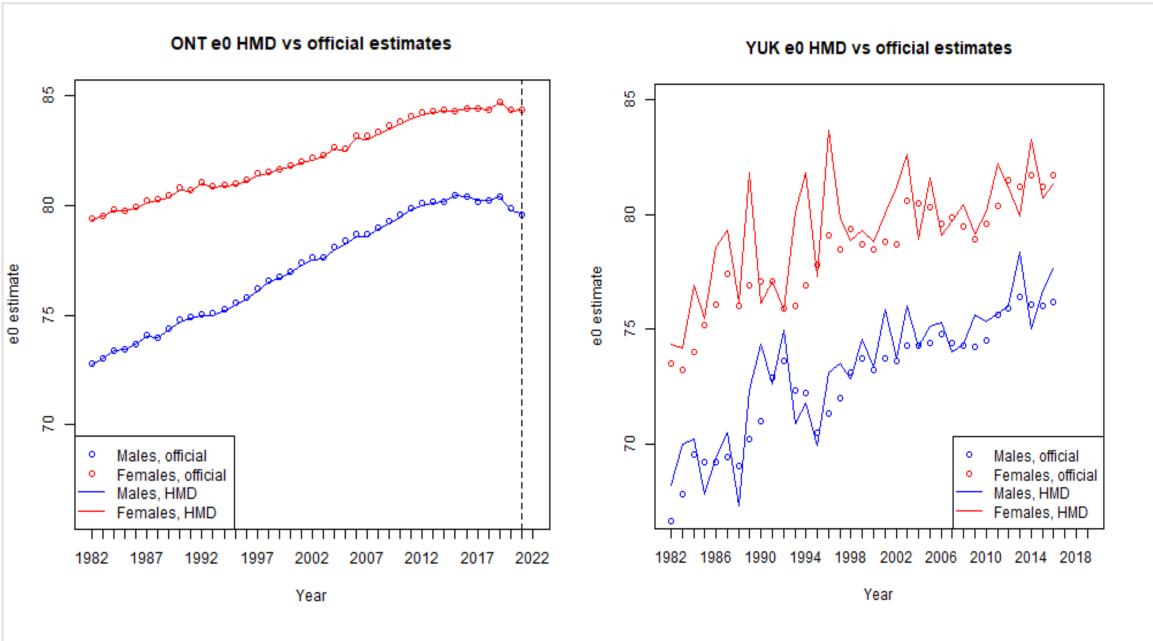
Section 3: Updating the CHMD Series

Individual-level mortality data were provided by Statistics Canada to Robert Bourbeau and tabulated by sex, single-year of age, birth cohort and, for the CHMD, province/territory for our own purpose. The birth and population data were downloaded from the website of Statistics Canada. The data were tabulated for each calendar year 2017-2021 as the 2017, 2018 and 2019 data previously used had been revised by Statistics Canada to take delayed registration (of births and deaths) into account. All of 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. Because the HMD Methods Protocol involves implementing two methods (the extinct cohort method and the survival ratio method) recalculating cohort data for many of the previous years with each new set of data, calculations apply to every calendar year in the series and not only to the new data point (2020-2021). The life tables have been calculated for each province and territory from the Lexis triangle counts of deaths and exposures, starting with the death rates, first for single-year of age and single-calendar year, and then for five- and ten-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 2017–2021 so the update does not include this territory.

In addition to standard internal consistency checks (described in Appendix A), the final life table values were compared with those published by Statistics Canada. Note that though the CHMD series starts in 1921 (1950 for Yukon and the Northwest Territories), Statistics Canada only started publishing official life tables at the province/territory level in 1980. Our analysis shows that the degree of consistency between life table 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. However, there were some in Newfoundland and Labrador and Prince Edward Island, and quite a lot in the Northwest Territories and Yukon. For illustration see Figure 3 where we chose a large and a small province for contrast. Note that Statistics Canada publishes life tables at the regional level for 3-year periods only for low-populated provinces and territories (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 differences in smaller provinces may thus be attributable to this difference in the reference periods between the official 3-year averages and the single-year CHMD estimates.

Figure 3

A COMPARISON OF LIFE EXPECTANCY AT BIRTH IN ONTARIO AND IN YUKON IN THE HMD LIFE TABLES AND IN THE LIFE TABLES PUBLISHED BY STATISTICS CANADA[1], 1982 THROUGH 2019-2021 (ONTARIO) AND 1980-1982 THROUGH 2014-2016 (YUKON)

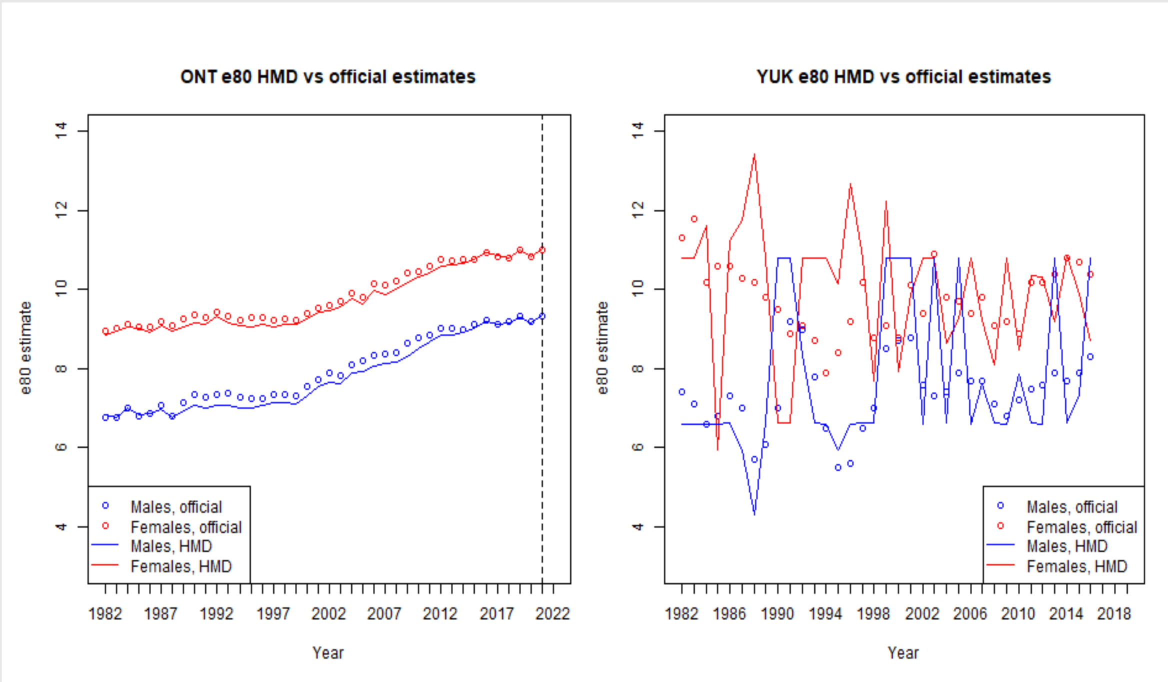


The pattern is very similar for the expectation of life at age 60 years but there are some differences at age 80 years, even in the most populated provinces (Figure 4). The estimates for the remaining length of life at age 80 tend to be higher in the life tables prepared by Statistics Canada than in the HMD, which is likely due to differences in the methods used to estimate mortality at ages 80 years 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 is expected to close progressively, as already seems to be the case for the most recent years.

[1] Sources: https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=1310083701 [accessed January 20, 2024]; and https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1310014001 [accessed January 20, 2024].

Figure 4

A COMPARISON OF LIFE EXPECTANCY AT AGE 80 YEARS IN ONTARIO AND IN YUKON IN THE HMD LIFE TABLES AND IN THE LIFE TABLES PUBLISHED BY STATISTICS CANADA[2], 1982 THROUGH 2019-2021 (ONTARIO) AND 1980-1982 THROUGH 2014-2016 (YUKON)



[2] Sources: https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=1310083701 [accessed January 20, 2024]; and https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1310014001 [accessed January 20, 2024].

Section 4: Acknowledgments

The Human Mortality Database and the Canadian Human Mortality Database research teams would like to thank the Canadian Institute of Actuaries and the Society of Actuaries for their generous financial support.

Appendix A: Internal Consistency Checks

Internal Consistency Check List:

1. Verification that raw death and population data cover the expected age and calendar range
2. Comparison of raw population data with exposure counts (after various adjustments are carried out)
3. 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
4. Compare male and female mortality to identify suspicious patterns
5. Compare single-year of age mortality rates with adjacent ages (for instance to identify particular age attractions)
6. 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)
7. 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)
8. Compare trends in life expectancy values with Sweden (HMD gold standard for data quality)
9. Compare age pattern of mortality with that in other HMD populations at the same level of life expectancy at birth
10. 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

About The Society of Actuaries Research Institute

Serving as the research arm of the Society of Actuaries (SOA), the SOA Research Institute provides objective, data-driven research bringing together tried and true practices and future-focused approaches to address societal challenges and your business needs. The Institute provides trusted knowledge, extensive experience and new technologies to help effectively identify, predict and manage risks.

Representing the thousands of actuaries who help conduct critical research, the SOA Research Institute provides clarity and solutions on risks and societal challenges. The Institute connects actuaries, academics, employers, the insurance industry, regulators, research partners, foundations and research institutions, sponsors and non-governmental organizations, building an effective network which provides support, knowledge and expertise regarding the management of risk to benefit the industry and the public.

Managed by experienced actuaries and research experts from a broad range of industries, the SOA Research Institute creates, funds, develops and distributes research to elevate actuaries as leaders in measuring and managing risk. These efforts include studies, essay collections, webcasts, research papers, survey reports, and original research on topics impacting society.

Harnessing its peer-reviewed research, leading-edge technologies, new data tools and innovative practices, the Institute seeks to understand the underlying causes of risk and the possible outcomes. The Institute develops objective research spanning a variety of topics with its strategic research programs: aging and retirement; actuarial innovation and technology; mortality and longevity; diversity, equity and inclusion; health care cost trends; and catastrophe and climate risk. The Institute has a large volume of topical research available, including an expanding collection of international and market-specific research, experience studies, models and timely research.

Society of Actuaries Research Institute
8770 W Bryn Mawr Ave, Suite 1000
Chicago, IL 60631
www.SOA.org