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Cite this article: Schacht R, Macfarlan SJ, Meeks H, Cervantes PL, Morales F. 2020 Male survival advantage on the Baja California peninsula. *Biol. Lett.* **16**: 20200600.
<http://dx.doi.org/10.1098/rsbl.2020.0600>

Received: 14 August 2020
Accepted: 13 October 2020

Subject Areas:

ecology, health and disease and epidemiology, behaviour

Keywords:

demography, mortality, fertility, survival, Baja

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Population ecology

Male survival advantage on the Baja California peninsula

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A consistent finding from contemporary Western societies is that women outlive men. However, what is unclear is whether sex differences in survival are constant across varying socio-ecological conditions. We test the universality of the female survival advantage with mortality data from a nineteenth century population in the Baja California peninsula of Mexico. When examined simply, we find evidence for a male-biased survival advantage. However, results from Cox regression clearly show the importance of age intervals for variable survival patterns by sex. Our key findings are that males: (i) experience significantly lower mortality risk than females during the ages 15–30 (RR = 0.69), (ii) are at a significantly increased risk of dying in the 61+ category (RR = 1.30) and (iii) do not experience significantly different mortality risk at any other age interval (0–14, 31–45, 46–60). We interpret our results to stem from differing intrinsic and extrinsic risk factors for sex-biased mortality across age intervals, highlighting the relevance of a life-course approach to the study of survival advantage. Ultimately, our results make clear the need to more broadly consider variability in mortality risk factors across time and place to allow for a clearer understanding of human survival differences.

1. Introduction

A female survival advantage appears to be a general feature of mammals [1]. Among humans, empirical support is so robust that the female advantage is often regarded as a universal human trait [2]. Various biological, cultural and behavioural arguments have been put forward to explain this relationship [3–6]. However, there is growing disagreement about whether sex differences in survival occur among groups experiencing conditions that differ from contemporary Western societies [7].

While a female survival advantage is regularly reported, the sex gap in life expectancy has been shown to be labile over time (e.g. [8]). Specifically, the life-expectancy gap was smaller in the past than it is today. Recent work using mortality data from across 17 Western countries found that during the nineteenth century the female survival advantage was usually less than 1 year [9]. This changed during the twentieth century, as country-specific rises in life expectancy rapidly occurred, and the survival gap extended to nearly 4 years on average. This gap has begun to shift again and, since the 1980s, nearly all countries have seen a narrowing by 0.5–1 years. Thus, while the survival gap is present today, and large under current conditions, that it has fluctuated dramatically challenges assumptions of both its persistence across time and universality across place. What, then, explains its presence and flexibility across Western societies?

Life expectancy is driven by both intrinsic (biological) factors, such as genetic and physiological traits, and extrinsic (contextual) factors, such as environmental and behavioural traits [10–12]. The reasons that men die younger than women can be driven by either set of factors, or their interaction [2,13,14]. For example, oestrogen has been argued to aid in female longevity because of its effects on serum lipids which likely have protective influences on cardiovascular diseases [15]. Additionally, males are hypothesized to be less resilient to infections as a result of testosterone's suppressive effects on immunity (e.g. the 'immunocompetence handicap hypothesis' [16]; although see [17]). Extrinsic factors affecting elevated male mortality rates include lifestyle and behavioural traits such as accidents, homicide and suicide, as well as heart disease and diabetes due to poor diet and lack of exercise [18]. For women, extrinsic factors influencing mortality rates include reproductive timing [19] and obstetric risk [20–22].

However, while the female survival advantage is well documented in twentieth-century high-income countries [9,23], it is much less well studied among low-income and small-scale societies [7]. A consideration for the study of survival advantage across time and place is that either male life expectancy could improve or female life expectancy could worsen through the alteration of risk factors. While few studies have explored survival differences among such groups, a female advantage is not universally observed where it has been examined. For example, during the frontier settlement era of the US state of Utah, distinguished by a series of food shortages and hardships of migration and establishing communities, women did not regularly outlive men [8]. Accordingly, we seek to test the universality of the female survival advantage by way of mortality data from a nineteenth century population in the Baja California peninsula of Mexico.

2. Material and methods

(a) Study site

The Baja California peninsula of Mexico contains two states, Baja California and Baja California Sur. The region is known as 'the Forgotten Peninsula' [24] or 'the Other Mexico' [25] owing to its unique history, where geographic remoteness and arid, mountainous landscapes led to poor infrastructure development and limited integration into the Mexican nation-state until the early twentieth century [26]. During the nineteenth century, healthcare was largely limited to home remedies and folk knowledge [27]. Men typically engaged in physically demanding, subsistence-level horticulture, ranching and/or ocean fishing; however, they engaged increasingly less in these rigorous subsistence activities as their sons matured [27–29]. Historical narratives and vital records indicate that women initiated reproduction early in life, were often substantially younger than their spouses and experienced relatively high fertility [27,29,30]. Additionally, although the peninsula experienced in-migration throughout the nineteenth century [28], its population was sparse (surficial land area = 143 390 km²; population estimate (year): 2938 (1812), 7921 (1850) and 47 624 (1900) [27]).

(b) Data source

Mortality data [31] from 1835–1900 across seven communities (figure 1) are sourced from the *Guía Familiar de Baja California: 1700–1900* [30]. The data contained within the text include

ecclesiastical records from Jesuit, Franciscan and Dominican missions, as well as parish records and governmental archives. Owing to deterioration related to natural causes and human carelessness, portions of the original source materials were not capable of being transcribed. However, there is no evidence that data deterioration was biased in any particular direction [30]. Ultimately, because national-level, systematic censuses were not employed in this region of the world until 1895 [29], these data represent the only source material for reconstructing demographic patterns on the Baja California peninsula prior to the twentieth century (see [28]).

(c) Analysis

Effects of sex on overall mortality were estimated using time-dependent Cox regression models. Individuals were followed from either birth or age at first record year depending on record location (whichever happened later) until death. Models were additionally adjusted for a calendar year as a time-varying covariate. Because the effect of sex on mortality was not constant across time, therefore violating proportionality assumptions, we applied a step function for sex using five age intervals (0–14, 15–30, 31–45, 46–60 and 61+ years old). A follow-up non-proportionality test shows no further time-dependent effects. All analyses were performed in R [32] using the *survival* package [33].

3. Results

(a) What explains age at death?

We begin our analysis by exploring the data descriptively. Across our sample ($N = 1159$), males lived on average 52.1 (s.d. = 22.8, min/max = 0/113) years and females 48.7 (s.d. = 25.8, min/max = 0/119) years. A simple *t*-test confirms that this male survival advantage of nearly 3.5 years is statistically significant ($p = 0.018$). Next, we plot survival curves for males and females (figure 2). A clear separation between male and female survival is present.

With this observation in mind, we begin our Cox regression analysis. We find that (i) males 15–30 years of age experience significantly lower mortality risk than females (relative risk (RR) = 0.69, CI = 0.53–0.91), (ii) males are at a significantly increased risk of dying in the 61+ category (RR = 1.30, CI = 1.06–1.59) and (iii) males do not experience significantly different mortality risk compared with females at any other age interval (0–14, 31–45, 46–60; table 1).

4. Discussion

A consistent finding from contemporary Western populations is that women live longer than men [23]. While flexible across time, this survival gap appears robust across high-income societies [9]. However, what is less well studied is the robustness of the female survival advantage in low-income societies and/or where cultural norms and aspects of social organization vary [7]. Our findings from a historical and primarily peasant population challenge notions of a universal sex gap in survival. Below we offer interpretations of our findings and situate them within the broader literature on the female survival advantage.

When examined simply, we find evidence for a male-biased survival advantage. However, results from Cox regression clearly show the importance of age intervals for variable survival patterns by sex. Specifically, we find that

Figure 1. Map of study site locations. BC, Baha California; BCS, Baha California Sur.

males (i) experienced significantly lower mortality risk than females during the ages 15–30, (ii) were at a significantly increased risk of dying in the 61+ category and (iii) did not experience significantly different mortality risk at any other age interval (0–14, 31–45, 46–60). The second result replicates much research on sex-biased mortality risk [1–7] and the third is consistent with findings from other historical populations indicating a small (or even absent) male–female life-expectancy gap [8,9]. However, we find females to be at a survival disadvantage during the early portion of their childbearing years.

We target two mechanisms, operating separately or in tandem, to explain elevated female mortality risk during the 15–30 age range: (i) risk factors associated with male mortality were dampened and/or (ii) risk factors associated with female mortality were heightened. Reports from historical accounts suggest that both processes may have been operating in this population [27,29]. With regards to the first mechanism, it is well documented that much male excess in mortality, particularly among young men, is tied to risk-taking and violent behaviour, often over social status and access to relationship partners [34]. However, as a strict Catholic population, sex before and outside of marriage, as well as divorce, was taboo (and formally punishable by church officials until the Liberal

Reforms of the 1850s [26,35]). Accordingly, because all men and women were expected to marry, and sex was largely confined to monogamous unions, motivators and payoffs to violently competitive male behaviour, at least within the mating arena, were blunted. [36]. As for the second mechanism, it has been clearly demonstrated that both early female reproduction [19] and increased obstetrical mortality risk (owing to either high fertility or limited access to healthcare) negatively impacts female life expectancy [20–22]. During this time period in Baja California, women typically married young [30], initiated reproduction directly after marriage [34] and achieved high fertility [27,29]. As such, we hypothesize that historical reproductive patterns led to an inversion in mortality risk by sex during the ages 15–30. Future work targeting historical populations where both fertility and mortality data are available will be able to adjudicate this claim.

That we find no sex difference in mortality risk among sexually immature individuals (0–14 years old) is consistent with ethnography in the region documenting gender complementarity within households and no child (son or daughter) preference [35]. However, we did observe the more typically found female survival advantage during the oldest age interval (61+). This could be the result of several factors. Most simply, this outcome reflects the general mammalian pattern

Figure 2. Survival probability by sex.

Table 1. Cox regression model results for the effects of sex on mortality.

	estimate (SE)	RR (CI)
year	0.07 (0.00)***	1.07 (1.07–1.08)
male: age 0–14	–0.08 (0.24)	0.92 (0.58–1.46)
male: age 15–30	–0.37 (0.14)**	0.69 (0.53–0.91)
male: age 31–45	0.07 (0.14)	1.07 (0.81–1.42)
male: age 46–60	0.03 (0.12)	1.03 (0.81–1.32)
male: age 61+	0.26 (0.10)*	1.30 (1.06–1.59)

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

where females outlive males (e.g. owing to the immunosuppressant effects of testosterone; [1]). Alternatively, research on modern rural ranching populations in the area indicates that older males disengage from productive economic activities at an earlier age (approx. 60 years) than females owing to the energetic demands of traversing long distances by foot [37,38]. Because this type of subsistence activity has been shown to have a protective effect on male heart health, the transition to a more sedentary lifestyle among older men could have promoted increased mortality risk through, for example, cardiovascular disease [36].

We would like to be direct about data limitations. Historical datasets typically suffer from missing data because not all vital events for all individuals are documented. Deaths of migrants, neonates and those socially and/or geographically isolated are less likely to be recorded. Data loss also occurs as a result of time, from record deterioration and misplacement. Ultimately, however, while missing data can produce biased estimates, there is no evidence of systematic under-reporting of mortality among these data from the Baja California peninsula [26].

Put simply, counter to conventional findings on sex differences in survival, we find evidence for a male survival advantage. However, depending on the age interval under study, a male advantage, a female advantage or no advantage are all observed. These results highlight the relevance of a lifecourse approach to the study of survival advantage and a consideration of variable sources of male and female mortality risk. For example, the female disadvantage during the ages of 15–30 was possibly generated by reduced male risk and/or increased female risk related to reproduction. The male disadvantage witnessed in the ages 61+ could be an outcome of increased cardiovascular disease risk among older, sedentary males and an increasingly more robust pool of females. The results of this work highlight three take-home points: (i) societies with variable intrinsic and extrinsic sources of mortality should be considered in order to broadly test generalizations about human survival universals, (ii) the importance of exploring survival advantages at various life stages, and (iii) the usefulness of historical data for providing us with a glimpse into pre-industrial life, which is necessary for a broader understanding of human survival patterns across time and place and for theory-building regarding the human niche.

Data accessibility. Our dataset is available in Dryad (<https://doi.org/10.5061/dryad.v41ns1rt5>) [39].

Authors' contributions. The study was conceived and designed by R.S. and S.J.M., with support from all authors. P.L.C. and F.M. coded and entered the data, with support from all authors. Analyses were performed by H.M., with support from all authors. The manuscript was written by R.S. and S.J.M., with support from all authors. All authors gave final approval for publication and agree to be held accountable for the work herein.

Competing interests. We declare we have no competing interests.

Funding. This research was funded in part through the Center for Latin American Studies at the University of Utah and the University Writing Program at East Carolina University.

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