Female-Male Relationship in Lifespan Variation

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1. Introduction

Females enjoy longer life expectancies than males throughout the lifecourse (Kannisto 1988; Austad 2011). This is true across countries and throughout history (Austad 2011; World Health Organization 2019). Studies have also shown that this advantage persists in communities with particularly healthy lifestyles and high fertility, such as Mormons, as well as in populations withstanding harsh living conditions (Lindahl-Jacobsen et al. 2013; Zarulli et al. 2018). Such research suggests that the female advantage in life expectancy may have, at least partially, an underlying biological cause (Austad and Fischer 2016).

However, Luy (2003) calculated that biological differences could account for only about a year of the sex gap, suggesting that differences in lifestyles determine the rest. Beltrán-Sánchez et al. (2015) underline that the sex gap in life expectancy first widened in the 1950s for cohorts born in the late 1880s as a result of increasing male mortality from cardiovascular diseases, caused by changing diets, as well as by decreased mortality from infectious diseases (Omran 2005). This shift also involves which ages drive the sex gap: before the middle of the XX century, infant and childhood ages contributed the most to the sex gap, while today older adult ages do (Zarulli et al. 2020; Zarulli et al. 2021). Janssen (2020) also showed the influence of smoking behaviours in widening and then narrowing this sex gap during the XX century.

While life expectancy measures the average age at death, lifespan variation captures the dispersion around this age, indicating the existence of heterogeneity in the mortality levels of a population (van Raalte et al. 2018). Lifespan variation has been shown to have a strong negative relationship with life expectancy, declining as life expectancy increased throughout the Western world (van Raalte et al. 2011), as the historical changes in mortality that led to an increase in life expectancy also happened to impact lifespan variation (Vaupel et al. 2011).

Females have also been found to hold an advantage in lifespan variation (i.e. experience narrower lifespan variation) (Colchero et al. 2016). However, the studies which have considered the sex gap in lifespan variation usually do not examine its trends over time, thus failing to contextualise more recent trends. We fill this gap by studying the long-term relationship between female and male lifespan variation in several countries. Analysing potential patterns and regularities in this relationship could shed light on the underlying mechanisms of sex inequality in lifespan variation, potentially contributing to more accurate mortality forecasting by providing insight into an additional dimension of mortality profiles.

While male and female life expectancies have progressed together in the past, differences in lifestyle have led to stark changes in the gap. On the contrary, our preliminary results show that the relationship between female and male lifespan variation seems to be much smoother than could have been expected based on trends in life expectancy. This suggests the existence of a strong underlying mechanism regulating this relationship, highlighting the need to delve deeper into its trends and their causes.

2. Methods and data

We use data from the Human Mortality Database (HMD, Barbieri et al. 2015), a high quality database for mortality data, covering more than 40 countries with time series for each going as far back as 1751. We use abdriged, single year period sex-specific lifetables for nearly all countries and for all available years (excluding 194 to 1918 and 1939 to 1945).

We use standard deviation (SD) as a measure of lifespan variation, because it is easy to understand and interpret and it is widely used in the literature (Edwards and Tuljapurkar 2005; van Raalte et al. 2011; García and Aburto 2019). We measure standard deviation at birth (SD_0), at age 15 (SD_{15}) and at age 50 (SD_{50}). We calculate SD for males and females separately for each country-year and calculate the correlation between them. In order to identify significant changes in this correlation, we use segmented regressions implemented with the R package *segmented* (Muggeo et al. 2008) and Likelihood Ratio tests to ascertain whether a breakpoint is significant or not. Once a breakpoint is confirmed, we analyse the change in the sex gap of SD between the 10 years before and after the breakpoint (this interval is narrowed when required by the data). We identify which ages have contributed to this change using

the Horiuchi decomposition method (Horiuchi et al. 2008).

3. Preliminary results

Analyses of SD_0 in figure 3 show a time trend from a more of a female disadvantage in earlier years, to a clear female advantage today. This points to the influence of changing social and environmental factors that may have influenced this relationship in the long run. At the same time, the overall relationship betwene female and male SD_0 is quite stable through time. in fact, about a third of populations have no breakpoint and no population has more than three identified breakpoints. Finally, Almost all breakpoints happen during the XX century and especially after 1950. Thus, the factors that influenced the sex gap in life expcetancy after World War II also seem to have impacted the sex gap in lifespan variation.

Looking at the relationship between female and male SD_15 allows us to understand what happens when we exclude the drastic mortality changes that very young ages experienced during the XX century. Figure **??** shows that results do not differ much from the previous figure. Thus, it seems that infants and children are not solely responsible for the relationship between female and male SD_0. Finally, figure **??** shows the relationship between female and male SD_{50}. Here, we see not clear relationship, nor time trend. Thus, it seems that at least a considerable part of the relationship between female and male SD_0 is driven not by very young ages, but rather by yougn adults.

Figures **??** to **??** show the age decomposition of the change in the sex gap in SD_0 betwene ten years before and ten years after each of the identified breakpoints. On main result emerges here. Breakpoints that happen early on see positive contributions up to around age 50, but especially at rather young ages (i.e. the mortality changes at these ages advanatge females in terms of SD_0), while later breakpoints, typically after 1960s and 1970s see positive contribtions from older ages, typically between ages 50 and 80. Thus, while in the past females were especially advantaged by the mortality developments at young ages, today, the sex gap in SD_0 in favour of females in mostly due to the influence of mortality changes for older adults.

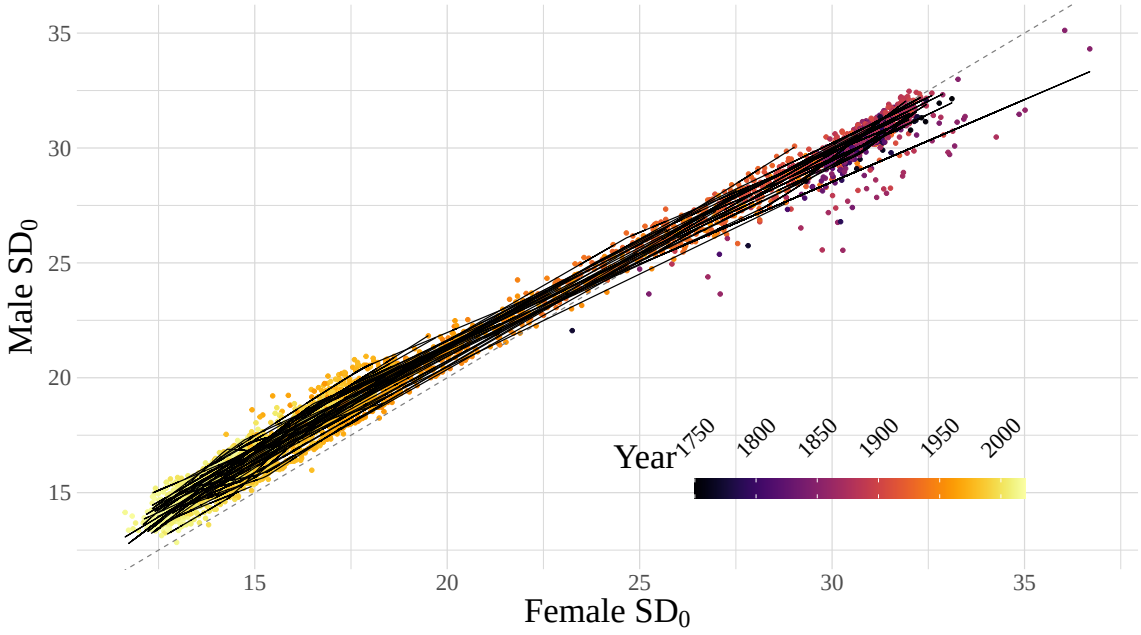
4. Next steps

We need to better understand the context of each breakpoint, in order to identify whether they can be linked, for example, to stages in the epidemiological transition or to specific levels of life expectancy or SD. We also plan to quantify the change in slope after each breakpoint and check whether a quantitative relationship with decomposition results can be identified.

We also plan to analyse the relationship between the sex gap in lifespan variation and that in life expectancy, to see whether regularities emerge and to better understand the relationship between the length and inequality of lifespans.

Finally, we will run sensitivity analyses. While measures of lifespan variation have been shown to be highly correlated (Wilmoth and Horiuchi 1999), we plan to check results using other indicators, such as the coefficient of variation. This will allow us to abstract from the life expectancy levels of single countries and explore potential differences between absolute and relative measures (van Raalte and Caswell 2013; Wrycza et al. 2015).

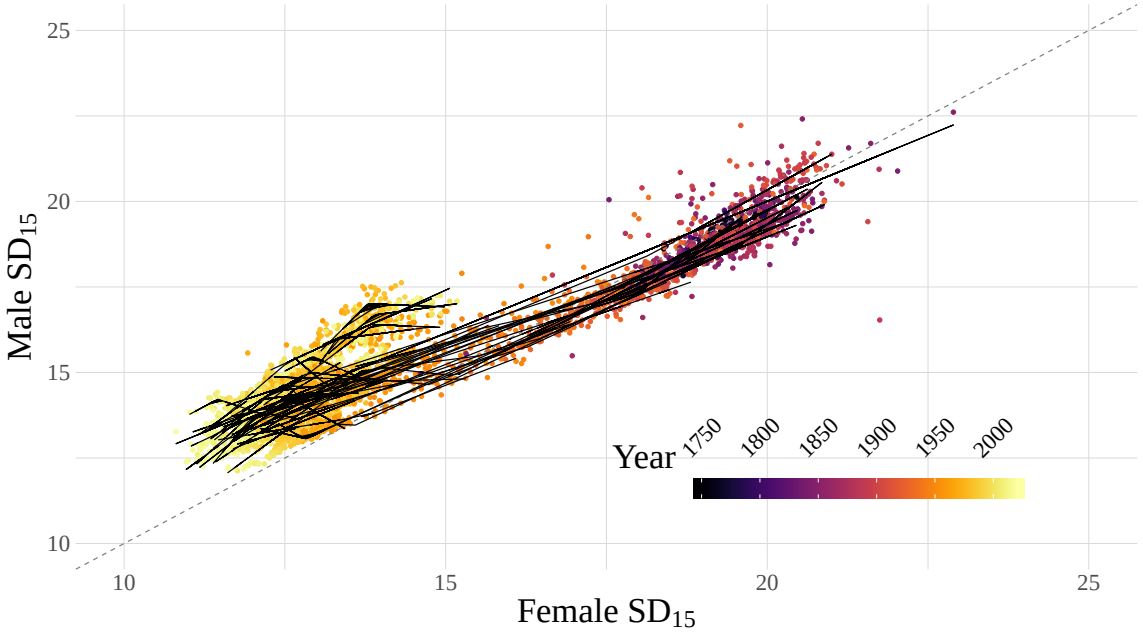
Figure 1: Observed and fitted relationship, female and male SD_0



Source: HMD

Fitted and observed values of female (x-axis) an male (y-axis) standard deviation at birth, for nearly all populations and all available years in the HMD (except from 1914 to 1918 and 1939 to 1945). Values for older years are shown in black/purple, for more recent years in light yellow. Colour-year correspondences are based on Sweden, which has the longest time series. Black lines show the segmented regression for each population, while equality is shown by the 45 degrees grey dashed line

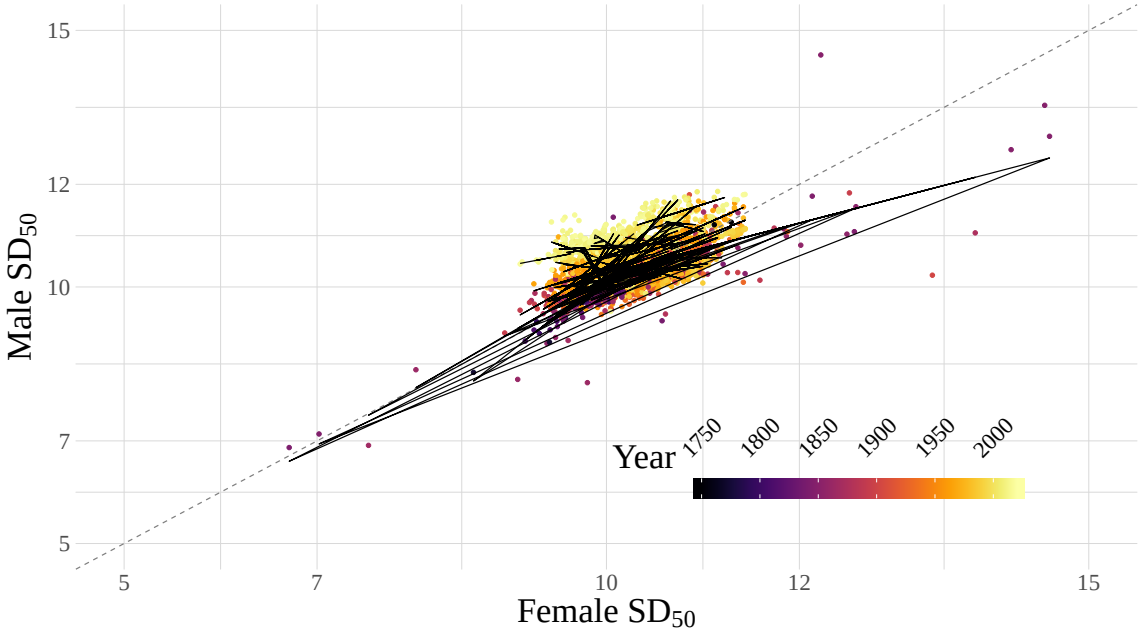
Figure 2: Observed and fitted relationship, female and male SD_{15}



Source: HMD

Fitted and observed values of female (x-axis) an male (y-axis) standard deviation at age 15, for nearly all populations and all available years in the HMD (except from 1914 to 1918 and 1939 to 1945). Values for older years are shown in black/purple, for more recent years in light yellow. Colour-year correspondences are based on Sweden, which has the longest time series. Black lines show the segmented regression for each population, while equality is shown by the 45 degrees grey dashed line

Figure 3: Observed and fitted relationship, female and male SD_{50}



Source: HMD

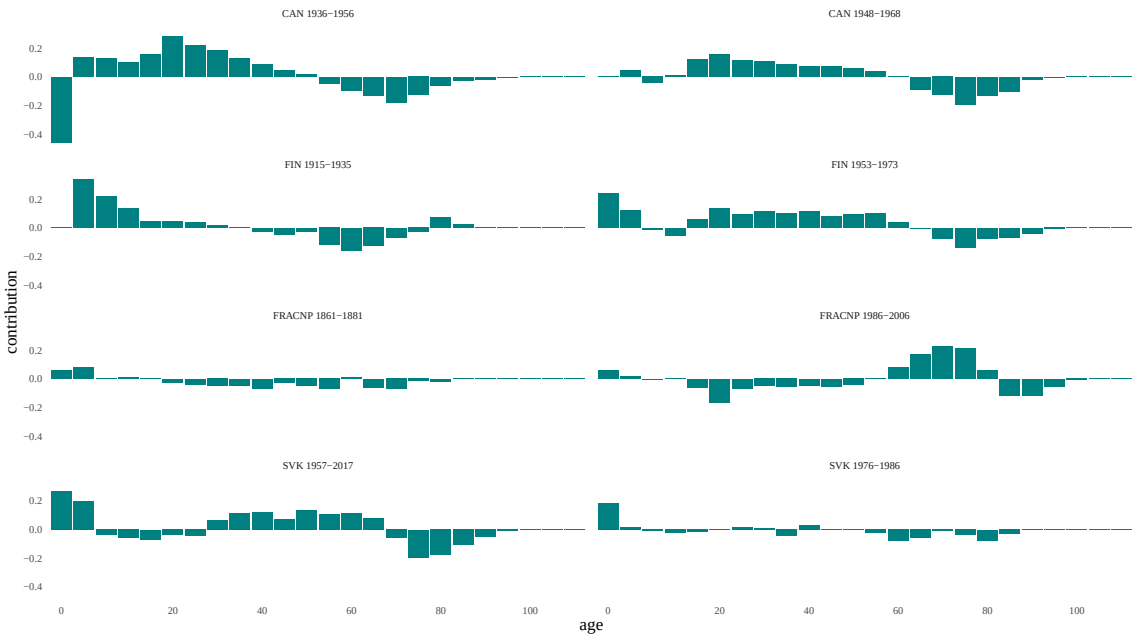
Fitted and observed values of female (x-axis) an male (y-axis) standard deviation at age 50, for nearly all populations and all available years in the HMD (except from 1914 to 1918 and 1939 to 1945). Values for older years are shown in black/purple, for more recent years in light yellow. Colour-year correspondences are based on Sweden, which has the longest time series. Black lines show the segmented regression for each population, while equality is shown by the 45 degrees grey dashed line

Figure 4: Decomposition of the change in the sex gap (SD_0), for countries with one breakpoint

Source: HMD

Results of the Horiuchi decomposition of the change in the sex gap of standard deviation at birth before and after breakpoints for each country with one breakpoint. Labels indicate the country and the years between which the difference is calculated. These years identify a 20 year interval (10 years before the breakpoint and 10 years after), or a shorter period if required by the available data. Age-groups are indicated on the x-axis, while the y-axis shows the magnitude of each contribution. Positive contributions show that the mortality change for females and males at those ages contributed towards a lower female SD_0

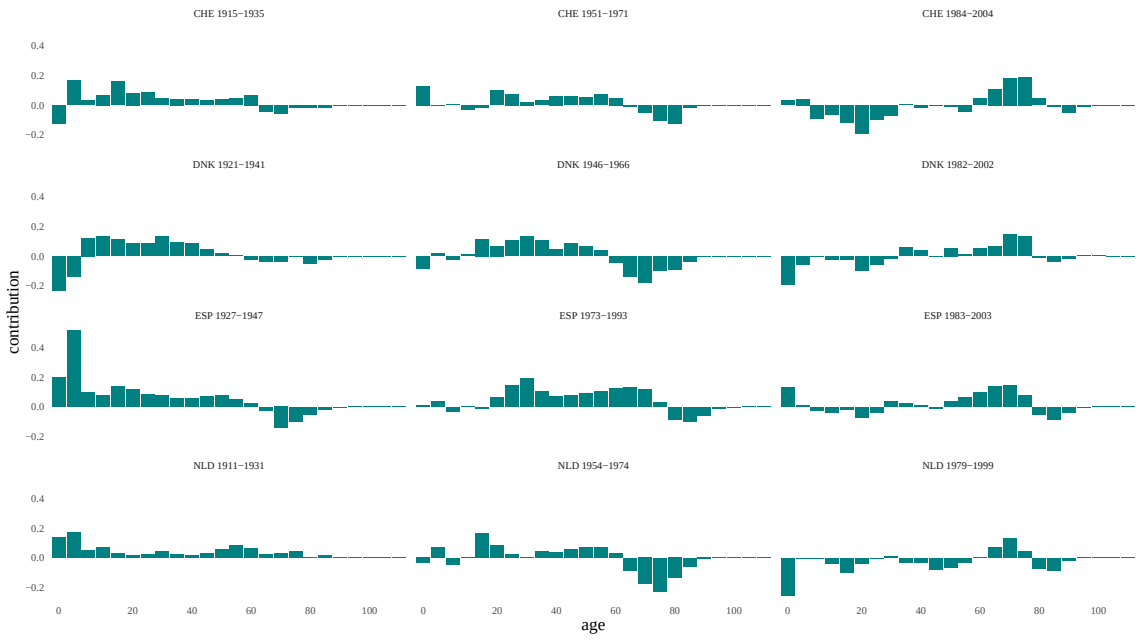
Figure 5: Decomposition of the change in the sex gap (SD_0), for countries with two breakpoints



Source: HMD

Results of the Horiuchi decomposition of the change in the sex gap of standard deviation at birth before and after breakpoints for each country with two breakpoints. Labels indicate the country and the years between which the difference is calculated. These years identify a 20 year interval (10 years before the breakpoint and 10 years after), or a shorter period if required by the available data. Age-groups are indicated on the x-axis, while the y-axis shows the magnitude of each contribution. Positive contributions show that the mortality change for females and males at those ages contributed towards a lower female SD_0

Figure 6: Decomposition of the change in the sex gap (SD_0), for countries with three breakpoints



Source: HMD

Results of the Horiuchi decomposition of the change in the sex gap of standard deviation at birth before and after breakpoints for each country with three breakpoints. Labels indicate the country and the years between which the difference is calculated. These years identify a 20 year interval (10 years before the breakpoint and 10 years after), or a shorter period if required by the available data. Age-groups are indicated on the x-axis, while the y-axis shows the magnitude of each contribution. Positive contributions show that the mortality change for females and males at those ages contributed towards a lower female SD_0

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