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Is There a Reproductive Cost for Human Longevity?

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Editor's Note: There has been a long argument in the aging literature about a possible tradeoff between gender and lifespan. It has taken the form of discussions regarding fecundity, fertility, age at menarche, and, occasionally, an almost metaphysical "energy" that the organism (or the species) must invest in and balance between having more offspring or a longer lifespan. Here, the Gavrilovs respond to a paper in Nature, *in which Westendorp and Kirkwood suggested that there was such a trade off. The Gavrilovs dispute the data and the analysis; Westendorp and Kirkwood respond. The question is whether human longevity is achieved at the cost of reproductive success. A difficult question. Should we abstain from the question, or perhaps from reproduction?*

ABSTRACT

This is a critical review of the recent claims by Westendorp and Kirkwood that human longevity is achieved at the cost of reproductive success. The criticism could be summarized in four statements. (1) Declaring that long-lived women have less progeny and older age at first childbirth, the authors failed to adjust the data for the age at marriage—the most important explanatory variable both for the number of children and for the age at first childbirth; (2) they also overlooked another important confounding variable—the husband's fertility; (3) the authors used the data that are inappropriate for fertility studies—extremely ancient and incomplete genealogies with many underreported records for daughters that led to incorrect estimates for the number of progeny and for the age at childbirth; and (4) the authors presented their study as completely new for humans and did not quote the opposite results from the earlier study by Le Bourg et al. where no trade-off between human longevity and fertility was observed. They also ignored findings of Bideau and of Knodel that the most fertile women live longer than the remainder or at least not shorter contrary to the author's claims. Thus, the conclusions of Westendorp and Kirkwood are inconsistent with the existing knowledge and should be reanalyzed using more appropriate methods and data.

THE TOPIC OF HUMAN AGING AND LONGEVITY has relevance to each of us. For this reason many people live with hope for a future possible scientific breakthrough in understanding the mechanisms of human longevity. These expectations seems to be justified by the recent mass-media reports about the scientific discovery published in *Nature*,[1] that human longevity is achieved at the cost of reproductive success. Using genealogic data for the British aristocracy for the historical period when no birth control was practiced, Westendorp and Kirkwood, the authors of this study[1] have found that long-lived women are espe-

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cially unsuccessful in their reproduction. In particular, as many as 50% of the married long-lived women were childless.[1] Even those long-lived women that succeeded in reproduction had, on average, less than 2 children and had the first child by the age of 27 years only.[1] The authors of this study claim that human longevity is achieved at the cost of reproductive success because of a genetic tradeoff between longevity and reproduction predicted by their "disposable soma theory of aging."[1]

The results of this study, if they are correct, are important and the authors present their results as being novel in humans. The authors did not, however, discuss contradictory results from the previous, widely known study on the same topic,[2] in which no tradeoff between human longevity and fertility was observed. Nor were there data suggesting that the most fertile women, particularly those who have borne 12 or more children, live longer than do others,[3] or at least do not have shorter lives,[3,4] contrary to the author's claims.[1] Thus, the results of this new study[1] are, in fact, inconsistent with already existing data and knowledge.[2–4] Here we discuss three possible causes for this scientific controversy.

First, the authors[1] did not adjust the data for the age at marriage—the most important explanatory variable both for the number of progeny and for the age at first childbirth.[4] For example, it is well known in historical demography that the mean number of progeny in the past was approximately 8 children for women married at 20–24 years and only 2 children for women married at 35–39 years.[4] For this reason, if the data are not adjusted for the age at marriage (age when the births of legitimate children start), the analysis of the number of progeny in humans can be seriously compromised.

A second fundamental predictor variable for the number of offspring is the husband's relative age (a proxy for husband's fertility). If the husband is 10+ years older than the wife, the number of births may be twice as low, compared to the situation in which the husband is younger than the wife.[4] The authors did not consider this well-known key explanatory variable for the number of progeny in the published data analysis.[1]

Failure to control for the age at marriage and for the spousal age gap could produce spurious evidence for the existence of a tradeoff, because women from particularly elite royal families may have a higher life expectancy (as a result of their privileged social status), a delayed age at marriage, and a larger spousal age gap (because of extremely narrow mating choices).

Finally, the authors have selected for the analysis the data set that seems to be inappropriate for the purpose of their study (analysis of the number of progeny) and used extremely ancient (dating back to as early as the year 740) and incomplete genealogies with many underreported records for women. The problem with this sex bias is most evident from the sex ratio in their initial data set—19,380 males and only 13,667 females (a sex ratio of 1.42).[1] The sex ratio in complete, high-quality genealogies is close to the sex ratio at birth,[4] which, for Caucasian populations, generally falls between 102 and 107 males per 100 females.[4,5]

The use of incomplete data could also result in a spurious tradeoff, because less reliable ancient data for obscure families are more likely to underreport the number of progeny and to contain more false claims on extreme longevity (longevity outliers are often a result of misprints or mistakes).

Due perhaps to incomplete data (underreporting of women), the mean number of progeny appears to be unrealistically low for the early historical periods—less than 2.8 (see Table 2 of Ref. 1).[1] Taking into account the extremely high infant mortality that was observed in the previous centuries,[4] and the significant proportion of childless women reported by the authors (more than 25%, see Table 1 in their article), the British monarchy and the aristocracy simply would not have survived by now, if the estimates provided by the authors were correct.

Fortunately, the British monarchy and aristocracy were much more successful in their reproduction, compared to the authors' estimates. For example, Queen Victoria had 9 children and 42 grandchildren, despite a severe genetic disease (hemophilia in her male progeny), so the mean number of progeny for her children was about 4.7 (42/9). These estimates

for the number of progeny follow from our database on European royal and noble families described elsewhere,[6,7] and they could be easily reconfirmed using other sources for British royal family.

It may be quite possible that human longevity is achieved at the cost of reproductive success and that there might be a genetic tradeoff between longevity and reproduction. However, before discussing this interesting hypothesis, we must first exclude the possibility of other trivial explanations related to the differences in the age at marriage, the husband's relative age (the husband's fertility), and the data quality.

There is also no question that the genealogical data and historical demographic data might be of great interest in the biology of aging and longevity.[2–4,6–10] However, this specific area of research requires extremely careful data analysis (data quality control and adjustment for important predictor variables, see above), described in the classical textbooks on historical demography.[4] We believe, therefore, that the published results[1] should be reanalyzed with these methodologic caveats in mind.

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