

Original Article



Low Grip Strength and Increased Mortality Hazard among Middle-Aged and Older Chinese Adults with Chronic Diseases*

XIE Kai Hong¹, HAN Xiao², ZHENG Wei Jun^{3,#}, and ZHUANG Su Fang^{4,#}

1. School of Nursing, Zhejiang Chinese Medical University, Hangzhou 311400, Zhejiang, China; 2. School of health humanities, Peking University, Beijing 100000, China; 3. School of Public Health, Zhejiang Chinese Medical University, Hangzhou 311400, Zhejiang, China; 4. Office of Disciplinary Inspection and Supervision, The Third Affiliated Hospital of Zhejiang Chinese Medical University, Hangzhou 311006, Zhejiang, China

Abstract

Objective This study aims to evaluate the association between lower grip strength and mortality hazard.

Methods We selected 10,280 adults aged 45 to 96 years old from the China Health and Retirement Longitudinal Study and used multivariate Cox proportional hazard models to assess the association of grip strength with mortality hazard. In addition, we explored the possibility of a nonlinear relationship using a 4-knot restricted spline regression.

Results We found that elevated grip strength was associated with lower mortality up to a certain threshold. The baseline quartile values of grip strength were 30, 37, and 44 kg for males and 25, 30, and 35 kg for females. After adjusting for confounders, with category 1 as the reference group, the adjusted HRs were 0.58 (0.42–0.79) in males and 0.70 (0.48–0.99) in females (category 4). We also found a linear association between grip strength values and all-cause death risk (males, $P = 0.274$; females, $P = 0.883$) using restricted spline regression. For males with a grip strength < 37 kg and females with a grip strength < 30 kg, grip strength and death were negatively associated.

Conclusion Grip strength below a sex-specific threshold is inversely associated with mortality hazard among middle-aged and older Chinese adults with chronic diseases.

Key words: Grip strength; Death; Chronic disease

Biomed Environ Sci, 2023; 36(3): 213-221 doi: 10.3967/bes2023.013

ISSN: 0895-3988

www.besjournal.com (full text)

CN: 11-2816/Q

Copyright ©2023 by China CDC

INTRODUCTION

Previous studies have explored the association of muscle-related factors with health outcomes^[1]. For most people, grip strength peaks in early adulthood and begins to decline people's fifties^[2]. Notably, grip strength has been found to be inversely associated with cardiovascular disease morbidity^[3-5], cancer

mortality^[6-8], and other mortality hazard^[9-11]. The latest data on chronic diseases worldwide predict that the number of new chronic diseases among the elderly (ECD) all over the world will increase from 12.7 million in 2008 to 21.4 million in 2030^[12], and the growing prevalence of chronic diseases is also associated with decreased normalized grip strength^[13]. Deteriorating physical functions may reduce the quality of life and increase death risks^[14].

*This study was supported by the Ministry of Education of Humanities and Social Science Project [Grant No. Y202145935].

#Correspondence should be addressed to ZHENG Wei Jun, Professor, Doctor of Medicine, Tel: 86-13505813834, E-mail: zwj@zcmu.edu.cn; ZHUANG Su Fang, Director, Bachelor Degree, Tel: 86-18958077820, E-mail: zsfzsf2021@163.com

Biographical note of the first author: XIE Kai Hong, female, born in 1997, Nurse, majoring in chronic disease prevention.

Muscular strength has been shown to predict chronic diseases^[15], morbidity, and mortality^[16]. Grip strength in particular can be measured by applying scientifically reliable tools that are simple, noninvasive, and cost-effective for nationwide surveys^[17,18]. Moreover, the tools may be used to diagnose sarcopenia and frailty across a person's lifespan^[19]. The criteria for categorizing grip strength differ among males and females, and are associated with social relationships^[20] and physical functions^[21,22]. Thus, we stratified our analysis by gender.

To date, there is a gap in research into predicting incidence of death by grip strength among middle-aged and older Chinese adults with chronic diseases, but the prospect of convenient prediction provides the impetus to explore the correlations between grip strength and mortality hazard. The purpose of this study is therefore to determine the association between grip strength and death from all causes by analyzing participants with chronic diseases from a nationally representative survey from China.

METHODS

Ethics Approval

This study was approved by an ethical review committee at Peking University (approval number IRB 00001052–11014).

Participant

The China Health and Retirement Longitudinal

Study (CHARLS) selected 24,805 participants in 10,257 households from 150 counties/districts and 450 villages within 28 provinces *via* multistage stratified probability-proportional-to-size (PPS) sampling. A baseline survey was conducted in 2011 with follow-ups in 2013, 2015, and 2018. All respondents completed a structured questionnaire on sociodemographic features, lifestyles, and health-related behaviors/conditions. The response rate of the baseline survey (2011) was 73.1%. CHARLS was approved by the Institutional Review Board at Peking University Health Science Center, and written informed consent was signed before every interview. Of the total 24,805 participants, 1,597 were excluded for being aged below 45 years old, 9,351 for having no chronic diseases, and 3,577 for not responding to grip strength examination. Therefore, 10,280 participants aged 45 to 96 years old remained for our analysis (Figure 1).

Ascertainment of Grip Strength Values

Before physical examinations, trained interviewers made sure that it would cause no harm to the participants and that participants had not reported surgery, swelling, inflammation, severe pain, injury with one or both hands, or other past contrary medical history within the last six months. Grip strength was collected by asking participants to keep squeezing the handle of a JAMAR dynamometer with an accuracy of 0.1 kg as hard as they could for several seconds before letting go. Interviewers measured grip strength of participants' right and left hands separately in two alternative

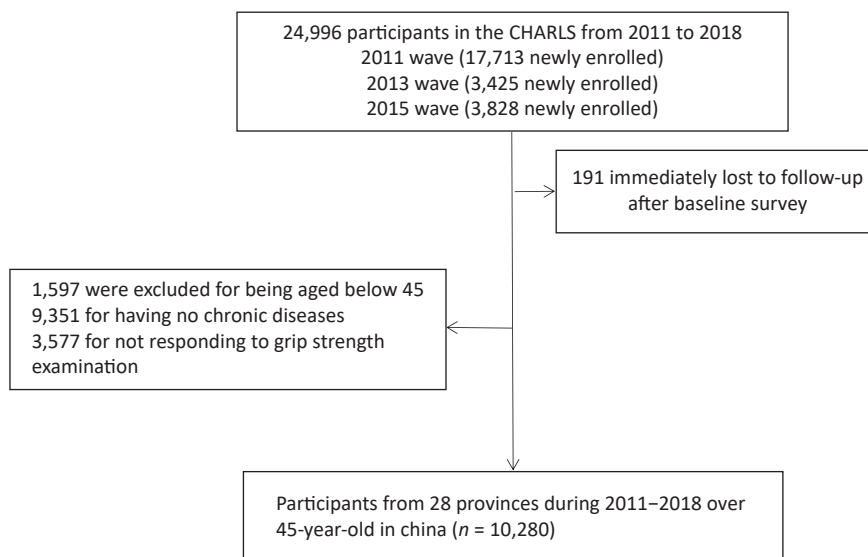


Figure 1. Flow chart of sample selection.

turns. The maximum grip strength of four measurements was recorded for the study^[22]. Values of grip strength were categorized into four subgroups by quartiles.

Measurement of Mortality Hazard

CHARLS obtained death information from registrations and certifications by asking the deceased's relatives or local communities in 2013, 2015, and 2018, or at the end of follow-up (March 31, 2019). Mortality hazard were identified as '1', survival and censorship '0'. For censored participants, survival time was defined as years of follow-up.

Covariates

Covariates encompassed demographic features, health behaviors, and physical conditions^[23]. Demographic features included age, *hukou* (household register in China), marital status, and education. Participants were classified as either married (no need for certificates) or not-married (denial of marriage experience, not living together anymore, divorce). Education was grouped by whether or not participants had finished primary school, middle or senior high school, or undergraduate training. Health-related behaviors included smoking and drinking, encoded as no such history, past lifestyle, or current engagement. Finally, physical conditions were characterized by physician-diagnosed chronic diseases (diabetes, hypertension, chronic lung disease, stroke, heart disease, and cancer), activities of daily living (ADLs), nighttime sleep or afternoon napping duration, falling down, hip fracture, physical functions, body mass index (BMI), and A body shape index (ABSI), which was calculated as $ABSI = \text{waist circumference} / (\text{BMI}^{2/3} \times \text{height}^{1/2})$ ^[24].

Statistical Analysis

For summary statistics, we employed means and standard deviations (SDs) to describe continuous variables. Categorical variables were described by frequency and percentage. We used the χ^2 test, analysis of variance, and Mann-Whitney U test to determine significance of inter-group differences. Missing values were imputed with multivariable imputation of classification or regression trees. A total of 10 imputed data sets were created and pooled into R software to perform our analysis.

To examine the association between grip strength and mortality hazard by gender, we used Cox proportional hazard models to calculate hazard

ratios (HRs) with 95% confidence intervals (CIs). Proportional hazards assumption were justified for males ($P = 0.878$) and females ($P = 0.514$). We calculated the incidence of all-cause death with the class interval set as quartiles in grip strength by gender and estimated four models. In Model 1, age was adjusted; in Model 2, BMI, marital status, educational level, *hukou*, and ABSI were adjusted; in Model 3, smoking and drinking were added; and all 20 covariates were included in Model 4. Following the literature, we controlled for significant confounders ($P < 0.1$) and some were chosen for clinical significance (fall down, hip fracture, and cancer)^[10,25-26].

To examine the association between grip strength and all-cause death further, we included grip strength in quartiles in Cox proportional hazards models with category 1 as the reference group, and potential nonlinear relationships were explored with 4-knot restricted spline regression. Restricted cubic splines with four knots at the 5th, 35th, 65th, and 95th percentiles were employed in an effort to model the association of grip strength and mortality hazard as flexibly as possible. Further, in subgroup analysis grip strength as a continuous variable was used to investigate the moderating role of the following covariates: marital status, *hukou*, smoking, drinking, falling down, diabetes, hypertension, chronic lung disease, stroke, and heart disease (physician-diagnosed). We assessed the P -values of interaction terms and probability proportion tests. In sensitivity analysis, we repeated all analyses on the original data without imputations.

RESULTS

Of the original CHARLS participants, 4,802 males (46.7%) and 5,478 females (53.3%) accepted follow-up interviews. The age of participants at baseline ranged from 45 to 96 years old, and the median number of years of follow-up was seven years. Baseline characteristics are summarized in Table 1. The quartiles of grip strength at baseline were 30, 37, and 44 kg for males and 20, 25, and 30 kg for females. The majority of participants (male, 3,618, 75.3%; female, 4,348, 79.4%) were of agricultural *hukou*. Before the follow-up, 1,106 death events had occurred, and these comprised 1,787 heart disease cases, 317 for stroke, and 1,591 for chronic lung diseases. For behavioral risk factors, 1,210 (25.2%) males and 4,796 (87.6%) females reported current tobacco use, and 2,243 (46.7%) males and 4,796 (87.6%) females reported currently drinking alcohol.

For metabolic risk factors, 3,667 (21.4%) participants reported hypertension and 903 (5.3%) reported diabetes.

Table 2 shows the association between grip strength and mortality hazard. After adjusting for confounders, with category 1 as the reference group, the adjusted HRs were 0.58 (0.42–0.79) in males and 0.70 (0.48–1.00) in females (category 4). A linear association was also found between the grip strength values and all-cause death risk (males, $P = 0.274$; females, $P = 0.883$) by using restricted spline regression. Here, we selected the median grip

strength as the reference point, for males with a grip strength < 37 kg and female with a grip strength < 30 kg, grip strength and death were negatively associated (Figures 2–3). Similar patterns were found in models of quantile values of grip strength (Table 2).

We compare the socioeconomic factors of participants before and after deleting those without chronic diseases. According to Table 3, the deleted 3,577 participants not responding to grip strength were significantly younger ($P < 0.001$), more likely not to be married ($P < 0.001$), had a non-agricultural

Table 1. Baseline characteristics of 10,280 participants according to gender

Baseline characteristics (<i>N</i> = 10,280)	Male (<i>n</i> = 4,802)				Female (<i>n</i> = 5,478)				<i>P</i>	SMD
	< 30 kg (<i>n</i> = 1,201)	30– kg (<i>n</i> = 1,200)	37– kg (<i>n</i> = 1,219)	> 44 kg (<i>n</i> = 1,182)	< 20 kg (<i>n</i> = 1,455)	20– kg (1,401)	25– kg (<i>n</i> = 1,448)	> 30 kg (<i>n</i> = 1,174)		
Age, mean (SD)	66.84 (9.45)	61.87 (8.83)	58.24 (8.23)	54.59 (7.28)	65.08 (10.44)	60.43 (9.04)	57.47 (8.50)	54.87 (7.79)	< 0.001	1.006
Education level, <i>n</i> (%)									< 0.001	0.322
No formal education	579 (48.2)	442 (36.8)	338 (27.8)	227 (19.2)	1,079 (74.2)	884 (63.1)	804 (55.5)	548 (46.7)		
Primary school	342 (28.5)	336 (28.0)	372 (30.5)	283 (23.9)	200 (13.8)	253 (18.1)	269 (18.6)	239 (20.4)		
Middle or high school	256 (21.3)	391 (32.6)	476 (39.1)	612 (51.8)	167 (11.5)	254 (18.1)	356 (24.6)	370 (31.5)		
College or above	23 (1.9)	31 (2.6)	32 (2.6)	60 (5.1)	8 (0.6)	10 (0.7)	19 (1.3)	17 (1.4)		
Married, <i>n</i> (%)									< 0.001	0.408
Yes	1,010 (84.1)	1,065 (88.8)	1,135 (93.1)	1,124 (95.1)	1,039 (71.4)	1,164 (83.1)	1,277 (88.2)	1,047 (89.2)		
No	191 (15.9)	135 (11.2)	84 (6.9)	58 (4.9)	416 (28.6)	237 (16.9)	171 (11.8)	127 (10.8)		
Hukou, <i>n</i> (%)									< 0.001	0.105
Agricultural	962 (81.7)	918 (77.4)	907 (75.4)	831 (72.3)	1,206 (84.0)	1,097 (79.9)	1,119 (78.9)	926 (79.9)		
Non-agricultural	216 (18.3)	268 (22.6)	296 (24.6)	319 (27.7)	230 (16.0)	276 (20.1)	299 (21.1)	233 (20.1)		
Smoking, <i>n</i> (%)									< 0.001	0.367
Never	632 (52.7)	665 (55.4)	707 (58.0)	691 (58.5)	112 (7.7)	107 (7.6)	81 (5.6)	59 (5.0)		
Formal	246 (20.5)	226 (18.8)	216 (17.7)	207 (17.5)	47 (3.2)	32 (2.3)	38 (2.6)	31 (2.6)		
Current	322 (26.8)	309 (25.8)	295 (24.2)	284 (24.0)	1,295 (89.1)	1,262 (90.1)	1,328 (91.8)	1,084 (92.3)		
Drinking, <i>n</i> (%)									0.068	0.078
Never	373 (31.1)	504 (42.0)	586 (48.1)	596 (50.4)	96 (6.6)	102 (7.3)	96 (6.6)	95 (8.1)		
Formal	122 (10.2)	115 (9.6)	122 (10.0)	140 (11.8)	60 (4.1)	84 (6.0)	69 (4.8)	79 (6.7)		
Current	705 (58.8)	581 (48.4)	511 (41.9)	446 (37.7)	1,298 (89.3)	1,215 (86.7)	1,283 (88.6)	1,000 (85.2)		
ADL, mean (SD)	13.1 (6.3)	10.5 (4.6)	9.6 (4.0)	8.6 (3.8)	13.5 (5.6)	11.5 (4.3)	10.9 (3.8)	10.1 (3.6)	< 0.001	0.627
Physical function, mean (SD)	13.7 (5.7)	11.12 (4.5)	10.0 (3.6)	9.1 (3.0)	14.9 (5.6)	12.8 (4.8)	11.7 (4.2)	10.9 (4.0)	< 0.001	0.673

Baseline characteristics (N = 10,280)	Male (n = 4,802)				Female (n = 5,478)				P	SMD
	< 30 kg (n = 1,201)	30– kg (n = 1,200)	37– kg (n = 1,219)	> 44 kg (n = 1,182)	< 20 kg (n = 1,455)	20– kg (1,401)	25– kg (n = 1,448)	> 30 kg (n = 1,174)		
	Sleep, mean (SD)	6.3 (2.1)	6.3 (1.8)	6.4 (1.8)	6.6 (1.6)	5.8 (2.2)	6.0 (2.0)	6.1 (1.8)		
Nap, mean (SD)	40.8 (47.3)	40.1 (43.9)	37.8 (44.9)	39.0 (41.9)	27.9 (40.1)	28.3 (41.1)	27.4 (40.1)	30.4 (42.1)	< 0.001	0.114
ABSI, mean (SD)	8.4 (3.2)	8.2 (2.5)	8.3 (3.5)	8.2 (3.4)	8.6 (3.4)	8.5 (3.7)	8.2 (1.1)	8.1 (0.8)	0.004	0.095
BMI, mean (SD)	22.1 (3.8)	22.8 (3.6)	23.6 (3.4)	24.8 (3.5)	23.4 (4.1)	24.0 (4.0)	24.7 (4.0)	25.4 (3.6)	< 0.001	0.438
Fall down, n (%)									0.263	0.627
Yes	238 (20.2)	220 (18.5)	196 (16.2)	144 (12.2)	383 (27.0)	314 (22.6)	261 (18.2)	188 (16.1)		
No	938 (79.8)	970 (81.5)	1,012 (83.8)	1,034 (87.8)	1,037 (73.0)	1,073 (77.4)	1,176 (81.8)	982 (83.9)		
Hip fraction, n (%)									0.327	0.034
Yes	31 (2.6)	18 (1.5)	23 (1.9)	15 (1.3)	32 (2.3)	28 (2.0)	25 (1.7)	17 (1.5)		
No	1,145 (97.4)	1,172 (98.5)	1,184 (98.1)	1,164 (98.7)	1,389 (97.7)	1,357 (98.0)	1,413 (98.3)	1,153 (98.5)		
History of comorbidities, n (%)										
Hypertension	439 (36.6)	394 (32.8)	385 (31.6)	407 (34.4)	607 (41.7)	494 (35.3)	518 (35.8)	423 (36.0)	< 0.001	0.187
Cancer	7 (1.0)	9 (1.3)	10 (1.4)	3 (0.4)	6 (0.7)	9 (1.1)	17 (2.0)	6 (0.9)	0.463	0.041
Chronic lung diseases	293 (24.4)	238 (19.8)	211 (17.3)	157 (13.3)	236 (16.2)	178 (12.7)	171 (11.8)	107 (9.1)	< 0.001	0.278
Heart disease	215 (17.9)	189 (15.8)	170 (13.9)	151 (12.8)	301 (20.7)	276 (19.7)	252 (17.4)	233 (19.8)	0.018	0.075
Diabetes	109 (9.1)	88 (7.3)	98 (8.0)	85 (7.2)	147 (10.1)	135 (9.6)	134 (9.3)	107 (9.1)	< 0.001	0.098
Stroke	77 (6.4)	41 (3.4)	31 (2.5)	28 (2.4)	61 (4.2)	42 (3.0)	37 (2.6)	19 (1.6)	< 0.001	0.075

Note. P-values are based on χ^2 or analysis of variance or Mann-Whitney U test. Calculated as weight in kilograms divided by height in meters squared. Measured in the sub-population of 10,280 participants. Grip strength grouped by quartiles. SMD, SD mean difference. Missing data instances: four for age, three for educational level, four for smoking, two for drinking, 177 for *hukou*, 114 for fall down, 114 for hip fraction, 260 for sleep hour, and 185 for nap. SD, standard deviation.

Table 2. Incidence of mortality hazard according to grip strength

Sex	Outcomes death of all causes			HR (95% CI)			
	Grip strength values (kg)	Cases, No	Incidence rate, per 1,000 person-years	Model 1	Model 2	Model 3	Model 4
Male (n = 4,802)	< 30	335	12.3	1 [Reference]	1 [Reference]	1 [Reference]	1 [Reference]
	30–	160	5.9	0.60 (0.50–0.73)*	0.64 (0.52–0.77)*	0.64 (0.52–0.77)*	0.75 (0.61–0.91)*
	37–	118	4.3	0.51 (0.40–0.64)*	0.55 (0.44–0.70)*	0.55 (0.44–0.70)*	0.68 (0.54–0.87)*
	> 44	62	2.3	0.38(0.28–0.51)*	0.44(0.30–0.60)*	0.45 (0.33–0.60)*	0.58 (0.42–0.79)*
Female (n = 5,478)	< 20	240	7.4	1 [Reference]	1 [Reference]	1 [Reference]	1 [Reference]
	20–	93	2.9	0.60 (0.47–0.77)*	0.61 (0.48–0.78)*	0.62 (0.48–0.79)*	0.71 (0.55–0.91)*
	25–	58	1.8	0.48 (0.35–0.64)*	0.51 (0.38–0.69)*	0.52 (0.38–0.70)*	0.62 (0.45–0.84)*
	> 30	40	1.2	0.53 (0.37–0.76)*	0.57 (0.39–0.81)*	0.58 (0.40–0.83)*	0.70 (0.48–0.99)

Note. Model 1 was adjusted for age. Model 2 was adjusted as model 1 plus BMI, ABSI, educational level, marriage, and *hukou*. Model 3 was adjusted as model 2 plus smoking, and drinking. All 20 items were entered simultaneously in model 4. HR, hazard ratio.

hukou ($P < 0.001$), and had a higher educational level ($P < 0.001$) than those performing grip strength examination.

The figures show *HRs* for death of all causes adjusted for age, *hukou*, marital status, education, smoking, drinking, history of diabetes, hypertension, heart disease, stroke, chronic lung disease, cancer, history of falls, hip fraction, ADL, physical function, BMI, ABSI, and sleep/nap duration. Data were fitted by a restricted spline Cox proportional hazard regression model. The reference values were the medians: 37 kg for males ($P < 0.001$) and 30 kg for females ($P = 0.008$).

Figure 4 shows the association between grip strength and mortality hazard stratified by gender. There was no interaction effect between handgrip strength and mortality hazard ($P > 0.05$) for either gender. Specifically, between-group differences

were statistically insignificant for any covariate. The *HRs* were insignificant or close to 1 in all subgroups. Additionally, the sensitivity analysis results did not significantly change in category 4 [males, 0.62 (0.44–0.86), $P = 0.004$; females, 0.53 (0.35–0.80), $P = 0.002$].

The figure show hazard ratios (*HRs*) and 95% *CI*s for mortality hazard adjusted for age, *hukou*, marital status, education, smoking, drinking, history of diabetes, hypertension, chronic lung disease, heart disease, stroke, cancer, history of falls, hip fraction, ADL, physical function, BMI, ABSI, and sleep/nap duration.

DISCUSSION

Using a nationally representative cohort survey of 10,280 middle-aged and older Chinese adults with

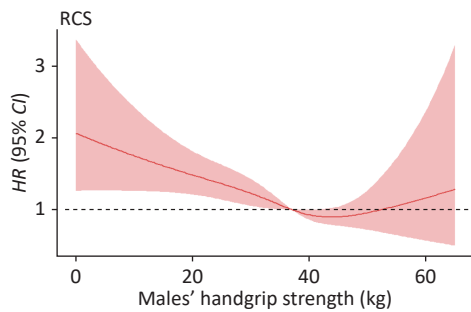


Figure 2. Adjusted hazard ratios (*HRs*) for mortality hazard according to grip strength in males. RCS, restricted cubic spline.

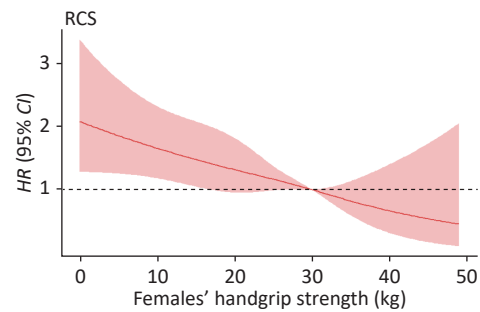


Figure 3. Adjusted hazard ratios (*HRs*) for mortality hazard according to grip strength in females. RCS, restricted cubic spline.

Table 3. Socioeconomic factor comparison between the population that responded to and did not respond to grip strength examination

Variables	Level	No response, <i>n</i> (%) <i>n</i> = 3,577	Response, <i>n</i> (%) <i>n</i> = 10,280	<i>P</i> *
Gender, <i>n</i> (%)	Males	1,693 (47.4)	4,795 (46.7)	0.469
	Females	1,879 (52.6)	5,478 (53.3)	
Age [mean (SD)]		58.16 (11.57)	60.02 (9.72)	< 0.001
<i>hukou</i> , <i>n</i> (%)	Agriculture	2,290 (67.5)	7,966 (79.4)	< 0.001
	Non-agriculture	1,104 (32.5)	2,073 (20.6)	
Education, <i>n</i> (%)	No formal education	1,422 (39.9)	4,901 (47.7)	< 0.001
	Primary school	717 (20.1)	2,294 (22.3)	
	Middle or high school	1,244 (34.9)	2,882 (28.0)	
	College or above	185 (5.2)	200 (1.9)	
Marriage, <i>n</i> (%)	Yes	2,700 (86.0)	8,402 (94.8)	< 0.001
	No	438 (14.0)	459 (5.2)	

Note. * *P* is used for comparison of dichotomous variables.

chronic diseases we found that elevated grip strength was linearly associated lower mortality hazard.

We found that grip strength is a predictor of death in the whole population in males and females. Our findings are consistent with previous studies on population aged 35 and above in Asia^[27,28], healthy middle-aged and older adults in Europe^[29-32], older adults in Russia^[33], participants aged over 20 in the US^[4], and the Prospective Urban-Rural Epidemiology (PURE) study using cohorts of varying incomes and sociocultural settings in 17 countries^[34]. Some studies have found muscle strength not to be predictive of mortality in women^[35,36]. However short follow-up times in these studies may have resulted in the findings of no significant statistical differences.

We found a statistically significant association among both males and females: negative correlation between death risk and grip strength in males with a grip strength < 37 kg and in females

with a grip strength < 30 kg. We also found that death risk varies more with grip strength in men than in women. This finding is consistent with a meta-analysis of 42 prospective cohort studies^[5] where the observed decline in grip strength was a linear independent predictor of all-cause mortality. However, muscle strength was not found to be predictive of death among women in some previous studies^[37,38]. The threshold of significant association between grip strength and death risk were larger among males (37 kg > 30 kg), and the range of grip strength predicting death risk was also wider, which may be responsible for different patterns among genders. One possible explanation for gender differences might be endocrine system modulation. Growth differentiation factor (GDF15)^[39] is essential for optimal physical performance, and GDF15 concentrations increase with age, higher in men than women. Elevated GDF15 is negatively associated with muscle mass

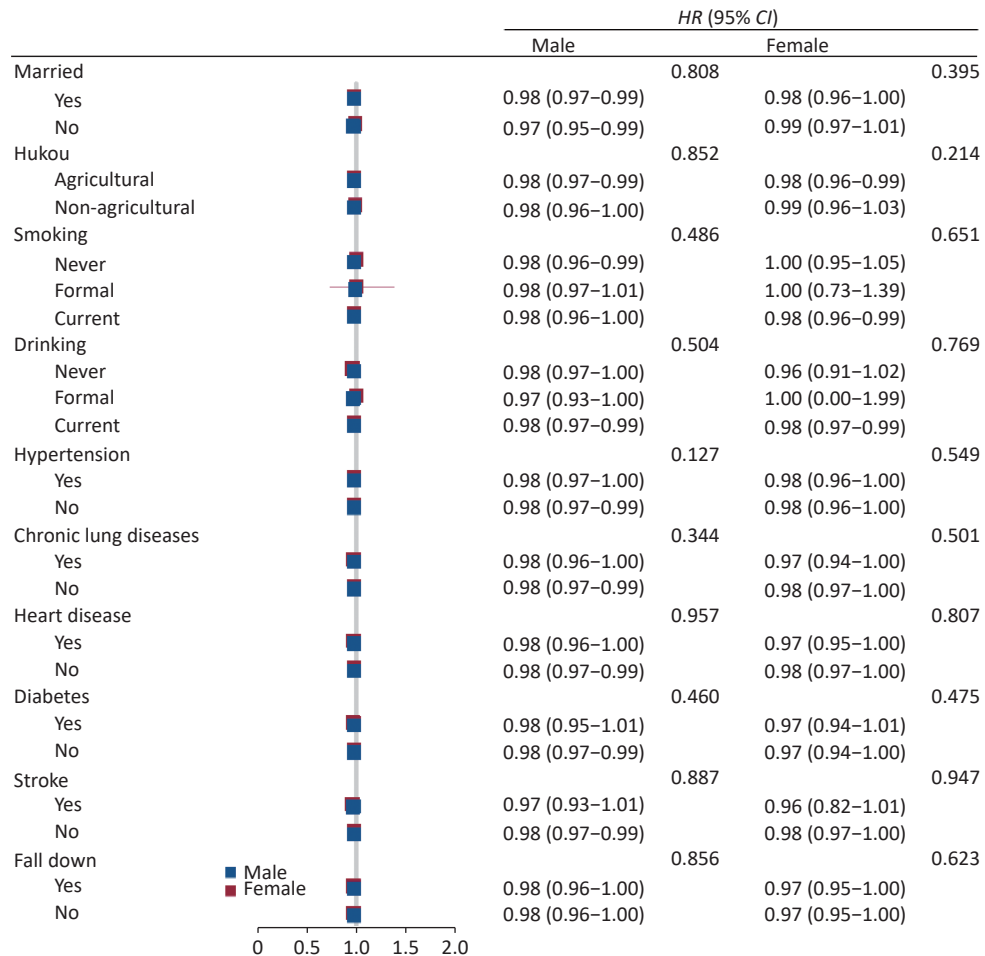


Figure 4. Gender-specific association between grip strength values and mortality hazard stratified by different factors.

among older males, while among women, there is no significant difference between those with elevated GDP15 and others. Myostatin has received recognition as a potent inhibitor of skeletal muscle growth, although it may only have adverse effects in elderly men^[40]. More efforts are needed to identify the specific mechanisms.

We explored all-cause death in middle-aged and older Chinese patients with chronic diseases using a nationally representative and dynamic long-term follow-up cohort study, CHARLS, which used an objective and standardized test for the assessment of grip strength. Furthermore, its nationally representative population-based PPS sampling likely further improved the reliability of the study. However, our exclusion of participants without chronic diseases may have increased the likelihood of reverse causality and reduce the statistical power of our tests. All-cause death captures all deaths and therefore may include death caused by external forces not directly related to health, such as car accidents.

CONCLUSION

In conclusion, low grip strength among Chinese adults was linearly associated with higher mortality hazard, though the specific mechanisms for this were unclear.

DECLARATIONS

The authors declare that all methods were performed in accordance with the relevant guidelines and regulations.

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY OF DATA AND MATERIALS

Publicly available datasets were analyzed in this study. This data can be found here: <https://charls.pku.edu.cn/en/>.

COMPETING INTERESTS

The authors declare that they have no competing interests.

AUTHOR CONTRIBUTIONS

XIE Kai Hong planned the study, supervised the

data analysis, and wrote the paper. HAN Xiao performed all statistical analyses and contributed to revising the paper. ZHUANG Su Fang and ZHENG Wei Jun helped find the source and analysis method. All authors have read and approved the manuscript and we have no conflicts of interest.

ACKNOWLEDGEMENT

The authors thank the participants of CHARLS project and AiMi Academic Services (www.aimieditor.com) for the English language editing and review services.

Received: June 29, 2022;

Accepted: September 20, 2022

REFERENCES

1. Marques A, Henriques-Neto D, Peralta M, et al. Exploring grip strength as a predictor of depression in middle-aged and older adults. *Sci Rep*, 2021; 11, 15946.
2. Dodds RM, Syddall HE, Cooper R, et al. Grip strength across the life course: normative data from twelve British studies. *PLoS One*, 2014; 9, e113637.
3. Liu YH, Lee DC, Li YH, et al. Associations of resistance exercise with cardiovascular disease morbidity and mortality. *Med Sci Sports Exerc*, 2019; 51, 499–508.
4. Lawman HG, Troiano RP, Perna FM, et al. Associations of relative handgrip strength and cardiovascular disease biomarkers in U. S. adults, 2011-2012. *Am J Prev Med*, 2016; 50, 677–83.
5. Wu YL, Wang WJ, Liu TW, et al. Association of grip strength with risk of all-cause mortality, cardiovascular diseases, and cancer in community-dwelling populations: a meta-analysis of prospective cohort studies. *J Am Med Dir Assoc*, 2017; 18, 551.e17–35.
6. Celis-Morales CA, Lyall DM, Steell L, et al. Associations of discretionary screen time with mortality, cardiovascular disease and cancer are attenuated by strength, fitness and physical activity: findings from the UK Biobank study. *BMC Med*, 2018; 16, 77.
7. Zhuang CL, Zhang FM, Li W, et al. Associations of low handgrip strength with cancer mortality: a multicentre observational study. *J Cachexia Sarcopenia Muscle*, 2020; 11, 1476–86.
8. García-Hermoso A, Ramírez-Vélez R, Peterson MD, et al. Handgrip and knee extension strength as predictors of cancer mortality: a systematic review and meta-analysis. *Scand J Med Sci Sports*, 2018; 28, 1852–8.
9. Kim S, Choi S, Yoo J, et al. Association of grip strength with all-cause mortality and cause-specific mortality: analysis of the Korean longitudinal study of ageing (2006-2016). *Korean J Fam Pract*, 2019; 9, 438–47.
10. Lee I, Kang H. The Combined impact of low hand grip strength and co-morbidity on the risk of all-cause mortality in Korean middle-aged and older adults. *Exerc Sci*, 2020; 29, 40–50.
11. García-Hermoso A, Caverio-Redondo I, Ramírez-Vélez R, et al. Muscular strength as a predictor of all-cause mortality in an apparently healthy population: a systematic review and meta-analysis of data from approximately 2 million men and women. *Arch Phys Med Rehabil*, 2018; 99, 2100–13.e5.
12. Xu XC, Huang XQ, Zhang XL, et al. Family economic burden of

- elderly chronic diseases: evidence from China. *Healthcare (Basel)*, 2019; 7, 99.
13. Yao SS, Meng XF, Cao GY, et al. Associations between multimorbidity and physical performance in older Chinese adults. *Int J Environ Res Public Health*, 2020; 17, 4546.
 14. Lo YP, Chiang SL, Lin CH, et al. Effects of individualized aerobic exercise training on physical activity and health-related physical fitness among middle-aged and older adults with multimorbidity: a randomized controlled trial. *Int J Environ Res Public Health*, 2021; 18, 101.
 15. Gu YQ, Dong J, Meng G, et al. Handgrip strength as a predictor of incident hypertension in the middle-aged and older population: the TCLSIH cohort study. *Maturitas*, 2021; 150, 7–13.
 16. Shields GS, Spahr CM, Slavich GM. Psychosocial interventions and immune system function: a systematic review and meta-analysis of randomized clinical trials. *JAMA Psychiatry*, 2020; 77, 1031–43.
 17. Kim SW, Park HY, Jung H, et al. Estimation of health-related physical fitness using multiple linear regression in Korean adults: national fitness award 2015–2019. *Front Physiol*, 2021; 12, 668055.
 18. Larcher B, Zanolin-Purin D, Vonbank A, et al. Usefulness of handgrip strength to predict mortality in patients with coronary artery disease. *Am J Cardiol*, 2020; 129, 5–9.
 19. Sousa-Santos AR, Amaral TF. Differences in handgrip strength protocols to identify sarcopenia and frailty - a systematic review. *BMC Geriatr*, 2017; 17, 238.
 20. Lee K. The association between occupational categories and grip strength in Korean male workers. *Int Arch Occup Environ Health*, 2021; 94, 567–74.
 21. Yu B, Steptoe A, Niu KJ, et al. Social isolation and loneliness as risk factors for grip strength decline among older women and men in China. *J Am Med Dir Assoc*, 2020; 21, 1926–30.
 22. Ahrenfeldt LJ, Scheel-Hincke LL, Kjærgaard S, et al. Gender differences in cognitive function and grip strength: a cross-national comparison of four European regions. *Eur J Public Health*, 2019; 29, 667–74.
 23. Li HB, Zheng DQ, Li ZW, et al. Association of depressive symptoms with incident cardiovascular diseases in middle-aged and older Chinese adults. *JAMA Netw Open*, 2019; 2, e1916591.
 24. Cho HW, Chung W, Moon S, et al. Effect of sarcopenia and body shape on cardiovascular disease according to obesity phenotypes. *Diabetes Metab J*, 2021; 45, 209–18.
 25. Christakoudi S, Tsilidis KK, Muller DC, et al. A Body Shape Index (ABSI) achieves better mortality risk stratification than alternative indices of abdominal obesity: results from a large European cohort. *Sci Rep*, 2020; 10, 14541.
 26. Gao JX, Qiu YD, Hou YF, et al. Influencing factors for the decline of limb muscle strength and the association with all-cause mortality: evidence from a nationwide population-based cohort study. *Aging Clin Exp Res*, 2022; 34, 399–407.
 27. Sasaki H, Kasagi F, Yamada M, et al. Grip strength predicts cause-specific mortality in middle-aged and elderly persons. *Am J Med*, 2007; 120, 337–42.
 28. Kim GR, Sun JY, Han M, et al. Impact of handgrip strength on cardiovascular, cancer and all-cause mortality in the Korean longitudinal study of ageing. *BMJ Open*, 2019; 9, e027019.
 29. Cai YN, Liu L, Wang JY, et al. Linear association between grip strength and all-cause mortality among the elderly: results from the SHARE study. *Aging Clin Exp Res*, 2021; 33, 933–41.
 30. Yates T, Zaccardi F, Dhalwani NN, et al. Association of walking pace and handgrip strength with all-cause, cardiovascular, and cancer mortality: a UK Biobank observational study. *Eur Heart J*, 2017; 38, 3232–40.
 31. Celis-Morales CA, Welsh P, Lyall DM, et al. Associations of grip strength with cardiovascular, respiratory, and cancer outcomes and all cause mortality: prospective cohort study of half a million UK Biobank participants. *BMJ*, 2018; 361, k1651.
 32. Tikkanen E, Gustafsson S, Ingelsson E. Associations of Fitness, physical activity, strength, and genetic risk with cardiovascular disease: longitudinal analyses in the UK Biobank Study. *Circulation*, 2018; 137, 2583–91.
 33. Turusheva A, Frolova E, Degryse JM. Age-related normative values for handgrip strength and grip strength's usefulness as a predictor of mortality and both cognitive and physical decline in older adults in northwest Russia. *J Musculoskelet Neuronal Interact*, 2017; 17, 417–32.
 34. Leong DP, Teo KK, Rangarajan S, et al. Prognostic value of grip strength: findings from the Prospective Urban Rural Epidemiology (PURE) study. *Lancet*, 2015; 386, 266–73.
 35. Minneci C, Mello AM, Mossello E, et al. Comparative study of four physical performance measures as predictors of death, incident disability, and falls in unselected older persons: the insufficienza Cardiaca negli Anziani Residenti a Dicomano Study. *J Am Geriatr Soc*, 2015; 63, 136–41.
 36. Veronese N, Stubbs B, Fontana L, et al. A comparison of objective physical performance tests and future mortality in the elderly people. *J Gerontol A Biol Sci Med Sci*, 2017; 72, 362–8.
 37. Eekhoff EMW, van Schoor NM, Biedermann JS, et al. Relative importance of four functional measures as predictors of 15-year mortality in the older Dutch population. *BMC Geriatr*, 2019; 19, 92.
 38. Arvandi M, Strasser B, Meisinger C, et al. Gender differences in the association between grip strength and mortality in older adults: results from the KORA-age study. *BMC Geriatr*, 2016; 16, 201.
 39. Herpich C, Franz K, Ost M, et al. Associations between serum GDF15 concentrations, muscle mass, and strength show sex-specific differences in older hospital patients. *Rejuvenation Res*, 2021; 24, 14–9.
 40. Tay L, Ding YY, Leung BP, et al. Sex-specific differences in risk factors for sarcopenia amongst community-dwelling older adults. *Age (Dordr)*, 2015; 37, 121.