CHANGES IN THE AGE-AT-DEATH DISTRIBUTION BY LEADING CAUSES OF DEATH IN CANADA: AN INNOVATIVE ANALYSIS THROUGH A NONPARAMETRIC METHOD

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Introduction

During the XX[th] century industrialised countries have experienced significant economic growth which has been largely driven by the development of technological innovations. During this era social change and economic development greatly improved the standard of living of human populations as more focus was directed towards sanitation habits and the development of new treatments and pharmaceutical drugs. Thereby, infectious diseases, which were the main causes of death in young children, as well as degenerative diseases, affecting mainly people aged 65 years and over, have greatly diminished. As a consequence, life expectancy in industrialised countries, such as Australia, Canada, France, Italy, Japan, New-Zealand, Spain and the United States, has increased by as much as 40 years during the last century thus causing important changes in the age-pattern of mortality. Therefore, the shape of age at death distribution and the survival curve have undergone substantial transformations over time. Consequently, some countries entered an old-age compression of mortality era defined as an increase of the adult modal age at death accompanied by a concentration of senescent deaths around this age.

A recent study by Ouellette and Bourbeau (2011) has shown that in Canada, such regime began around 1930 and 1970 among females and males, respectively. Moreover, for the latest years, female mortality has even been showing signs of a shifting rather than a compression of mortality regime, suggesting that adult mortality may currently be shifting to higher ages while the shape of the distribution of deaths remains intact. However, several questions have yet to be answered: Are there signs of male and female mortality compression when looking at the changes in the age-at-death distribution by leading cause of death? If so, which causes of death are responsible for the overall (all causes combined) compression of Canadian mortality? Moreover, did some causes of death contribute more than others to this general phenomenon of compression of male and female mortality? Similarly, which causes are responsible for the shifting of female mortality which has been observed in recent years in Canada? To our knowledge, no research has addressed these questions in the Canadian context.

Answering these questions will enable us to determine if the shifting mortality scenario observed lately in Canada will likely be accompanied by a postponement or a prolongation of morbidity and disability episodes. More precisely, in the event of a shift of adult mortality towards higher ages, will morbidity and disability episodes occupy a smaller or a larger proportion of the typical human life span? Thus the analysis of mortality by causes of death will allow a better understanding of this phenomenon. Moreover, the analysis of the changes in the cause-of-death patterns will give us some insight on the evolution of the determinants of mortality and may improve our understanding of the processes that have fuelled the compression of mortality.

Since our analysis is conducted for male and female separately, we will also be able to determine which causes of death are responsible for the later onset of male mortality compression compared to their female counterparts, and to explain why male mortality hasn't yet entered the shifting regime.

In Canada the five leading causes of death for men and women are cancer, heart diseases, cerebrovascular diseases, chronic lower respiratory diseases, and unintentional injuries. In 2007, deaths from these diseases accounted for about 65% of all deaths (Statistics Canada, 2012). During the past twenty years, death rates for most causes of death have declined, except those for chronic lower respiratory diseases. Indeed, in 2007, the level of mortality for this type of diseases is higher than the one observed in 1981 among women (Milan, 2011). In Canada, as in many other countries, men mortality is higher than female mortality but the sex gap in life expectancy seems to narrow as female chronic lower respiratory mortality increases. Another disease that seems to contribute to this phenomenon is the malignant neoplasms of trachea, bronchus and lung. As a matter of fact, female mortality follows an upward trend since 1981 while that of men has been quite stable until 1988 after which it started a pronounced decline.

The aging of the population has also caused changes in the patterns of other causes of death such as diabetes and Alzheimer's disease, which in 2009 are ranked 5th and 8th respectively. In recent years, there has been a downward trend in the number of deaths due to diabetes, possibly because of greater individual awareness and publicity campaigns. As for the Alzheimer's disease, changes in the international classification of this disease make comparisons before 2000 difficult. Since 2000 however, a downward trend seemingly more pronounced for males than for females is observed in the number of deaths caused by this disease (Milan, 2011).

While the evolution of the mortality rate by cause of death is quite well documented, changes in the age-at-death distribution of cancer diseases, heart diseases, cerebrovascular diseases, chronic lower respiratory diseases, and unintentional injuries are not. Thereby, this study focuses on identifying which of these leading causes of death have undergone major changes in their age mortality pattern and hence are responsible for the overall phenomenon of mortality compression. We refine the analysis by also examining the general categories of causes of death in greater detail. For example, we similarly analyse changes in the shape of the age-at-death distribution by sub-categories of cancer such as breast (females) and prostate (males) cancer.

Methods and Data

In order to determine which causes of death among those cited earlier show signs of mortality compression and which ones do not, we analyse the evolution through time of their respective modal age at death (*M*) and standard deviation above the mode (*SD(M+)*). Changes in the age-at-death distribution, monitored through these two indicators, are evaluated using a nonparametric smoothing approach, known as the P-*splines* method (Ouellette and Bourbeau, 2011). P-splines, initially developed by Eilers and Marx (1996) and widely used in applied sciences, have gained great popularity in the domain of mortality analysis (Camarda, 2008; Currie *et al.*, 2004, 2006; Eilers *et al.*, 2006). As opposed to parametric approaches, this smoothing method relaxes the hypotheses made on the expected structure of mortality trajectories according to age and/or calendar years. It therefore allows us to preserve the richness of the data and to obtain detailed and accurate mortality representations as described by the actual data.

Even though the modal age at death has been introduced long ago by Lexis (1878) as the most central and natural characteristic of human longevity, it has been underused in contemporary demography. However, following its reintroduction by Kannisto (2000, 2001), this measure has become quite popular among demographers when analysing changes in the age-at-death distribution (Brown et al., 2012; Canudas-Romo, 2008, 2010; Cheung et Robine, 2007; Cheung et al., 2005, 2008, 2009; Kannisto, 2000, 2001, 2007; Ouellette and Bourbeau, 2011; Ouellette et al. (forthcoming); Paccaud et al., 1998; Robine, 2001; Thatcher et al., 2010). One of the main arguments being that after the fall in infant and childhood mortality, increases in duration of adult life, due to major declines in old-age mortality, were no longer reflected as well by increases in life expectancy. Hence, the modal age at death is a more suitable indicator in an era of longevity extension (Kannisto, 2001; Horiuchi, 2003).

Through the “Data Liberation Initiative”, a program initiated by Statistics Canada to improve access to data resources at Canadian postsecondary institution, we got access to the Canadian Vital Statistics Data set, which contains confidential information on causes of female and male deaths that have occurred between 1974 and 2008 in Canada. This data set provides detailed information on the causes of death by sex, single-year of age and calendar year. The causes of death are classified according to the World Health Organization "International Statistical Classification of Diseases and Related Health Problems" (ICD). Given that our study period extends from 1974 to 2008, it covers three revisions of the international classification: ICD-8, ICD-9, and ICD-10. Important modifications were made to the ICD-9 version (compared to the subsequent ICD-10 version), the main one being the replacement of the numeric code with an alphanumeric one thereby increasing the number of possible categories and sub-categories. Hence, our analysis of mortality trends over time by underlying cause of death becomes more challenging.

We are also facing an interesting methodological challenge. As previously mentioned, one of our objectives here is to determine the contribution of each leading cause of death to the overall compression of mortality outcome. In order to do so in a entirely comprehensive manner, modifications will be made to the general Poisson P-splines method so that the age-at-death distribution by cause of death sums up to the age-at-death distribution for all causes combined.

Preliminary results

Our preliminary results show that between 1974 and 2008, the modal age at death has increased while the standard deviation above the mode has decreased for the top two leading causes of death in Canada: cancers and heart diseases. Moreover, premature deaths seem to have also progressed towards older ages indicating an improvement in prevention, screening, and treatment. Similar trends are obtained when analysing the age-at-death distributions of ischaemic heart diseases as well as cerebrovascular diseases, the main sub-categories of heart diseases. Indeed, in 2008 men and women die later on from these illnesses than in 1974 as indicated by the increasing modal age at death. However, men perish at younger ages than women. These results are also observed when examining the breast and prostate cancer mortality profiles by age and sex.

This is an ongoing project and we intend to conduct similar analysis for the following causes of death: cancer of the trachea, bronchus, and lungs, colorectal cancer and chronic lower respiratory diseases.

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