Women Survive Severe Famines and Epidemics Better Than Men

Zarulli, Virginia; Barthold, Julia A.; Oksuzyan, Anna; Lindahl-Jacobsen, Rune; Christensen, Kaare; Vaupel, James W.

Publication date: 2016

Citation for published version (APA):

Terms of use
This work is brought to you by the University of Southern Denmark through the SDU Research Portal. Unless otherwise specified it has been shared according to the terms for self-archiving.

If no other license is stated, these terms apply:
- You may download this work for personal use only.
- You may not further distribute the material or use it for any profit-making activity or commercial gain.
- You may freely distribute the URL identifying this open access version.

If you believe that this document breaches copyright please contact us providing details and we will investigate your claim. Please direct all enquiries to puresupport@bib.sdu.dk

Download date: 01. Oct. 2020
“Women survive severe famines and epidemics better than men”

V. Zarulli\textsuperscript{1,2}, J.A. Barthold\textsuperscript{1,2}, A. Oksuzyan\textsuperscript{3}, R. Lindahl-Jacobsen\textsuperscript{1,2}, K. Christensen\textsuperscript{1,2,6,7} and J.W. Vaupel\textsuperscript{1,2,4,5}

\textsuperscript{1}Max Planck Odense Center on the Biodemography of Aging, University of Southern Denmark, DK-5000 Odense, Denmark;
\textsuperscript{2}Department of Public Health, Unit of Epidemiology, Biostatistics and Biodemography, University of Southern Denmark, DK-5000 Odense, Denmark;
\textsuperscript{3}Max Planck Research Group Gender Gaps in Health and Survival, Max Planck Institute for Demographic Research, 18057 Rostock, Germany;
\textsuperscript{4}Max Planck Institute for Demographic Research, 18057 Rostock, Germany;
\textsuperscript{5}Duke University Population Research Institute, Duke University, Durham, NC 27708-0989;
\textsuperscript{6}Department of Clinical Genetics, Odense University Hospital, DK-5000 Odense, Denmark;
\textsuperscript{7}Department of Clinical Biochemistry and Pharmacology, Odense University Hospital, DK-5000 Odense, Denmark.

Abstract

Women in almost all modern populations live longer than men. Research to date provides evidence for both biological and behavioral factors modulating this gender gap, leaving open the question of what are its fundamental determinants. An unexplored source of information is when both men and women experience extremely high levels of mortality risk. Finding that women have longer life expectancy under very harsh conditions would support the hypothesis that fundamentally the survival advantage of women is biologically determined. In this study we investigate the survival of both sexes in 8 populations under high mortality from famines, epidemics and slavery. We find that women survived better than men. In all populations they had lower mortality across almost all ages and, with the exception of one slave population, they lived longer on average than males. Infant ages contributed the most to the gender gap in life expectancy, indicating that newborn girls were able to survive extreme mortality hazards better than newborn boys. Our results confirm the
ubiquity of a female survival advantage, even when mortality is extraordinarily high, lending support to the hypothesis that the gender survival gap has deep biological roots.

**Keywords**
Famines, epidemics, mortality, survival, gender, difference.

**Introduction**

Women are the life-expectancy champions: they can expect to live longer than men almost anywhere in the world today (Austad 2006; Barford et al. 2006; Glei and Horiuchi 2007). This pervasive inequality has intrigued researchers for decades. The cumulative corpus of research supports the conclusion that the gap appears to have biological underpinnings modulated by social, behavioral and environmental conditions. Strong support for a biological root stems from studies of groups in which men and women have more similar lifestyles than in the general population, such as among non-smokers or within religious groups (Lindahl-Jacobsen et al. 2013; Luy 2003; Rogers and Powell-Griner 1991). The premise is that in these groups men are sheltered from common risk factors. Therefore, most remaining male excess mortality is due to biological factors or residual confounding from unmeasured environmental factors. An untapped source of information is the reverse situation, where both men and women experience similarly high, perhaps extreme, levels of mortality risk. A finding that men and women have similar life expectancies under these conditions would challenge the notion that the survival advantage of women is fundamentally biologically determined. Therefore, we study here the survival of both sexes in populations experiencing mortality crises.

While women have lower mortality than men in modern populations, evidence for a female survival advantage under crisis conditions is sparse. A well-known story concerns the Donner Party, a group of settlers that lost twice as many men than women when stranded in the mountains of Sierra Nevada in the extreme winter for six months (Grayson 1993). While accounts like this might be anecdotal, a variety of studies provide evidence that women may be able to survive cardiovascular diseases, cancers and disabilities longer than men (Ferlay et al. 2013; Isaksson et al. 2011; Jagger et al. 2008; Nusselder et al. 2010; Van Oyen et al. 2010). However, the generality of this notion needs
to be treated with caution since findings on sex differences in survival after myocardial infarction and stroke are mixed (Andersen, Andersen and Olsen 2011; Koek et al. 2006; Nielsen et al. 2014).

Additional support for female hardiness comes from the fact that, in most countries, the sex difference in remaining healthy life expectancy is smaller than the difference in total life expectancy. The difference becomes even smaller later in life. For example, the gender gap in life expectancy at 65 for France and Sweden in 2013 was 4.3 and 2.5 years respectively, while the gap in healthy life expectancy at age 65 was only 0.9 and 0.1 years (Eurostat 2016). So women live more years than men and are able to do so even though they are in bad health for a substantial part of those extra years of life. This suggests a biological explanation for the male-female survival gap, even though some analyses suggest that biological factors may not be the sole determinants of this gap (Thorslund et al. 2013).

In the following, we investigate whether the ability of women to survive better under difficult circumstances extends to crises such as famines, epidemics or slavery—which would lend strong support to a fundamentally biological survival advantage of women over men.

**Data and methods**

**High-mortality populations**

We analyzed 8 reliably documented cases of populations with extremely low life expectancies (20 years or less) for at least one of the sexes, due to extreme conditions such as famines, epidemics or slavery:

- **Freed Liberian slaves** (Mc Daniel 1992; McDaniel and Preston 1994). Between 1820 and 1843, freed American slaves were encouraged to migrate back to Africa. Many undertook the risky trip and went to Liberia, where they encountered a very different disease environment compared to the one in which they grew up. (Mc Daniel 1992) used data collected by the American Colonization Society from 1820 to 1843 and estimated life tables for the former slaves. The data show the highest ever registered mortality in recorded human history. The arrival in Liberia was a mortality shock. About 43% died during the first year and life expectancy at birth was 1.68 years for men and 2.23 for women.
• **Plantations slaves in Trinidad** (Meredith John 1988a, 1988b). At the beginning of the 19th century pro and anti-slavery forces clashed about the emancipation of the slaves in the British Caribbean. The anti-slavery campaign obtained an annual registration of the slaves in the colony of Trinidad. Since unregistered slaves were confiscated by the Crown, owners had a strong incentive to comply with the order. The register contains the age of slaves in 1813 and in 1816, as well as how many slaves died during the period. (Meredith John 1988a) analyzed the data and produced period life tables for the male and female slaves in the plantations of Trinidad. She concluded that life expectancy could have been as low as 15.18 and 13.21 for males and females respectively.

• **The Ukrainian famine in 1933** (Meslé and Vallin 2012). In the twentieth century, the Ukraine experienced particularly turbulent demographic trends that mirror a history of major crises. Among these, the great famine in 1933 that followed the collectivization of agriculture is documented by (Meslé and Vallin 2012), who painstakingly reconstructed several data series. They estimated that period life expectancy during the crisis dropped to 7.3 for men and 10.9 for women from 43.5 and 47.9 for men and women, respectively, 2 years before.

• **The Swedish famine in 1772-1773** (Dribe, Olsson and Svensson 2015). This is described as the last major famine due to starvation experienced across most of Sweden. Abnormal weather conditions in the summer of 1771, followed by widespread crop failures, caused a sudden and sharp increase in food prices. Consequently, mortality due to starvation increased. When the difficult crop conditions continued throughout 1772, mortality increased even further in 1773. Approximately 50% of the excess mortality was due to dysentery, a disease related to the malnutrition (Dribe et al. 2015). Since the famine affected most of the Swedish population, we used male and female life tables for Sweden in 1773 from the Human Mortality Database (www.mortality.org). Life expectancy plummeted to 17.15 for males and 18.79 for females.

• **The Icelandic epidemics in 1846 and 1882** (Cliff, Haggett and Graham 1983). In these two years Iceland experienced its two major measles epidemics of the 19th century. The disease spread rapidly through most of southern Iceland, the most populated area of the country. Even though official registration of deaths by measles started only in 1904, the two epidemics were documented in parish registries and the reports from physicians. Both epidemics spread from Danish boats landing in the late spring of the respective year. Severe
weather and unsanitary wet conditions facilitated the spread of the disease by causing many complications such as diarrhea and chronic bronchitis (Cliff et al. 1983). We used life tables from the Human Mortality Database that show a sudden drop in life expectancy of both sexes in 1846 (to 17.86 for males and 18.82 for females) and 1882 (to 16.76 for males and 18.83 for females).

- **The Irish famine in 1845-1849** (Boyle and O Grada 1986). By 1845 potatoes were the staple food for the majority of the Irish. When the mold Phytophthora infestans infected the plants and caused near-total crop failures over 3 consecutive years, the Irish population starved. The population shrank due to extremely high mortality, emigration, and fewer births. Life tables for the famine years were constructed combining various data sources (Boyle and O Grada 1986). Life expectancy dropped from about 38 years for both sexes in the pre-famine years, to 18.7 for men and 22.4 for women.

- **Cholera epidemic in France in 1832** (Rollet and Souriac 1974). Between April and October 1832 a cholera outbreak hit the French region of Seine-et-Oise. Because of the centralized administrative system at that time, population counts by sex and age are available for each district. (Rollet and Souriac 1974) computed probabilities of death by five year age groups. Based on these probabilities, we found that life expectancy during the cholera outbreak in the region of Seine-et-Oise was 14.0 years for men and 18.9 for women.

**Mortality comparison**

We compared mortality between the sexes and among the populations using different mortality measures, including the probability to survive from birth to age \( x \) (from here on “survival”), the probability of dying between age \( x \) and \( x + 1 \) (from here on “mortality”), life expectancy at birth, and the age at which 5% of a synthetic same-sex cohort would still be alive. We took these measures from the life tables, where available, and otherwise applied standard demographic methods to compute the life tables (Preston, Heuveline and Guillot 2001). For comparing mortality between the sexes, we further computed male-female mortality ratios and differences for each population and decomposed the sex differences in life expectancy by age (Andreev, Shkolnikov and Begun 2002).

**Results**
Life expectancy was higher for women than for men for all populations except for the Trinidad slaves, where males lived slightly longer than females (Figure 1, Table 1). The general survival advantage of women is also reflected in the fact that the ages at which only 5% of a synthetic same-sex cohort would still be alive was higher for females than for males for all populations (Figure 1). This held also for the Trinidad slaves due to a reversal in the age pattern of mortality by sex: until age 25 female slaves suffered from higher mortality than male slaves but afterwards they experienced lower mortality.

<table>
<thead>
<tr>
<th>Population</th>
<th>Male e(0)</th>
<th>Female e(0)</th>
<th>Female – Male</th>
<th>(Female–Male)/Male</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liberia, 1820-1843</td>
<td>1.68</td>
<td>2.23</td>
<td>0.55</td>
<td>0.33</td>
</tr>
<tr>
<td>Trinidad, 1813-1816</td>
<td>15.18</td>
<td>13.21</td>
<td>-1.27</td>
<td>-0.08</td>
</tr>
<tr>
<td>Ukraine, 1933</td>
<td>7.30</td>
<td>10.85</td>
<td>3.55</td>
<td>0.49</td>
</tr>
<tr>
<td>Sweden, 1773</td>
<td>17.15</td>
<td>18.79</td>
<td>1.64</td>
<td>0.09</td>
</tr>
<tr>
<td>Iceland, 1846</td>
<td>17.86</td>
<td>18.82</td>
<td>0.96</td>
<td>0.05</td>
</tr>
<tr>
<td>Iceland, 1882</td>
<td>16.76</td>
<td>18.83</td>
<td>2.07</td>
<td>0.12</td>
</tr>
<tr>
<td>Ireland, 1845-1849</td>
<td>18.7</td>
<td>22.4</td>
<td>3.70</td>
<td>0.2</td>
</tr>
<tr>
<td>France, 1832</td>
<td>14.0</td>
<td>18.88</td>
<td>4.88</td>
<td>0.35</td>
</tr>
</tbody>
</table>

The sex difference in life expectancy varied among the populations (Table 1). Women among the freed slaves migrating back to Liberia had the smallest absolute advantage over men (0.55 years), while women during the cholera outbreak in France had the biggest one (4.88 years). Only in Trinidad, as mentioned above, did males live longer than females (1.27 years). In relative terms, however, the largest advantage of women over men was in the Ukraine (almost 50% difference), then in France (35%), Liberia (33%) and Ireland (20%). Among the other populations the relative advantage was around 10% or smaller.
A decomposition of the difference in life expectancy by age in all study populations shows that the biggest contribution to these differentials comes from strikingly large mortality differences between male and female infants (Figure 2). Afterwards, mortality differences between the sexes contributed less and less to the total gap in life expectancy with the exception of the cholera epidemic in France, when the ages between 10 and 15 contributed the most.

Fig. 1 – Survival curves (shaded areas), life expectancies (solid vertical lines) and ages at which only 5% of a synthetic same-sex cohort would still be alive (dashed vertical lines) for eight high-mortality populations.

Source: authors' calculations.

Women lived longer than men in almost all populations and more women than men survived from birth to each age (Figure 1). The female survival curves were higher than the male ones at all ages, again with the exception of the Trinidad slaves. Here survival was higher for men than for women until age 50, as a consequence of the higher female mortality from age 0 to age 25.
The absolute and relative difference in male to female mortality at each age reveals further details on the sex differences in mortality (Figure 3). Within the study populations, the absolute and relative differences mostly follow a similar age trajectory, so that both absolute and relative differences are largest at similar ages. An exception is Ukraine, where the absolute difference increases sharply from age 40, whereas the relative difference rapidly increases from age 0 to age 20 and then decreases from age 60.

The ages vary at which the relative difference is highest. Almost all populations show a relative female survival advantage across all ages, with the exception of Liberia and Trinidad. Here males had a survival advantage at adult ages for Liberia (between age 35 and age 49), and at infant and juvenile ages for Trinidad (until age 25).
Fig. 3. Male-female mortality ratios (upper panels) and differences (lower panels) over age for four high-mortality populations. Grey lines represent the unsmoothed data, blue lines the smoothed data and the grey shaded areas the standard errors of the smoothing.

Source: authors’ calculations.
Discussion

The conditions experienced by the people in the analyzed populations were horrific. We found that women survived better than men. In all populations males had equal or higher mortality than females across almost all ages. Furthermore, in all populations except the Trinidad slaves females lived longer than males. These results indicate an important distinction: in populations that are exposed to harsh famines and epidemics the female survival advantage holds at all ages, whereas in slave populations in which stressors are or have been under some human control, males can have higher life expectancy and lower mortality than females, at least across some ages. Therefore, females seem to be better equipped than males to survive extremely harsh but natural environmental conditions, lending support to the hypothesis that explanations for the female survival advantage have to go beyond sex differences in behavior.

Fig. 3 – Cont. Male-female mortality ratios (upper panels) and differences (lower panels) over age for the remaining four high-mortality populations. Grey lines represent the unsmoothed data, blue line the smoothed data and the grey shaded areas the standard errors of the smoothing.

Source: authors’ calculations.
The slave populations differ from the other populations in that their age-structure and mortality are heavily influenced by humans. Among the Trinidad slaves, young males might have had a higher monetary value than females, so that a premium was placed on their survival. This may explain why men had lower mortality than women until age 25. The higher male mortality after age 25 could instead reflect their harder working conditions and the possibility that women gradually acquired more value with age, in virtue of their potential to have children. A similar explanation is not available for Liberia, where males had lower mortality than females between age 35 and age 49. Several explanations can be hypothesized. It is possible that determination of gender of individuals, which had to be done with special software and a name dictionary and which failed to identify gender in almost 200 cases, caused some bias in the sex-specific death rates. A second explanation could be related to the need for establishing a stable colony in an initially very hostile environment, which might have favored the individuals considered more important for this purpose, namely men in the adult and most productive ages. Overall males in Liberia still had a lower life expectancy than females because adult ages contributed little to life expectancy, as shown by the age decomposition analysis.

At the onset of famines and epidemics, the populations at risk had age structures shaped by natural mortality, fertility and migration patterns. The risk of death then suddenly rose to extreme levels for everyone. Under these conditions, it was the infant ages that contributed the most to sex differences in life expectancy, apart from the case of the French cholera epidemic. Infant ages affect life expectancy the most when infant mortality is high, even in non-crisis years. However, it is striking that during epidemics and famines as harsh as those analyzed here, newborn girls still survived better than newborn boys. And even in Liberia, newborn girls were hardier than newborn boys.

Further support for the hypothesis of an overall ability of women to withstand high-mortality crises better than men comes from a different mortality measure: for all populations, the age to which 5% of the female population survived was higher than the equivalent age for males. Compared to life expectancy, the age at 5% survival is less sensitive to sex differences in mortality in those ages that have a stronger impact on life expectancy, such as for example infant ages among the Trinidad slaves.
A growing body of research on sex differences in mortality and immunoresponse among humans and other mammals supports the fundamentally biological underpinnings of sex differences in human mortality. Biological factors include hormonal and chromosomal genetic differences. Sex hormones seem to play a key role (Vaccarino et al. 2010; Waldron 1983): oestrogens have anti-inflammatory, vaso-protective effects (Babiker et al. 2002; Wise et al. 2005; Xing et al. 2009), whereas testosterone seems to increase the mortality risk for certain diseases (Haring et al. 2010; Holmegard et al. 2016), although the evidence on this point is mixed (Ruige et al. 2011; Schooling 2015). Moreover, while estrogens enhance immune defenses, testosterone and progesterone may have immunosuppressive effects (Bouman, Heineman and Faas 2005; Giefing-Kröll et al. 2015; Pennell, Galligan and Fish 2012). The presence of two X-chromosomes may pose a further advantage with respect to specific X-linked diseases (e.g. hemophilia A) due to an amelioration of harmful gene mutations through non-mutated alleles on the other X-chromosome. The possibility of having two different alleles on the two X-chromosomes further contributes to the physiological diversity that can be advantageous when encountering new immune challenges (Christensen et al. 2000; Christensen, Ørstavik and Vaupel 2001; Morris and Harrison 2009; Spolarics 2007).

Mammalian females generally outlive males in species in which males compete with each other for opportunities to mate (Clutton-Brock and Isvaran 2007; Promislow 1992). This occurs in polygynous species and is commonly accompanied by sexual dimorphism in body size, which helps males to compete for females. The sexual dimorphism in human body size indicates that our evolutionary history contained a long period of polygynous reproduction (Mitani, Gros-Louis and Richards 1996). Furthermore, in polygynously mating species, the ratio of testes to body size is larger than in monogamous species (Harcourt et al. 1981). The relative testes size of humans in comparison to other species is further evidence that humans mated polygynously during their evolutionary history (Harcourt et al. 1981). The observed sex differences in human mortality are therefore, from an evolutionary perspective, not exceptional; instead humans fall well within the range of observed sex differences in other mammal species (Clutton-Brock and Isvaran 2007; Promislow 1992). Furthermore, among vertebrates males are more likely to be infected with parasites and to carry a greater intensity of infection than female conspecifics (Zuk and McKean 1996). It has been argued that this is due to an immunosuppressive effect of testosterone (Zuk and McKean 1996), but evidence is mixed (Nunn et al. 2009). An alternative explanation comes from one experimental study that points towards a role of testosterone in altering social behavior as to
increase exposure to infection rather than to the hormone acting as an immunosuppressant (Grear, Perkins and Hudson 2009). It has further been argued that increases in Darwinian fitness accompanying a higher investment into the immune system in females but not in males may be sufficient to explain the observed sex differences in immunosresponse (Nunn et al. 2009; Roth et al. 2011). Female mammals seem to not only be better at dealing with infection, they also survive better than male mammals under harsh environmental conditions—an observation confirmed among others by a large comparative study on 26 ungulate populations (Toïgo and Gaillard 2003).

Research evidence shows that an apparent female advantage in immune protection also exists among humans: the incidence of many bacterial, viral, parasitic, and fungal infectious diseases (e.g. leptospirosis, chistosomiasis, brucellosis, rabies, leishmaniasis, pulmonary tuberculosis, hepatitis A, meningococcal and pneumococcal infections, and seasonal influenza) is substantially higher in men than in premenopausal women. This suggests that progesterone and testosterone have mainly immunosuppressive effects, whereas estrogens enhance immune defenses (Bouman et al. 2005; Giefing-Kröll et al. 2015; Pennell et al. 2012). Moreover, autoimmune diseases are more prevalent in women than in men, as well as stronger immune response to vaccinations (Giefing-Kröll et al. 2015; Whitacre 2001). These findings led researchers to conclude that low male immunocompetence contributes to sex differences in mortality (Owens 2002) but the mechanisms through which sex hormones affect immune responses in humans have not been fully elucidated.

On the other hand, behavioral factors have also been identified as important determinants of the male-female survival difference. Higher preponderance of risk-taking behaviors among men contributes substantially to the sex gap in life expectancy. Men consume tobacco, alcohol, and psychoactive substance in greater quantities, drive less safely and eat less salubriously: this results in elevated risks of cardiovascular diseases, lung cancer, liver cirrhosis, and accident fatalities (Waldron 1985; Wardle et al. 2004). In high-income countries cigarette smoking has been identified as the largest factor contributing to the mortality differential (Beltrán-Sánchez, Finch and Crimmins 2015; Preston and Wang 2006). Although behaviors are important factors, they cannot fully explain the sex difference in survival, as suggested by the fact that some female advantage is found among non-smokers, devout Mormons and Catholic nuns vs. monks (Lindahl-Jacobsen et al. 2013; Luy 2003; Rogers and Powell-Griner 1991).
In almost all human populations women live longer than men. The ubiquity of the female survival advantage extends to high-mortality crises. This supports the hypothesis that the female body—in its anatomy, physiology, morphology and development—is build to withstand adverse conditions better than the male body.

References


Eurostat. 2016.


Schooling, C.M. 2015. "Could androgens be relevant to partly explain why men have lower life expectancy than women?" Journal of Epidemiology and Community Health.