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The onset of the old-age gender gap in survival

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Descriptive Finding

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Demographic Research: Volume 42, Article 25
Descriptive Finding

The onset of the old-age gender gap in survival

Virginia Zarulli[1]

Rune Lindahl-Jacobsen[2]

James W. Vaupel[3]

Abstract

BACKGROUND
The male–female life expectancy gap is increasingly driven by mortality differences at older ages. However, the dynamics of the onset of the old age contribution to the sex gap in survival have not been analyzed yet.

OBJECTIVE
We investigate how much of the gender gap in life expectancy is attributable to older ages and when the old-age contribution to the gap started to increase in different countries.

METHODS
Using data from the Human Mortality Database, we computed age-specific contributions to the sex gap, investigated their rate of increase over time, and identified breakpoints.

RESULTS
We found a heterogenous picture in Eastern Europe, while in the other countries the contributions of those aged 65–80 are declining, while the contributions of those aged 80+ are increasing. The pace of increase accelerated after 1950. At the end of the observation some countries show signs of stagnation, but this is not related to the level of life expectancy.

CONCLUSIONS
The timing and pace of the increasingly old-age-driven sex difference in life expectancy differ among countries. The complexity of the patterns that emerged calls for country-specific, in-depth investigation.

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CONTRIBUTION
We analyzed trends, temporal breakpoints, and differences among countries of the increasing contribution of older ages to the sex gap in life expectancy. This provides additional information about health transitions and offers new evidence for the development of policies targeting specific age groups and aimed at reducing the sex gap in survival.

1. Introduction

Women live longer than men (Austad and Fischer 2016; UN 2017). Research on the causes of the male disadvantage provides evidence for both biological factors such as the Y chromosome, mitochondrial DNA, and sex hormones (Giuliani, Garagnani, and Franceschi 2018; Marais et al. 2018; Rogers et al. 2010), and behavioral factors such as the tendency of men to engage in more reckless behaviors, as shown by the mortality hump for men (Goldstein 2011). Cigarette smoking has been identified as one of the most important factors in high-income countries (Beltrán-Sánchez, Finch, and Crimmins 2015).

Beltrán-Sánchez and colleagues (2015) find that among cohorts born between 1800 and 1935 in 13 developed countries, absolute levels of male excess mortality were greatest at ages 50–70. Other analyses focus on a single country or a group of countries and specific causes of death. Excess male mortality increased at ages 45–64 in the USA between 1929–1931 and 1956–1958, mostly due to heart disease and cancer (Enterline 1961). In the 1920s male excess cardiovascular mortality emerged at ages 35–74 in England and the USA (Nikiforov and Mamaev 1998). The gap substantially widened at the same ages and from the same group of causes of death between 1950 and 1998 (Lawlor, Ebrahim, and Smith 2001). Smoking-attributable deaths played a prominent role in the observed male-excess mortality at ages 40–69 in 16 countries (Preston 1970).

Most of the evidence compiled so far refers to excess male mortality between ages 30 and 70; the dynamics of age-specific trends at older ages have been less investigated. Because, however, mortality declines at old ages are more pronounced for women than for men (Rau et al. 2008), older ages are becoming more crucial in determining the sex difference in life expectancy.

In this article we analyze the increasing contribution of old ages to the sex gap in life expectancy by investigating time trends, focusing on whether this process is taking place gradually or started abruptly. We explore whether it is possible to identify an onset of an old-age-driven gap and if there are differences among countries. This provides

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additional information about the health transition and new evidence relevant for the development of policies aimed at reducing the survival gap between men and women.

2. Data and methods

We used sex-specific life tables for 34 populations from the Human Mortality Database (HMD). We selected populations bigger than 1 million and data available for more than 50 years. We removed the years for non-neutral countries during the two world wars and the year of the Spanish flu. A discrete age-decomposition method was applied to compute age-specific contributions to the sex difference in life expectancy. The method to take into account the interdependence of age groups in the determination of life expectancy was first introduced by Pollard (1982) in continuous time and then proposed in discrete time by Arriaga (1984). The discrete method, which is easier to apply to conventional life tables, was later operationalized by Andreev, Shkolnikov, and Begun (2002).

Using the age-specific contributions to the gap in life expectancy, we produced mortality surfaces to provide a clear overview and to describe trends over time. Furthermore, we used regression analysis to investigate the rate of increase (or decrease) in the importance of different ages' contribution to the sex gap in life expectancy and to identify any breakpoints in these age-specific trends. This helped identify the onset of an old-age-driven sex gap in survival.

We applied Davies tests (Davies 1987) to check for a non-constant regression parameter in the linear predictor. The results pointed to the presence of different slopes over time. We performed a segmented linear regression to identify the breakpoint/s in the time trend of the age-specific contributions. We used the R package 'Segmented' (Muggeo 2008), which estimates a broken-line model where the relationship between the response variable and the explanatory variable is piece-wise linear. The straight lines are connected at unknown points that represent the breakpoints estimated by the model.

Because the linear regression showed that only the contributions of old-adult ages had pronounced increasing trends over time (all the other groups showed positive but modest slopes, in some cases close to zero) and because the focus of this article is on old ages, we decided to perform the segmented regression for ages 65 and older. To more easily identify general patterns we grouped the ages into two: 65–80 years and 80+ years. Even though death rates at ages 80+ are often affected by erratic fluctuations, age heaping, and other problems, the Human Mortality Database ensures high standards of quality and comparability over time and across countries by applying rigorous demographic methods and quality checks, such as the use of the Kannisto model for old ages. Detailed information about methods and data issues is available online in Wilmoth et al. (2019).

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For each age group we estimated segmented linear models with different numbers of breakpoints and we selected the best model with a likelihood ratio test. In our analyses each data point had the same weight. First, we performed the analysis on all the populations combined in order to uncover long-term general age patterns. However, because the length of the time series is different for each country, some countries have shorter or longer time series. Therefore, in a second step we performed country-specific analyses, which allowed us to identify groups of populations characterized by similarities in pace, shape, timing of the trends, and length of available data, thus improving the comparability of the results.

3. Results

Over the 264 years analyzed (from 1751 to 2015), the contribution of ages 0 to 5 decreased (the only group that shows a negative trend). The ages 65 to 70 experienced the greatest increase. The ages 50 to 85 had pronounced increasing trends; all the other groups showed positive but modest positive slopes (Table 1). The Davies test indicated that all the age groups except 95–99, 100–104, and 105+ had a non-constant pattern over time (results not showed here).

Table 1: Estimated slope coefficients for the contribution of each age group to sex gap in life expectancy (from linear regression, all HMD countries combined)

Age	Slope	Age	Slope
0–4	–0.0086 (–0.0087 – –0.0085)	55–59	0.0034 (0.0119 – 0.0122)
5–9	0.0001 (0.0086 – 0.0089)	60–64	0.0045 (0.0130 – 0.0133)
10–14	0.0006 (0.0091 – 0.0094)	65–69	0.0050 (0.0135 – 0.0138)
15–19	0.0010 (0.0095 – 0.0098)	70–74	0.0050 (0.0134 – 0.0137)
20–24	0.0001 (0.0086 – 0.0089)	75–79	0.0042 (0.0127 – 0.0130)
25–29	0.0010 (0.0095 – 0.0098)	80–84	0.0028 (0.0113 – 0.0116)
30–34	0.0016 (0.0101 – 0.0104)	85–89	0.0015 (0.0100 – 0.0103)
35–39	0.0016 (0.0100 – 0.0103)	90–94	0.0005 (0.0090 – 0.0093)
40–44	0.0015 (0.0100 – 0.0103)	95–99	0.0001 (0.0086 – 0.0089)
45–49	0.0015 (0.0100 – 0.0103)	100–104	0.0000 (0.0085 – 0.0088)
50–54	0.0023 (0.0108 – 0.0111)	105+	0.0000 (0.0085 – 0.0088)

For all the populations combined, the adjusted R^2 showed that the segmented linear regression models fit better than the non-segmented linear models. Among the segmented models, having two break points gave a better fit than having 1 break point (confirmed

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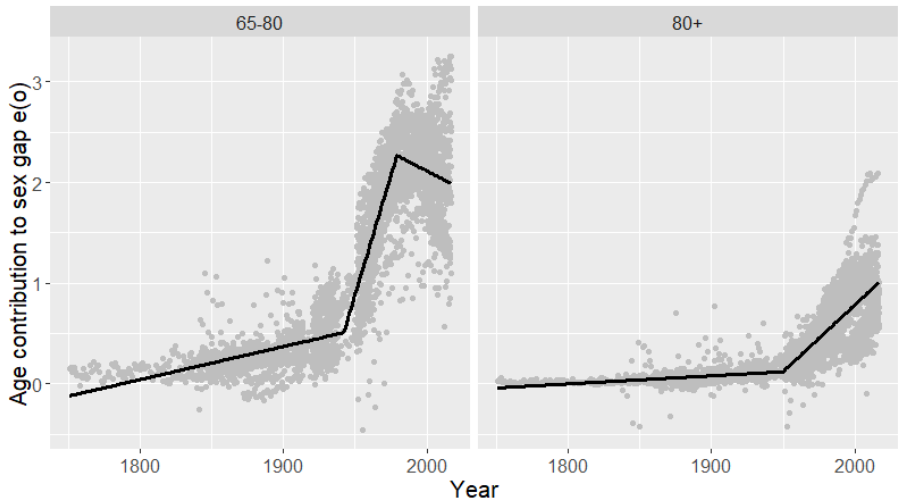
by the likelihood ratio test). The highest predictive power was obtained with a segmented model with two breakpoints for the ages 65–80 and 1 break point for ages 80+.

Figure 1: Age-specific contributions to sex gap in life expectancy over time (in grey) and linear trend line (in black)



The contribution of ages 65–80 to the sex gap in life expectancy accelerated at the beginning of the 1940s, going from an annual increase of 0.3% to an annual increase of 4%. It continued to grow until 1979, when it began to decrease. The oldest ages (80+) followed a different pattern: their contributions, initially very small, increased at a very slow pace (annual increase of 0.1%) until the mid-point of the 20th century. After 1950 they show a 1% acceleration in their increasing trend. In most populations where the contribution of ages 65–80 to the sex gap declined, the decline was partly due to a rise in the contribution of ages 80+ (Figure 1) and partly due to a decline in the sex gap.

The general picture hides population differences in the timing, shape, and pace of the process. We grouped them according to the pattern followed by the contributions of ages 80+ because this group, contrary to the age group 65–80, showed more diverse trends: increasing with a break point of acceleration, increasing with no break point of acceleration, decelerating after increase, leveling off after increase, non-increasing/slightly decreasing. The first three groups can be further split according to whether the breakpoint happened earlier or later in time. Table 2 reports the estimates of

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the breakpoints and the slopes of the populations. Figure 2 reports the results for five populations, each of them representing one of the main groups that were identified.

Figure 2: Age-specific contributions to sex gap in life expectancy (grey) and linear trend line, for selected countries from the Human Mortality Database

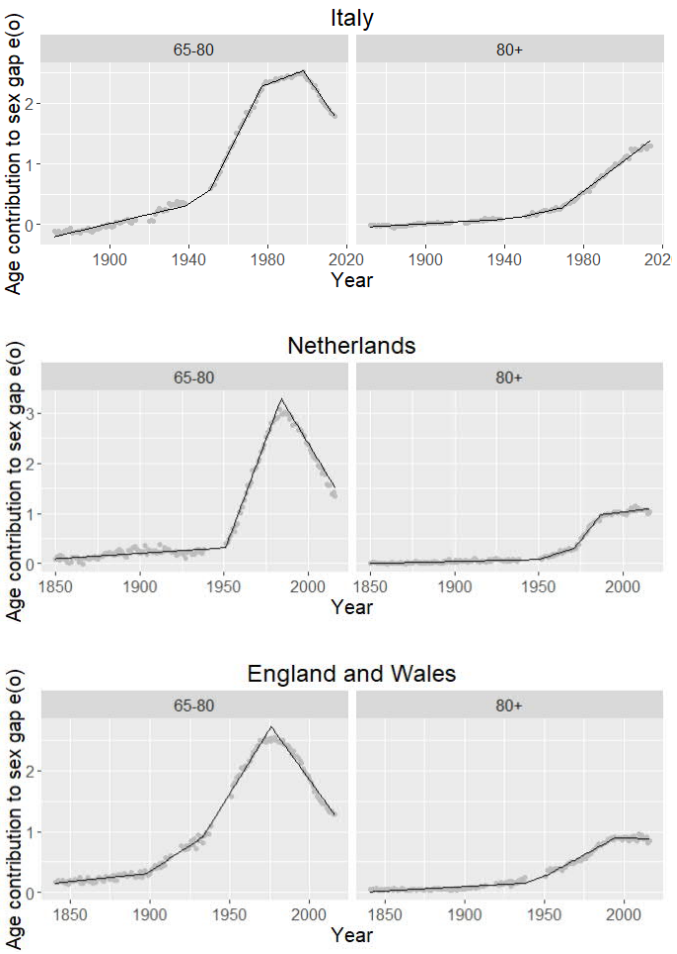

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Figure 2: (Continued)

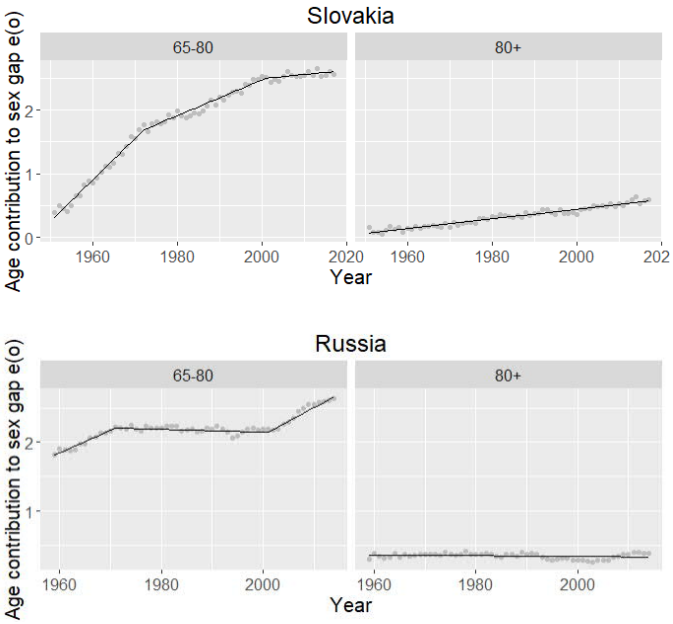

Table 2: Country-specific estimated slopes, break points, and confidence intervals of the contribution of ages 80+ to the total sex gap in life expectancy, classified by time pattern of the contributions

	Break 1	Break 2	Break 3	Slope 1	Slope 2	Slope 3	Slope 4
Early acceleration							
France	1928 (1924–1933)	1966 (1964 – 1969)	–	.001 (.001 – .001)	.009 (.008 – .010)	.023 (.022 – .024)	–
Finland	1962 (1959 – 1964)	–	–	.001 (.000 – .001)	.020 (.019 – .021)	–	–
Italy	1944 (1934–1954)	1969 (1967–1971)	–	.002 (.001–.002)	.007 (.004–.010)	.025 (.024–.026)	–
Spain	1938 (1930–1947)	1975 (1975–1978)	–	.003 (.002–.005)	.008 (.007–.009)	.022 (.021–.023)	–
Portugal	1979 (1976–1981)	–	–	.005 (.004–.006)	.020 (.019–.022)	–	–
Late acceleration							
Belarus	1976 (1972–1979)	2002 (2000–2004)	–	.010 (.003–.016)	–.015 (–.018– –.012)	.026 (.018–.034)	–
Czech Republic	1996 (1990–2001)	–	–	.006 (.005–.007)	.015 (.012–.019)	–	–
Lithuania	1998 (1993–2003)	–	–	.003 (.001–.004)	.017 (.012–.022)	–	–
Latvia	2003 (1997–2008)	–	–	.003 (.001–.005)	.021 (.011–.031)	–	–
Poland	1998 (1995–2001)	–	–	.006 (.005–.007)	.020 (.017–.023)	–	–

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Table 2: (Continued)

	Break 1	Break 2	Break 3	Slope 1	Slope 2	Slope 3	Slope 4
Early deceleration							
Denmark	1959 (1956–1962)	1981 (1976–1986)	–	.000 (.000–.001)	.026 (.021–.030)	.010 (.007–.012)	–
Netherlands	1950 (1944–1956)	1971 (1969–1973)	1987 (1985–1988)	.001 (.000–.001)	.010 (.006–.014)	.042 (.037–.048)	.004 (.002–.006)
Switzerland	1929 (1919–1939)	1967 (1965–1970)	1991 (1988–1994)	.000 (.000–.002)	.006 (004–.007)	0.31 (.028–.034)	.007 (.004–.010)
Late deceleration							
Austria	1973 (1968–1979)	1999 (1989–2009)	–	.008 (.005–.011)	.017 (.015–.020)	.012 (.008–.016)	–
East Germany	1987 (1985–1990)	1998 (1995–2000)	–	.008 (.006–.010)	.043 (.031–.055)	.008 (.004–.012)	–
West Germany	1972 (1969–1974)	1993 (1991–1995)	–	.008 (.004–.012)	.027 (.024–.029)	.005 (.003–.007)	–
Early leveling off							
Australia	1965 (1962–1968)	1996 (1993–1998)	–	.006 (.005–.007)	.024 (.021–.026)	–.001 (–.006–.003)	–
Belgium	1970 (1968–1971)	1996 (1993–1998)	–	.002 (.002–.002)	.030 (.027–.033)	.004 (.000–.008)	–
Canada	1961 (1958–1964)	1990 (1987–1992)	–	.006 (.005–.008)	.027 (.025–.030)	.001 (–.003–.005)	–
England Wales	1945 (1940–1946)	1995 (1992–1998)	–	.001 (.001–.002)	.014 (.013–.015)	–.001 (–.004–.002)	–
Scotland	1950 (1945–1953)	1993 (1989–1996)	–	.001 (.001–.002)	.014 (.013–.016)	–.003 (–.006–.000)	–
Sweden	1956 (1955–1958)	1995 (1992–1997)	–	.000 (.000–.001)	.025 (.022–.026)	.000 (–.004–.003)	–
Late leveling off							
Estonia	2000 (1998–2003)	2011 2007–2016)	–	.003 (.001–.005)	.043 (.027–.059)	.006 (–.034–.045)	–
Ireland	1974 (1969–1979)	2010 (2007–2012)	–	.007 (.004–.010)	.020 (.018–.022)	–.024 (–.061–.013)	–
North. Ireland	1961 (1954–1968)	2000 (1995–2005)	–	.005 (.002–.008)	0.19 (0.16–0.21)	–.007 (–018–.004)	–
Japan	1981 (1979–1982)	2007 (2006–2009)	–	.013 (.011–.015)	.056 (.054–.059)	.005 (–.007–.017)	–
New Zealand	1948 (1941–1954)	2000 (1995–2006)	–	.000 (–.003–.003)	.017 (.015–.020)	–.014 (–.046–.018)	–
Norway	1960 (1957–1962)	2005 (2001–2008)	–	.001 (.000–.001)	.022 (.021–.024)	–.005 (–.019–.009)	–
United States	1994 (1992–1996)	2001 (1996–2006)	–	.016 (.015–.017)	–.021 (–.039–.002)	–.003 (–.008–.003)	–
Steady increase							
Bulgaria	–	–	–	.004 (.004–.005)	–	–	–
Hungary	–	–	–	.008 (.006–.009)	–	–	–
Slovakia	–	–	–	.008 (.006–.009)	–	–	–
No increase							
Russia	–	–	–	–.001 (–.002–.001)	–	–	–
Ukraine	–	–	–	–.002 (–.003– –.001)	–	–	–

The group that shows a breakpoint in acceleration followed by an ongoing increase includes early accelerators with a breakpoint in the 1960s and 1970s (France, Finland, Italy, Spain, and Portugal) and late accelerators with a breakpoint in the 1990s and 2000s (Belarus, Czech Republic, Lithuania, Latvia, and Poland are late accelerators). Among the accelerators the rate of annual increase almost tripled, from values between 0.1% and

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0.9% to values between 1.7% and 2.6%. Belarus is the only country for which the trend is inverted, from a –1.5% annual decrease to a 2.6% annual increase.

Bulgaria, Hungary, and Slovakia form the group with a steady annual increase (between 0.4% and 0.8%) in the contribution of ages 80+ to the sex gap in life expectancy.

Another group consists of the populations where the contribution of ages 80+, even though still increasing, has started to decelerate. Early decelerators are Denmark, the Netherlands, and Switzerland (breakpoint in the 1980s); late decelerators are Austria, East Germany, and West Germany (breakpoint in the 1990s). In these populations the annual increase went from values between 2.6% and 4.3% to values between 0.4% and 1.2%.

The most numerous group comprises the populations whose 80+ contributions level off after a period of increase that proceeded at different rates, ranging from 1.4% in Scotland to 5.6% in Japan. These populations can be classified in two subgroups: early plateau populations with a plateau starting in the 1990s (Sweden, Belgium, England and Wales, Scotland, Canada, and Australia) and late plateau populations with a plateau starting in the 2000s (Japan, Norway, Northern Ireland, Ireland, New Zealand, Estonia, and the USA). The USA is the only country where the plateau was preceded by a short period of decline starting in 1994, thus being the only country where ages 80+ display a significantly negative slope.

Finally, the group of non-increasing/decreasing contributions of ages 80+ consists of Russia and Ukraine. Here, the contribution of ages 80+ is still small and shows a negative trend, annually decreasing by 0.2% in Ukraine and 0.1% in Russia (even though the slope for Russia is not significantly different from 0).

Regarding the trend of the contributions of ages 65–80 to the sex gap in life expectancy, the populations can be divided into two groups: those where these ages are experiencing a sharp decline in their contribution after decades of an increasing trend, and those where these ages are still increasing their contribution. This last group includes all the populations of the former Soviet block except for Poland, where these ages started a declining trend in 2004. In the other populations the decline started in the second half of the 1970s in England and Wales, Scotland, New Zealand, Denmark, and the USA, in the 1980s in Sweden, Norway, the Netherlands, Belgium, Switzerland, Canada, Australia, and Finland, in the 1990s in West Germany, Austria, Italy, France, Spain, Portugal, Northern Ireland, and Ireland, and in the 2000s in East Germany, Japan, and Poland.

In 23 populations in our study the contribution of ages 65+ to the sex gap is now greater than the contribution of ages less than 65. This occurred first in England and Wales in 1975 and was followed by 22 other countries, including Japan in 1985, Italy in 1993, and France in 1998. Except for the Czech Republic, where the shift occurred in

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2013, ages below 65 are still more important than ages above 65 in the Eastern European countries. This is also the case for the United States.

4. Conclusion

The sex gap in life expectancy is increasingly driven by differences in mortality at older ages. The middle of the 20th century was a turning point, when the increase in the contribution of ages 80+ to the sex gap in life expectancy accelerated. Younger age groups, after a long period of growing importance in determining the gap, are currently undergoing a decreasing trend that started in the late 1970s. In some countries (Nordic countries, Western European countries, and English-speaking countries outside Europe) the breakpoint in old age acceleration occurred as early as the beginning of the late 1940s, but until then the rate of increase of the oldest-old contribution was rather modest (in some cases not significantly different from zero). In Italy, Spain, and Portugal the acceleration started about two decades later, but the increase in the contributions of the ages 80+ was more pronounced. In Japan the acceleration started even later, at the beginning of the 1980s, but at a rate of more than 5% per year, which is the highest rate of increase of all the countries of this study. Finally, in Eastern Europe the picture is more heterogenous. In the Baltic countries, Poland, the Czech Republic, and Belarus the oldest ages have experienced a slight acceleration since the end of the 1990s; in Hungary, Bulgaria, and Slovakia they have slowly increased but have not experienced a breakpoint in acceleration; while in Russia and the Ukraine these ages are still contributing very little to the total sex gap in life expectancy and present a negative trend.

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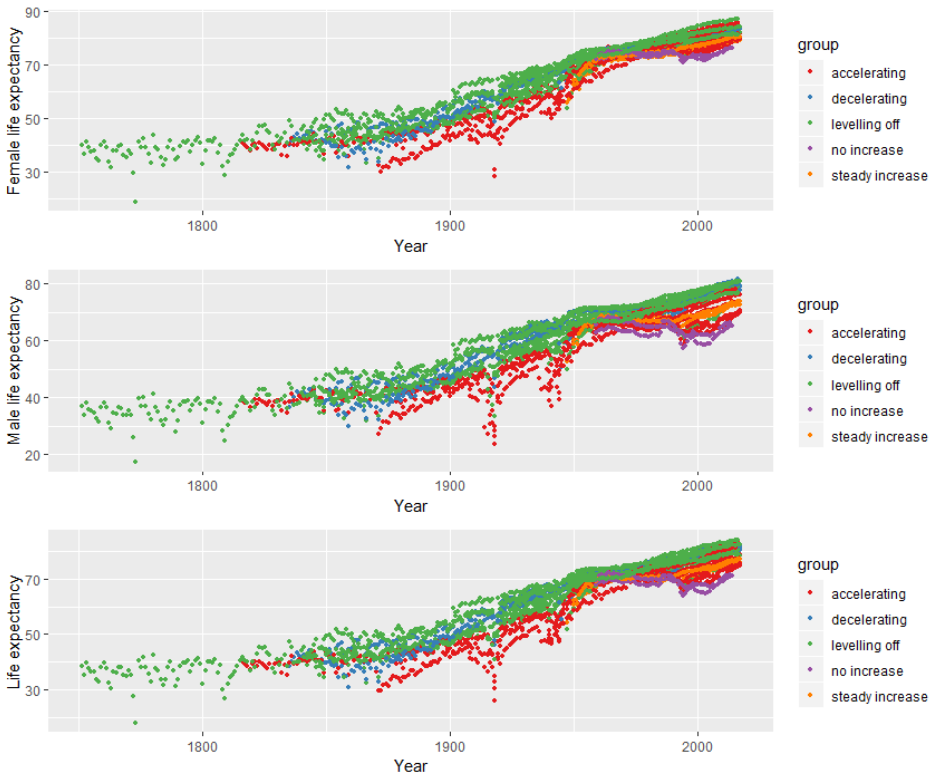
Figure 3: Female, male, and total life expectancy by country, grouped according to the pattern of the contribution of ages 80+ to the total sex gap in life expectancy



In 19 of the 34 populations analyzed the contribution of the oldest-old ages is increasing, in 13 populations it is stagnating after a long period of increase, while in 2 populations it is stagnating or decreasing.

The stagnation or the deceleration of the contributions of ages 80+ cannot be interpreted as a sign of mortality compression related to having reached a high level of life expectancy. Among the longevity leaders there are populations where the contributions of ages 80+ are leveling off and others where they are still increasing. (Figure 3). This leaves open questions with respect to the interpretation of this stagnation, which requires country-specific, in-depth investigation.

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The populations where the ages 80+ are still increasing their contribution or have done so until recently (before entering a period of stagnation) follow different patterns, timings, and paces, but share the same basic dynamic: The increase was generally slow until the middle of the century and faster afterwards. At the same time, while the age group 80+ keeps increasing its contribution to the sex gap in life expectancy, younger ages show a decreasing trend.

At the end of the observation period in some populations there are signs of stagnation of the increase of the contributions of the oldest old to the gender gap in life expectancy, but in others not. At the same time, in most of the populations analyzed in this study the contribution of younger ages is declining. This opens the way to a convergence and possible cross over between the contributions of the ages 80+ and ages 65–80. In Sweden in 2017 (the last available year in the data set) the difference between the contribution of the age group 65–80 and that of the age group 80+ approached 0 (0.089 years), while in the other western populations the difference is getting progressively smaller. This introduces the possibility that in the future the oldest ages will contribute the biggest share of the gap in life expectancy between men and women.

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