Healthy longevity variability: first insights from the Global Burden of Disease

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Introduction

Since the concept of healthy life expectancy was introduced by Sanders [1] and later operationalized by Sullivan [2], the increasing interest in distinguishing healthy longevity from longevity without regard to health has generated a vast literature [3-6]. However, the focus has so far been on expected values and inequalities between groups, disregarding the fundamental distributional question of how the healthy lifespan is distributed between the individuals within the populations. Similar levels of mean healthy life expectancy can be achieved by different distributions of healthy lifespans: one more concentrated, where many individuals share more similar number of years in good health, and one less concentrated, where some individuals enjoy substantially higher numbers of years in good health than other individuals, who suffer from ill health early on.

In the last decade or so, demographers working on mortality have recognized the importance of supplementing analyses of average longevity (such as life expectancy) with analyses of variation in ages at death in the assessment of population health [7]. This interest led to important discoveries such as the evidence of higher lifespan uncertainty in lower educated groups [8], divergent trends of lifespan inequality by social status in some countries [9] but not in others [10] and the remarkably stable inverse correlation between life expectancy and lifespan variation [11, 12].

To date, a systematic assessment of the trends in healthy lifespan variation is missing. In this paper we provide the first systematic, international series of trends in the variance of healthy longevity among individuals and test the hypothesis that an inverse relation holds between healthy lifespan length and healthy lifespan variation.

Studying patterns and trends of healthy lifespan variation is important. First, in addition to its relevance to the debate around questions of distributive justice, the variation within healthy life expectancy also has crucial economic implications, as highlighted by the analysis of the trends in working life expectancy at age 50 in Europe, which found that this indicator has a higher correlation with healthy life expectancy (based on self-reported health) than with total life expectancy [13]. Second, the analysis of gender differences in healthy lifespan variation is likely to be and important piece of the puzzling male-female survival paradox, which is the fact that women live longer than

men, but they are in worse health [14]. Recent results, indeed, suggest the health-survival paradox appears to be also a function of indicators of population health and their gender differences. [15, 16].

Finally, more and more findings support the hypothesis that the increase in survival has been accompanied by a compression of morbidity at older ages [17], even though there are notable exceptions such as the United States, where an inversion of trend has been reported between 1998 and 2006 [18]. However, as the compression of morbidity can happen from both sides (from the side of the end of life and from the side of the entry into the morbid state), this is not necessarily informative about the distribution of healthy life expectancy.

Caswell and Zarulli [19] introduced an innovative, matrix-based approach to the demography of health that allows the computation, at the same time, of mean values and statistics of variation (the variance, the standard deviation, the coefficient of variation and so on). They found that in nine European countries the variation in healthy life expectancy was lower than the variation in total life expectancy, for both men and women and over the life course. Based on the calculations in Caswell and Zarulli [19]) we produced preliminary results, reported in Fig. 1. They show that while there is a negative correlation between life expectancy and life span variation (expressed as standard deviation), the relationship seems reversed in the case of healthy life expectancy: longer healthy life span is positively correlated with higher healthy lifespan variation. This would reject the hypothesis of an inverse relation between healthy lifespan length and healthy lifespan variation.

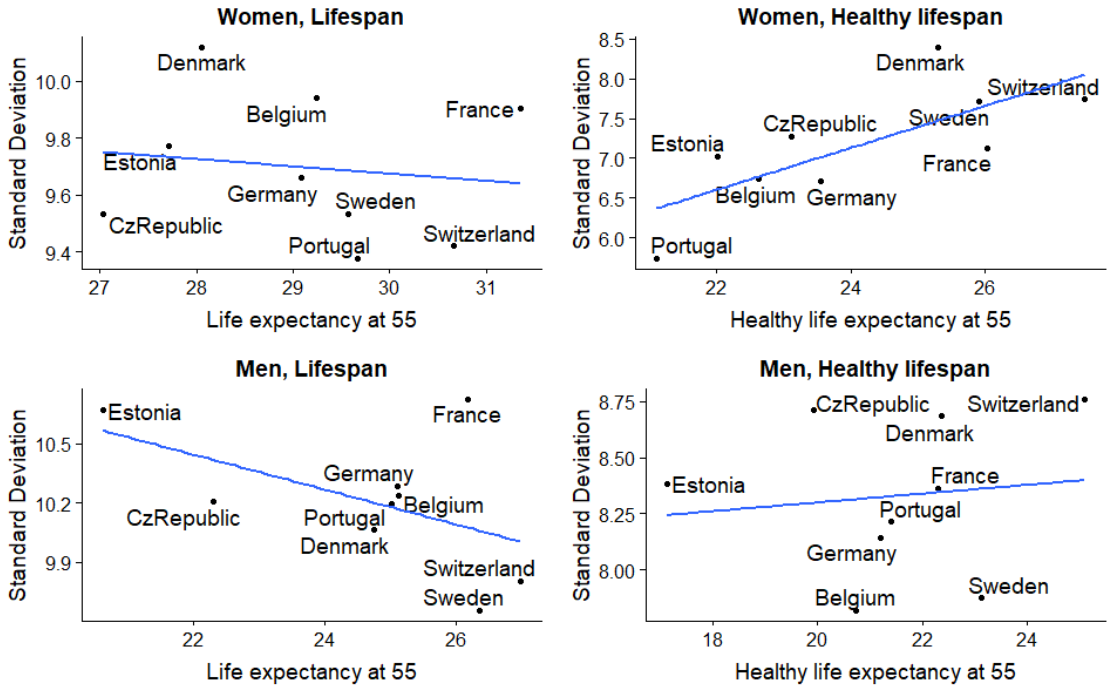

Fig. 1 – Total and healthy lifespan at age 55 (x axis) and its standard deviation (y axis) for men and women in nine European countries in 2011 - *based on the calculations in Caswell and Zarulli [19]*.

During the last century, the most successful countries in terms of life expectancy increase were also the ones who succeeded in reducing individual variation in the age at death [12]. The development of extensive and increasingly accessible healthcare systems during the last decades has undoubtedly played a role in reducing the uncertainty in age at death for individuals but little is known about the ability to reduce the uncertainty around the number of healthy years of life. The preliminary results reported in fig. 1 suggest that they might have been less good at reducing the uncertainty around the expectation of healthy life. The exploratory findings reported show the importance to investigate the relation between healthy span of life and its variance between individuals. Using the Markov chain with rewards method, we can calculate this using sensitivity analysis developed in [20] Deepening our knowledge about this relation would allow us to answer fundamental questions such as: are individuals subject to similar levels of variance in years of life and healthy life or is the variation in healthy longevity lower than the variation in total longevity? Were the variations in healthy longevity and total longevity similar in the past, but followed different dynamics over time, so that today the variation in healthy longevity is lower than the one in total longevity? Would the result that a longer healthy lifespan is accompanied by higher variance confirmed by a more thorough analysis, while it is the opposite for the total life expectancy?

Data and methods

The most commonly used approach to incorporating health into longevity analysis is the Sullivan method, which modifies the length of life by a system of weights that describe, on some scale, the quality of that life. Often these weights are prevalence rates of disability, variously defined. The Sullivan method produces estimates of the mean, or expected value, of healthy longevity, but not of its inter-individual variability. The matrix model for health demography developed by Caswell and Zarulli [19] is a stochastic approach that provides any desired statistic of inter-individual variability. Healthy longevity is described as an absorbing Markov process with rewards. Age classes appear as transient states, and death is an absorbing state. Healthy longevity is given by the lifetime accumulation of the reward, represented by the fractional years in a specified health condition over the life course. Matrix models have been used in demography for a long time, as adjunct to the life table methods [21]

The Caswell-Zarulli method requires only a set of disability or health prevalence rates and a mortality schedule by age. The country specific mortality schedules can be found on the Human Mortality Database [22]. A valuable collection of data on disability/health prevalence has been created by the Global Burden of Disease Study [23]. This dataset provides reliable, comparable data over time, for 195 countries around the world from 1990 to 2017. In this study we will use age-sex specific years lost to disability (YLDs) that is available also in the form of rate per 100K. This

metric is used by the GBD [6] study to compute Health Adjusted Life Expectancy (HALE; note that this measure provides no information on inter-individual variation) using life table methods. We will combine the YLD rates and the mortality schedules to parameterize the Markov chain model and use it to compute measures of variability in healthy longevity at every age. By doing so, we will provide the first systematic, international series of trends of healthy life expectancy variation.

Expected findings

Fig. 2 shows the trends in mean Health Adjusted Life Expectancy for Usa and Japan. The two countries are known to have different and somehow opposite longevity profiles: one is one of the world leader in longevity, the other one, despite being one of the most developed and industrialized countries, is lagging behind. As figure 2 shows, they differ also with respect to healthy adjusted life expectancy. A lag of about 20 years exist between their levels of HALE: today's female HALE in the Usa is approximately equivalent to the male's HALE in Japan 20 years ago. We expect to find different trends of variance in healthy longevity as well.

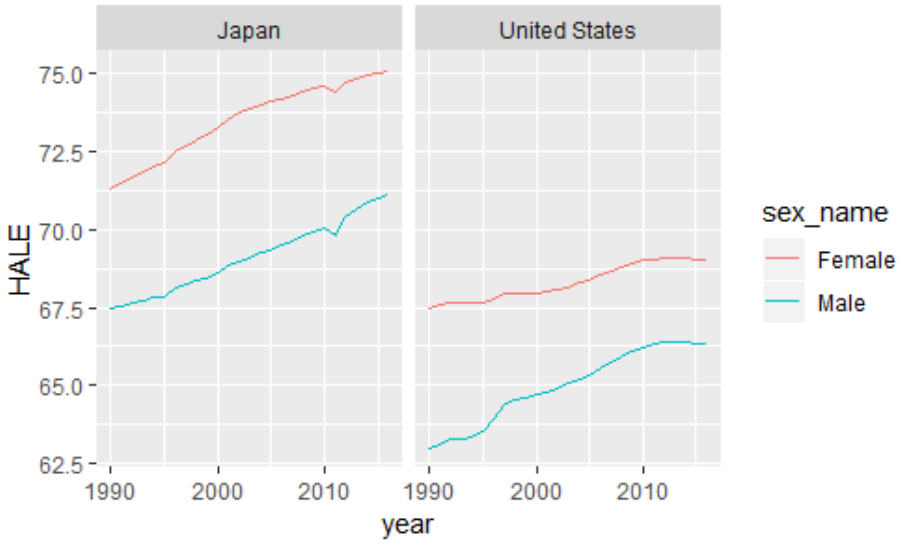

Fig. 2 – HALE (health adjusted life expectancy) at age 0 for Usa and Japan, men and women, over time.
Data from Global Burden of Disease Collaborative Network [23], available from http://ghdx.healthdata.org/gbd-results-tool (accessed on 26/09/2019).

We will extend the analysis to many countries from the GBD study and draw the first international landscape of healthy longevity variability. We expect different areas of the world, as well as high and low-income countries, to show different levels and trends of healthy lifespan variability.

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