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Education and mortality among older adults in China

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ABSTRACT

This study examines the relationship between education and mortality, its underlying mechanisms, and its gender and age variations among older adults in China, using data from the 2002 to 2011 waves of the Chinese Longitudinal Healthy Longevity Survey. There is an inverse relationship between education and mortality risk. The relationship is explained in full by each of the three mechanisms: other socioeconomic attainments, social relationships and activities, and health status, and partially by physical exercise. In addition, primary education has a stronger effect on mortality for men than for women and the effect of education is stronger for the young old than for the oldest old. These findings underscore the importance of national and subpopulation contexts in understanding the relationship between education and mortality.

1. Introduction

The inverse relationship between educational attainment and mortality has been well documented in the developed countries (Elo, 2009; Hummer and Lariscy, 2011), and recent studies showed a similar relationship in less developed countries, like China, though the evidence remains scarce (Liang et al., 2000; Liu et al., 1998; Zhu and Xie, 2007). Previous research also suggests that the strength of education–mortality relationship varies across subgroups and social settings. Two demographic factors, age and gender, have received much attention as important moderators of this relationship, but the findings are inconsistent. Although different theories have been advanced to explain these findings, there is a relative lack of empirical research testing the underlying mechanisms that produce age and gender variations (Montez et al., 2009; Zajacova and Hummer, 2009).

A few studies examined education–mortality relationship in Taiwan and mainland China. Although very informative, each has its own limitations. For example, Liu et al. (1998) tested three mediating factors among older Taiwanese—health status, health behaviors, and social relationships—but it did not examine gender and age variations. Zhu and Xie (2007) only included the oldest-old Chinese and did not examine the mechanisms for the effect of education on mortality. Liang et al. (2000)'s sample was drawn from one city which limits its generalizability. Our study extends previous research by examining the relationship between education and mortality and its gender and age variations using a national longitudinal survey of Chinese older adults. We address four questions. First, is there an inverse relationship between education and mortality among older Chinese adults? Second, what are the possible underlying mechanisms of this relationship? Third, do the education–mortality relationship and its underlying mechanisms differ between men and women? And fourth, do the education–mortality relationship and its underlying mechanisms differ between the young old and the oldest old?

1.1. Education and mortality

Our conceptual framework for the relationship between education and mortality is depicted in Fig. 1. This theoretical framework stems from the human capital explanation which posits that education enhances human capital—knowledge, skills, and resources—which shapes health over the life course and ultimately, how and when individuals die (Mirowsky and Ross, 2003). There are three mechanisms through which education may affect health and mortality. First, a higher level of educational attainment helps individuals acquire better and more stable employment and increase their earning power. Research consistently found a positive association between education and other socioeconomic attainments (e.g., higher status occupations and more income) and access to

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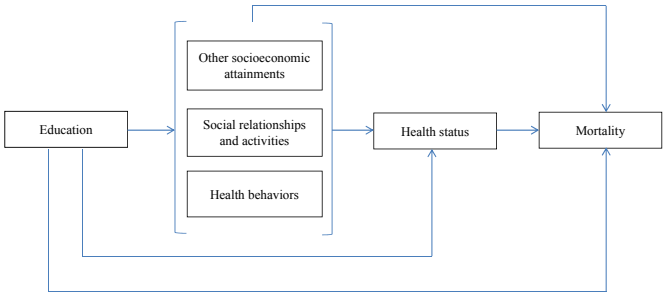

Fig. 1. Conceptual model of the relationship between education and mortality.

health resources (e.g., health care), which are associated with better health and survival (Lantz et al., 1998; Marmot et al., 2001). Second, a higher level of education helps individuals build psychosocial resources, such as heightened sense of personal control, more supportive social relationships and active participation in cognitive stimulating activities, and more psychosocial resources are associated with better health and lower mortality (House et al., 1988). Third, more educated people are more likely than less educated people to adopt positive health behaviors, such as exercising regularly, drinking moderately, and avoiding or quitting smoking, which in turn lead to better health and lower mortality (Lantz et al., 1998; Ross and Wu, 1995). In addition, health is conceptualized as a more proximal predictor of mortality and some of the aforementioned factors may affect mortality through their effects on health. There is strong evidence that health status predicts mortality (Ariyo et al., 2000; Idler and Benyamini, 1997; Okun et al., 2010; Sabia et al., 2010).

Based on this conceptual model, we hypothesize that *education is negatively associated with mortality risk and that the education effect on mortality is mediated by other socioeconomic attainments, social relationships and activity participation, and health behaviors*.

1.2. Gender, education, and mortality

Research on gender differences in the effect of education on health and mortality is limited and the findings are mixed. While earlier research showed a stronger education effect on mortality among women than men (Kitagawa and Hauser, 1973), more recent data show a stronger education effect for men than women (Backlund et al., 1999). Still others found no gender difference (McDonough et al., 1999; Zajacova, 2006), or the difference only exists among certain groups (Hummer and Lariscy, 2011; Montez et al., 2009; Zajacova and Hummer, 2009).

In addition, previous research suggests that gender differences in education–mortality relationship may exist in the pathways that link education to health and mortality (Zajacova, 2006). For example, there is evidence that women still earn less than men of comparable education (Blau and Kahn, 2007), which could contribute to gender differences in education–mortality relationship since economic resources can affect health and mortality through access to health care, exposure to stress, availability of coping resources and other pathways (Zajacova, 2006). In addition, the association between education and health behaviors may vary by gender (Bloomfield et al., 2006; Mackenbach et al., 2004), and health behaviors, especially smoking and excess alcohol consumption, account for a meaningful share of excess male mortality (Liang et al., 2003). Furthermore, social relationships may also play a role. It is well documented that married adults experience better health and survival than unmarried adults and this disparity appears to be greater among men than women, and such a gender differential persists at very old ages (Zhu and Gu, 2010). The less-educated men may be less likely to have access to health-enhancing social ties such as marriage, and thus are more likely to engage in risky health behaviors (Montez et al., 2009; Zajacova and Hummer, 2009). Based on these explanations, we hypothesize that *the effect of education on mortality is stronger for men than for women.*

1.3. Age, education, and mortality

Most studies reported that the strength of education–mortality relationship declines in old age (Elo and Preston, 1996; House et al., 1994; Hummer and Lariscy, 2011; Kitagawa and Hauser, 1973; Montez et al., 2011). There are several explanations for the mortality convergence at old ages (Hoffmann, 2008; House et al., 1994; Zhu and Xie, 2007). First, with age, biological processes assume dominance over social determinants and, eventually, everybody must die regardless of social class. Second, most older adults gradually disengage from the economic activities that mediate the relationship between education and health, and thus they are less influenced by some of the mechanisms through which education affects health (e.g., working conditions). Third, in some developed countries, social welfare policies that favor the elderly population contribute to some redistribution between social groups and thus reduce socioeconomic differentials in health. Fourth, unhealthy behaviors, such as smoking and heavy drinking, are less prevalent among older people due to selective mortality that has already removed many smokers and heavy drinkers from the population before they reach old ages. Selective mortality also drops less healthy people before they reach old ages, leaving the surviving population more homogenous and contributes to declining differences observed on the aggregate level.

In contrast, a few studies, most of which focused on health status indicators rather than mortality, found increasing or stable educational differences (Huisman et al., 2003; Lynch, 2003; Ross and Wu, 1996). Possible explanations include the vulnerability hypothesis and the cumulative advantage/disadvantage hypothesis. The vulnerability hypothesis suggests that vulnerability increases in old age and makes differential exposure to health hazards more harmful (House et al., 1994). The cumulative advantage/disadvantage hypothesis suggests that health benefits of education, such as economic and social capital, accumulate over the life course, producing a larger gap in health among older adults than younger adults. In addition, the impact of past unhealthy experiences, such as smoking, is unlikely to cause health problems among younger people, but over time, the effects accumulate to produce disease, disability, and death (Dannefer, 2003; Ross and Wu, 1996).

Despite the growing interest in age variations in education–mortality relationship, few studies have compared the young old and the oldest old. As Zhu and Xie (2007) suggest, it is important to make this distinction because the young old and the oldest old are different in several significant respects. For example, the oldest old are far more detached from social and economic activities than the young old. Because there is strong evidence for the convergence hypothesis when mortality is the outcome, we hypothesize that *the effect of education on mortality is stronger among the young old than the oldest old.*

1.4. The China context

China is experiencing rapid population aging and the proportion of older people (65 years and older) is expected to reach 24% (331 million) by 2050 (United Nations, 2013). Because China and developed countries are substantially different in population

structure, cultural traditions, economic development, societal organization and health care system, the magnitude of the effect of education on mortality and its underlying mechanisms in China may differ from those in developed countries (Liang et al., 2000; Zhu and Xie, 2007). Lowry and Xie (2009) suggest that the SES and health linkage may be weaker in China for two reasons. First, national mass health campaigns since the founding of the People's Republic of China in 1949 which aimed at improving environmental sanitation and hygiene and preventing and controlling infectious diseases have achieved impressive health results for the Chinese population across SES groups (Sidel and Sidel, 1982). Other programs, such as the wide dissemination of health knowledge, the subsidized health care, and a government-sponsored medical insurance system, may have helped alleviate SES gradient in health (Lowry and Xie, 2009; World Bank, 1983). Second, in a collective society like China, health behaviors and health care decisions tend to be a family affair rather than a personal matter and as the result, individual education levels may play a smaller role in determining health behaviors and health care decisions (Lowry and Xie, 2009). For example, previous studies in China showed a weak and inconsistent association between education and smoking among men and women (Hermalin and Lowry, 2012). In addition, the high illiterate rate among the elderly Chinese (over 60%), a strong social norm for family to economically assist one another throughout the life course as well as to provide primary support for older persons, and a relatively equalitarian income distribution before the economic reform may further dampen age and gender variations in education–mortality relationship among older adults.

Have China's unique cultural traditions and social and economic developments eliminated educational differentials in health and mortality among older adults? Several studies suggest the answer is no. There is evidence that education, and SES in general, reduces physical impairment, delays the onset of physical disability, improves self-rated health, reduces mental distress, and reduces mortality among elderly Chinese (Beydoun and Popkin, 2005; Chen et al., 2010; Gu and Zeng, 2004; Liang et al., 2000; Lowry and Xie, 2009; Ross and Zhang, 2008; Zhu and Xie, 2007; Zimmer and Kwong, 2004; Zimmer et al., 2010). Additional research, however, is needed to understand the pathways between education and mortality, and how these relationships may vary by gender and age.

2. Methods

2.1. Data

Data for this study come from the Chinese Longitudinal Healthy Longevity Survey (CLHLS), which is conducted in the randomly selected half of the counties and cities of 22 provinces in mainland China (Zeng et al., 2002). The survey attempted to interview all centenarians who agreed to participate. For each centenarian, one nearby octogenarian (aged 80–89) and one nearby nonagenarian (aged 90–99) of pre-designated age and sex were selected for an interview. Age and sex were predefined so that the sample could have comparable numbers of male and female octogenarians and nonagenarians at each age from 80 to 99. The baseline survey was conducted in 1998 and five follow-up surveys with replacement of deceased elders were conducted every two or three years. Since 2002, the survey has been expanded to also include those aged 65–79 years. The interviews were carried out at the interviewee's home by an enumerator and a doctor, nurse, or medical school student who also performed a basic health examination. The baseline survey had a response rate of 88%, and 12–20% respondents were lost to follow up depending on the survey year.

Since our target population is older adults in general, including both the young old and the oldest old, we used data collected in 2002, 2005, 2008, and 2011 waves. We pooled data from the first three waves and created a person-wave dataset which allows us to incorporate time-varying covariates and produce more robust results than using data from the respondents in 2002 only. Our analysis excluded 556 respondents aged over 105 at their first interview because previous research showed that age reporting of the Chinese older adults was generally reliable up to age 105 (Zeng et al., 2002). Further excluding 7531 cases lost to a subsequent follow-up survey, 449 cases missing on the date of death and 192 cases missing on other key variables, our analytical sample includes 39,470 observations from 26,748 respondents. Because additional analysis showed that compared to those who survived and were reinterviewed, those who were lost to follow up tend to be more educated, but older and less healthy, we also used multiple imputation method to impute survival status and survival time for these cases, and survival analysis including these cases (not shown) produced similar results to those excluding them.

2.2. Measures

2.2.1. Mortality

The dates of death for the period 2002 through 2011 for the deceased respondents were collected from various sources including death certificates, next of kin, and neighborhood committees. All dates were validated, and the dates reported on death certificates were used when available; otherwise the next of kin's report was used, followed by neighborhood registries (Gu and Dupre, 2008). Survival time was calculated for the 15,980 respondents who died between 2002 and 2011. For the survivors, the survival time was the days from the first interview date since 2002 to the interview date in 2011. For those lost to follow-up, the survival time was the days from the first interview date to the date of their last interview if they had at least one follow-up interview during the period of 2002–2011.

2.2.2. Education

Because the number of years of schooling is highly skewed, we recoded this variable into three categories: no schooling, primary school (1–6 years), and middle school and more (7 or more years).

2.2.3. Other socioeconomic attainments

Three dummy variables measuring occupation, financial independence, and adequate access to medical service are included. Occupation was coded 1 if the respondent's primary occupation before age 60 was “professional or technical personnel,” “government, institutional or managerial personnel,” or ‘military personnel.” Financial independence was coded 1 if the respondent relies on retirement wage and/or own employment as the primary means of financial support. Adequate access to medical services was coded 1 if the respondent can get adequate medical service when he/she is sick.

2.2.4. Social relationships and activities

Marital status (currently married versus not married), living arrangement (living alone or with only spouse, living with children, living in an institution), number of visiting children, social and solitary leisure activity participation are included. The inclusion of a category for institution also accounts for oversampling of institutionalized persons in the CLHLS. Number of visiting children is a count of non-coresident children who frequently visit the respondent. Respondents were asked how often they participated in different types of activities with the 5-point response scale ranging from “never” to “almost every day.” Social activity participation is indicated with the average score of (i) playing cards and/or mahjong and (ii) organized social activities. Solitary leisure activity

participation is indicated with the average score of (i) gardening (including both indoor and outdoor gardening), (ii) reading newspaper/books, and (iii) watching TV and/or listening to radio. The score for each activity type ranges from 0 to 4 with higher values associated with higher levels of participation.

2.2.5. Health behaviors

Smoking status (currently smoking or ever smoked versus never smoked), drinking status (currently drinking versus not drinking), and physical exercise (currently participating regularly versus not participating) are included as three dummy variables.

2.2.6. Health status

Measures of self-rated overall health, functional health, mental well-being, and cognition are included. A dummy variable was created for self-rated health (very poor/poor versus others). About 10% of respondents were unable to answer this question due to illness and were indicated with a dummy variable. A dummy variable for activities of daily living (ADLs) was created to indicate if the respondent needs assistance in any of six activities (bathing, dressing, toileting, transfer, continence, and feeding). A dummy variable for instrumental activities of daily living (IADLs) was created to indicate whether the respondent needs assistance in or can't do any of eight activities (visiting neighbors, shopping, cooking, washing clothes, walking for one kilometer, lifting a weight of 5 kg, crouching, and taking public transportation). Respondents were coded as having a chronic disease if they reported one or more of seventeen serious health conditions, such as hypertension, stroke, heart diseases, cerebro-vascular diseases (CVD), pneumonia, Parkinson's disease.

Cognitive functioning was based on a Chinese version of the Mini-Mental State Examination (MMSE) which includes questions on orientation, registration, attention, calculation, recall, and language with a maximum score of 30 (Zeng and Vaupel, 2002). We used the same cutoffs as the MMSE international standard, defining a score below 24 as cognitively impaired (Deb and Braganza, 1999). Two mental well-being measures were created by first summing positive (e.g., "Do you always look on the bright side of things?") items and negative items (e.g., "Do you often feel fearful or anxious?") separately from seven predisposition questions and then recoding each into a dummy variable. Another dummy variable was created to indicate that the respondent was unable to answer any of these questions. In addition, the CLHLS allowed a proxy respondent to answer some of the questions when the respondent was too impaired to participate, and we created a dummy variable to indicate whether a proxy respondent was used for any of the questions.

2.2.7. Demographic covariates

In multivariate models, we control for age, gender, ethnicity (Han vs. non-Han), and residence (urban vs. rural).

2.3. Analytical strategy

We first calculated descriptive statistics on education stratified by gender, age group and survey year, and on other variables by gender and level of education. Parametric hazard models with Weibull distribution were used to estimate the hazard ratios because the proportional hazards assumption in Cox regression was violated for education and many other covariates (e.g., adequate access to medical services). Because preliminary analysis showed that education effects on mortality risk vary by gender and age, we estimated separate models for men and women and then for the young old and the oldest old within each gender. Descriptive statistics were weighted by the sampling weight at each wave to account for special design of the CLHLS (Zeng et al., 2002). The multivariate analyses were not weighted as research has shown that including variables related to sample selection in the regression produces unbiased coefficients without weights (Winship and Radbill, 1994).

We estimated mortality between 2002 and 2011 as a function of time-invariant covariates measured in 2002, including gender, ethnicity, education, and occupation before age 60, and time-varying covariates measured in 2002, 2005, and 2008, including all other variables. We estimated seven models for each gender and each age group. The first model includes education and demographic variables to examine the effect of education on mortality risk after controlling for demographics and survey year. Models 2 to 5 add measures of the other socioeconomic attainments, social relationships and activities, health behaviors, and health status, separately to Model 1 to test how each set of variables mediates the education effect on mortality. Because in our conceptual model, some of the effects of other socioeconomic attainments, social relationships and activities, and health behaviors on mortality are mediated by health status, we estimate the joint effect of these three groups of variables on education–mortality relationship in Model 6 and add measures of health status to this model in Model 7.

3. Results

3.1. Descriptive statistics

The weighted distributions of education by gender and age show that nearly half of the older adults did not have any formal schooling (47%) and only about 15% had middle school education (Table 1). Educational attainment does not vary much by survey year. However, it varies substantially by gender and age group. Generally, larger proportions of men and the young olds had primary school and middle school education.

Table 2 shows that from 2002 to 2011, 13% of older adults died, and for both men and women, the proportion of death decreases with increasing education. Table 2 further shows that with the exception of coresidence with children for both men and women and drinking status for women, educational differentials in each variable are statistically significant for both men and women. Generally, education is positively associated with other socioeconomic attainments, being married, social and solitary leisure

Table 1
Percentage distribution of educational attainment by gender, age, and survey year.

	Total	Men		Women	
		Ages 65–79	Ages 80+	Ages 65–79	Ages 80+
Year 2002					
No education	51.5	26.0	34.5	71.8	84.6
Primary school	36.2	52.5	49.4	23.5	12.4
Middle school or more	12.3	21.5	16.1	4.7	3.0
Year 2005					
No education	47.4	22.8	40.2	65.4	82.4
Primary school	37.4	50.6	45.2	28.0	13.9
Middle school or more	15.2	26.6	14.6	6.6	3.7
Year 2008					
No education	43.8	20.8	39.0	58.4	83.6
Primary school	39.1	51.1	46.3	32.0	13.1
Middle school or more	17.1	28.1	14.7	9.6	3.3
All years					
No education	47.3	23.0	38.1	64.9	83.6
Primary school	37.7	51.4	46.8	28.0	13.1
Middle school or more	15.0	25.6	15.1	7.1	3.3

Note: Results are weighted.

Table 2
Descriptive statistics by gender and educational attainment: pooled CLHLS data.

	Total	Men			Women		
		No education	Primary school	Middle school or more	No education	Primary school	Middle school or more
	Mean/%(Std)	Mean/%(Std)	Mean/%(Std)	Mean/%(Std)	Mean/% (Std)	Mean/%(Std)	Mean/%(Std)
Died between adjacent waves	13.1	18.1	13.4	10.6**	14.1	9.7	5.7**
Male	48.3						
Age	72.87(6.20)	73.97(6.27)	72.29(5.69)	70.85(5.30)**	74.40(6.57)	71.17(5.60)	70.85(5.78)**
Han	93.6	94.7	93.1	94.2+	92.8	94.7	96.2**
Urban	37.5	26.9	33.9	59.3**	29.6	45.2	78.7**
Professional occupation	11.2	3.5	10.3	50.5**	0.6	4.4	46.3**
Financially independent	44.9	43.6	57.6	79.6**	23.3	41.8	74.8**
Adequate medical service	91.9	89.0	92.5	96.1**	90.2	92.8	98.1**
Married	62.3	68.6	76.6	83.7**	45.5	56.0	61.5**
Living with children	48.7	42.3	44.8	44.9	53.2	52.7	48.9
Living in an institution	1.2	2.3	1.3	0.9**	0.9	1.1	1.7+
Number of children visiting	3.19(1.86)	3.06(1.98)	3.16(1.83)	2.79(1.70)**	3.45(1.93)	3.18(1.71)	2.48(1.49)**
Social activities	0.57(0.87)	0.45(0.78)	0.65(0.89)	0.87(1.02)**	0.38(0.71)	0.69(0.95)	0.89(1.06)**
Solitary leisure activities	1.54(1.06)	1.19(0.84)	1.76(1.00)	2.55(1.09)**	1.04(0.78)	1.67(1.01)	2.60(1.11)**
Ever smoked	40.9	67.0	72.2	69.8**	12.9	16.2	9.6**
Drinking	23.0	34.7	40.8	34.1**	9.3	9.7	7.3
Physical exercise	37.3	30.3	39.6	60.2**	26.3	43.2	58.8**
Self-rated health bad	15.6	17.2	12.9	11.5**	18.2	15.8	14.8*
Missing on self-rated health	1.4	2.0	1.2	0.5**	1.9	0.9	1.2**
Any ADL difficulty	6.1	7.1	4.9	4.3**	7.7	5.3	5.8**
Any IADL difficulty	34.1	35.2	24.0	17.9**	47.6	31.0	31.1**
Any chronic condition	60.5	56.2	58.1	62.8**	60.2	65.1	71.7**
Cognitively impaired	13.8	17.4	7.6	3.6**	22.8	8.8	6.0**
Positive mental well-being	59.1	51.5	60.5	64.9**	55.9	62.8	74.4**
Negative mental well-being	45.5	47.4	39.2	29.5**	54.9	46.1	38.9**
Missing on mental well-being	4.9	6.2	4.1	2.9**	6.5	3.3	2.8**
Proxy	17.8	21.0	14.1	10.5**	24.1	13.2	10.4**
Observations	39,470	6099	7969	2928	18,538	3099	837

Note: Results are weighted. Significance between educational groups: $+p < 0.1$, $*p < 0.5$, $**p < 0.01$.

Table 3
Hazard ratios of educational attainment on mortality from 2002 to 2011 by gender.

	Men							Women						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Primary school (cf. no education)	0.92**	0.95+	1.02	0.94*	0.99	1.02	1.03	0.99	1.01	1.10**[a]	1.00	1.04	1.10**[a]	1.10**
Middle school or more (cf. no education)	0.88**	0.98	1.12**	0.93+	0.97	1.13**	1.11*	0.83**	0.92	1.04	0.87*	0.89+	1.06	1.02
Professional occupation		0.95				1.05	0.98		0.94				1.07	1.00
Financially independent		0.77**				0.90**	0.90**		0.75**				0.87**	0.93
Adequate medical service		0.83**				0.90*	0.98		0.92**				0.97	1.01
Married			0.84**			0.84**	0.83**			0.84**			0.84**	0.85**
Living with children			1.17**			1.18**	1.10**			1.24**			1.23**	1.11**
Living in an institution			1.39**			1.38**	1.27**			1.48**			1.50**	1.34**
Number of children visiting			1.01+			1.01+	1.02**			0.99			0.99	1.00
Social activities			0.86**			0.88**	0.94**			0.81**			0.83**	0.89**
Solitary leisure activities			0.80**			0.84**	0.91**			0.77**			0.79**	0.86**
Ever smoking				1.13**		1.13**	1.11**				1.10**		1.13**	1.09**
Drinking				0.82**		0.83**	0.90**				0.91**		0.95+	0.98
Physical exercise				0.69**		0.79**	0.87**				0.70**		0.79**	0.87**
Self-rated health bad					1.30**		1.26**					1.19**		1.16**
Missing on self-rated health					1.15*		1.13*					1.23**		1.21**
Any ADL difficulty					1.40**		1.37**					1.52**		1.47**
Any IADL difficulty					1.66**		1.54**					1.57**		1.45**
Any chronic condition					1.05+		1.08**					0.99		1.01
Cognitive impairment					1.21**		1.13**					1.34**		1.27**
Positive mental well-being					0.90**		0.96					0.91**		0.96
Negative mental well-being					1.12**		1.07*					1.07**		1.04
Missing on mental well-being					1.04		1.01					1.01		0.98
Proxy					1.18**		1.14**					1.17**		1.15**
Age	1.08**	1.08**	1.07**	1.08**	1.06**	1.07**	1.05**	1.08**	1.08**	1.07**	1.08**	1.05**	1.07**	1.05**
Han	1.00	1.03	1.07	1.01	0.93	1.07	0.97	1.16**	1.16**	1.21**	1.17**	1.02	1.21**	1.05
Urban	0.94*	1.03	1.04	0.98	0.94*	1.08**	1.03	0.95*	0.97	1.01	0.97	0.94*	1.03	0.98
2005 wave (cf. 2002 wave)	0.78**	0.78**	0.79**	0.76**	0.79**	0.77**	0.78**	0.76**	0.76**	0.74**	0.76**	0.76**	0.74**	0.76**
2008 wave (cf. 2002 wave)	0.74**	0.75**	0.74**	0.71**	0.76**	0.73**	0.76**	0.74**	0.74**	0.74**	0.73**	0.75**	0.74**	0.76**
Chi-square	3880.10	3978.16	4363.04	4131.93	4862.18	4511.53	5089.60	5958.65	6005.58	6519.75	6143.24	7181.59	6614.32	7415.49
df	7	10	13	10	17	19	29	7	10	13	10	17	19	29

Note: Results are based on Weibull model. $N = 16{,}996$ observations from 11,190 men and 22,474 observations from 15,558 women.
[a] Indicates the hazard ratio of education is significantly different between men and women at $p < 0.1$ level. $+p < 0.1$; $*p < 0.05$; $**p < 0.01$.

Table 4
Hazard ratios of educational attainment on mortality from 2002 to 2011 by gender and age.

	Men							Women						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Ages 65–79														
Primary school (cf. no education)	0.80**	0.86+	0.90	0.83*	0.91	0.93	0.94	0.99[a]	1.02	1.09	1.03	1.09	1.10	1.10
Middle school or more (cf. no education)	0.78*	0.94	1.06	0.83+	0.93	1.10	1.11	0.55*	0.53*[a]	0.65[a]	0.59*	0.62+	0.58+[a]	0.53*[a]
Ages 80+														
Primary school (cf. no education)	0.94*[b]	0.96	1.04	0.95	1.00	1.03	1.04	1.01	1.02	1.11**	1.02	1.05	1.11**	1.10*
Middle school or more (cf. no education)	0.91*	0.99	1.12**	0.95	0.99	1.12*	1.10+	0.88+[b]	0.97[b]	1.07[b]	0.92[b]	0.94	1.10[b]	1.06[b]

Note: Results are based on Weibull model. All models include education and demographic covariates. In addition, Model 2 includes other socioeconomic attainments; Model 3 includes social relationships and activities; Model 4 includes health behaviors; Model 5 includes health status measures; Model 6 includes other socioeconomic attainments, social relationships and activities, and health behaviors; Model 7 includes other socioeconomic attainments, social relationships and activities, health behaviors, and health status measures.

[a] Indicates the hazard ratio of education is significantly different between men and women at $p < 0.1$ level.

[b] Indicates the hazard ratio of education is significantly different between the young old and the oldest old at $p < 0.1$ level. $+p < 0.1$; $*p < 0.05$; $**p < 0.01$.

activity participation, exercise, self-rated health, physical functioning, mental well-being, and cognition.

3.2. Education and mortality

Results from hazard models show that education is negatively associated with mortality risk for both men and women (Table 3, Model 1). For men, the risk of death for those with primary and middle school education are 8% and 12% respectively lower than for those without education. When other socioeconomic attainments are added in Model 2, the effects of education decline substantially and become marginally significant or non-significant. When social relationships and activities are added in Model 3, the sign of the association between education and mortality risk becomes positive. While the difference between primary education group and no education group is no longer statistically significant, the middle school group has a *higher* mortality risk than no education group (OR = 1.12). Additional analysis which added each variable separately showed that the cross-over relationship between education and mortality only occurs when solitary leisure activity participation was added. When health behaviors are added in Model 4, education effects are slightly attenuated but remain significant for primary education and marginally significant for middle school education. In Model 5 which adds health measures to Model 1, there are no significant differences between the two more educated groups and no education group. With other socioeconomic attainments, social relationships and activities and health behaviors controlled for in Model 6, men with primary education are not significantly different from men without education, and mortality risk for men with middle school education is 13% *higher*. When all four groups of mechanisms are included in Model 7, the difference between men with primary education and men with no education is not significant, but mortality risk for middle school educated men is 11% *higher* than men without education.

For women, the education effects on mortality are somewhat different from those for men, though few of them are statistically significant. Controlling for demographics and survey year, women with middle school education are 17% lower in mortality risk, but women with primary education are not significantly different from women without education (Model 1). When other socioeconomic attainments are added in Model 2, the difference between middle school education and no education becomes non-significant. This difference also becomes non-significant when social relationships and activities are added in Model 3, but women with primary education have significantly *higher* mortality risk than women with no education (OR = 1.10). Additional analysis showed that this is mainly attributed to solitary leisure activity participation, which is similar to the case for men. When health behaviors are added in Model 4, the difference between middle school education group and no education group decreases, but remains significant. This difference is marginally significant when health variables are added in Model 5. When other socioeconomic attainments, social relationships and activities, and health behaviors are taken into account in Model 6, women with middle school education are not significantly different from those without education, but women with primary education have *higher* mortality risk. These education effects remain largely unchanged when health measures are added in Model 7.

There are several notable age differences in education–mortality relationship for men (Table 4, left panel). First, net of demographics and survey year, education has a stronger negative effect on young–old men than oldest-old men. Compared with those without education, the mortality risk is 20% and 22% respectively lower for young–old men with primary and middle school education while the mortality risk for the oldest-old men in those two education groups are 6% and 9% respectively lower. Second, for young–old men, the difference between primary education and no education decreases when other socioeconomic attainments (Model 2) or health behaviors (Model 4) are added, but it remains significant or marginally significant, while for oldest-old men, this difference becomes non-significant when each of these two sets of variables are added. Third, for young–old men, the difference between middle school education and no education becomes non-significant when social relationships and activity measures are added, but for the oldest old, this effect becomes positive and significant when relationships and activity measures are added.

The education–mortality relationship also differs between the two age groups for women (Table 4, right panel). First, middle school education has a stronger negative effect on mortality for young–old women than for oldest-old women (OR = 0.55 vs. 0.88) when only demographics and survey year are controlled for. Second, for the young old, the difference in mortality risk between middle school group and no education group becomes non-significant when social relationships and activities are added (Model 3), but it does not decrease when other socioeconomic attainments are added (Model 2), and it decreases but remains significant when health behaviors and health status variables are added (Model 4 and Model 5). Even with all mediating factors included, this difference remains significant for young–old women, but it is not significant for oldest-old women (Model 7). Third, only among oldest-old women, we observe a positive effect of primary education on mortality when social relationships and activities are added (Model 3), and it remains significant when all mediating factors are added (Model 7).

4. Discussion

This study extends the literature on education and mortality in several important ways. First, it focuses on a rapidly aging China where most older adults have very low education and they have limited social and economic resources to improve their health and survival under the context of fewer family caregivers, greater mobility, rising health care costs, and the lack of a national social security system (Yip and Hsiao, 2008). The relationship between very low level of education (e.g., elementary or low vs. no formal school) and old-age mortality in developing countries is not well understood. Our paper shed light on this important issue. Second, this study is based on a large national longitudinal survey of older adults, including a large number of respondents over age 80, and thus the results are more representative of both the young old and oldest old Chinese than previous studies on older adults in China which were limited to selected regions or age groups (Liang et al., 2000; Zhu and Xie, 2007). Third, this study includes a rich set of social, economic, behavioral, and health variables that are likely to mediate the relationship between education and mortality and it provides a thorough analysis of the contribution of each mediating mechanism. And finally, this study contributes to the debate on gender and age differences in the effect of education on mortality by examining these variations and their possible underlying mechanisms in a different social context.

Our first hypothesis of an inverse relationship between educational attainment and mortality among older Chinese adults is supported by the data. This finding is generally consistent with the literature on education–mortality relationship in both developed and developing countries. It suggests that educational differentials in health and mortality persist among older adults despite China's collective cultural tradition and the government's effort to eliminate such inequalities.

Previous research in developed countries showed a strong and robust relationship between education and mortality (Huisman et al., 2003; Hummer and Lariscy, 2011). Although it is difficult to compare our results with these studies because of different study populations and how education was measured, the magnitude of education effect on mortality for older Chinese adults seems moderate. This finding is consistent with several studies in developing countries and in Asia (Liang et al., 2000; Liu et al., 1998; Luo and Xie, 2014; Zhu and Xie, 2007). In a meta-analysis of education–mortality relationship in Asia, Vathesatogkit et al. (2014) found that the relationship between education and mortality varies in Asia, and it is weaker in older adults and in East Asia. Taken together, these findings underscore the importance of social contexts in shaping the relationship between SES and health outcomes.

Our hypothesis that education–mortality relationship is mediated by other SES attainments, social relationships and activities, and health behaviors is also supported. The finding that the association between education and mortality is no longer statistically significant after controlling for other socioeconomic attainments indicates more direct associations between these attainments and mortality, especially the economic status. We speculate that economic resources play a crucial role in survival among older adults in contemporary China where there are few social security safety nets and out-of-pocket payments for health care have soared (Hu et al., 2008). When the daily expenses and health care costs are not the primary concerns of most older adults in more developed countries, educational advantages in terms of knowledge, perceived control, and social support may become more important than economic factors (Ross and Wu, 1995).

What is also interesting to note is that the addition of solitary leisure activity participation causes a cross-over of the education effect for both men and women. Additional analysis showed that education is moderately correlated with the three items in the solitary activity index (reading: $r = 0.57$; TV/radio: $r = 0.33$; gardening: $r = 0.33$), and although reading is the main trigger, the cross-over effect is significant only when all three are included. Ross and Zhang (2008) suggest that better-educated people may engage in activities that require and reinforce cognitive skills which may benefit health and well-being. Reading is considered high on cognitive stimulation. Although Watching TV and listening to radio are considered low on cognitive stimulation in the West, it is considered more cognitive stimulating among older Chinese adults perhaps because of the more informative and stimulating TV programs and the lack of other venues for intellectual stimulation in China. Gardening, as a physical activity, a productive activity, and a hobby, can stimulate cognitive functioning and improve physical and mental health.

It is also possible that the three solitary leisure activities may exhibit elements of some of the other groups of explanatory factors not captured by the measures included. For example, gardening may reflect physical capacity and capture severity of health problems; reading may reflect cognitive health and literacy; and watching TV may reflect having the economic resources necessary to own a TV. Previous research has shown that both social and solitary leisure activities are associated with reduced mortality (Sun and Liu, 2006), improved physical (Everard et al., 2000) and cognitive functioning (Glei et al., 2005), and better subjective well-being (Ross and Zhang, 2008; Simone and Haas, 2013). However, activity participation, especially solitary leisure activity participation, has not been included in many existing studies of the education–mortality linkage. Our finding calls for greater attention to this mechanism.

On the other hand, the typical health behavior variables explain a relatively small amount of the educational differentials in mortality, and additional analysis indicated that only physical exercise mediates the education–mortality association. Smoking and drinking do not mediate the education–mortality relationship because the proportions of older adults who ever smoked and who drink alcohol do not vary substantially across the three education levels; also older Chinese men and women who are most likely to have ever smoked and older Chinese men who are most likely to drink alcohol are those with primary education instead of those without education (Table 2). This finding is inconsistent with most studies using data from the developed countries, but consistent with several studies conducted in China (e.g., Luo and Wen, 2002). According to the literature, higher SES people are more like to smoke, which may be due to the Chinese culture in which smoking is regarded as a form of etiquette in social contact, and even represents success in career and business, affluence and sophistication (Tu et al., 2000). These findings suggest that social contexts play an important role in determining which factors are more crucial in explaining SES disparities in health.

Our hypothesis of a stronger education effect on mortality for men than for women received mixed support. Our findings indicate that for Chinese older adults, the major gender difference seems to be in the primary education category: while men with primary education have lower mortality risk than men without education, women with primary education are not significantly different from women without education. This gender pattern holds for both the young old and the oldest old. The lack of health benefits of a primary education for older women is puzzling and deserves more research in the future.

We observed weaker effects of education on mortality for the oldest old than for the young old for both men and women, which lend support to the convergence hypothesis. Once measures of the mechanisms are added, education effects are no longer significantly different between the young–old men and the oldest-old men,

even though middle school education has a marginally significantly positive effect for the oldest-old men. For women, however, middle school education still has a stronger effect for the young old than for the oldest old. These findings suggest that men's age convergence can be explained by the different influences of the four mechanisms, but women's age convergence cannot be explained by these mechanisms. Future research needs to identify additional mechanisms that may explain the particularly strong effect of middle school education on mortality for the young–old women.

Our study is limited in the number of educational attainment categories because only a small number of older adults in the CLHLS sample had education beyond middle school (less than 5%) and even a smaller number of them went to college (less than 2%). Future research that uses more refined categories of education may shed greater light on the nature of education–mortality relationship. In addition, our test of age convergence is limited because the CLHLS sample does not include respondents aged below 65 years. Furthermore, older adults' health may also be influenced by spousal education and children's education (Elo, 2009; McDonough et al., 1999; Zimmer et al., 2007) and future research should examine how these effects may interact with respondent's own education and how they may differ by gender and age.

In sum, this study joins a small number of studies which reveal a moderate education effect on mortality among older Chinese adults despite the speculation that China's unique social, economic, political and cultural context may have dampened the education–mortality linkage. China's unique social setting, however, does play an important role in the pathways between education and mortality as this study shows that the education effect is largely explained by the associations between education and other socioeconomic attainments, social relationships and activity participation, and physical exercise, but not by smoking and drinking. In addition, our findings on age and gender variations in the magnitude of education effect on mortality and their pathways suggest that future research needs to go beyond verifying the existence of an inverse relationship between education and mortality and uncover subgroup variations and their underlying social and biological mechanisms.

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