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Research Article

Links Between Mortality and Socioeconomic Characteristics, Disease Burden, and Biological and Physical Functioning in the Aging Chinese Population

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Abstract

Objectives: Determinants of mortality may depend on the time and place where they are examined. China provides an important context in which to study the determinants of mortality at older ages because of its unique social, economic, and epidemiological circumstances. This study uses a nationally representative sample of persons in China to determine how socioeconomic characteristics, early-life conditions, biological and physical functioning, and disease burden predict 4-year mortality after age 60.

Methods: We used data from the China Health and Retirement Longitudinal Study. We employed a series of Cox proportional hazard models based on exact survival time to predict 4-year all-cause mortality between the 2011 baseline interview and the 2015 interview.

Results: We found that rural residence, poor physical functioning ability, uncontrolled hypertension, diabetes, cancer, a high level of systemic inflammation, and poor kidney functioning are strong predictors of mortality among older Chinese.

Discussion: The results show that the objectively measured indicators of physical functioning and biomarkers are independent and strong predictors of mortality risk after accounting for several additional self-reported health measures, confirming the value of incorporating biological and performance measurements in population health surveys to help understand health changes and aging processes that lead to mortality. This study also highlights the importance of social and historical context in the study of old-age mortality.

Keywords: China Health and Retirement Longitudinal Study (CHARLS), Death and dying, Life course analysis, Socioeconomic status

Mortality at older ages is affected by individual-level characteristics as well as the social, economic, epidemiological, and political contexts to which a person has been exposed. A large body of research in Western developed settings has yielded insights into the relationship of mortality to numerous demographic, social, biological, behavioral, and environmental factors (Cooper et al., 2010; Fried et al., 1998; Rogers et al., 2010; Sasaki et al., 2007; Turra et al., 2005). However, these findings may not directly translate to developing countries. Although chronic diseases have become the leading causes of death in China (He et al., 2005; Yang et al., 2008; M. Zhou et al., 2019), China's unique cultural, social, economic, and epidemiological contexts and the social patterns of behavioral risk factors that are different from those in developed countries may indicate unique determinants of mortality among the current cohort of the aging Chinese population. This study used data from the 2011–2015 China Health and Retirement Longitudinal Study (CHARLS) to understand the important links of mortality to socioeconomic characteristics, disease burden, and biological and physical functioning. Identifying the critical factors that contribute to mortality among older Chinese will help identify priorities and targets of public health programs and potential interventions; therefore, it is critical for achieving healthy aging in China.

Background

Multidimensional Health Measures as Predictors of Mortality at Older Ages

Mortality at older ages generally results from health deterioration that typically is initiated by physiological dysregulation followed by diagnoses of diseases and conditions and then by loss of physical functioning (Crimmins et al., 2010). A vast literature has investigated the relationships between a broad spectrum of risk factors and subsequent mortality risk. A general although not universal finding is that individuals with higher socioeconomic status (SES) have lower mortality risk than those with lower SES, although the gradients vary across time, subpopulations, and populations (Hayward et al., 2015; Rosero-Bixby & Dow, 2009; Sudharsanan et al., 2020). The higher rate of male mortality compared to female mortality is largely due to greater vulnerability to cardiovascular disease and relatively greater prevalence of smoking behaviors among men than women (Crimmins et al., 2019; Rogers et al., 2010). Beyond sociodemographic factors, many studies have identified important links between multiple indicators of the morbidity process and mortality. For example, disability in activities of daily living, instrumental activities of daily living, and functional impairments are strongly predictive of subsequent mortality (Majer et al., 2011; Reuben et al., 1992; Studenski, 2011). Also, performance-based measures of physical and organ-specific functional indicators, such as walking speed, handgrip strength, lung function, as well as serum creatinine and cystatin C (indicators of kidney function), are found to be strong independent predictors of mortality in older adults (Rosero-Bixby & Dow, 2012). Some studies have reported associations between excess mortality risk and major chronic diseases, including hypertension (Lewington et al., 2016), diabetes (Morgan et al., 2000), and chronic kidney disease (Tonelli et al., 2006; Wen et al., 2008). The effect of chronic diseases on mortality risk is affected by treatment (Bonneux, 2011) and is dependent on the sociodemographic group, time period examined, and location (Lee et al., 2008; Zang et al., 2021).

In recent decades, much research has incorporated measured biological indicators across physiological systems into models of mortality. These biomarkers can signal physiological dysregulation that precedes diseases and functioning loss and therefore can help uncover the underlying mechanisms through which social, behavioral, and environmental factors have consequences for health and more effectively model the process of health changes that lead to mortality (Crimmins et al., 2010; Crimmins & Vasunilashorn, 2011; Turra et al., 2005). In population studies of older adults, C-reactive protein (CRP), the most commonly collected marker of the general systemic level of inflammation, has been linked to elevated mortality (Harris et al., 1999; Strandberg & Tilvis, 2000), while the relationships between mortality and blood pressure, cholesterol, and triglycerides are less clear, especially at advanced ages (Bundy et al., 2017; Cooney et al., 2009; Criqui et al., 1993; Lv et al., 2015, 2018; Ravindrarajah et al., 2017; Ravnskov et al., 2016). Because measured biological indicators and physical assessments can provide warning signs of deteriorating health and functioning, they can be valuable tools for assessing health risks and identifying vulnerable older adults (Ailshire & Crimmins, 2011; Crimmins & Vasunilashorn, 2011).

The process of health deterioration is affected substantially by sociodemographic, behavioral, and environmental factors, resulting in variability in the links between health indicators and mortality across populations and subpopulations. Goldman et al. (2016) in a multinational study evaluated a wide range of mortality predictors. They found that disability, mobility limitations, CRP, and performance-based measures of physical function are among the top predictors of mortality in all countries. They also found some cross-country variations in the relative effect of health measures on mortality. For example, HbA1c is a strong predictor of mortality in Costa Rica but not in England, Taiwan, or the United States; and diastolic blood pressure (DBP) is a critical mortality predictor in Taiwan but not in other countries. In the U.S. population, Goldman et al. (2017) found substantial variation in the links between health measures and mortality across demographic groups, most notably by race and ethnicity. Andrasfay and Goldman (2020) found that, among older Americans, physical functioning limitations are less strongly associated with mortality for African Americans and Hispanics than for Whites.

The Chinese Context

There are compelling reasons to expect the determinants of mortality to be somewhat unique in the Chinese context. First, the link between SES and mortality depends on the SES patterns of psychosocial, behavioral, and resource factors as well as environmental exposure. Contrary to patterns in Western developed countries where higher SES is associated consistently with fewer behavioral risk factors and better health, studies from developing countries generally indicate that obesity and cardiometabolic diseases are more prevalent among higher SES groups, because individuals with high SES are the first to adopt unhealthy behaviors, such as smoking, drinking, and diets that are rich in fat, sugar, and refined carbohydrates (Caballero, 2007; Dinsa et al., 2012; Mayén et al., 2014; Miranda et al., 2019; Popkin, 2001). Jones-Smith et al. (2011) used data from 37 developing countries between 1989 and 2007 to assess within-country trends in SES patterns of overweight. They found an association between higher SES and higher gains in overweight prevalence in 27 of the 37 countries. However, high-SES individuals also have greater financial, psychosocial, and medical resources that may lead to improvements in many downstream adverse health outcomes, such as poor cognitive and physical functioning, disabilities, chronic conditions, and mortality (Karlamangla et al., 2010; Link & Phelan, 1995; Lowry et al., 1996; Marmot, 2005; Stringhini et al., 2018). In addition, from a life course perspective, the current cohort of older Chinese was born and lived their early lives at a time when extreme poverty, inadequate sanitation, poor hygiene, and infectious diseases were prevalent and mortality among the young was very high. These life experiences differ from those in the developed world. When examining an older population that represents a select group of survivors, significant mortality selection could affect the association between social factors and health and mortality in later life. Thus, we hypothesize that the relationship between SES and mortality in China is not as strong as in western countries.

Second, urban–rural differences and divisions play a further role in producing health inequalities in China. Due to China's long history of discrepancies in terms of development, its urban and rural areas differ markedly in their physical and social environments. As the official household registration system, *hukou* defines a person's eligibility for social resources and welfare benefits. Generally, the urban Chinese population has better education, higher incomes, better medical knowledge, and greater access to high-quality health services than the rural population (Li et al., 2018; Wu, 2011; Wu & Treiman, 2004; Zhu & Österle, 2017). Despite the unprecedented scale and pace of urbanization in recent decades, China's *hukou*-based social welfare system sets strict institutional barriers for rural-to-urban migrants (Cai, 2011), which is likely to result in urban–rural differentials in health and mortality in later life (Gong et al., 2012; Song & Smith, 2019). In this study, we hypothesize that urban residents with urban *hukou* will have significantly lower mortality risks than rural residents.

Third, inadequate access to high-quality and affordable health care coupled with low health literacy has led to a lack of awareness and deficient management of chronic diseases, particularly in the less economically developed regions. A study that involved 1.7 million Chinese found that nearly half of the sample had hypertension; however, fewer than half of these persons had been diagnosed with the condition, only a third were being treated, and fewer than 8% had their blood pressure controlled (Lu et al., 2017). A study of diabetes among older Chinese based on the CHARLS sample showed that, in 2011–2012, 17.4% of Chinese aged 45 years and older had diabetes. Among those with diabetes, about 60% were undiagnosed, which represented 10.3% of the entire Chinese middle-aged and older population (Zhao et al., 2016). The prevalence of underdiagnosis is much higher in rural and noncoastal areas compared to urban areas (Zhao et al., 2016). Poor disease diagnosis and management are likely to increase the mortality burden of chronic diseases because the diseases that people do not know they have and/or are uncontrolled can be especially life-threatening. Another concern that arises with low health literacy and poor awareness of chronic diseases is the lack of accuracy of reporting and comparability across individuals and subpopulation groups. In light of this concern, it is important to incorporate measured markers of physiological dysregulation and performance assessments of physical functioning in the models of mortality prediction, because such markers can serve as objective indicators of health and reflect health conditions that individuals may not be able to report (Ailshire & Crimmins, 2011). We hypothesize that individuals with measured high biological risk and poor physical functioning have an elevated mortality risk.

Gaps in the Literature

Previous research into old-age mortality in the Chinese population was focused primarily on socioeconomic differences in mortality and provided significant insights into important risk factors for mortality. For example, being female and having urban residence are shown to be associated with a reduced risk of mortality in old age (Huang & Elo, 2009; Wen & Gu, 2011; Yu et al., 1998). Evidence for educational differences in mortality is mixed (Luo et al., 2015; Sudharsanan et al., 2020; Wen & Gu, 2011; S. Zhou et al., 2019; Zhu & Xie, 2007). Poor self-rated health, disability, frailty, uncontrolled hypertension, diabetes, and poor kidney function have been linked to higher mortality risk (Bragg et al., 2017; Falk et al., 2017; Gu et al., 2009; Wang et al., 2018; Yu et al., 1998). Chronic respiratory diseases also present a substantial health burden. It is estimated that chronic obstructive pulmonary disease and lung cancer have become the third and fourth most common causes of mortality in China (M. Zhou et al., 2019).

Due to the availability of data, almost all studies of mortality among older Chinese have focused on a relatively old population or used nonrepresentative samples. Wang et al. (2018) used a sample that included only the urban Chinese population. Zhu and Xie (2007) and Huang and Elo (2009) focused only on the oldest old whereas other studies, that is, Luo et al. (2015) and Wen and Gu (2011), included a wider age range; however, their samples consisted primarily of the 80 and older population. The oldest old are a highly selective population, and the determinants of mortality could be different in the younger old population (Lu et al., 2017). Also, most research that examined the link between health and mortality has used a small number of subjective health measures that cannot capture multiple aspects of age-related health changes and cannot provide objective information for a population in which access to health care, knowledge of physiological measures of health, and awareness of chronic diseases may be limited and differential.

With the goal of examining determinants of mortality in the older Chinese population, this study focused on Chinese aged 60 and older using data from the nationally representative survey, CHARLS. The baseline demographics of the CHARLS sample closely match those of the population census in 2010 (Zhao et al., 2014). The representativeness of the study sample thus makes our results representative of the entire older Chinese population. Using the rich health data collected in CHARLS, this study conceptualizes health as multidimensional, including indicators of physiological dysregulation, diagnosis of diseases and conditions, and physical functioning measures that capture the process of health change with age. Incorporating objectively measured indicators of health is of particular importance in China where a significant proportion of older Chinese has limited access to regular, high-quality health care, and unawareness of chronic diseases is common.

Data and Methods

Data come from CHARLS, a nationally representative survey of those aged 45 and older in China. The national baseline survey was conducted by Peking University from June 2011 to March 2012. As described in detail elsewhere (Zhao et al., 2014), CHARLS collects detailed information about individuals and households through in-depth household interviews including demographic characteristics, health status, health care utilization, physical and cognitive functioning, family characteristics, and intergenerational relationships. A set of standardized physical, anthropometric, and blood pressure measurements was collected in the home along with the household surveys. Blood was collected in a subsequent visit to a township hospital or local office of the China Center for Disease Control and Prevention. Respondents were asked to fast overnight before the blood draw, but blood was collected even if the respondent had not fasted. Written consent forms were obtained from all respondents. The study protocol was approved by the ethical review committee of Peking University. Biomarker weights were created by the CHARLS team to correct for both initial nonparticipation in the survey and nonparticipation in blood sample collection.

Because the goal of this study is to investigate determinants of mortality in the older Chinese population in which chronic diseases are the major causes of death, we restricted the age of the participants to 60 years and older. Of the 7,724 participants aged 60 and older at the initial interview, 4,176 provided a fasting blood sample and physical assessment. We excluded an additional 311 participants because they did not provide information about chronic diseases, did not participate in some physical assessments, or did not provide information about adult SES. The final analytic sample consisted of 3,865 persons (Supplementary Appendix Figure A). We compared the characteristics of the 3,865 individuals in our analytic sample to the 3,859 individuals who were excluded from the sample. Advanced age and living in an urban area were associated with a greater likelihood of being excluded from the final analytic sample. No educational differences were observed. Supplementary Appendix Tables A1 and A2 provide details about sample selection and analysis of missing data and loss to follow-up.

Measures

Mortality

CHARLS followed respondents of the 2011 baseline survey with interviews in 2013, 2014, and 2015. At each interview wave, interviews with earlier respondents were sought. If a respondent's death was reported, the CHARLS team attempted to identify a knowledgeable informant (typically a family member) and conducted exit interviews to obtain information about the death. In this study, we assessed 4-year all-cause mortality between the baseline interview and the 2015 interview. Deaths after 4 years were censored. During the 4-year follow-up period, 292 individuals (7.40%) had died. Those who had been observed more than once but were lost by 2015 were included in the study. The exposure time for these individuals was the time from the baseline study to their most recent interview.

Social and demographic predictors of mortality.—We included age and sex as covariates in all analyses. Age was measured in years. Sex was coded as 1 for females and 0 for males. A three-category variable represented one's educational attainment: no formal schooling (reference group), primary school, and junior high school and above. We classified respondents based on their usual residence and official *hukou* registration into two dummy variables: urban residency with rural *hukou* and urban residency with urban *hukou* (with rural residency as the reference group). The small percentage (<2%) who lived in rural areas but had urban *hukou* were classified with other rural residents. We categorized household per capita expenditure into tertiles. We used per capita expenditure instead of income because it is a preferred measure of household resources in settings such as China where significant economic activity does not pass through markets (Deaton, 1997).

Indicators of health as predictors of mortality.—We included multiple dimensions of health among the predictors of mortality risk: physical functioning, biomarker indicators of risk, and diagnosis of disease. The assessment of physical functioning through performance-based tests was an essential component of the evaluation of the physical functioning of the CHARLS respondents. In this study, we used four performance-based physical functioning measures that have been shown to be predictive of health outcomes associated with aging and mortality: grip strength, lung function, gait speed, and balance. Grip strength was measured using a hand dynamometer. Two measures were taken for each hand. Lung function was assessed using peak expiratory flow; three measurements were taken at 30-s intervals. Gait speed (m/s) was measured with a timed walk of 2.5 meters, completed twice. For each functioning assessment, we took the maximum value as the functioning score and classified as poor functioning those participants in the worst 25% for each measure and each sex. Balance was assessed using the semitandem balance test. Individuals who were unable to hold a semitandem stand for 10 seconds were considered as having poor balance. For each assessment, those who were unable to perform the tests, or those who did not complete the tests because either they or their interviewers thought it was unsafe or because of health reasons, were classified as poor functioning.

The biomarker measurements used in this analysis were obtained from physical assessments and venous blood samples (Zhao et al., 2014). These measurements reflect the health of multiple physiological systems, including cardiovascular functioning (systolic blood pressure [SBP], DBP, and pulse rate), metabolic functioning (HbA1c, plasma glucose, total cholesterol, and triglycerides), kidney functioning (serum creatinine and blood urea nitrogen, or BUN), and inflammation (CRP). For each biomarker, we devised a dichotomous indicator to indicate "high risk" and "not high risk" based on clinical cutoff values for high risk (given in Table 1). Those who had elevated SBP/DBP were defined as having hypertension (Lu et al., 2017), and those who had high HbA1c or high plasma glucose were defined as having diabetes (Zhao et al., 2016).

CHARLS respondents were asked if they had ever been diagnosed with a chronic disease: hypertension, diabetes, cancer, chronic lung disease, heart problems, stroke, and/or kidney disease. The actual prevalence of chronic diseases among older Chinese is believed to be higher than reported because of underdiagnosis and/or underreporting (Lu et al., 2017; Zhao et al., 2016). Because blood pressure, HbA1c, and plasma glucose were measured in CHARLS, we combined measured biomarkers and self-reported diagnosis to create categories for indicators of hypertension (no hypertension, undiagnosed [did not report being diagnosed with hypertension but SBP was 140 mmHg or greater or DBP was 90 mmHg or greater], controlled [diagnosed with hypertension but measured blood pressure is not at high-risk level], and uncontrolled [diagnosed with hypertension and measured blood pressure is at high-risk level]) and diabetes (no diabetes, undiagnosed diabetes [not diagnosed with diabetes but HbA1c or plasma glucose is at high-risk level], and diagnosed diabetes). As a critical behavioral indicator, smoking status was also included in the analysis as a predictor of mortality. Because the prevalence of smoking is very high in men and low in women in China, we combined gender and smoking status to create a four-category variable—nonsmoking women, smoking women, nonsmoking men, and smoking men.

Table 1. Clinical Cut Points Defining High Risk

Measure	High-risk criteria
High systolic blood pressure (SBP)	≥140 mmHg
High diastolic blood pressure (DBP)	≥90 mmHg
Measured high blood pressure	SBP ≥140 mmHg and/or DBP ≥90 mmHg
High HbA1c	≥6.5%
High fasting glucose	≥126 mg/dL
Measured diabetes	HbA1c ≥6.5% and/or fasting glucose ≥126 mg/dL
Rapid pulse	≥90 (60 s)
High total cholesterol	≥240 mg/dL
High triglycerides	≥200 mg/dL
High C-reactive protein	≥3 mg/L
High creatinine	>1.4 mg/dL
High blood urea nitrogen	>20 mg/dL

Statistical Analyses

Analyses were weighted using biomarker weights to account for the complex sample design, nonresponses to the household interview, and nonparticipation in the blood collection. We employed a series of Cox proportional hazard models based on exact survival time to predict 4-year all-cause mortality. We examined age, gender, and adult SES differences in mortality in Model 1 and successively added the multiple indicators of health, that is, physical functioning, chronic diseases, and biomarkers of physiological functioning, in Models 2, 3, and 4, respectively and then added smoking (Model 5). We also estimated parametric survival models (Weibull, Gompertz, and exponential models). All models produced very similar results (Supplementary Appendix Table A3).

Results

Sample Description

As given in Table 2, respondents' ages at baseline ranged from 60 to 98 years, with a mean of 68.72. The sample was about equally split between men and women. About

Table 2. Sample Characteristics, the China Health and Retirement Longitudinal Study, 2011–2015

	All sample (N = 3,865)		Alive (N = 3,573)		Dead (N = 292)		
	N	%	N	%	N	%	Difference between the alive and dead
Baseline characteristics							
Age, mean (SD)	68.72 (6.48)		68.35 (6.27)		73.51 (7.34)		$p < .001$
Women	1,949	51.46	1,836	52.33	113	40.23	$p < .001$
Adulthood SES							
Education							$p = .004$
No formal schooling	2,288	54.57	2,090	53.47	198	68.73	
Primary school	948	26.05	886	26.43	62	21.17	
Junior school+	629	19.37	597	20.10	32	10.10	
Urban–rural							$p = .105$
Rural residency	2,526	55.00	2,319	54.06	207	67.07	
Urban residency, rural *hukou*	720	19.46	672	19.57	48	18.07	
Urban residency, urban *hukou*	619	25.54	582	26.38	37	14.86	
Household expenditure							$p = .392$
Bottom tertile	1,400	31.33	1,284	30.79	116	38.25	
Middle tertile	1,283	30.44	1,198	30.73	85	26.71	
Top tertile	1,164	37.66	1,075	37.90	89	24.60	
Missing	18	0.57	16	0.58	2	0.44	
Smokers	1,636	39.53	1,470	38.17	166	56.94	$p < .001$
Physical assessments							
Low grip strength (lowest 25% within gender)	1,049	28.22	904	26.30	145	52.84	$p < .001$
Poor lung function (lowest 25% within gender)	1,075	28.72	931	26.88	144	52.23	$p < .001$
Poor balance (cannot perform semitandem stance)	245	7.39	189	6.41	56	19.84	$p < .001$
Slow walking (lowest 25% within gender)	1,053	28.32	915	26.91	138	46.43	$p < .001$
Missing	117	3.14	114	3.24	3	1.82	
Diseases							
Hypertension							$p < .001$
No hypertension	1,877	46.90	1,760	47.62	117	37.60	
Undiagnosed hypertension	741	18.85	679	18.32	62	25.66	
Controlled hypertension	499	14.48	468	14.90	31	9.15	
Uncontrolled hypertension	748	19.77	666	19.16	82	27.59	
Diabetes							$p = .102$
No diabetes	3,170	81.65	2,944	82.14	226	75.34	
Undiagnosed	262	7.45	237	7.38	25	8.35	
Diagnosed	433	10.90	392	10.48	41	16.31	
Cancer	33	0.80	28	0.69	5	2.20	$p = .097$
Chronic lung disease	560	15.47	497	15.08	63	20.44	$p < .001$
Heart problems	614	17.68	570	17.89	44	15.01	$p = .691$

Table 2. Continued

	All sample (N = 3,865)		Alive (N = 3,573)		Dead (N = 292)		Difference between the alive and dead
	N	%	N	%	N	%	
Stroke	125	4.06	109	4.01	16	4.80	p = .024
Kidney disease	267	6.37	247	6.28	20	7.58	p = .967
Biomarkers at high risk							
Rapid pulse	216	5.05	191	4.86	25	7.60	p = .021
High total cholesterol	462	11.11	425	11.13	37	10.89	p = .694
High BUN	728	18.53	666	18.17	62	23.13	p = .276
High CRP	808	22.82	694	21.30	114	42.37	p < .001
High creatinine	54	1.51	42	1.26	12	4.69	p < .001
High triglycerides	439	13.93	413	14.32	26	8.82	p = .169

Notes: BUN = blood urea nitrogen; CRP = C-reactive protein; SES = socioeconomic status. *Ns* are not weighted. Percentages are weighted by the 2011 biomarker weights.

55% of the sample did not have any schooling, 55% lived in a rural area, about 20% lived in an urban area but still had rural *hukou*, and a quarter lived in an urban area and had urban *hukou*. About 40% of the sample had smoked. The percentage with low grip strength, poor lung function, and slow walking speed was about 25%, as they were coded to represent the bottom 25% (before weighting) in physical functioning. We included an indicator of missing data for the timed walk test because about 3% did not take this test. About 47% of the respondents did not have hypertension and 14% had controlled hypertension, that is, they had been diagnosed with hypertension but had measured blood pressure below 140/90 mmHg when blood pressure measures were taken in the CHARLS physical examination. About 20% had been diagnosed with hypertension and had an average SBP of at least 140 mmHg or an average DBP of at least 90 mmHg. Almost 20% of the sample had undiagnosed hypertension. Diabetes was found in about 20% of the sample, and most participants were undiagnosed (7.45% vs. 10.9%). Also, 15.47% reported chronic lung disease, and 17.68% reported heart problems. The prevalence of reported cancer, stroke, and kidney disease was low. High CRP levels were found in 22.82% of the sample, 18.53% had high BUN levels, 13.93% had high triglycerides levels, and 11.11% had high total cholesterol levels. Relatively few individuals had a rapid pulse (5.05%) or high creatinine levels (1.51%). Bivariate analyses revealed significant age, gender, and educational differences in mortality; the deceased were more likely to be those who had smoked, had hypertension, cancer, chronic lung disease, and stroke, were at high risk for physical dysfunction and physiological dysregulation.

Regression Analyses

Table 3 presents hazard ratios (HRs) for mortality. Advanced age is associated with higher mortality (HR = 1.09, p < .001). This result is fairly consistent across all models (HR = 1.05–1.06, p < .001 in Models 2–5). Men have a substantially higher mortality risk than women. Much of the gender difference in mortality risk can be attributed to smoking (Model 5). The mortality risk for smoking among both men and women is 200% higher than for women who have never smoked (HR = 2.02 for smoking women, HR = 2.25 for smoking men); and the mortality risks for nonsmoking men and nonsmoking women are not significantly different. We also observed some educational differences in mortality. Individuals who had junior school or higher education had a 30%–40% lower mortality risk compared to those without formal schooling, although the differences were not statistically significant. Being an urban resident with urban *hukou* is associated with almost 50% lower mortality than being a rural resident. We found little association between household expenditure and mortality. Among the indicators of physical functioning, weak grip strength, poor lung function, and poor balance are strongly

Table 3. Hazard Ratios From Weighted Cox Proportional Hazard Regression Models Predicting 4-Year Mortality, $N = 3,865$

	M1	M2	M3	M4	M5
Age	1.09(1.07–1.11)***	1.06 (1.04–1.08)***	1.06 (1.04–1.08)***	1.05 (1.03–1.08)***	1.06 (1.03–1.08)***
Men (ref = women)	1.84 (1.32–2.58)***	1.86 (1.32–2.63)***	1.99 (1.42–2.78)***	1.80 (1.25–2.59)**	
Gender × Smoking (ref = nonsmoking women)					
Smoking women					2.02 (1.13–3.59)*
Nonsmoking men					1.31 (0.76–2.28)
Smoking men					2.25 (1.53–3.33)***
Adulthood SES					
Education (ref = no formal schooling)					
Primary school	0.79 (0.52–1.22)	0.89 (0.59–1.36)	0.94 (0.62–1.41)	0.93 (0.61–1.42)	0.98 (0.65–1.49)
Junior school+	0.58 (0.33–1.02)	0.65 (0.37–1.14)	0.66 (0.39–1.14)	0.71 (0.41–1.22)	0.71 (0.41–1.23)
Urban–rural (ref = rural residency)					
Urban residency, rural *hukou*	0.83 (0.55–1.26)	0.75 (0.47–1.20)	0.79 (0.52–1.20)	0.77 (0.51–1.15)	0.77 (0.51–1.16)
Urban residency, urban *hukou*	0.57 (0.33–1.00)*	0.58 (0.33–1.01)	0.56 (0.32–0.98)*	0.53 (0.30–0.93)*	0.57 (0.33–0.98)*
Household expenditure (ref = bottom tertile)					
Middle tertile	0.79 (0.57–1.09)	0.75 (0.52–1.07)	0.75 (0.55–1.04)	0.75 (0.55–1.03)	0.73 (0.53–1.00)*
Top tertile	1.18 (0.82–1.69)	1.22 (0.84–1.75)	1.16 (0.813–1.66)	1.14 (0.79–1.64)	1.11 (0.78–1.58)
Physical assessments					
Low grip strength		1.51 (1.11–2.05)**	1.48 (1.09–2.01)*	1.45 (1.07–1.96)*	1.42 (1.05–1.92)*
Poor lung function		1.81 (1.40–2.33)***	1.79 (1.39–2.32)***	1.74 (1.34–2.26)***	1.74 (1.35–2.26)***
Poor balance		1.71 (1.07–2.72)*	1.71 (1.10–2.67)*	1.70 (1.09–2.65)*	1.72 (1.10–2.68)*
Slow walking		1.25 (0.91–1.73)	1.27 (0.92–1.76)	1.25 (0.90–1.72)	1.27 (0.92–1.74)
Diseases					
Hypertension (ref = no hypertension)					
Undiagnosed hypertension			1.28 (0.88–1.87)	1.22(0.84–1.77)	1.21(0.84–1.75)
Controlled hypertension			0.71 (0.40–1.28)	0.70 (0.40–1.23)	0.68 (0.38–1.22)
Uncontrolled hypertension			1.63 (1.14–2.33)**	1.55 (1.08–2.23)*	1.52 (1.07–2.18)*
Diabetes (ref = no diabetes)					
Undiagnosed diabetes			1.39 (0.87–2.24)	1.41 (0.88–2.27)	1.42 (0.87–2.30)
Diagnosed diabetes			1.47(1.02–2.11)*	1.43 (0.98–2.09)	1.44(0.98–2.11)
Cancer			3.55 (1.34–9.43)*	3.81 (1.44–10.05)**	3.90(1.50–10.15)**
Chronic lung disease			1.20 (0.86–1.66)	1.14 (0.82–1.59)	1.08 (0.77–1.52)
Heart problems			0.93 (0.61–1.43)	0.98 (0.63–1.52)	0.95 (0.61–1.48)
Stroke			1.02 (0.53–1.95)	1.03 (0.54–1.96)	1.02 (0.52–1.98)
Kidney disease			1.11 (0.67–1.85)	0.93 (0.53–1.62)	0.92 (0.54–1.60)
Biomarkers					
Rapid pulse				1.27 (0.75–2.15)	1.28 (0.76–2.14)
High total cholesterol				1.15 (0.74–1.77)	1.13 (0.73–1.73)
High BUN				0.92 (0.66–1.29)	0.90 (0.64–1.27)
High CRP				1.88 (1.36–2.60)***	1.87 (1.35–2.59)***
High creatinine				2.78 (1.49–5.19)**	2.65 (1.40–5.01)**
High triglycerides				0.63 (0.34–1.16)	0.62 (0.34–1.15)

Notes: BUN = blood urea nitrogen; CRP = C-reactive protein; SES = socioeconomic status. Results are weighted by the 2011 biomarker weights. Missing indicators of household expenditure and the timed walk test were included in the models. 95% Confidence intervals are in parentheses.

Statistical significance: $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$.

predictive of mortality. The HR for mortality for those with weak grip strength relative to having normal/strong grip strength is about 1.5. The HR for mortality for those with poor lung function relative to normal lung function is around 1.8. Those who failed the balance test showed about 70% higher mortality risk than those who passed the test. Regarding chronic diseases and conditions, uncontrolled hypertension is related to an about 50% greater risk of mortality. Undiagnosed diabetes is associated with about 40% higher risk but it is not statistically significant. The prevalence of self-reported cancer is very low in China; however, the mortality risk for those who reported having cancer is almost 4 times that of those who did not report cancer. Among the blood-based biomarkers, high CRP and high creatinine are consistently predictive of mortality.

Conclusions

This study investigated the links of mortality to socioeconomic characteristics, diseases, and biological and physical functioning in the older Chinese population. We began by estimating the association between adult SES and mortality with age and sex adjusted. We used three indicators (education, urban–rural, and household per capita expenditure) to represent different dimensions of adult SES. Our results show strong urban–rural differentials in the risk of mortality in 4 years. Urban residents with urban *hukou* had about 50% lower mortality risk than those living in rural areas. This difference remained after adjusting for education, household expenditure, and a variety of health measures. Our results show strong urban–rural differentials in the risk of mortality over 4 years. Urban residents with urban *hukou* had about 50% lower mortality risk than those living in rural areas. This difference remained after adjusting for education, household expenditure, and a variety of health measures. Urban residents with rural *hukou* also have a lower mortality risk than rural residents, but the magnitude of the difference is relatively small and not statistically significant. The striking urban–rural differences in social, physical, and service environments, coupled with the rigid *hukou* system, have created social divisions and stratified individuals' life experiences and risk exposure, leading to inequalities in various aspects of health and mortality. Compared to those who were born and grew up in rural areas, those who were born and live in urban areas tend to experience fewer hardships and adversities in early life, have better nutritional status and health in childhood, are more likely to have occupations that offer benefits, and have better access to high-quality health care (Gong et al., 2012; Song & Smith, 2019, 2021), thereby resulting in better health in adulthood and lower mortality risk in later life for urban residents with urban *hukou*. However, those who reside in urban areas but do not have urban *hukou* are faced with limited accessible resources and opportunities because they are not considered full citizens in urban cities and are ineligible for many vital services and welfare entitlements associated with an urban *hukou* (Song & Smith, 2019). The deprivations of early life and reduced accessibility to urban resources in adult life prevent urban residents with rural *hukou* from experiencing an urban survival advantage.

We found some educational gradient in mortality risk, but these differences are not statistically significant; household expenditures were not related to mortality risk. These findings are generally consistent with our hypotheses and the literature about SES and mortality in China and other developing countries. Several studies have reported a weak or no relationship between economic resources and mortality in other developing countries (Rosero-Bixby & Dow, 2009; Sudharsanan, 2019). However, the true relationship between adult SES and later-life mortality may be more pronounced than the results from the present study and many other studies of older adults suggest, given that mortality selection is likely to be significant in early life. Individuals who had severe adversities in their early years of life and/or those with poor childhood health may have died prior to this study; therefore, those individuals in the study sample, especially the low SES older adults and rural residents, are selectively healthier individuals. Another possibility is that those individuals who managed to survive hardships could have fostered especially strong resilience that protects them against the effects of stress, immune dysregulation, and disease and contributes to better health in old age and longevity (Fagundes et al., 2012; Pruchno & Carr, 2017; Taylor et al., 2019). In addition, because severe deprivation in early life is linked to lower SES and higher mortality risk in adulthood (Johnson & Schoeni, 2011; Neelsen & Stratmann, 2011; van den Berg et al., 2009), the association between adult SES and mortality would be expected to be strongest among those who did not survive long enough to be observed in studies of older adults. Taken together, the observed SES gradient in mortality in this study is likely to be biased toward null. In other words, our results regarding the association between adult SES and mortality are thus likely to be conservative.

Although not statistically significant at the 5% level, our results showed that older adults with junior school education have a substantially lower mortality risk than those with no formal education. Over recent decades, education in China has been expanding rapidly. The enrollment for secondary schools increased from about 50% in the 1990s to about 90% in the 2010s and the enrollment for tertiary schools also has reached more than 50% in the 2010s. As the more educated younger cohorts enter old age, mortality at older ages in China will likely decline substantially in the next decades. However, educational access and quality remain uneven between urban and rural areas. Therefore, the urban advantage in life expectancy is likely to persist or even strengthen in the future. Our study also found that smoking is a major predictor for mortality in both men and women and controlling for it eliminates the gender difference in mortality. In China, the prevalence of smoking is high in men and low in women (Liu et al., 2017); however, a recent study reported a worrying increase in adolescent smoking in both genders despite smoking-free policies being implemented in China (Wang et al., 2019). This trend may result in substantial adverse health and mortality consequences in the future.

We also found that uncontrolled blood pressure, diabetes, and cancer are associated with higher mortality risk. This finding reflects the high chronic disease burden and limited awareness, treatment, and control of such diseases. Blood pressure measures offer the opportunity to identify those with uncontrolled high blood pressure. The rise of obesity in younger cohorts has raised critical concerns about the consequences of obesity for many cardiometabolic conditions for future older cohorts. Although the prevalence of cancer reported by respondents is very low, the mortality risk for those diagnosed with cancer is almost 400% higher than for individuals who did not report cancer diagnosis. The low diagnosis rate and substantial mortality risk certainly reflect both late diagnosis and poor treatment of cancer—the top cause of death in China. Our results indicate that other biomarkers, including CRP and creatinine, and objectively measured physical functioning measures (except slow walking) are independent and strong predictors of mortality risk after accounting for diseases. These findings highlight the value of incorporating biological and performance measurements in population health surveys. Also, it is important to note that the biomarkers and physical tests that are predictive of health should be viewed as indicators of health problems or function deterioration, but not factors that cause death.

One limitation of the present study is that our analytic sample was reduced significantly by nonparticipation in the blood sample collection process and physical assessments. However, by applying biomarker weights to correct for this nonresponse, our analytic sample is representative of middle-aged and older Chinese adults. In addition, like most longitudinal cohort studies, CHARLS suffers from loss to follow-up. We conducted additional analyses to examine the characteristics of those lost to follow-up and used various approaches to assess the robustness of our results. The results obtained from different models are virtually the same. Also, because only 4-year mortality was assessed, the number of deaths was relatively small in our sample. This may be the reason that our study was unable to detect some statistically significant differences. Despite these limitations, our study used a large nationally representative sample of middle-aged and older persons to study old-age mortality determinants. Although the factors we examined in this study are intertwined and the results cannot be given causal interpretations, identifying major determinants of mortality at old ages can open up opportunities to generate future hypotheses in observational and clinical research (Puterman et al., 2020), identify priorities and targets for public policy and screening, and promote critical preventive health behaviors that are important for healthy aging in China.

Supplementary Material

Supplementary data are available at *The Journals of Gerontology, Series B: Psychological Sciences and Social Sciences* online.

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Conflict of Interest

None declared.

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