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EDITORIAL

Gender differences in survival across the ages of life: an introduction

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Abstract

This thematic series explores the complex nature of the survival gap between genders across the lifespan. It highlights how, although women generally have a longer life expectancy than men globally, the complexity of this advantage challenges simplistic explanations. The text emphasizes several areas of interest, such as mortality differences between genders at different life stages, the aging process, and epidemiological differences between the sexes. Additionally, it discusses the role of biological and socio-behavioral factors in explaining the female survival advantage and how this gap has evolved and been influenced by historical, behavioral, and lifestyle changes. With six compelling articles from diverse disciplinary angles, this series underscores the interdisciplinary approach essential for unraveling the intricacies of gender differences in survival across the lifespan.

Keywords: Gender gap in survival, Mortality by sex, Interdisciplinary perspectives on gender gap in survival, Aging dynamics, Biodemography

Introduction

Women live longer than men almost everywhere. Nowadays, they not only have longer life expectancy, but they have lower mortality throughout the age spectrum, with some exceptions regarding maternal mortality, especially in the past (Loudon, 1988), and childhood mortality (for example, for ages 0 to 4 in 2021, in Algeria, Bangladesh, Egypt, India, and Iran female mortality was higher than male childhood mortality) (Chao et al., 2023). Such mortality differences, as well as a skewed sex ratio at birth towards the male sex (Beltrán Tapia & Raftakis, 2022; Bongaarts, 2013; Das Gupta & Mari Bhat, 1997; Guilmoto 2009; Guilmoto 2012), highlight the potential presence of gender-based discrimination practices.

On the other hand, studies estimating the rate of aging tend to point to a slightly faster senescence process for women. Typically, the rate of aging is assessed by mortality doubling time in adulthood and old age, averaging around 8 years in various human populations (Finch, 1994; Finch et al., 1990). However, these estimates often overlook mortality deceleration due to selection effects and cohort composition changes. More sophisticated models, such as gamma-Gompertz and gamma-Makeham–Gompertz, yield lower doubling time estimates, generally below 7 years. When applied separately to male and female cohorts, these models suggest a slightly faster aging process in women compared to men (Barbi, 2003; Salinari & De Santis, 2014). Consequently, female longevity at adult ages may stem from their hazard function being shifted downwards relative to males, allowing for longer average lifespans despite steeper hazard function slopes.

Furthermore, despite a general postponement of debility and a global increase in healthy life expectancy in the last decades, the health improvement has been slower for women compared to men and the female advantage in healthy life expectancy is narrower than in life expectancy"(Eurostat, 2021; IHME, 2019WHO, 2020). The literature refers to these differences with the term "male–female health-survival paradox", to indicate that women live longer than men, but men are physically stronger, have fewer disabilities and higher health scores while showing substantially higher mortality at all ages compared with women (Alberts et al., 2014; Austad & Fischer, 2016; Crimmins et al., 2011; Luy & Minagawa, 2014; Oksuzyan et al., 2008).

These health differences are also reflected in different epidemiological profiles, as we observe variations in the prevalence, outcomes of diseases and how diseases influence lifespan between the two sexes (Janssen, 2020; Westergaard et al., 2019; Zazueta-Borboa et al., 2023) and, even when men and women experience the same disease, differences in disease manifestations, progression, and outcomes are often observed. For example, heart disease may present differently in women than in men, leading to underdiagnosis and undertreatment in women (Bots et al., 2017; Regitz-Zagrosek & Gebhard, 2023; Vogel et al., 2021).

Nevertheless, that women seem to benefit from a longer survival than men is today well established. They have even been showed to resist better than men to hostile, sudden events like famines and epidemics (Zarulli et al., 2018); the recent COVID-19 pandemic seems to have confirmed this point even in contemporary times (Ahrenfeldt et al., 2021; Aleksanyan & Weinman, 2022; Raimondi et al., 2021; Takahashi & Iwasaki, 2021; Takahashi et al., 2020).

The female survival advantage is traditionally explained from biological and socio/behavioral factors, which can be very crudely summarized as "women are biologically stronger than men and men are more reckless than women". This picture is so widely accepted that we frequently forget that a widespread and solid gender gap at the population level has emerged only during the twentieth century, a relatively recent time (Beltrán-Sánchez et al., 2015; Crimmins et al., 2019; Gjonça et al., 1999; Wisser & Vaupel, 2014), and that the life expectancy gap largely resulted from excess deaths of infant boys, historically, and, more recently, from higher mortality among men 60+, while the higher mortality of males at ages 15 to 40 has played a modest role (Zarulli et al., 2021). Furthermore, we will see how the evolution of the gender gap presents features that cannot be easily interpreted with the set of biological and behavioral factors just mentioned.

The evolution of the mortality differential between men and women has undergone a somewhat atypical development in the last century and a half. The two fundamental features of this evolution, which has been reconstructed in its essential lines in a recent article by Beltrán-Sánchez et al. (2015), are that (1) the survival differential in post-reproductive age (i.e., excluding maternal mortality) begins to widen from the last decades of the nineteenth century (before this period, the advantage of female survival in post-reproductive ages was relatively modest) and that (2) the spread of cigarette smoking, which begins in this era among men but not among women, can explain no more than 30–40% of the overall increase in the sex gap in survival.

The evolution of the male–female differential represents a counter-trend, as it increased in a historical phase when inequalities in survival among individuals were decreasing along with the rapid reduction in general mortality, caused by a multitude of factors such as public health interventions (for example sewage systems and aqueducts), the bacteriological revolution, and significant medical discoveries (for example vaccines and antibiotics). This process, often referred to as reduction of lifespan inequality, was a general and "democratic" mortality reduction, as age at death become increasingly similar among individuals (Aburto et al., 2020; Németh, 2017; Permanyer & Scholl, 2019; Smits & Monden, 2009; Vaupel et al., 2011). Likewise, later, when other types of differentials began to widen in the second half of the twentieth century, as it is the case for socioeconomic differentials (Bengtsson et al., 2020; Gagnon et al., 2011), the male–female differential started to decrease (García González & Grande, 2017; Maiolo & Reid, 2020; Rosella et al., 2016; Trovato & Heyen, 2006; Yang et al., 2012).

The recent decline in the survival advantage of women over men can be attributed, in part, to the convergence of lifestyles between the two genders, particularly the increased prevalence of cigarette smoking among women (Preston & Wang, 2006; Wensink et al., 2020). However, it is more challenging to comprehensively explain the trend over a longer time frame. For instance, there are biological factors that generally explain greater female survival: women have two copies of the X chromosome, which makes them more resistant to certain genetic problems, they have a more optimized mitochondrial DNA, a more robust immune system, and are, at certain ages, less affected by diseases of the cardiovascular system. Given this biological foundation, one would anticipate a gradual reduction in the gender gap as public health and medical innovations worked to minimize biological disparities between the sexes. The introduction of antibiotics, antihypertensive drugs, and coronary bypass surgery, for example, should (at least in theory) improve the survival rates of everybody, but even more so for men, who are less adept at combating infections or are more exposed to cardiovascular risks. However, the gender gap in survival was minimal before the implementation of these innovations and increased over time after their introduction.

On the other hand, women, on average, are more cautious than men, and are known to adopt healthier habits and lifestyles: they tend to follow a healthier diet, consume less alcohol, smoke less, and adhere more closely to health recommendations (Rogers et al., 2010). However, a female survival advantage has been observed also in religious populations where both sexes share similar and healthier lifestyles compared to the general population (Lindahl-Jacobsen et al., 2013; Luy, 2003); furthermore, the ages when the recklessness of men peaks, that is, the young adult ages of the famous (among demographers) accident hump (Goldstein, 2011; Remund et al., 2018), have been showed to contribute very little to the overall gender gap in life expectancy, both in modern and historical populations (Zarulli et al., 2021).

It is then likely that other factors have intervened in the historical emergence of the female survival advantage. One of them could be survival–reproduction trade-off, a fundamental concept in evolutionary biology, reflecting the allocation of limited resources towards either maximizing individual survival or investing in reproductive efforts

(Edward & Chapman, 2011; Kirkwood, 1977; Westendorp & Kirkwood, 1998). Organisms must balance these two competing demands to optimize their overall fitness in their respective environments. Allocating more resources towards reproduction may come at the cost of investing less in self-maintenance and survival-related activities. Conversely, reducing the effort for reproduction might increase the resources available for maintenance, repair and, ultimately, survival. From research in historical demography, we know that in historical populations female life expectancy was sometimes lower than male life expectancy and not infrequently males had lower mortality rates than women at young adult ages, perhaps because of the high levels of maternal mortality and maternal depletion. We also know that in some populations such as in Utah, the emergence of the female survival advantage appears linked to the process of fertility decline (Bolund et al., 2016) and, based on the sparse information available on the diffusion of this phenomenon, the emergence of the gender gap started among the wealthier social strata (Martin, 1951).

The creation of a collection of articles on Gender Differences in Survival Across the Ages of Life is warranted due to the somewhat counterintuitive nature of its evolution, as mentioned earlier. Despite conventional understanding and existing theories, the historical trajectory of this gender gap presents complexities and contradictions that demand a comprehensive and multidisciplinary investigation.

Enlarging the historical horizon of the research entails broadening the research on the evolution of the gender gap in survival to a multidisciplinary investigation that focuses on different ages and specific circumstances, which all can work as case studies that contribute to deepening our understanding of gender gap in survival. By examining various case studies and adopting diverse perspectives, researchers can elucidate the nuanced dynamics underlying this phenomenon. For this reason, this thematic series consists of six papers that adopt different perspectives, from an actuarial-oriented point of view to a more traditional demographic approach, passing by analyses in the realms of biology, genetic and epidemiology of covid-19. The broad heterogeneity of the contributions, which may at first may appear surprising, does nothing but reflecting the inherent interdisciplinarity that has accompanied, from the very beginning, research on gender differences in survival across the ages of life, both in terms of the factors at the origin of such differences and of their socioeconomic realizations and implications.

The contributions in this thematic series

The gender gap in survival has such a major intrinsic biological component and many studies in the fields of biology, genetics, evolutionary biology and human ecology, for decades have extensively analyzed, and partly uncovered, the determinants that promote longer life in females with respect to males (Lagou et al., 2021; Milot et al., 2017; Viña et al., 2005). The fact that this is found in virtually all mammals and in numerous other species seems to suggest that this advantage is functional to the survival of the species and is the product of an evolutionary process (Austad & Fischer, 2016). The research performed in the more recent years has allowed to investigate not only the role of genetics but also of epigenetics, which is how the environmental factors interact with the genetic components to modulate the magnitude of the sex gap in survival. It then becomes apparent, and we think this is a great opportunity, that demography and biology can and should come together in the quest aimed at unraveling the last pieces of the puzzle. Part of the difficulty, so far, in reaching an extensive level of collaboration between the two disciplines, derives, in our opinion, from the differences in methods and approaches that sometimes can set the two disciplines apart. To foster more partnerships, demographers should engage with biology research, overcoming barriers of complexity and unfamiliarity. One way to do so could be accessing contributions that synthesize biological literature for easier comprehension and integration into demographic studies. This is what Iannuzzi et al. (2023) have done, in an excellent recognition of the genetic and epigenetic literature, with the aim to summarize the role of the genetic and epigenetic mechanisms in promoting female advantage from the early in life ("INNATE" features), and in influencing the magnitude of the gap in sex differences in survival and ageing ("VARIABLE" features). After briefly discussing the biological bases of sex determination in humans, they provide evidence showing that "innate" mechanisms (both genetic and epigenetic) play a major role in sex differences in lifespan and that "variable" genetic and epigenetic patterns, that vary according to context, populations and exposures to different environments, can affect the magnitude of the gap in sex differences in survival. They illustrate how the use of analyses such as epigenetic clocks can uncover sex differences in biological age and, therefore, mortality and finally argue that environmental factors cannot be kept apart from the biological factors providing evidence from the field of human ecology.

Historical data are an extremely valuable source of information for demographers. Demographers are often able to uncover or test possible biological or evolutionary explanations for observed phenomena, because demographic events in historical populations are much closer to "natural" dynamics than in modern populations. As an example, one should think of the lack of effective contraceptive methods that makes it possible, for some populations, to reach the levels known as natural fertility. This equally holds for survival, as effective medical interventions were not available in these populations. This is particularly true for the neonatal phase: up to relatively recent times, almost everything related to gestation, delivery, and neonatal phase, were almost at the mercy of chance. Thanks to a painstaking data reconstruction exercise, using panel data techniques to consider the possible effect of stillbirth misreporting, the analysis of Ruiu et al. (2022) investigates the relationship between seasonal agricultural workload and the number of male and female stillbirths in the Italian regions at the turn of the twentieth century. They found that, although stillbirth rates were lower for females, agricultural workload seasonality had a more substantial effect for them than for males. The authors suggest their finding may be explained by the adaptive sex ratio adjustment hypothesis (Trivers & Willard, 1973) that suggests that when maternal conditions worsen, a lower ratio of males to females is observed, both before and after birth. From an evolutionary point of view, this biological mechanism may have evolved to manage the additional resources needed to raise male offspring compared to females.

The second half of the twentieth century has witnessed unprecedented epidemiological shifts, well described by Omran (2001). These shifts have been accompanied by the emergence and widening of the gender gap in survival (in favor of women) first, and by its gradual reduction, later. It has also emerged that, at the population level, men and women tend to have different epidemiological profiles and die from different causes of deaths. Today women still have longer life expectancy than men, but the advantage is somewhat smaller than a few decades ago. A multitude of factors has contributed to this reduction, one of them being the convergence in lifestyles (for example increasing smoking among women) that has made men and women more similarly vulnerable to the same diseases. Nevertheless, different causes of deaths continue to affect men and women to different extents. This is still a very central epidemiological question, as demonstrated by the longevity and never fading popularity of demographic analyses using age- and cause- decomposition methods (Andreev et al., 2002; Arriaga, 1984; Horiuchi et al., 2008) that allow to identify how much of the gap in survival is determined by which cause and at which age. The study of Feraldi and Zarulli (2022) takes the decomposition approach a steps further: it first decomposes the gender gap in life expectancy into age-cause specific contributions and then uses indicators of location, magnitude and dispersion to further investigate not only how the overall cause-specific contributions are changing (if increasing or decreasing), but also how the distribution of the contributions over age has evolved over time, in order to assess whether there has been a compression or an expansion of the age ranges where the cause-specific differences in mortality between men and women act to create the differential survival. They found that neoplasm, heart diseases and external causes are the main drivers of the gender gap in life expectancy, in some cases with an increased overall contribution to the gap. However, even if the gender difference in life expectancy by some causes of death is widening, its age-specific distribution is compressing on a narrower range. This means that, at some ages there is, anyway, a reduction of the inequality between men and women, consistently with the general trend of convergence.

The scientific community has been lively debating for a long time about the factors that might be determining this survival advantage, which has been traditionally explained both from biological and socio/behavioral factors (Austad & Fischer, 2016; Luy & Wegner-Siegmundt, 2015; Rogers et al., 2010). Biological factors pertain to the different biological endowments which would characterize females compared with males. Behavioral explanations, instead, point towards smoking or alcohol and drug abuse and, more reckless behavior typical of males. It is not always easy to clearly disentangle these factors. For example, reckless behaviors could be partly attributed to gender roles and masculinity of which the socialization of young adult males is permeated (Courtenay, 2000), and partly to testosterone surges, even though it is not clear if high testosterone is the consequence, rather than the cause, of aggressive and risky behaviors and situations (Archer, 2006; Casto & Edwards, 2016; Mehta & Josephs, 2006). To further increase the confusion, there is also the evidence that a pronounced female survival advantage as we know it today seems to have emerged during the late nineteenth and early twentieth century (Beltrán-Sánchez et al., 2015). On the other hand, evidence exist on what can be defined as some innate biological better ability to survive of female infants over male infants way back in the past and when mortality conditions were much worse than today's. The analysis of Salinari et al. (2022) contributes to the debate by testing, in the Italian context, an innovative hypothesis that, as of today, has been scrutinized only in a handful of studies (Bolund et al., 2016; Gagnon et al., 2009; Helle & Lummaa, 2013; Hurt et al., 2006; Jasienska, 2009; Le Bourg, 2007): the idea that women's mortality advantage might have emerged thanks to historical process of decreasing fertility during the demographic transition, in a context of trade-off between survival and reproduction. To test this hypothesis, the authors of the study analyzed various survival indicators at post-reproductive ages of pre- and post-transitional cohorts of women, based on their completed fertility histories and found that large progenies (and, to a lesser extent, childlessness) lead to lower survival chances, and that this relationship was strong enough to affect the female-to-male ratio in old age as fertility declined.

As we have just discussed, the epidemiological profile of men and women is somewhat different. Sometimes, men and women can even have profound differences in the susceptibility to the same diseases or being markedly susceptible to different diseases. The world was recently and very suddenly faced with a display of such difference during the COVID 19 pandemic. The first results, later confirmed by more comprehensive and in-depth analyses, spoke of marked gender differences in infection and fatality rates (Bhopal & Bhopal, 2020; Gianicolo et al., 2021; Kontopantelis et al., 2021; Modig et al., 2021; Nielsen et al., 2021). Namely, despite higher infection rates (mostly attributed to the overrepresentation of women among the workers of the health care sector), women would show lower mortality directly attributed from Covid than men. Explanations for this pattern referred to immunological differences between the two sexes. Because a correct estimate of the direct effects of the virus, especially during the first wave, was hindered by important data problems such as misclassification and misreporting of the deaths, researchers started to focus on the analysis of the effect of the pandemic in terms of excess death observed during Covid, compared to the previous years. However, evidence on sex differences in excess death during the first wave of the COVID-19, as well as during previous epidemics, such as SARS, Swine Flu, and MERS, was sparse and inconsistent, as highlighted by the recognition of the literature by Rizzi et al. (2022). In their analysis, they focused on the sex differences in excess death in the Italian region during the first wave and accounted for the spatial gradient of the spread of the virus. Their general finding was that males up to 75 years old suffered more excess death compared to females but the picture was less clear-cut at older ages. Nevertheless, even during Covid, the work of Rizzi et al. (2022), as well numerous other analyses, find evidence of a female survival advantage.

As life expectancy is getting longer and longer, more people survive at older ages and the share of elderly is increasing. Paired with the lower fertility typical of the last decades, increased survival leads to what social scientists call population aging. For societies, population aging is at the same time an opportunity (think of more active and healthier individuals into old ages) and a challenge (higher health care and pension costs). One of the most debated (and heated) challenges that surrounds population aging is about the pension system, the realization of public intergenerational transfer schemes and their long-term sustainability. Governments all around the high-income countries are developing pension reforms, being the postponement of the age at retirement the most used intervention. Gender differences in survival are de facto a central part of the whole debate about retirement age. Women, in fact, on average live longer than men, but traditionally have lower retirement age. They also have, typically, lower contribution levels, due to both lower salaries and fewer years of contributions. Coppola et al. (2022) implement a comparative analysis of the OECD countries to assess the adequacy of the corresponding gender-specific normal retirement ages, when faced with growing life expectancy and identify groups of countries where the gender gap in crucial characteristics such as life expectancy, follows the same dynamics. In line with the current debate about pension reforms, this study is motivated by the need to determine optimal retirement age shifts necessary to match growing life expectancy while accounting for model risk for mortality projections and determines the extent to which adjustments to the normal retirement age are advisable for the sustainability of the system and the preservation of the principles of equality and solidarity.

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