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Title:

Centenarian overestimation: Using vital statistics to evaluate centenarians enumerated in recent Canadian Census and to produce accurate estimates.

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Short Abstract:

As a result of gains in life expectancy, an increasing number of Canadians are reaching advanced ages. Centenarians are currently among the fastest growing age-groups in Canada. Studies have shown that the number of centenarians has been overestimated, especially for males, in older Canadian censuses and were also proportionally higher than in other countries with similar low levels of mortality.

The goal of this paper is first to assess the accuracy of the number of centenarians reported in recent censuses using various indicators, administrative data and international comparisons. Second, it is to produce, using death record, estimates of number of centenarians using the *extinct cohort* and *survival ratios* methods, and to compare results with census. Finally, it is to assess the impact of a new question introduced in 2011 Census asking age in addition to the date of birth of respondents on overestimation of centenarians.

Long Abstract:

Background

One of the major changes related to Canada's age and sex structure in the last several decades is population aging. This phenomenon is linked to a number of significant social and economic issues such as renewal of the working age population, financing of public health care and retirement programs. The Canadian population have been rapidly aging over the last few decades. The proportion of seniors doubled in Canada between 1971 (8%) and 2011 (15%). Recent international data[1] of OECD countries shows that the proportion of seniors in Canada remains below levels in Japan (23%), Germany (21%), France (17%) and the United Kingdom (16%), but slightly higher than in the United States (13%). In Canada, centenarians are currently the fastest growing age group. In 2011, the number of centenarians increased more than 42% from 2001 (11% overall) and 138% from 1971 (43% overall). Other industrialized countries have seen a similar growth in the number of centenarians: France (Vaupel and Jeune 1995; Vallin and Meslé 2001), U.S (Krach and Velkoff 1999; Kestenbaum and Ferguson 2005; US Census Bureau 2012), Brasil (Gomes and Turra 2009) and in other countries (Human Mortality Database 2013; Office for National Statistics 2013).

Some studies (Lebel 1999; Bourbeau and Lebel 2000) have demonstrated that the number of centenarians has been overestimated in older Canadian censuses (1971-1991) and proportionally higher than other countries with similar low levels of mortality. In those countries, it has been demonstrated (Kannisto 1999) that for the 1990s there was five centenarians per 100,000 persons compared to 11 centenarians per 100,000 persons in Canada (Bourbeau and Lebel 2000). The last Census available (2011) shows that there were 5,825 people aged 100 or older in Canada or 17.4 centenarians per 100,000 persons. This was slightly below the average of 19.7 among G8 countries, including Japan (36.8), Italy (26.6), France (25.8) and United Kingdom (20.3) (Statistics Canada, 2012:2). Compared to Canada, these countries have however older populations and higher life expectancy level. In the United States, the rate of centenarians was slightly lower (17.3) than in Canada despite the fact that its population has a slightly lower life expectancy.

The goal of this paper is first to assess the accuracy of the number of centenarians reported in recent census using various indicators, administrative data (pensioners and tax filers) and international comparisons. Second, it is to use death records to estimate the number of centenarians using the *extinct cohort* method and *survival ratios* for non-extinct cohorts, and to compare results with census figures. Number of centenarians estimated with these methods will be used to produce official Canadian population estimates. Third, it is to assess the impact on age declaration among centenarians of a

[1] 2011 World Population Data Sheet from the Population Reference Bureau

new question in 2011 asking age and not only the date of birth of respondents to derive age.

Data source and data quality

Death:

Microdata on deaths were obtained from the Health Statistics Division of Statistics Canada for the calendar years 1951 to 2011, by date of deaths, sex and date of birth of deceased (up to 119 years old). Deaths were organized by individual triangles of the Lexis diagram in census cohort, i.e. people who died between census day (May 10) of two consecutive year (x and x+1). For instance, a person dying at 100 years in census year 2010/2011 was not necessarily born in census year 1910-1911(younger cohort or lower triangle); she could have been born in census year 1909/1910 (older cohort or upper triangle). The creation of census cohorts allows for a more precise estimation of population on census day as compare to using calendar (January to December) year cohort and doing an average to get to a date closer to census day. This classification of deaths by cohort is essential when applying Vincent's method of extinct cohorts (Vincent, 1951) to the reconstitution of the population at advanced ages (85 years old and over).

It is documented (Bourbeau and Lebel 2000) that death records in Canada have been in past years, especially in the 1950s and 1960s, suffering from the overestimation of age at death, and from age and cohort heaping. For example, cohort heaping results from an attraction to declare a younger cohort at death, from the calculation of the year of birth as the difference between the date of the current year and the age at death. It has also been demonstrated that the quality of vital statistics declarations of deaths among centenarians is superior to that of census declarations (Bourbeau and Lebel 2000). There are still problems of age misreporting at death in vital statistics, mainly net age overstatement in particular for centenarians and supercentenarians (Lebel 1999; Bourbeau and Desjardins 2002; Beaudry-Godin and al. 2008; Desjardins and Bourbeau 2010).

Population:

Census Population:

The most recent Canadian census was held on May 10th 2011 and information by age and sex released on May 29th 2013. The Canadian Census of Population is taken to meet statutory requirements (Statistics Canada 2011). The oldest age group published in Census from 1911 to 1966 was the 95 years old and over (95+), with the exception of censuses between 1911 and 1931 where it was temporary available for the 100 years and over (100+). Since 1971, Statistics Canada has published every 5 years, the number of centenarians living in Canada.

For centenarians, the types of errors and the magnitude of their effect can vary from one census to another, with error of misreporting (from illiteracy, cognition difficulties, proxy reporting, voluntary or non voluntary false declaration) or data capture and processing errors (optical reader issues). Raw data collected in Canadian censuses goes over validation process before being released. For example, any outlier age value, such as declaration of age above 120 or supercentenarians (110+) living in private households are verified, edited and imputed according to characteristics available in the census form.

Moreover, in 2006, all census questionnaires containing a centenarian were manually validated and any false centenarians detected were corrected (35%). A stratified sample of questionnaire containing people age 95-99 years old was selected for verification for which 4% incorrect age declaration were corrected. In 2011, an additional question was added in the census, asking age, in addition to the date of birth (DOB) of respondents which was before the only way to derived age of individuals. This addition allowed for consistency validations or concordance of age derived by DOB or directly asked. The proportion of inconsistent declarations by more than one year reached overall 1.79% but was significantly higher for nonagenarians (6.62%) and centenarians (33.33%). These cases were corrected prior to release of the latest census data on age and sex.

Unpublished Centenarians counts from 1971 to 2011 censuses were obtained by single years of age, up to 121 years old and sex. Overall, Statistics Canada's published population counts of very high quality. Among centenarians, overestimation problem were raised for Canadian censuses between 1971 and 1991 and to a greater extent for males than females (Bourbeau and Lebel 2000). The proportion of centenarians in Canada was found for that period to be higher than other countries with similar low levels of mortality (Bourbeau and Lebel 2000; Kannisto 1999).

Population estimates:

Statistics Canada's population estimates program is used in the calculation of demographic, social and economic indicators. Population estimates produced by the Population Estimates Program (PEP) is based on data from the last available self-declared census adjusted for net undercoverage (CNUC) and incompletely enumerated Indian reserves (Statistics Canada 2010) and on a cohort-based demographic accounting system using administrative files and/or other sources (Statistics Canada 2012:1).

Through its Population Estimates Program, Statistics Canada disseminates since 2001, each year, estimate of the number of centenarians in Canada and in each province and territory by sex (Statistics Canada 2012:3). The overall population estimates contain a certain margin of inaccuracy stemming both from errors in corrections for CNUC and errors arising in estimating the components. Census coverage studies produce estimates by age. Due to small sample, CNUC can show irregular pattern over ages, and especially above age 65. For that reason, CNUC is smoothed using splines method. For the 65 years and over, the CNUC was estimated at -1.39% in 2006

meaning that a few centenarians were actually added with this procedure. New estimate for CNUC by age and based on the 2011 Census will be released in November 2013.

In order to assess the quality of population estimates, the errors of closure is often used. It can be defined as the difference between the most current postcensal population estimates as of Census Day and the enumerated population of the most recent census adjusted for CNUC. A positive error of closure means that the postcensal population estimates have overestimated the census population. By dividing the error of closure by the census population, the differences in 2006 are relatively small for male (0.26%) and female (0.38%) but does vary among age groups, notably higher in 25-29 and 30-34 year groups (around 2%). For centenarians, the error of closure stood at -0.12% for male and 0.05% for female in 2006, which mean that postcensal estimates underestimated the number of males but overestimated the number of females observed compared to the 2006 census.

Latest postcensal population estimate for centenarians as of July 2011 released in 2012 by Statistics Canada and based on the 2006 Census suffer also from overestimation when compared to 2011 Census figures. The estimates are 29% higher for females and 88% higher for males. This seems to indicate that not all false centenarians were removed in the manual validation of the 2006 Census questionnaires and that the number removed in the 95-99 years group and reaching 100 year old in 2011 was not sufficient. This lead the PEP of Statistics Canada to explore other methods in order to produce new estimates now based on the 2011 Census and also, to revise estimates of the last two intercensal cycles (2001/2006 and 2006/2011) age and sex estimates.

Methods

Using mortality statistics, generally offering better coverage, populations are estimated with the help of the method of *extinct cohort* (Vincent, 1951). This method has been used by many researchers to estimate populations at advanced ages (80 years old and over) and their mortality. Assuming that these sub-populations are not affected by international migration, both entries and exits, the principle of the method is very simple; when all member of a given cohort have died, the numbers alive in past year can be calculated by summing the deaths, beginning with the oldest. The quality of population estimates using this method has been demonstrated in many researches for countries with good quality of deaths (Coale and Kisker 1990; Coale and Caselli 1990; Kannisto and al. 1994; Human Mortality Database 2013). In this paper, we have chosen 110 years as the age at which cohorts is consider being extinct. Since1950, very few deaths were declared above age 110 in Canada (349 over 10.6 million deaths overall).

For non-extinct cohorts, the *survival ratio* method (Thatcher 1992; Thatcher and al. 2002; Andreev 2004) is often used to estimate population in a similar way but under the assumption that deaths of non-extinct cohorts are distributed by age like those who are extinct, assuming that mortality is invariable. Recent development proposing the introduction of correction factor to take into consideration possible improvement in life expectancy among the oldest-old and calibration to join estimate with official statistics

(Thatcher and al. 2002) will be explore in this paper. The Population Estimates Program of Statistics Canada will use these methods to reconstitute and therefore estimate historical series of the centenarian population in Canada just like United Kingdom's Office of National Statistics did recently (Office for National Statistics 2013).

Preliminary findings

The population estimate of centenarians is under *embargo* until November 25th, 2013 when they will be officially released by Statistics Canada. In consequence, we are just allowed to present here some broad results.

According to our preliminary results of estimated centenarians derived using death information, the accuracy of the number of centenarians reported in recent censuses (2001, 2006 and 2011) has been improving compared to Censuses held from the 1970s to 1990s. In recent censuses, the overestimation in the size of centenarian populations is still more important for males (between 25% and 45%) than for females (less than 5%). Furthermore, new estimates show than centenarians have increased at slightly faster pace that census numbers reveal, by 154% since 1971 compared to a rate of 138% using Census.

Compare to recent censuses, the new centenarian estimates also gives lower male-female ratio, around 17% for estimates vs. 22% for censuses, a level closer to countries with similar low levels of mortality. Preliminary results also show that new estimates produced for 2011 a lower number of centenarians, with 15.6 per 100,000 persons compared to 17.4 for censuses. Finally, according to preliminary results, the impact of the introduction of the new question in 2011 census asking age in addition to the date of birth of respondents seems to be marginal on the overestimation issue among population age 100 years and older.

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