Effects of Paternal and Maternal Longevity on Mortality Trajectories in Human Offspring

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Abstract

Positive effects of paternal and maternal longevity on offspring's lifespan are well established. However little is known about effects of parental longevity on the shape of offspring's mortality trajectories. To address this problem, we studied familial transmission of human lifespan from parents to offspring using particularly reliable and complete data on European royal and noble families for extinct birth cohorts (born 1800-1880). Mortality of four categories of offspring was analyzed: (1) having long-lived parents (both parents lived 80 years or more); (2) having short-lived parents; (3) having long-lived father and (4) having long-lived mother. Mortality in all groups of offspring demonstrates a convergence at older ages for both sexes. Although children of long-lived parents have lower mortality at younger ages, their actuarial aging rate is consistently higher compared to the children of short-lived parents. Thus, the familial advantage in lifespan practically disappears at ages over 100.

Introduction

Effects of parental longevity on the offspring survival are being studied for more than 100 years. In 1899 the founder of biometrics, Karl Pearson (1857-1936) and his student, Mary Beeton analyzed the correlation of parent/child ages at death based on English genealogies (using data from the English Peerage and Landed Gentry) dating back to the 17th century (Beeton and Pearson, 1899). As a result of their studies, these authors concluded that expectation of life is heavily influenced by the ages of death of one's relatives (Beeton and Pearson, 1901, p. 77).

More extensive studies on the topic were subsequently conducted by Raymond Pearl (Pearl, 1931; Pearl and Dewitt, 1934; Pearl and Pearl, 1934). Raymond Pearl discovered in what is now the famous Baltimore Longevity Study that the ancestors of long-living persons (nonagenarians) had a substantially higher life span compared to a control population. Following these initial studies on the familial transmission of human longevity early in the 20th century, a number of other scientists have addressed the same issue (see Gavrilov et al., 2002 for review).

In spite of a century of research on familial longevity, there is still no consensus among scientists on many of the fundamental issues regarding familial longevity. For example, the role of genetics in familial longevity resemblance was challenged by some authors (Murphy, 1978; Philippe, 1978; Jacquard, 1982) who not only found that the familial resemblance is weak, but also emphasized the importance of social explanations.

The mode of longevity inheritance in humans is also not yet determined (Carnes et al., 1999).

More recent studies suggest that it may be reasonable to revise some of the underlying assumptions behind existing controversies about maternal versus paternal inheritance, and to develop more refined methods of familial analysis of human longevity (e.g., see Gavrilov and Gavrilova, 1991). Recent research demonstrated that transmission of human longevity from parents to offspring is not linear (Gavrilova et al., 1998a;b; Gavrilova, Gavrilov, 2001a; Gavrilov, Gavrilova, 2001b). As a result of this non-linearity, the familial transmission of lifespan after age 80 is significantly higher than below this age. On the other hand, there is no correlation between lifespan of spouses, who share the same familial environment. These two observations taken together suggest that survival beyond age 75-80 years is significantly influenced by genetic factors rather than shared familial environment (at least in our dataset). These new findings may explain the existing longevity paradox: although the heritability estimates for lifespan were reported to be rather low (McGue et al., 1993; Finch and Tanzi, 1997; Ljungquist et al., 1998; Mitchell et al., 2001), it is well known that cases of extreme longevity have a strong familial association (Pearl, Pearl, 1934; Perls et al., 1998). This paradox is explained by our finding that heritability of human lifespan is low only when studied in the whole range of parental lifespan (because most of the parents did not survive to advanced ages in historical populations studied so far), but is quite high when estimated specifically for longer-lived parents. Absence of a similar relationship between lifespan of individuals and their spouses (who share the same familial environment) provides additional evidence for the role of genetic factors in human longevity (Gavrilova et al., 2001).

Studies of age-specific changes in additive genetic variance of lifespan, which demonstrated its rapid increase with age provided the first results for humans (Gavrilova et al., 1998a; Gavrilova, Gavrilov, 2001a) that support the mutation accumulation theory of aging (Charlesworth, Hughes, 1996; Promislow, Tatar, 1998).

One unresolved problem remaining is a question about the effects of familial longevity on the shape of the offspring's mortality trajectories.

Methods

In this study we collected, computerized and analyzed the detailed genealogical records on lifespan of 14,955 adult sons and daughters (40+ years) and their parents, using particularly reliable and complete database on European royal and noble families for extinct birth cohorts (born 1800-1880). More details about the dataset used in this study was published elsewhere (Gavrilova, Gavrilov, 2001).

In order to account for lifespan secular trends and fluctuations data were adjusted in the following way. First, the data on individual lifespan were centered around the mean lifespan in the same birth cohorts in order to control for secular changes in lifespan. In other words, the residuals were calculated as the differences between individual lifespan and the cohort mean lifespan for the same calendar year of birth. These residuals (deviations from population mean) were then added to the average of the total sample

(sex-specific). These values of adjusted lifespan were then used in calculating survival and mortality rates and estimating parameters of the Gompertz equation.

Mortality of four categories of offspring was analyzed: (1) having long-lived parents (both parents lived 80 years or more); (2) having short-lived parents; (3) having long-lived father and (4) having long-lived mother. The cutpoint (80 years) was selected based on our previous results showing significantly higher heritability of lifespan after parental age equal to 80 years.

Gompertz parameters were calculated for adults survived to age 40 years and over using Stata streg procedure.

Results

Table 1 shows Gompertzian parameters according to longevity of parents for sons and daughters. Note that the intercept parameter is increasing and the alpha parameter (actuarial aging rate) is decreasing with decreasing longevity of parents. The lowest intercept parameter and the highest actuarial aging rates have sons and daughters of long-lived parents. Offspring with one long-lived mother and one long-lived father have very similar values of Gompertzian parameters. Thus lower values of mortality at intercept age (40 years) are compensated by higher relative rate of mortality growth with age.

Figure 1 demonstrates this compensation effect. Mortality in all groups of offspring demonstrates a convergence at older ages for both sexes. Although children of long-lived parents have lower mortality at younger ages, their actuarial aging rate is consistently higher compared to the children of short-lived parents. Thus, the familial advantage in lifespan practically disappears at ages over 100.

Table 1. Gompertz parameters for mortality trajectories of four groups of offspring with different parental longevity.

Offspring group	Intercept	95% CI	alpha	95% CI
	Sons			
Both parents long-lived N=285	-9.21	-9.79, -8.62	.089	.081, .098
Long-lived mother N= 1,401	-8.81	-9.05, -8.57	.086	.082, .089
Long-lived father N= 1,026	-8.95	-9.24, -8.66	.086	.082, .090
Both parents short-lived N=4,736	-8.49	-8.61, -8.37	.083	.081, .085
	Daughters			
Both parents long-lived N=323	-11.08	-11.80, -10.36	.107	.098, .116
Long-lived mother N=1,390	-9.93	-10.22, -9.65	.093	.090, .097
Long-lived father N=940	-10.17	-10.53, -9.80	.097	.092, .102
Both parents short-lived N=4,854	-9.60	-9.74, -9.45	.091	.089, .093

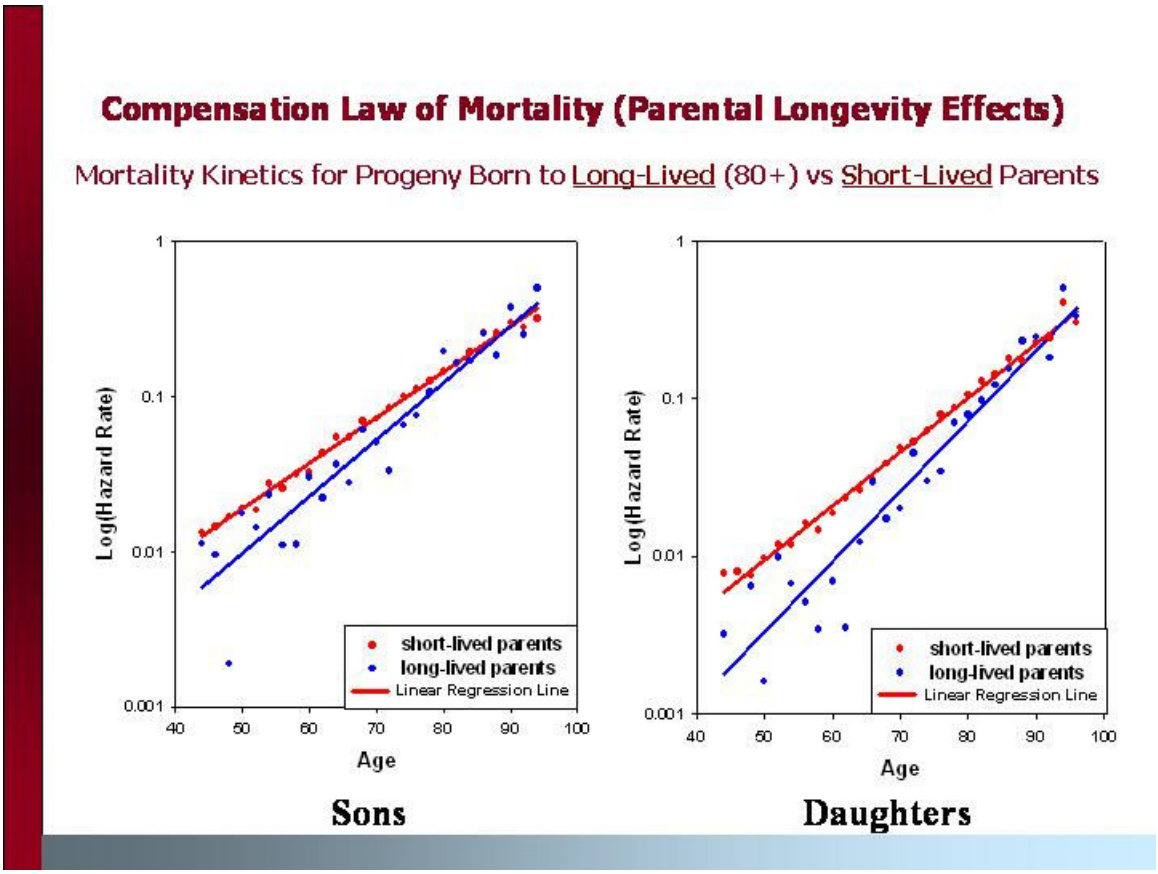

Figure 1. Mortality trajectories for the progeny of long-lived and short-lived parents. European aristocratic families.

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