Familial Transmission of Human Longevity among the Oldest-old in China [1]

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Abstract: This paper aims to investigate the relationship of exceptional longevity (survive to 80 years old or beyond) of offspring to longevity of parents, by using data from the first three waves of the Chinese Longitudinal Healthy Longevity Survey. Fixed-Attributes Dynamics method and logistic models are applied to the data. Results of both methods show a relatively strong same-sex inheritance of longevity between parents and offspring, that is, a strong association between father's and son's longevity or between mother's and daughter's longevity, but a weak or no association of longevity between father and daughter or between mother and son. And both mother and father are long-lived would contribute somehow to children's exceptional longevity.

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INTRODUCTION

Is human longevity inheritable? To which extent is the life span of offspring associated with that of parents? As higher life expectancy has been attained by a larger proportion of population than before, these questions are more intriguing.

Although it is generally believed that longevity is only moderately inheritable, many studies have consistently supported the conventional wisdom that long life runs in family (Pearl, 1931; Cohen, 1964; Abbott et al., 1974; Philippe, 1978; Bocquet-Appel and Jakobi, 1990; Mayer, 1991; McGue et al., 1993; Herskind et al., 1996; Ljungquist et al., 1998; Gavrilova et al., 1998; Robine et al., 1998; Cournil et al., 2000; Gudmundsson et al., 2000; Korpelainen, 1999, 2000b; Kerber et al., 2001; Perls et al., 2002; Kemkes-Grottenthaler, 2004). That "If you would live long, choose your parents well" (Cournil et al., 2001) indicates a common belief in academic field about familial component to longevity. As to the extent to which longevity is inherited, scholars have shown various estimates, in part because of "differences in the types of paired relationships examined, the time periods and number of generations considered, and the quality of data among source population"(Kerber et al., 2001). The estimates of heritability have been varied from nearly zero to 0.89 with most studies yielding a low but consistent figure less than 0.3 (Philippe, 1978; Bocquet-Appel and Jakobi, 1990; Mayer, 1991; McGue et al., 1993; Gavrilova et al., 1998; Cournil et at., 2000; Mitchell et al., 2001; Korpelainen, 1999, 2000b). The highest estimate of heritability is obtained among aristocratic Europeans in a study by Korpelainen (2000b). However, in the same study, Korpelainen shows the rural Finns possessed either no inheritable component or a clearly low level of heritability. This suggests that there might be a complex interplay of environmental and genetic effects (Westendorp and Kirkwood, 2001). Environmental or social explanations are also emphasized by other scholars (Murphy, 1978; Philippe, 1978; Jacquard, 1982; Alter, 2001; Perls et al., 2002), who likewise argue that familial resemblance may be the results of shared environmental or behavioral effects associated with common rearing.

As regards to the relative importance of maternal or paternal line of inheritance, no consensus, as yet, is reached. Some studies found heritability is more strongly along the paternal line (Bell, 1918; Cohen, 1964; Philippe, 1978; Bocquet-Appel and Jakobi, 1990); others show the maternal contribution outweighs the paternal component (Abbott et al., 1974; Crawford and Rogers, 1982; Brand et al., 1992; Korpelainen, 1999, 2000b; Kemkes-Grottenthaler, 2004). Several studies also show that daughters receive a greater portion of the genetic endowment than their male siblings (Cournil et al., 2000; Cournil, 2001; Kemkes-Grottenthaler, 2004).

Among the considerable research on longevity, however, almost no research has been done in developing countries and most studies are based on small sample sizes (Vaupel, 2001). The Chinese Longitudinal Healthy Longevity Survey (CLHLS) opens an opportunity to study longevity in a developing country based on much larger sample size. This paper aims to examine the association of life spans among family members in China by using the data from the CLHLS. The main purpose of the paper is to investigate whether exceptional longevity of the oldest-old Chinese is related to their parent's longevity and to examine whether there is a sex-linked heritability.

DATA AND METHODS

The data used in this paper are from the CLHLS, which is the largest longitudinal survey of very old people ever undertaken (Zeng and Vaupel, 2004). The baseline survey and the first and second follow-up survey were conducted in 1998, 2000, and 2002, respectively, in randomly selected 50% of the counties or cities in 22 provinces. The CLHLS is specially designed with age-matching, oversampling of the oldest-old males and institutionalized persons. For each centenarian (aged 100+) with a pre-designated random code, one nearby octogenarian (aged 80-89) and one nearby nonagenarian (aged 90-99) with pre-designated age and sex were interviewed. The term ‘nearby’ mainly indicate the same village or the same street if applicable, or the same town, county, or city. The aim of this design is to have comparable numbers of randomly selected male and female octogenarians and nonagenarians at each age from 80 to 99. Participants interviewed in 1998 were re-interviewed in 2000 and 2002 if they were still alive. For those deceased respondents who died between survey intervals, more than thirty questions including the date of death were collected from the next-of-kin. New respondents were added to replace the deceased or respondents lost to follow-up in order to keep the adequate sample size in later waves. Evaluations showed that the data quality of the CLHLS was generally good and the age reporting was generally accurate (Gu, 2006; Gu and Dupre, 2006; Zeng and Gu, 2006; Zeng et al., 2001). Excluding siblings, there are 8,585 respondents aged 80 to 105 in 1998. Of them, 3,226 died before the 2000 survey and 1,530 died after the 2000 survey but before the 2002 survey, reaching a total of 4,756 deceased interviewees. We use both the information of the interviewees in the baseline survey and those who died between the 1998 and the 2002 waves.

There is a large proportion of missing values for parents’ ages at death in the baseline wave of the CLHLS. Of the 8585 respondents, 3,547 (41%) have no information on father’s age at death and 3,031 (35%) have no information on mother’s age at death. Therefore, missing value analyses were conducted based on multiple imputation technique (Allison, 2002). The imputed results are very close to those un-imputed.[2] In the body text, we use un-imputed data while listing the imputed results in the appendix.

Survivorship ratios of elders having long-lived parents to those have no long-lived parents are calculated by using the Fixed-Attributes Dynamics (FAD) method and logistic models are applied to the data to examine the association of the life span between parents and children. The Fixed-Attributes Dynamics (FAD) method, also known as the Survival Attribute Assay, was initially proposed by Vaupel (1992), developed by him and Yashin (Yashin et al,. 1998; 1999; 2000; Gerdes et al., 2000), and extended by Zeng and Vaupel (2004). The basic idea of the method is that the prevalence of a fixed attribute can change with age even though no individual can change his or her variant of the attribute, and that therefore much can be learned about the impact of the attribute on survival. Fixed attributes that affect survival at older ages include genetic factors and various non-genetic factors that are fixed in earlier life. Given that both parents of all respondents had died when respondents were interviewed in the 1998 study,[3] the parents’ ages at death of the respondents could be considered as a fixed attribute of the respondents at the time of the interview in 1998. The basic FAD method for use in a study of longevity when estimates of cohort survivorship are not available can be formulated as follows[4]:

$$RS_{(a/-a)} = \frac{(1-p_a(x))\,p_a(x+n)}{p_a(x)(1-p_a(x+n))}, \qquad (1)$$

where $RS_{(a/-a)}$ is the ratio of survivorship of those with the fixed attribute a to those without the attribute a from age x to $x+n$; $p_a(x)$ and $p_a(x+n)$ are the proportions of individuals who have the fixed attribute a at age x and $x+n$, respectively. If $RS_{(a/-a)}$ is

[2] There is a difference between imputed and un-imputed data for male respondents in the logistic regression when we use the 10 percentile of age at death to define long-lived parents. But there was no obvious source of bias that might distort the patterns of association of longevity within families for whom all the necessary information was recorded.
[3] There are few than 10 respondents whose parents were still alive. They are excluded from the present study.
[4] For details, refer to Zeng Yi and James W. Vaupel. 2004. Association of Late Childbearing with Healthy Longevity among the Oldest-old in China, *Population Studies*: 58(1), 2004, 37-53.

greater than 1, the attribute is positively associated with longevity. Statistical tests can be performed to test whether there is a statistically significant difference of survivorship between the two populations (Mantel and Haenszel, 1959).

When compare the survivorship ratio of those with the fixed attribute a to those with attribute b, we extend the FAD method to the following formula:

$$RS_{(a/b)} = \frac{p_a(x+n)\, p_b(x)}{p_a(x)\, p_b(x+n)} . \qquad (2)$$

The main strength of the FAD method is that it does not require prospective tracking of study participants to ascertain the occurrence of exit events. It could be used to investigate the association of a fixed attribute with longevity based on one cross-sectional survey dataset. The FAD method also assumes that the number of migrants is small or, alternatively, migrants do not differ significantly from non-migrants with respect to the fixed attribute and survival. The magnitude of international and internal migration before the 1980s in China was small due to slow economic development and policies restricting residential movement. Mobility greatly increased after 1980, but not among the oldest-old.

Longevity of parents in this paper is defined according to different standards. First, we use 70 years of the age at death as the cut point age, that is, those who died at or after age 70 were regard as long-lived. Second, we try age 80 as the cutting age. Lastly, longevity is defined according to a percentile of the age-at-death distribution. The percentile 10 is chosen to denote exceptional longevity of parents.[5]

The FAD method is applied to the 1998 baseline dataset of the CLHLS in this paper to investigate the association of having long-lived parents with offspring's longevity. Formula (1) is used to obtain the survivorship ratio of those who have long-lived father or mother to those who have no long-lived father or mother. Formula (2) compares the survivorship ratio of those only having long-lived father, or only having long-lived mother, or having both long-lived father and mother to those neither having long-lived father nor having long-lived mother.[6]

Logistic regressions are employed to test the difference in the frequency of having father or mother surviving to age 70 (or 80) or older and the difference in the frequency of having the top ten percentile of parental longevity among the deceased centenarians and octogenarians who died between the 1998 and 2002 waves. If the respondent's longevity is associated with the parental longevity, the frequency of having long-lived parents will change with increasing age as a result of differential survivals. Given that the life span of those deceased interviewees who died between the 1998 and 2002 waves have been determined and their parents were all dead at the time of the 1998 survey, we are able to examine the distribution of frequency of having long-lived parents among these deceased respondents.[7] This approach is similar to the one that examines the associations of genotype with longevity in terms of the frequency of having a given genotype across ages when the data are cross-

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[5] The cut point ages for the top 10 percentile of parental longevity among both un-imputed and imputed datasets are the same: 90 for mother and 83 for father. Literature has shown that the percentile range of 20-35 corresponded to the definitions of parental longevity has the strongest influences on the offspring's longevity and the association of longevity between parents and offspring appeared to be rather stable in this range (Cournil, et al., 2000). Our choice of the cut point age at 70 or 80 falls in this range. However, the choice of the 10 percentile is restricted to parental exceptional longevity.

[6] Given that there are only less than 1% of respondents whose parents both survived to the top 10 percentile of age at death, we did not examine such survivorship ratios based on the top 10 percentile of parental longevity.

[7] Unlike some designs in modeling the associations of genotype and longevity where distribution of genotype is fixed, the frequency of having long-lived parents for different age groups in a population is not fixed. This is because that the cohort of subjects under studying has not extinguished and their parents might be still alive at a given time. Therefore, we only focus on those deceased persons in logistic model to ensure that the frequency of parental age at death is fixed at the time of analysis.

sectional or when the length of the follow-up in a survey is insufficient (e.g., Tan et al., 2003).[8] Because the historical and epidemiological background of the parents of the octogenarian respondents is similar to that of the parents of the centenarian respondents, such a comparison is practicable and meaningful.[9] Four sequential models are constructed to test the difference in frequency of having long-lived parents in the presence of different confounders. Model I only examines the difference of the frequency distribution of having long-lived parents between the deceased centenarians and octogenarians by sex. Previous studies have found that some familial biological factors, such as age at childbirth (specially the first birth and the last birth) and birth order, are associated with individual's longevity (e.g., Doblhammer 2000; Müller et al. 2002; Perls et al. 1997; Zeng and Vaupel 2004). We therefore, include parents' ages at the birth of the respondent, the birth order of the respondent, and respondent's age at first childbirth in Model II to investigate what is the difference in frequency of having long-lived parents between two groups of respondents are modified. Ethnicity is also included in Model II. The literature is well-documented that the SES variable has a significant impact on individual mortality (e.g., Duleep 1989; Lantz et al. 1998). We, thus, add parents' proxy of SES into Model III measured by father's occupation, the place of birth of the respondent, type of drinking water for the family when the respondent was a child, whether the respondent received any education in childhood, whether respondent went to bed hungrily in childhood, and whether respondent got adequate medication in childhood.[10] Model IV further adds respondent's factors in terms of SES and health practice.[11] The primary purpose of such a model design aims to examine how the frequency of distribution of having long-lived parents among two groups of the deceased interviewees is modified by various confounders. The estimated frequencies in different models are derived from the procedure given by Retherford and Choe (1993:142-147).

In order to minimize the effects of accidents, war, contagious diseases, or other environmental hazards on the life span during childhood, many researchers normally set a line of minimum age for parents under study. For instance, Korpelainen (2000) sets the minimum age as age 40, and Cournil and her colleagues (2000) set it as age 50. We have tried to only include those parents who reached age 50 to test the association of longevity between parents and offspring in both FAD method and Logistic models, and found similar results with those in the body text. As to the respondents (offspring), they had already survived to age 80 in 1998, thus no early mortality are included in our analyses. That is to say, our paper focuses on the association of late survival between parents and offspring. It remains unknown if our conclusion could still be valid when childhood survival or early-adult survival is included in this Chinese case. Further exploration would be helpful.

[8] In the study of associations of genotype with longevity, several other methods have been developed, such as non-parametric relative risk model and parametric survival analysis (Toupance, Godelle, Gouyon, and Schächter 1998; Yashin et al. 1999). However, both non-parametric relative risk model and parametric survival analysis are based on the method of combining the individual genetic data with population life table (i.e., survival information), which is not applicable to this study because both respondent' life span and ages at death of his/her parents are not fixed attributes in the early ages if the life table is employed.

[9] We assume life spans for parents of centenarians and octogenarians are similar. If the life span of parents of octogenarian interviewees were longer than that of parents of those centenarians, our study would underestimate the associations of familial longevity between parents and offspring. But this is unlikely.

[10] Given that there is very few information relevant to parents' SES in the 1998 wave of the CLHLS, these variables available in the 1998 wave are used to serve as a proxy of parents' SES. Other information for parents is not unavailable in the 1998 wave.

[11] Coding of all covariates used in this study is not presented in the text due to space limits but available upon request.

FINDINGS

Considering that the life expectancy in China is 69.6 years for males and 73.3 years for females in 2000, the interviewees aged 80-105 at the time of the 1998 survey are long-lived elders compared to their peers who were born in the same period. Our data show that these long-lived elders tend to have long-lived parents. The distributions of age at death of parents are shown in Table 1. It may be surprising that more than two third of the parents survived to age 60 and about one fifth of the fathers and one third of the mothers survived to age 80, considering the fact that all of them were born before 1910 and the majority (over 90 percent) were born between 1861 and 1890. The mean and median age at death for father is 64 and 66, respectively, and for mother is 68 and 71, respectively, which are 5-10 years higher than the expected average life span for those survived to age 20 in 1930s. According to some scholars, the life expectancy at birth in China in 1930s was only about 35 years, and the life expectancy at age 20 is about 40 for both male and female (Seifert, 1935). It seems reasonable if we presume that the parents of the long-lived elders have longer life span than their cohort peers, but this presumption should be further tested. In this paper, we are unable to examine this presumption because data for the whole cohort born nearly one hundred ago were not available; instead, we examine the distribution of proportion of having long-lived parents for centenarians as compared to those who died in their eighties and nineties using the CLHLS. In other words, we examine whether exceptional longevity of the respondents is inherited from longevity of their parents among the oldest old in China by using both the information of the interviewees in the 1998 baseline survey and the information of those deceased who died between 1998 and 2002.

Table 1 Distributions of age at death of parents (%)

	father's age at death		Mother's age at death	
	Percent	Inverse-Cumulative %	Percent	Inverse-Cumulative %
under 50	18.86	100.00	16.42	100.00
50-59	15.62	81.15	10.77	83.59
60-69	22.25	65.53	17.34	72.82
70-79	24.24	43.28	23.05	55.48
80+	19.04	19.04	32.43	32.43

Findings among 1998 baseline interviewees

One of the main strengths of the FAD method is that it can be used to analyze the association between fixed attributes and longevity based on two or more independent cross-sectional samples, rather than on a longitudinal survey. By applying the FAD method to the data from 1998 baseline survey, Table 2 presents the survivorship ratios. The upper two panels of the table list the survivorship ratio of elders having father or mother surviving to age 70+, 80+, or top 10 percentile of parental age at death to those having no such a long-lived father or mother. Estimates of the survivorship ratio show that the likelihood of survival from ages 80-85 to 100-105 and the likelihood of survival from ages 90-95 to 100-105 for males who have fathers surviving to age 70+, 80+, and top 10 percentile of longevity are 20-40% greater as compared to those males who do not have such a long-lived father, suggesting an association between father's longevity and son's exceptional longevity. The first two panels of Table 2 also show an association between daughter's exceptional longevity and mother's. The ratios of survivorship show that the likelihood of survival from ages 80-85 to 100-105 and the likelihood of survival from ages 90-95 to 100-105 for females who have a long-lived mother are 1.26-2.09 times greater as compared to those females who have no such a long-lived mother. However, no or a weak association of longevity between daughter and father or between son and mother was observed except one case when the long-live mother is measured in terms of the top 10 percentile of age at death. Combining the status of longevity of parents together and setting different age standard for parental longevity, we get the two low panels in Table 2, which show the survivorship ratios of elders only having long-lived father, or only having long-lived mother, or having both long-lived father and mother as compared to those neither having long-lived father nor having long-lived mother. The results still indicate same-sex inheritance although both mother and father are long-lived would contribute somehow to children's longevity.

An analysis based on the FAD method does not ascertain whether the association of the fixed attribute and survival is due to the attribute per se or is caused or mediated by other factors. And, for longevity studies, it is better if the analyses could focus on an extinct population. Thus, in next section we apply logistic regression models to the data of the deceased to investigate the association of parental longevity with offspring's exceptional longevity controlling various confounding factors.

Table 2 Survivorship ratio of elders having long-lived parents to those having no long-lived parents, 1998 CLHLS

	Ages 100-105 vs. 80-85			Ages 100-105 vs. 90-95		
	P_1(80-85)	P_1(100-105)	*RS*	P_1(90-95)	P_1(100-105)	*RS*
Father's death age						
Males						
70+	40.78	49.08	1.40*	42.76	49.08	1.29#
80+	17.60	23.08	1.40*	19.87	23.08	1.21#
Top 10 percentile	10.61	14.43	1.42#	11.49	14.43	1.30
Females						
70+	38.49	43.97	1.25*	43.87	43.97	1.00
80+	16.21	19.34	1.25	20.16	19.34	0.95
Top 10 percentile	7.88	10.17	1.32	8.62	10.17	1.20
Mother's death age						
Males						
70+	53.77	51.60	0.92	53.37	51.60	0.93
80+	29.48	32.38	1.15	30.13	32.38	1.11
Top 10 percentile	7.67	14.59	2.06***	9.46	14.59	1.64*
Females						
70+	53.72	59.47	1.26*	52.62	59.47	1.32**
80+	30.12	38.66	1.46***	32.30	38.66	1.32*
Top 10 percentile	9.00	12.81	1.49*	6.56	12.81	2.09***
Had long-lived parents (survived to age 70)						
Males						
No	31.67	28.63	---	29.40	28.63	---
Father only	14.69	20.56	1.55*	18.69	20.56	1.13
Mother only	28.48	22.58	0.88	28.49	22.58	0.81
Both parents	25.16	28.23	1.24	23.41	28.23	1.24
Females						
No	32.61	29.99	---	34.55	29.99	---
Father only	14.84	13.63	1.00	15.02	13.63	1.05
Mother only	29.06	27.12	1.01	21.46	27.12	1.46*
Both parents	23.49	29.27	1.35*	28.97	29.27	1.16
Had long-lived parents (survived to age 80)						
Males						
No	60.41	57.66	---	60.62	57.66	---
Father only	10.09	11.29	1.17#	11.25	11.29	1.05
Mother only	22.48	20.56	0.96	20.33	20.56	1.06
Both parents	7.02	10.48	1.56#	7.80	10.48	1.41
Females						
No	60.74	55.81	---	59.23	55.81	---
Father only	10.97	9.90	0.98	10.73	9.90	0.98
Mother only	23.03	26.11	1.23#	21.24	26.11	1.30#
Both parents	5.26	8.18	1.69*	8.80	8.18	0.99

Note: (1) The proportion of respondents whose both parents survived to age of the top 10 percentile of parental longevity was less than 1%. Therefore, we didn't examine the difference in frequency of both parents' longevity across ages in terms of the top 10 percentile. (2) ***, p<=0.001; **, p<=0.01; *, p<=0.05; #, p<=0.1.

Findings among the deceased

The 2000 and 2002 waves of the CLHLS provide information of the 4,756 deceased interviewees who died after 1998 baseline survey but before 2002 follow-up survey. All of the parents of the deceased interviewees died before the 1998 survey and information on their ages at death is available. Thus, we could use this extinct population to see if their life spans are associated with those of their parents. Table 3a shows the distribution of age at death of parents by age at death of interviewees who died between 1998 and 2002. The male interviewees who died at or after age 100 have about 10 percent more fathers surviving to age 80 than those respondents who died in their 80s, showing a certain association between exceptional longevity of son and longevity of father. Similar association is also found between the life spans of female elders and their mothers. However, there is no association between the life spans of male elders and their mothers and no association between that of female elders and their fathers. Table 3b combines longevity status of both father and mother. The results also indicate an association of longevity between son and father and between daughter and mother. These findings are consistent with earlier ones found among baseline interviewees in 1998.

Table 3a distribution of fathers' and mothers' ages at death by respondents' ages at death (% within column)

		Male Respondents' age at death			Female Respondents' age at death		
		80-89	90-99	100+	80-89	90-99	100+
Fathers' age at death	under 70	58.27	55.22	48.46	62.88	52.78	56.96
	70-79	26.56	23.91	25.60	20.96	25.39	23.48
	80+	15.18	20.87	25.94	16.16	21.83	19.57
	Total (%)	100	100	100	100	100	100
	(count)	369	527	293	229	449	690
	χ^2 Test:		0.011			0.162	
Mothers' age at death	under 70	43.08	44.76	45.07	48.52	45.21	40.68
	70-79	27.42	25.04	22.70	22.22	20.11	20.58
	80+	29.50	30.20	32.24	29.26	34.67	38.74
	Total (%)	100	100	100	100	100	100
	(count)	383	563	304	270	522	826
	χ^2 Test:		0.709			0.056	

Note: Respondents' age at death was obtained in the 2000 and 2002 follow-up waves.

Table 3b respondent's age distribution at death by status of parents' longevity (% within column)

	Respondent's age at death					
	Male			Female		
Status of parents' longevity	80-89	90-99	100+	80-89	90-99	100+
neither father or mother lived to age 80	62.32	59.88	54.89	61.50	58.54	55.10
only father lived to age 80	7.83	11.32	14.29	11.27	10.49	10.05
only mother lived to age 80	22.90	19.96	20.68	22.54	20.98	26.69
both lived to age 80	6.96	8.85	10.15	4.69	10.00	8.16
Total (%)	100.00	100.00	100.00	100.00	100.00	100.00
(count)	345	486	266	213	410	637

Note: Respondents' age at death was obtained in the 2000 and 2002 follow-up waves.

Results above are reached without controlling any confounding factors. In order to examine if exceptional longevity of the respondents is inherited from longevity of their parents among the oldest old Chinese by controlling confounding factors, we perform logistic regressions to compare the frequency of having long-lived parents among interviewees who died at their centenarians to those died at their octogenarians. Table 4 provides sequential model design controlling for various confounders and Table 5 provides the estimated frequency derived from sequential logistic regressions for having father or mother living to age 70+, age 80+, and to the top 10 percentile of longevity among the interviewees who died in their 100s to the interviewees died in their eighties in 1998-2002. The results reveal that the frequency of having long-lived father or mother across models did not change much, suggesting other confounders have slight influence on the associations in longevity between parents and offspring. The results of all models show that males died as centenarians are more likely to have longer-lived father compared to males died in their 80s in 1998-2002, but they are not more likely to have long-lived mother except in the case when we use the top 10 percentile of age at death for mother.[12] The deceased females are more likely to have mothers surviving to age 80 or older for centenarians compared to those died as octogenarians, however, the chances to have long-lived father for centenarians are not significantly different with the chances for octogenarians. Consistent with the results of the FAD method and Tables 3a and 3b, the logistic models suggest there is a strong association between father's longevity and son's exceptional longevity, and an association between mother's and daughter's, but no or weak association between mother's and son's or between father's and daughter's, emphasizing a same-sex link of longevity. It is interesting to note that status of longevity of mother significantly influence exceptional longevity of daughter only when we use cut point age at 80 or older rather than at age 70, which is slightly different from the relation of longevity between son and father. Children's presence may contribute to parental longevity because of possible stronger emotional or financial support and better caring when needed. This causal link is regard as negligible in our study since all of the children (respondents) survived to at least 80 years old. The same-sex link of longevity between parents and children are thus mainly due to the downward transmission of longevity from parents to children or shared environment.

Table 4 Independent variables in logistic regressions of having long-lived father or mother

Model 1	Model 2 (added variables)	Model 3 (added variables)	Model 4 (added variables)
	Familial biological factors	**Proxy of parents' SES**	**Respondent's characteristics**
Status of interviewees' longevity	(1) Mother's age at respondent's birth (2) Father's age at respondent's birth (3) Birth order of the respondents (4) Respondent's age at first child bearing (5) Ethnicity	(1) Father's occupation (2) Place of birth of the respondent (3) Type of drinking water in the childhood of respondent (4) Respondent's education (5) Whether respondent went bed often hungrily in childhood (6) Whether respondent got adequate medication in childhood	(1) Economic independence (2) Marital status (3) Living arrangement (4) Proximity with children (5) Religious activities (6) physical labor (7) Smoking history (8) Strong alcohol drinker (9) Exercise history

Note: Models are run by males and females separately.

[12] Based on the imputed data, the association between mother's longevity measured by the top 10 percentile of age at death and son's longevity is much weaker, suggesting such a relation is not robust. Further studies are clearly warranted.

Table 5 Estimated frequency of having long-lived parents between the deceased centenarians and octogenarians

	Model I		Model II		Model III		Model IV	
Age of the deceased respondents	80s	100s	80s	100s	80s	100s	80s	100s
Male Respondents								
Having father surviving to Age 70+	45.77*	55.72*	44.54*	57.30*	44.13**	57.83**	44.81#	56.96#
Having father surviving to Age 80+	19.15**	30.63**	19.28**	30.39**	19.39*	30.20*	19.58	29.88
Having father surviving to the top 10 percentile of longevity	13.13**	22.43**	13.29*	22.12*	13.43*	21.85*	13.52*	21.69*
Having mother surviving to Age 70+	56.00	53.77	55.61	54.28	54.88	55.23	55.11	54.93
Having mother surviving to Age 80+	30.34	31.32	30.05	31.70	29.53	32.41	28.59	33.72
Having mother surviving to the top 10 percentile of longevity	8.81**	19.21**	9.24*	18.18*	8.90**	18.97**	8.61**	19.72**
Female Respondents								
Having father surviving to Age 70+	39.48	44.39	37.89#	44.95#	38.70	44.66	39.07	44.54
Having father surviving to Age 80+	17.06	19.42	16.56	19.61	17.46	19.27	17.99	19.09
Having father surviving to the top 10 percentile of longevity	9.10	13.21	8.94	13.29	9.43	13.06	8.94	13.29
Having mother surviving to Age 70+	53.54	59.13	53.18	59.25	53.26	59.23	52.53#	59.46#
Having mother surviving to Age 80+	30.91*	39.01*	30.51*	39.16*	30.48*	39.17*	30.40#	39.20#
Having mother surviving to the top 10 percentile of longevity	8.10#	13.94#	8.12#	13.93#	8.62	13.68	7.97#	14.01#

Note: (1) respondents' ages at death were obtained in the 2000 and 2002 follow-up waves. (2) Comparisons were made between two groups of the deceased respondents. ***, p<=0.001; **, p<=0.01; *, p<=0.05; #, p<=0.1.

CONCLUDING REMARKS

To study familial component to longevity, complete cohort data are usually necessary. Rather than based on complete cohort data, this paper, on the other hand, investigates whether exceptional longevity of the oldest-old Chinese is related to their parent's longevity by using the data from the CLHLS, a longitudinal survey that includes a baseline survey in 1998 and two follow-up surveys in 2000 and 2002. This is the first attempt to examine inheritance of familial longevity based on a relatively short follow-up interval of a survey. With the features of the dataset, the FAD method and logistic regression that have been widely used in longevity studies are employed to examine inheritance of familial longevity. More importantly, unlike previous studies that are entirely based on data in developed societies, this study provides some evidence for inheritance of familial longevity from a developing country, which makes a potential contribution to the literature.

The results of both FAD method and logistic models indicate a same-sex inheritance of longevity, that is, a strong association between fathers' and sons' longevity or between mothers' and daughters' longevity, but weak or no association of longevity between fathers and daughters or between mothers and sons. By using top 10 percentile of age at death of parents, we find exceptional longevity of mother (a death age of 90 or over) has certain positive effect on longevity of son. However, the un-imputed and imputed results are not consistent in significance. Thus, further exploration is needed. Even the top 10 percentile of long-lived mothers have some effect on son's longevity, this would not lessen the same-sex link. Our results are neither in line with the studies that usually emphasize relative importance of the maternal or paternal contribution to life spans of offspring regardless of child's sex (Bell, 1918; Cohen, 1964; Abbott, 1974; Philippe, 1978; Welter, 1978; Crawford and Rogers, 1982; Bocquet-Appel and Jakobi, 1990; Brand et al, 1992; Korpelainen, 1999, 2000; Kemkes-Grottenthaler, 2004), nor in along with those studies that emphasize only child's sex (Cournil et al, 2000; Cournil, 2001; Kemkes-Grottenthaler, 2004). The sex-specific pathway of longevity transmission in most studies often refers to parent-sex-specific pathway to children, regardless of child's sex, or refers to child-sex-specific reception of longevity from parents, regardless of parent's sex. One of the exceptions is the study by Westendorp and Kirkwood (2001). In the study on British aristocracy, Westendorp and Kirkwood found that the probability of longevity of men but not women was dependent on longevity of the parents, especially the father, in the period of 700-1700 and the strong paternal effect on the longevity of sons was consistent with the predominantly patrilinear inheritance of wealth. Our study shows not only a strong father-son association of longevity, but also a strong mother-daughter association, indicating inheritance of longevity among these Chinese is not only sex-linked, but also same-sex-linked.

Although our results suggests a same-sex association of longevity between parents and offspring among the Chinese studied, the underlying mechanism of longevity transmission remains an open question. We neither know if the same-sex transmission of longevity is due to genes or environmental factors, nor understand whether genes associated with longevity are sex-linked. It is widely believed that the trait shared commonly within families could be environmental, behavioral or genetic in origin (Perls, et al, 2002). In the study on British aristocracy, Westendorp and Kirkwood have shown that other than genetic factor, behavioral and environmental factors might also produce sex-linked association of longevity between offspring and parents. In Chinese case, it is possible that sons are more likely to imitate their fathers' behavior and daughters imitate mothers'. And, in traditional Chinese society, which emphasizes paternal authority and patrilinear inheritance of wealth, sons may be more likely to share resources, wealth with father, and daughters may be more like mothers.

REFERENCES

Abbott, M.H., E.A. Murphy, D.R. Bolling, and H. Abbey, 1974. The familial component in longevity. A study of offspring of nonagenarians. II. Preliminary analysis of the completed study. *Hopkins Medical Journal* 134: 1-16.

Allison, P. 2002. *Missing data.* Thousand Oaks, California: Sage Publications.

Bell, A.G. 1918. The Duration of life and conditions associated with longevity. *A Study of the Hyde Genealogy*. Washington : Genealogical Records Office.

Bocquet-Appel, J.P. and L. Jakobi, 1990. Familial transmission of longevity. *Annals of Human Biology* 17: 81-95.

Brand, F.N., D.K. Kiely, W.B. Kannel, and R.H. Myers, 1992. Family patterns of coronary heart disease mortality: The Framingham longevity study. *Journal of Clinical Epidemiology* 45: 169-174.

Carnes, B.A. et al. 1999. Human Longevity: nature vs. nurture; fact or fiction. *Perspectives in Biology and Medicine* 42: 422-441.

Cohen, B.H. 1964. Family patterns of mortality and life span: A critical review. Quarterly Review of Biology 39: 130-191.

Cournil, A., J.M Legay; F. Schachter, 2000. Evidence of sex-linked effects on the inheritance of human longevity: a population-based study in the Valserine Valley (French Jura), 18-20th centuries. *Proceedings of the Royal Society London B* 267: 1021-1025.

Cournil, A. and T.B.L. Kirkwood, 2001. If you would live long, choose your parents well. *Trends in Genetics* 117: 233-235.

Crawford, M.H. and L. Rogers, 1982. Population genetic model in the study of aging and longevity in a Mennonite community. *Social Science and medicine* 16: 149-153.

Doblhammer, G. 2000. Reproductive history and mortality later in life: A comparative study of England and Wales and Austria. *Population Studies* 54(2): 169-176.

Doblhammer, G. and J. Oeppen, 2003. Reproductive and Longevity among the British peerage: the effect of frailty and health selection. *Proceedings of the Royal Society London B* 270: 1541-1547.

Duleep, H.O. 1989. Measuring socioeconomic differentials over time. *Demography* 26:345–51.

Lantz, P.M., J.M. House, J.M. Lepkowski, D.R. Williams, R.P. Mero, and J. Chen. 1998. Socioeconomic factors, health behaviors, and mortality: results from a nationally representative prospective study of US adults. *The Journal of American Medical Association* 279:1703–8.

Elliott, B.A., 1992. Birth order and health: major issues. *Social Science and Medicine* 35: 443-452.

Fisher, R.A., 1930. *The Genetical Theory of Natural Selection* (Oxford: Oxford University Press).

Frederiksen, H., M. McGue, B. Jeune, D. Gaist, H. Nybo, A.E. Skytthe, J.W. Vaupel, and K. Christensen, 2002. Do children of long-lived parents age more successfully? Epidemiology 13: 334-339.

Gavrilova, N.S. et al, 1998. Evolution, mutations and human longevity: European royal and noble families. *Human Biology* 70: 799-804.

Gavrilov, L.A. and N.S. Gavrilova, 1997. Parental age at conception and offspring longevity. Reviews in Clinical Gerontology **7**: 5-12.

Gavrilov, L.A. and N.S. Gavrilova, 2001. Biodemographic study of familial determinants of human longevity, *Population: An English Selection* 13: 197-222.

Gavrilov, L.A. and N.S. Gavrilova, 2002. Evolutionary theories of aging and longevity. *The Scientific World Journal* 2: 339-356.

Gavrilov, L.A., N.S. Gavrilova, S.J. Olshansky and B.A. Carnes. Genealogical Data and the biodemography of Human Longevity. Social Biology 49(3-4): 160-173.

Gerdes, L.U., B.Jeune, et al. 2000. Estimation of Apolipoprotein E genotype-specific relative mortality risks from the distribution of genotypes in centenarians and middle-aged men: Apolipoprotein E gene is a ‘frailty gene’, not a ‘longevity gene’, *Genetic Epidemiology* 19: 202-210.

Gu, D. 2006. General data assessment of the Chinese Longitudinal Healthy Longevity Survey in 2002 (forthcoming). In Y. Zeng, D Poston, and J. Smith. *Healthy longevity in China: Demographic, socioeconomic, and psychological dimensions*. New York: Springer Publisher.

Gu, D, and M.E. Dupre. 2006. Reliability of mortality and morbidity in the 1998, 2000, and 2002 CLHLS (forthcoming). In Y. Zeng, D Poston, and J. Smith. *Healthy longevity in China: Demographic, socioeconomic, and psychological dimensions*. New York: Springer Publisher.

Gudmundsson, J., D.F. Gudbjartsson, et al. 2000. Inheritance of human longevity in Iceland. *European Journal of Human Genetics* 8: 743-749.

Herskind, A.M., M. McGue, N.V. Holm, T.I. Sorensen, B. Harvald, and J.W. Vaupel. 1996. The heritability of human longevity: A population-based study of 2872 Danish twin pairs born 1870-1900. *Human Genetics* 97: 319-323.

Jacquard, A. 1982. Heritability of human longevity, p.303-313, *In*: S.V. Preston (ed.) *Biological and social aspects of mortality and the length of life*. Ordinia Edition, Liege.

Kemkes-Grottenthaler A., 2003. Parental effects on offspring longevity-evidence from 17th to 19th century reproductiove histories. *Annals of Human Biology* 31(2): 139-158.

Kerber R.A., E. O'Brien, K.R. Smith, and R. M. Cawthon. 2001. Familial excess longevity in Utah Genealogies. *Journal of Gerontology* 56A(3): B130-B139.

Korpelainen, H. 1999. Genetic maternal effects on human life span through the inheritance of mitochondrial DNA. *Human Heredity* 49: 183-185.

Korpelainen, H. 2000a. Fitness, reproduction and longevity among European aristoctatic and rural Finnish families in the 1700s and 1800s. *Proceedings of the Royal Society of London B* 267: 1765-1770.

Korpelainen, H. 2000b. Variation in the heritability and evolvability of human life span. *Naturwissenschaften* 87: 566-568.

Ljungquist, B. et al. 1998. The effect of genetic factors for longevity: A comparison of identical and fraternal twins in the Swedish twin registry. *Journal of Gerontology* 53A: M441-M446.

Mantel, N. and W. Haenszel. 1959. Statistical aspects of the analysis of data from retrospective studies of diseases, *Journal of the National Cancer Institute* 22: 719-748.

Mayer, P.J. 1991. Inheritance of longevity evinces no secular trend among members of six New England families born 1650-1874. *American Journal of Human Biology* 3: 49-58.

McGue, M., J.W. Vaupel, N. Holm, B. Harvald. 1993. Longevity is moderately heritable in a sample of Danish twins born 1870-1880. *Journal of Gerontology* 48, 237-244.

Mitchell, B.D., W.-C. Hsueh, T.M. Kind, T.I. Pollin, J. Dorkin, R. Agarwala, A.A. Schäffer, and A.R. Schuldiner. 2001. Heritability of life span in old order Amish. *American Journal of Medical Genetics* 102: 346-352.

Müller, H.-G., J.-M. Chiou, J.R. Carey, and J-L, Wang. (2002). Fertility and life span: late children enhance female longevity. *The Journals of Gerontology, Series A: Biological Sciences and Medical Sciences* 57(5), pp. B202-B206.

Murphy, E.A. 1978. Genetics of longevity in man, p.261-301, *In*: E.L. Schneider (ed.) *The genetics of aging*. Plenum Press, New York.

Pearl, R. 1931. Studies on human longevity. IV. The inheritance of longevity. Preliminary Report. *Human Biology* 3: 245-269.

Perls, T., L.M. Kunkel, and A.A. Puca. 2002. The genetics of exceptional human longevity. *Journal of the American Geriatric Society* 50: 359-368.

Perls, T.T., J. Wilmoth, et al. 2002. Life-long sustained mortality advantage of siblings of centenarians, *PNAS* 99(12): 8442-8447.

Philippe, P. 1978. Familial correlations of longevity: An isolate-based study, *American Journal of Medical Genetics* 2: 121-129.

Retherford, R.D., and M.K. Choe. 1993. *Statistical models for causal analysis.* New York: John Wiley & Sons Inc.

Seifert, H.E.1935. Life tables for Chinese farmers. *Milbank Memorial Fund Quarterly* 13(3): 223-236.

Vaupel, J.W. 1988. Inherited Frailty and Longevity, *Demography*, 25(2), pp.277-287.

Vaupel, J.W. 1992. Analysis of population changes and differences. Paper presented at the annual meeting of the Population Association of America, April 1992.

Vaupel, J.W. 2001. Demographic insights into longevity, *Population: An English Selection* 13(1): 245-249.

Tan, Q, L. Bathum, L. Christiansen, G. De Benedictis, J. Dahlgaard, N. Frizner, W. Vach, J.W. Vaupel, A.I. Yashin, K. Christensen, and T.A. Kruse. 2003. Logistic regression models for polymorphic and anatagonistic pleiotropic gene action on human aging and longevity. *Annals of Human Genetics* 67: 598-607.

Toupance, B., B. Godelle, P.H. Gouyon, and F. Schächter. 1998. A model for anagonistic pleiotropic gene action for mortality and advanced age. *American Journal of Human Genetics* 62: 1525-1534.

Wang, Z.L., Zeng Yi, B.Jeune, and J.W. Vaupel. 1998. Age validation of Han Chinese centenarians, *Genus* 54(1/2): 123-141.

Westendorp R.G.J. and T.B.L. Kirkwood. 1999. Longevity-does family size matter? *Nature* 399:522.

Westendorp R.G.J. and T.B.L. Kirkwood. 2001. Maternal and paternal lines of familial longevity. *Population: An English Selection* 13(1): 223-235.

Yashin, A.I., G. De Benedictis, J. W. Vaupel, et al. 1998. Combining genetic and demographic information in population studies of aging and longevity, *Journal of Epidemiology and Biostatistics* 3(3): 289-294.

Yashin, A.I., G. De Benedictis, J. W. Vaupel, Q. Tan, K. F. Andreev, I.A. Iachine, M., Bonafe, M. De Luca, S. Valensin, L. Carotenuto, and C. Franceschi. 1999. Gene, demography and life span: the contribution of demographic data in genetic studies of aging and longevity, *American Journal of Human Genetics* 65: 1178-1193.

Yashin, A.I., G.D.Benedictis, J.W.Vaupel, et al. 2000. Genes and longevity: lessons from centenarian studies, *Journal of Gerontology: Biological Sciences* 55A(6): B1-B10.

Zeng, Y. and D. Gu. 2006. Reliability of age reporting among the Chinese oldest-old in the CLHLS data sets (forthcoming). In Y. Zeng, D Poston, and J. Smith. *Healthy longevity in China: Demographic, socioeconomic, and psychological dimensions*. New York: Springer Publisher.

Zeng, Yi, J. W.V aupel, Z. Xiao, C. Zhang, and Y. Liu. 2001. The health longevity survey and the active life expectancy of the oldest old in China, *Population: An English Selection* 13(1): 95-116.

Zeng Yi, J. W .Vaupel, Z. Xiao, C. Zhang, and Y. Liu. 2002. Sociodemographic and health profiles of the oldest old in China, *Population and Development Review* 28: 251-273.

Zeng, Yi, and J.W.Vaupel. 2004. Association of late childbearing with healthy longevity among the oldest-old in China, *Population Studies* 58(1): 37-53.

Appendix:

Table A-1 Comparison of imputed and not-imputed percentage distributions for parents' age at death, 1998 CLHLS (%)

	<30	30-39	40-49	50-59	60-69	70-79	80+	Total	Valid # of obs.
Mother's age at death									
Not imputed	3.08	5.71	7.63	10.77	17.34	23.05	32.43	100.00	5,554
Imputed	2.52	4.78	7.59	11.12	18.59	23.81	31.59	100.00	8,585
Father's age at death									
Not imputed	2.30	6.49	10.06	15.62	22.25	24.24	19.04	100.00	5,038
Imputed	1.90	5.04	8.85	14.54	23.81	26.74	19.11	100.00	8,585

Table A-2 Ratio of having long-lived parents to those having no long-lived parents based on the imputed data, 1998 CLHLS

	Ages 100-105 vs. 80-85			Ages 100-105 vs. 90-95		
	P_1(80-85)	P_1(100-105)	*RS*	P_1(90-95)	P_1(100-105)	*RS*
Father's death age						
Males						
70+	41.86	48.47	1.31*	45.63	48.47	1.12
80+	17.20	21.83	1.34*	18.97	21.83	1.19
Top 10 percentile	9.75	13.32	1.42*	10.92	13.32	1.25
Females						
70+	42.74	48.39	1.26**	46.92	48.39	1.06
80+	18.33	20.10	1.12	19.98	20.10	1.01
Top 10 percentile	7.98	11.35	1.48**	10.14	11.35	1.13
Mother's death age						
Males						
70+	54.19	51.75	0.91	54.83	51.75	0.88
80+	29.62	31.44	1.09	30.92	31.44	1.02
Top 10 percentile	8.28	12.88	1.64**	10.34	12.88	1.28
Females						
70+	52.80	56.81	1.18*	54.37	56.81	1.10
80+	28.87	34.11	1.28**	32.21	34.11	1.09
Top 10 percentile	9.97	13.01	1.35*	7.95	13.01	1.73***
Had long-lived parents (survived to age 70)						
Males						
No	29.25	27.51	---	25.75	27.51	---
Father only	16.56	20.74	1.33#	19.43	20.74	1.00
Mother only	28.89	24.02	0.88	28.62	24.02	0.79
Both parents	25.3	27.73	1.17	26.21	27.73	0.99
Females						
No	29.15	24.36	---	27.24	24.36	---
Father only	18.04	18.83	1.25#	18.39	18.83	1.14
Mother only	28.11	27.24	1.16	25.84	27.24	1.18
Both parents	24.69	29.57	1.43***	28.53	29.57	1.16
Had long-lived parents (survived to age 80)						
Males						
No	59.61	56.77	---	56.9	56.77	---
Father only	10.76	11.79	1.15	12.18	11.79	0.97
Mother only	23.18	21.4	0.97	24.14	21.4	0.89
Both parents	6.44	10.04	1.64*	6.78	10.04	1.48**
Females						
No	58.21	53.54	---	55.96	53.54	---
Father only	12.92	12.35	1.04	11.83	12.35	1.09
Mother only	23.46	26.36	1.22*	24.06	26.36	1.15
Both parents	5.413	7.752	1.56**	8.151	7.752	0.99

Table A-3 Distribution of father and mother's ages at death by respondents' ages at death (% within column) based on the imputed data

		Male Respondents' age at death			Female Respondents' age at death		
		80-89	90-99	100+	80-89	90-99	100+
Fathers' age at death	under 70	56.34	54.21	51.14	56.39	52.65	52.33
	70-79	28.27	26.98	26.29	25.30	26.65	27.99
	80+	15.40	18.80	22.57	18.31	20.69	19.67
	Total (%)	100	100	100	100	100	100
	(count)	513	819	483	415	923	1,585
	χ^2 Test:		0.078			0.571	
Mothers' age at death	under 70	42.69	42.98	44.72	48.43	44.75	43.32
	70-79	28.07	26.86	23.19	22.89	22.10	21.82
	80+	29.24	30.16	32.09	28.67	33.15	34.87
	Total (%)	100	100	100	100	100	100
	(count)	513	819	483	415	923	1,585
	χ^2 Test:		0.482			0.204	

Note: Respondents' age at death was obtained in the 2000 and 2002 follow-up waves.

Table A-4 respondent's age distribution of death by status of parent's longevity (% within column) based on the imputed data

status of parents' longevity	Respondent's age at death: Male			Female		
	80-89	90-99	100+	80-89	90-99	100+
neither father or mother lived to age 80	61.60	58.36	54.66	57.11	54.06	52.96
only father lived to age 80	9.16	11.48	13.25	14.22	12.78	12.17
only mother lived to age 80	23.00	22.83	22.77	24.58	25.24	27.36
both lived to age 80	6.24	7.33	9.32	4.10	7.91	7.50
Total (%)	100.00	100.00	100.00	100.00	100.00	100.00
(count)	513	819	483	415	923	1,585

Note: Respondents' age at death was obtained in the 2000 and 2002 follow-up waves.

Table A-5 Estimated frequency of having long-lived parents between the deceased centenarians and octogenarians based on the imputed data

	Model I		Model II		Model III		Model IV	
Age of the deceased respondents	80s	100s	80s	100s	80s	100s	80s	100s
Male Respondents								
Having father surviving to Age 70+	46.25#	51.48#	45.36*	52.43*	45.46*	52.33*	46.62	51.08
Having father surviving to Age 80+	18.72**	26.94**	18.18**	27.70**	18.20**	27.67**	18.87*	26.73*
Having father surviving to the top 10 percentile of longevity	11.68*	17.84**	11.55*	18.05*	11.63*	17.92*	12.14#	17.18#
Having mother surviving to Age 70+	56.30	54.26	55.85	54.74	55.71	54.89	56.39	54.15
Having mother surviving to Age 80+	30.65	33.57	30.31	33.95	30.49	33.74	30.04	34.25
Having mother surviving to the top 10 percentile of longevity	8.97	12.39	8.84#	12.58#	8.75#	12.70#	8.34*	13.34*
Female Respondents								
Having father surviving to Age 70+	45.63	49.71	44.85*	49.92*	45.20	49.82	45.69	49.69
Having father surviving to Age 80+	18.98	20.38	18.61	20.48	18.69	20.46	19.44	20.25
Having father surviving to the top 10 percentile of longevity	9.13#	12.69#	9.09#	12.70#	9.65	12.51	9.62	12.52
Having mother surviving to Age 70+	54.14#	59.20#	53.86#	59.27#	53.58*	59.34*	51.98*	59.74*
Having mother surviving to Age 80+	31.69*	38.19*	31.37*	38.28*	31.09**	38.36**	30.07*	38.65*
Having mother surviving to the top 10 percentile of longevity	10.48*	15.10*	10.39*	15.13*	10.62*	15.05*	10.11*	15.23*

Note: (1) respondents' ages at death were obtained in the 2000 and 2002 follow-up waves. (2) Comparisons were made between two groups of the deceased respondents. ***, p<=0.001; **, p<=0.01; *, p<=0.05; #, p<=0.1.