Does Exceptional Human Longevity Come with a High Cost of Infertility?

Testing the Evolutionary Theories of Aging

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ABSTRACT: The purpose of this study is to test the prediction of the evolutionary theory of aging that human longevity comes with the cost of impaired reproductive success (higher infertility rates). Our validation study is based on the analysis of particularly reliable genealogical records for European aristocratic families using a logistic regression model with childlessness as a dependent (outcome) variable, and woman's life span, year of birth, age at marriage, husband's age at marriage, and husband's life span as independent (predictor) variables. We found that the woman's exceptional longevity did not increase her chances of being infertile. It appears that the previous reports by other authors of high infertility among long-lived women (up to 50% infertility) are related to incomplete data, that is, births of children not reported. Thus, the concept of the high cost of infertility for human longevity is not supported by the data when these data are carefully cross-checked, cleaned, and reanalyzed.

KEYWORDS: evolutionary theory of aging; higher infertility rates

INTRODUCTION

The purpose of this study was to test the prediction of the evolutionary theory of aging that human longevity comes with the cost of impaired reproductive success (higher infertility rates, see Westendorp & Kirkwood[1]). Our validation study is based on the analysis of particularly reliable genealogical records for European aristocratic families. This data set is appealing to use for two reasons: (1) it has high data accuracy and completeness; and (2) confounding effects of socioeconomic status are minimized in this socially elite group. The data set is comprised of 3,723 married women born from 1500 to 1875 and belonging to the upper European nobility. Every case of childlessness was cross-checked using at least two different sources. Data analyses were based on a logistic regression model using childlessness as a dependent (outcome) variable, and the woman's life span, year of birth, age at marriage,

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husband's age at marriage, and husband's life span as independent (predictor) variables. We found that a woman's exceptional longevity does not increase her chances of being infertile. It appears that the previous reports of high infertility among long-lived women (up to a 50% infertility rate, see Westendorp & Kirkwood[1]) are related to incomplete data, that is, births of children not reported. Indeed, data cross-checking revealed that at least in 32% of the cases the allegedly "childless" women did, in fact, have children. Thus, the concept of heavy infertility cost for human longevity is not supported by data, when these data are carefully cross-checked, cleaned, and reanalyzed. Additional relevant information is available at our scientific Web site (http://longevity-science.org/).

THE IMPORTANCE OF DATA QUALITY CONTROL

Previous analysis of childlessness among aristocratic women[1] was made on the assumption that the data was complete. When claims were made that many long-lived women were childless,[1] we found it important to cross-check the data and to make sure that the lack of children was real.

An obvious step was to cross-check the initial data set with other data sources. For example, we examined 335 claims of childlessness in the Bloore's data set used by Westendorp and Kirkwood. When we cross-checked these claims with other professional sources of data, we found that at least 107 allegedly childless women (32%) did have children Thus, at least 32% of childlessness claims proved to be wrong (false-negative claims).

This example demonstrates that extreme caution should be exercised when claims for common childlessness among long-lived women are made. The incompleteness of genealogies can itself generate a spurious increase in the prevalence of allegedly childless women among those who live long lives. This happens because children often are not mentioned in particularly obscure, side branches of genealogical trees (remote relatives). It is also known that long-lived people have more chances of being mentioned in incomplete genealogies, because of their longer paper trail in various archives generated during their long life. Thus, incompleteness of genealogies generates two types of biases—underreporting of children and inflated prevalence of long-lived people, thereby producing a spurious increase in claimed childlessness with increased life span.

Incomplete reporting of children may seriously affect and compromise scientific studies of human fertility. For example, Westendorp and Kirkwood reported: "None of the six women who were born before 1700 and who reached the exceptional age of 90 years and over had more than two children" (p. 745).[1] Our data cross-checking with other data sources revealed that, in fact, none but one of these women had less than three children.

Among these six women was Antoinette de Bourbon (1493–1583) who allegedly had only one child according to the Bloore's database. Study of other data sources revealed that this well-known person (grandmother of Mary Stuart, Queen of Scots) had as many as 12 children! This fact is well known to professional genealogists and is even reported in The Catholic Encyclopedia (Vol. VII, House of Guise, Robert Appleton Company, 1909). Thus, if we compute an average number of children for women who lived 90–99 years with corrected data for Antoinette de Bourbon alone,

TABLE 1. Proportion of childlessness by women's age at death: comparison of our data set with similar data for the historical German population[2] and data for the British aristocracy[1]

	Proportion of childless women in different data sets		
Age at death, yr	Gavrilova data set on European upper nobility	Lycett *et al.*[2] German data	Westendorp and Kirkwood[1] British aristocracy
20–29	0.17	0.15	0.39
30–39	0.10	0.08	0.26
40–49	0.14	0.08	0.31
50–59	0.13	0.11	0.28
60–69	0.12	0.09	0.33
70–79	0.10	0.09	0.31
80–89	0.15	0.10	0.45
90+	0.12	—	0.49

their average number of progeny would be even higher than average number of progeny for shorter-lived women.

This example demonstrates that genealogical data should be carefully checked against multiple genealogical and historical sources before using them in the scientific studies and making strong conclusions.

RESULTS AND DISCUSSION

This section describes the results obtained with cross-checked, corrected data. TABLE 1 presents the dependence of the frequency of childlessness as a function of the women's life span (univariate analysis).

The data obtained by other researchers are also presented in the same table for comparison. Note the extremely high proportion of childless women in data published by Westendorp and Kirkwood.[1] On the other hand, German data[2] as well as our data for aristocratic women are consistent with each other and do not demonstrate any increase in childlessness for long-lived women. Our estimates of childlessness also are consistent with estimates of childlessness among the British peerage reported by Thomas Hollingsworth in his fundamental historical study.[3]

Results presented in TABLE 1 were obtained using univariate analyses, which do not take into account many important explanatory variables. To avoid the omitted variable bias and to study the true relationship between childlessness and longevity, we need to take into account many other explanatory variables that influence infertility rate. Therefore, we applied multivariate logistic regression with childlessness as a dependent binary variable and calendar year of birth, female age at marriage, husband's age at marriage, female life span, and husband's life span as predictor variables.

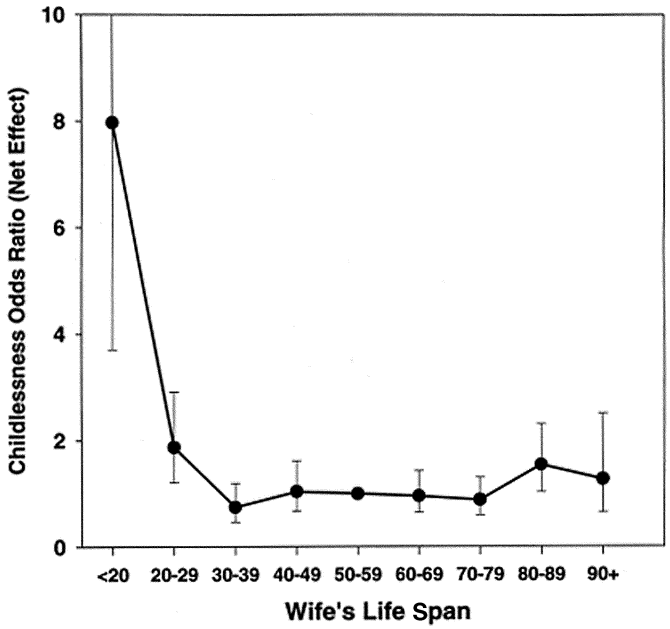

FIGURE 1. Childlessness odds ratio as a function of female life span. Net effects are adjusted for female calendar year of birth, female age at marriage, husband's life span, and husband's age at marriage. Multivariate regression analysis of 3,723 European aristocratic families.

The main result of our study is presented in FIGURE 1. This figure shows odds of being childless as a function of female life span, adjusted for other important confounding variables. The odds of childlessness are particularly high, when the women's life span is too short (under age 30), which is not surprising. What is really important is that the chances of being childless do not demonstrate any increase for long-lived women (life span 90+ years). This result confirms findings from our univariate analyses (TABLE 1) as well as from other studies,[2,4] which demonstrated that long-lived women do not have a higher rate of childlessness even when controlled for other important confounding variables.

Our study does not support the previous published claims that human longevity comes at a high cost of infertility. This conclusion may have both theoretical significance (testing some evolutionary theories of aging), as well as practical implications for the future of life extension. It helps to relax concerns over a question: "Is it morally acceptable to extend human longevity at the cost of infertility?" Some authors have already raised their concerns on the unintended consequences of life span extension: "… increasing longevity through genetic manipulation of the mechanisms of aging raises deep biological and moral questions. These questions should give us pause before we embark on the enterprise of extending our lives."[5] This study helps to alleviate some concerns on these issues.

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