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Original research

Association of handgrip strength with all-cause mortality: a nationally longitudinal cohort study in China

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ABSTRACT

Objectives: Handgrip strength is considered a vital and reliable measure of comprehensive physical assessments, whereas the association of handgrip strength with overall mortality risk among Chinese adults was less studied. We prospectively investigated the association between handgrip strength and all-cause mortality among Chinese middle-aged and older people based on data from the China Health and Retirement Longitudinal Study (CHARLS).[3]
Design: Longitudinal cohort study.
Methods: Grip strength was assessed for both hands by a dynamometer. Odds ratios (ORs)[4] and 95 % confidence intervals (CIs)[5] were estimated applying logistic regression models with adjustments for age, body mass index, ethnicity, education level, annual household income, marital status, drinking, smoking, physical activity, and medical insurance among men and women. Deaths were ascertained by each follow-up survey in which the household member who lived with the participants were inquired.
Results: Over an average follow-up period of approximately 8 years among the screened 11,618 participants ≥45 years old, 1290 deaths were documented. The age range was 45–93 for men and 45–96 for women. Greater handgrip strength was associated with a lower overall mortality risk, with adjusted ORs (comparing with extreme tertiles) of 0.47 (95 % CI: 0.35–0.64; *P*-trend<0.001) in men and 0.51 (95 % CI: 0.24–1.08; *P*-trend = 0.059) in women. Such inverse association seemed stronger among younger men (OR = 0.29, 95 % CI: 0.18–0.45), compared with the older men (OR = 0.49, 95 % CI: 0.33–0.73; *P*-interaction = 0.023).
Conclusions: Handgrip strength was inversely associated with all-cause mortality risk, especially among the younger men. Further investigations are warranted to elucidate the underlying mechanism.

Key messages

Handgrip strength was inversely associated with all-cause mortality.

For men, those middle-aged with stronger handgrip strength would greater decrease the risk of overall mortality than older men.

Practical implications

Handgrip strength is a cheaper and more dependable measure of comprehensive physical assessments.

There is an inverse relationship between handgrip strength and all-cause mortality, but less attention was paid to the Chinese adults aged 45 and above.

The CHARLS represents middle-aged and older people in China.

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[3] CHARLS: China Health and Retirement Longitudinal Study.
[4] ORs: odds ratios.
[5] CIs: confidence intervals.

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Increasing handgrip strength might significantly reduce the risk of death and increase life expectancy.

1. Introduction

All-cause mortality is an indicator of the population's overall health, and its relation to healthcare and socioeconomic problems has been explored previously.[1] Therefore, it is important to investigate the driving forces behind all-cause mortality. In China, it is reported that the all-cause mortality rate increased from the year 2005 to 2018, rising from 685.37 per 100,000 to 755.54 per 100,000.[2] The increased prevalence of all-cause mortality is multifactorial etiology and unclear. Identifying modifiable risk factors related to a decreased probability of all-cause mortality has substantial public health implications.

Involving the motion of fingers and wrist and forearm muscles,[3] handgrip strength has been proved to be an easy, inexpensive, and reliable measure in comprehensive physical assessments.[4,5] Weak handgrip strength has been proved to be linked with poor physical outcomes and higher total mortality in Korean, European, and US populations.[4–7] However, to our knowledge, the relationship between handgrip strength and all-cause mortality risk was less studied in China. As reported in previous research, body compositions and muscle strength are different with age.[8] Aging also leads to impaired function and increased vulnerability to death.[9] Although the association between handgrip strength and hypertension in specific Chinese populations was reported in previous literature,[10,11] to pay attention to the state of health of middle-aged and older adults, a research in this specific cohort in China is thus urgently needed.

Our study aimed to investigate the association between handgrip strength and all-cause mortality among middle-aged and older adults in China, using data from the China Health and Retirement Longitudinal Study (CHARLS), a nationwide sample of Chinese residents. We hypothesized that handgrip strength was inversely linked with overall mortality risk in Chinese middle-aged and older people.

2. Methods

The CHARLS, a representative cohort study, randomly assesses and collects information on individuals and households' social, economic, and health conditions from 450 urban communities and rural villages across 28 provinces in China.[12] Applying multistage stratified Probability Proportionate to Size Sampling (PPS),[6] 17,708 participants aged 45 and above were selected from the CHARLS baseline survey. Participants were initially interviewed and followed up via a face-to-face computer-assisted personal interview (CAPI)[7] every two or three years.[12] Detailed information on the CHARLS is available on the website: http://charls.pku.edu.cn/en.

In this study, data about these candidates were extracted from a baseline investigation in 2011–2012 (wave 1), 2014 (life history survey), and follow-up investigations in 2013, 2015, and 2018. In the follow-up surveys, we excluded individuals <45 years, with incomplete handgrip strength information or missing death data. Consequently, 11,618 participants were involved in the final stage in 2018 (Supplementary Fig. 1). Peking University's Ethical Review Committee approved the study protocol (IRB: 0000105211015). All participants signed informed consents before the trial.

To measure handgrip strength, interviewers asked interviewees, “Did your hand have surgery, swell, inflammation, pain, or injury?” If interviewees' answers were no and willing to do the handgrip strength measurement, interviewers would demonstrate the dynamometer's use before the measurement. And then, participants held the dynamometer with their forearm resting on an armrest and their elbow bent to a 90 angle. Afterwards, participants were guided to clench the dynamometer's handle with their maximal strength for 3 s. The strengths of both hands were assessed. The right and left-hand values were added and divided by 2 to calculate the average value.[13]

All deaths occurred from April 2011 to March 2019, and the baseline survival status of the participants was investigated in 2011–2012 before the follow-up. All death data were obtained from 2013, 2014 (life history survey), 2015, and 2018, and the range of the follow-up period was about 8 years. Interviewers ascertained the survival status of the participants by field investigation with the CAPI system during the four-time follow-ups. Interviewers went to the residence of the participants. If the participants died, interviewers would collect related information by asking the household member who lived with the participants.

At baseline, age, body height and weight, gender, ethnicity, education degree, annual household income, marital status, drinking, smoking, physical activity, and medical insurance status were gathered by experienced interviewers via a standard questionnaire in the field investigation. Body mass index (BMI)[8] was estimated by dividing weight (kg) by the square of the height (m^2). Physical activity was assessed via a standard questionnaire which was based on International Physical Activity Questionnaire (IPAQ),[14,15] and was categorized into four levels. Physical activity status was first confirmed by asking participants whether they had the habits of daily physical exercise. Those interviewees who answered no were classified as “none”. If participants affirmed they had, they would be further inquired about their weekly exercise. Specifically, vigorous intensity represented that participants breathed harder than normal and participated in several heavy activities such as plow, aerobics, lifting with a heavy load, and fast bicycling. Moderate level meant participants' breath was, to some extent, harder than normal, and they may participate in some activities such as mopping the floor and light lifting. Some activities for relaxation and recreation, such as walking, were categorized as mild. Medical insurance status was collected from participants' responses, “are you the policyholder/primary beneficiary of any types of health insurance listed below?”. Drinking and smoking were obtained from lifestyle and health behaviors questionnaires. Participants who drank any alcohol more than once over the past year were considered as current drinkers, and former drinkers were those who used to drink any alcohol more than once a year and were not drinking at the moment, and never drinkers meant they never had an alcoholic drink. Further details of each variable can be found on the CHARLS website.

The mean ± standard deviation was utilized to describe continuous variables. All categorical variables were performed using number and proportion (%). Differences among categorical variables were examined by a Chi-square test, whereas one-way ANOVA checked continuous variables' differences. Handgrip strength was classified into low, middle, and high (tertile 1, tertile 2, and tertile 3).

Univariate logistic regression analyses were used to explore potential confounders (including age, BMI, ethnicity, education level, annual household income, marital status, drinking, smoking, physical activity, and medical insurance status) with handgrip strength and overall mortality. And multivariate logistic regression analyses were performed in men and women, respectively. Model 1 was adjusted for age. Model 2 was additionally adjusted for ethnicity, education level, annual household income, marital status, and medical insurance. Model 3 was further adjusted for BMI, drinking, smoking, and physical activity. Meanwhile, trend tests were performed in terms of tertiles of handgrip strength.

We tested whether age (≤65, >65 years), BMI (≤23, >23 kg/m^2), education degree (<middle school, ≥middle school), household annual income (≤30,000, >30,000 yuan), marital status (live with a spouse, live without a spouse), drinking (never drinker, ever drinker, current drinker), smoking (never smoker, ever smoker, current smoker), medical insurance status (no, yes), and physical activity (none, mild,

[6] PPS: Probability Proportionate to Size Sampling
[7] CAPI: face-to-face computer-assisted personal interview
[8] BMI: body mass index

moderate, vigorous) modified the relationship of grip strength with overall mortality. Stratified analyses were performed to profoundly explore the association of grip strength with deaths from all causes in the 8-year follow-up to further detect the association of handgrip strength with all-cause mortality.

Several analyses were performed to further validate the stabilization of the results: (1) individuals who died between 2011 and 2013 were excluded via a full model. (2) Based on five replications and a chained equation approach method, multiple imputations were used to deal with the missing data. (3) Participants with cardiovascular disease (CVD) and cancer at baseline were excluded. (4) We considered that the dominant hand might be essential in measuring handgrip strength. Thus, the primary results conducted the maximal handgrip strength assessed by the dominant hand. (5) We further divided the handgrip strength into percentiles[16] and conducted the results. (6) We also calculated the main results with a relative handgrip strength value.

Analyses were performed using Empower (R) (http://www.empowerstats.com, X&Y solutions, Boston, Massachusetts, USA) and R (http://www.R-project.org; version 3.6.3). It was considered statistically significant when a two-sided P value was <0.05.

3. Results

Based on tertiles of handgrip strength, Table 1 presented the baseline characteristics of the participants. 11,618 participants consisted of 6055 women (45–96 years old) and 5562 men (45–93 years old) with complete handgrip strength and survival data entered the longitudinal analyses. Of these subjects, the mean of low, middle, and high grip strength (tertile 1, tertile 2, and tertile 3) was 19.03 ± 4.54 kg, 29.06 ± 2.46 kg, and 41.10 ± 6.16 kg, respectively. In general, the participants with higher handgrip strength than those with lower handgrip strength tended to be male, Han, smoker, drinker, younger age, keep relatively higher BMI, have higher education level and higher household annual income, live with a spouse, have moderate and vigorous physical activity, and hold medical insurance. Those who died were more likely to be male, have low handgrip strength, be older, keep low BMI, hold low education level, have low income, live without a spouse, have a drinking history, keep smoking, have no or mild physical activity, and lose protection from medical insurance (Supplementary Table1).

Tables 2 and 3 demonstrated univariate and multivariate analysis between characteristics of participants with mortality during the follow-up. In univariate factor analysis, we analyzed the relationship between each factor [age, BMI, handgrip strength (tertiles), gender (male, female), ethnicity (Han, other), education level (<middle school, ≥middle school), household annual income (≤30,000, >30,000 yuan), marital status (live with a spouse, live without a spouse), drinking (never, ever, current), smoking (never, ever, current), physical activity (none, mild, moderate, vigorous), and medical insurance (no, yes)] and all-cause mortality. The inverse association of all-cause mortality with handgrip strength (tertiles) was significant (odds ratio tertile 2 [OR]: 0.62, 95 % CI: 0.54–0.71; and tertile 3 [OR]: 0.40, 95 % CI: 0.34–0.46, compared with tertile 1) after univariate analysis. The negative association of handgrip strength with mortality remained robust in males (adjusted ORs: 0.56, 95 % CI: 0.45–0.70 for tertile 2 and 0.33, 95 % CI:

Table 1
Baseline characteristics of participants according to tertiles of handgrip strength.

Characteristic	Handgrip strength			
	Tertile 1	Tertile 2	Tertile 3	*P*-value
N	3871	3860	3887	
Handgrip strength (kg)	19.03 ± 4.54	29.06 ± 2.46	41.10 ± 6.16	<0.001
Relative handgrip strength	0.85 ± 0.24	1.27 ± 0.23	1.76 ± 0.35	<0.001
Age(years)	63.31 ± 10.36	59.00 ± 9.22	56.44 ± 7.90	<0.001
BMI (kg/m^2)	23.08 ± 4.14	23.54 ± 4.13	23.75 ± 3.55	<0.001
Gender, %				<0.001
Male	611 (15.78 %)	1577 (40.87 %)	3374 (86.80 %)	
Female	3260 (84.22 %)	2282 (59.13 %)	513 (13.20 %)	
Ethnicity, %				0.007
Han	3236 (92.75 %)	3264 (92.62 %)	3378 (94.30 %)	
Other	253 (7.25 %)	260 (7.38 %)	204 (5.70 %)	
Education level, %				<0.001
<Middle school	3280 (84.84 %)	2794 (72.38 %)	2044 (52.60 %)	
≥Middle school	586 (15.16 %)	1066 (27.62 %)	1842 (47.40 %)	
Household annual income (yuan), %				<0.001
≤30,000	2777 (80.24 %)	2673 (74.37 %)	2519 (68.40 %)	
>30,000	684 (19.76 %)	921 (25.63 %)	1164 (31.60 %)	
Marital status, %				<0.001
Living with spouse	2897 (74.86 %)	3247 (84.12 %)	3496 (89.94 %)	
Living without spouse	973 (25.14 %)	613 (15.88 %)	391 (10.06 %)	
Drinking status, %				<0.001
Never	2958 (76.61 %)	2443 (63.31 %)	1396 (35.93 %)	
Abstainer	268 (6.94 %)	343 (8.89 %)	369 (9.50 %)	
Current	635 (16.45 %)	1073 (27.81 %)	2120 (54.57 %)	
Smoking status, %				<0.001
Never	3113 (81.03 %)	2529 (65.81 %)	1294 (33.44 %)	
Former	177 (4.61 %)	278 (7.23 %)	546 (14.11 %)	
Current	552 (14.37 %)	1036 (26.96 %)	2030 (52.45 %)	
Physical activity, %				<0.001
None	222 (20.90 %)	160 (9.60 %)	122 (7.69 %)	
Mild	449 (28.03 %)	343 (20.58 %)	304 (19.16 %)	
Moderate	469 (29.28 %)	538 (32.27 %)	452 (28.48 %)	
Vigorous	462 (28.84 %)	626 (37.55 %)	709 (44.68 %)	
Missing	2269 (58.62 %)	2193 (56.81 %)	2300 (59.17 %)	
Medical insurance status, %				0.022
No	262 (6.81 %)	231 (6.00 %)	206 (5.31 %)	
Yes	3584 (93.19 %)	3618 (94.00 %)	3672 (94.69 %)	

Values were means ± SD or n (percentages).
Values of polytomous variables may not sum to 100 % due to rounding.

Table 2
Univariate analysis between characteristics of participants and all-cause mortality.

Variables	Statistics	All-cause mortality
Relative handgrip strength	1.30 ± 0.47	0.59 (0.52, 0.68)
Age(years)	59.58 ± 9.64	1.11 (1.11, 1.12)
BMI (kg/m^2)	23.46 ± 3.96	0.89 (0.88, 0.91)
Handgrip strength, %		
Tertile 1	3871 (33.32 %)	1.0 (Reference)
Tertile 2	3860 (33.22 %)	0.62 (0.54, 0.71)
Tertile 3	3887 (33.46 %)	0.40 (0.34, 0.46)
Gender, %		
Male	5562 (47.88 %)	1.0 (Reference)
Female	6055 (52.12 %)	0.53 (0.47, 0.60)
Ethnic group, %		
Han	9878 (93.23 %)	1.0 (Reference)
Other	717 (6.77 %)	1.15 (0.89, 1.49)
Education level, %		
<Middle school	8118 (69.91 %)	1.0 (Reference)
≥Middle school	3494 (30.09 %)	0.47 (0.41, 0.55)
Household annual income (yuan), %		
≤30,000	7969 (74.21 %)	1.0 (Reference)
>30,000	2769 (25.79 %)	0.67 (0.58, 0.78)
Marital status, %		
Living with spouse	9640 (82.98 %)	1.0 (Reference)
Living without spouse	1977 (17.02 %)	2.43 (2.13, 2.77)
Drinking status, %		
Never	6797 (58.57 %)	1.0 (Reference)
Abstainer	980 (8.44 %)	2.17 (1.81, 2.59)
Current	3828 (32.99 %)	1.12 (0.98, 1.27)
Smoking status, %		
Never	6936 (60.03 %)	1.0 (Reference)
Former	1001 (8.66 %)	2.70 (2.27, 3.23)
Current	3618 (31.31 %)	1.63 (1.43, 1.85)
Physical activity, %		
None	504 (4.34 %)	1.0 (Reference)
Mild	1096 (9.43 %)	0.67 (0.51, 0.89)
Moderate	1459 (12.56 %)	0.34 (0.26, 0.46)
Vigorous	1797 (15.47 %)	0.26 (0.19, 0.34)
Missing	6762 (58.20 %)	0.53 (0.42, 0.66)
Medical insurance status, %		
No	699 (6.04 %)	1.0 (Reference)
Yes	10,874 (93.96 %)	0.63 (0.51, 0.77)

Values were means ± SD or n (percentages).
Values of polytomous variables may not sum to 100 % due to rounding.

0.26–0.41 for tertile 3, compared with tertile 1) and females (adjusted ORs: 0.78, 95 % CI: 0.60–0.99 for tertile 2 and 0.45, 95 % CI: 0.24–0.85 for tertile 3, compared with tertile 1). After adjustment in model 1, and further adjustment for ethnicity, education level, household annual income, marital status, and medical insurance in model 2, the association remained stable in men (ORs: 0.65, 95 % CI: 0.49–0.84 for tertile 2 and 0.42, 95 % CI: 0.31–0.55 for tertile 3, compared with the lowest group) and women (ORs: 0.81, 95 % CI: 0.60–1.10 for tertile 2 and 0.47, 95 % CI: 0.22–0.99 for tertile 3, compared with tertile 1). After final adjustment for BMI, drinking, smoking, and physical activity in model 3, the association kept significant in men (ORs: 0.70, 95 % CI: 0.53–0.93 for tertile 2 and 0.47, 95 % CI: 0.35–0.64 for tertile 3, compared with tertile 1), but not in women (ORs: 0.84, 95 % CI: 0.62–1.15 for tertile 2 and 0.51, 95 % CI: 0.24–1.08 for tertile 3, compared with tertile 1). Simultaneously, a trend test found that the risk of death from all causes decreased with growing handgrip strength tertiles among males (P-trend <0.001), not among females (P-trend = 0.059).

In terms of stratified and interaction analyses, further variable relationships were found. Age modified the relationship of grip strength and overall mortality in males. The protective effect might be greater in younger male (P-interaction = 0.023) (Supplementary Table 7). In addition, although the protective effect kept stable, alcohol assumption might attenuate the protective effect among women. However, the modified effect was not found in other factors. Meanwhile, most stratified results showed an inverse effect between grip strength and mortality and were significant. Thus, there is evidence from multiple sources that the negative association did exist. Several sensitivity analyses

Table 3
Relationship between handgrip strength and the risk of all-cause mortality in different models.

Exposure	OR (95 % CI)		
	Model I[a]	Model II[b]	Model III[c]
Handgrip strength group			
Men			
Tertile 1	1.0 (Reference)	1.0 (Reference)	1.0 (Reference)
Tertile 2	0.56 (0.45, 0.70)	0.65 (0.49, 0.84)	0.70 (0.53, 0.93)
Tertile 3	0.33 (0.26, 0.41)	0.42 (0.31, 0.55)	0.47 (0.35, 0.64)
P for trend	<0.001	<0.001	<0.001
Women			
Tertile 1	1.0 (Reference)	1.0 (Reference)	1.0 (Reference)
Tertile 2	0.78 (0.60, 0.99)	0.81 (0.60, 1.10)	0.84 (0.62, 1.15)
Tertile 3	0.45 (0.24, 0.85)	0.47 (0.22, 0.99)	0.51 (0.24, 1.08)
P for trend	0.003	0.026	0.059

Abbreviations: OR, odds ratio; CI, confidence interval.
[a] Adjust for Age (years).
[b] Adjust for Age (years), Ethnicity (Han, Other), Education level (<Middle school, ≥Middle school), Household annual income (30,000≤, >30,000 yuan), Marital status (Live with spouse, Live without spouse) and Medical insurance (No, Yes).
[c] Adjust for Age (years), BMI (kg/m^2), Ethnicity (Han, Other), Education level (<Middle school, ≥Middle school), Household annual income (≤30,000, >30,000 yuan), Marital status (Live with spouse, Live without spouse), Drinking (Never, Abstainer, Current), Smoking (Never, Former, Current), Physical activity (None, Mild, Moderate, Vigorous, Missing) and Medical insurance (No, Yes).

assured that handgrip strength decreased the probability of all-cause deaths (Supplementary Tables 2–6).

4. Discussion

This large prospective cohort study suggested that handgrip strength was associated with lower mortality risk after adjustments for other variables.

The inverse association between handgrip strength and overall mortality was consistent with previous research of 9393 adults aged 45 years or above in Korea, which documented that weaker grip strength was significantly in relation to increasing overall mortality with an 8-year follow-up.[7] In a longitudical study involving around 500,000 participants from UK Biobank, handgrip strength was negatively related to mortality.[6] Grip strength was also proved to be inversely related to all-cause mortality in a Prospective Urban Rural Epidemiology (PURE) study of 142,861 people from different sociocultural settings across 17 countries.[17] In addition, handgrip strength was considered to be an accurate predictor of overall mortality in a 2014 cohort study and a meta-analysis.[18,19]

However, our data on the negative association between grip strength and mortality differ from a previously published study. According to Katzmarzyk et al., handgrip strength and upper body strength were not significantly associated with the risk of death from all causes.[20] Nonetheless, this finding was based on the survey in the year 1981, including only the Canadian population. Additionally, our result of a stronger handgrip strength correlated with a reduced probability of all-cause deaths among the general population aged 45 and older contradicts previously published studies.[21,22] For example, the KORA-age study suggested a statistically insignificant association of handgrip strength by tertiles with all-cause mortality.[21] One possible reason for the inconsistency could be characteristics of the study sample as we restricted to the Chinese people in middle-age and older. In contrast, the study sample in the KORA-age study was people aged 65 and more in Augsburg, moreover, the sample size was relatively small. The current 8-year cohort study with a special design for the specific Chinese population is of great public health significance. Further research of differences among races and ages is of interest.

Our study also investigated that the association between handgrip strength and all-cause mortality was modified by age among men, with a stronger association shown in men who were younger than 65.

For men aged 65 and below, those with stronger grip strength tended to have a lower likelihood of all-cause deaths compared with those with weak strength. The modified effect between handgrip strength and age on all-cause mortality may be related to aging-specific characteristics.[23] As the previous research reported, older adults generally had smaller and weaker muscles and their physiological systems declined with age.[23] Moreover, the older the people were, the less likely to take part in physical activities or increase the intensity of exercise.[23] In terms of survival difference between males and females in our study, it has been found that females had a longer life span than males.[24] The gender difference may attribute to genetic variation and multiple behavioral and environmental factors.[24] Nonetheless, grip strength was correlated with lower mortality risk for both males and females, and applying handgrip strength measurement in health screening settings provides significant public health implications.

Given the finding of our study, it is worth heeding the underlying mechanism linking handgrip strength with all-cause mortality. Muscle weakness and dysfunction, as typically characterized as sarcopenia, has been commonly regarded as a disease with an independent risk factor for higher mortality.[25] The impact of muscle strength on mortality may be connected with its function during the disabled process, as muscle is the greatest reserve of protein in the body.[26] As indicated in previous literature, people with weak strength were prone to difficulties in daily physical activities.[26] Meanwhile, the trouble in operating body movements may lower the likelihood of taking the physical activities.[27] Therefore, people who had weak muscle endurance and strength tended to be physically torpid and slothful, making them more tender facing accidents and other acute diseases.[26] In addition, an inverse relationship between grip strength and fasting insulin levels has been investigated.[28] Increased insulin levels are regarded to be the driving force of the insulin-resistance syndrome (syndrome X),[22] which is associated with obesity, hypertension, and dyslipidemia.[29] As previous evidence reported, age 40 is the general time of declines in muscle mass and strength of individuals, and since then, the rate of decline has accelerated to some extent.[7] Consequently, accumulated muscle weakness in body systems among middle-aged and older people might be a complicated mechanism interpreting the relationship between grip strength and mortality.

The strengths of our study is ascribable to prospective design and a large sample size. Nevertheless, there are several limitations to our research. First, though we have adjusted for a wide range of potential confounders, other unmeasured variables such as dietary habits and psychological conditions might have distorted the observed association. Second, excluding patients who could not perform handgrip strength measurements may lead to selection bias. Third, this study only included participants aged 45 years or older; thus, the current findings may not be generalized to the entire population in China. Fourth, handgrip strength was assessed twice in the current study, and potential misclassification in handgrip strength values might exist. However, it is also reported that the maximal handgrip strength decreased significantly at the second and third attempts, and our measurement might be reasonable.[30] Fifth, physical activity status in our study was obtained from standard questionnaire in the CHARLS rather than the IPAQ questionnaire, an international standardized instrument. Though our questionnaire was based on and similar to the short form of the IPAQ questionnaire,[14,15] it might have limited validity and reliability. In addition, body composition is related to handgrip strength and physical activity. Although physical activity is considered and body mass index is a good approximation for comprehensive population studies, a rigorous body composition analysis was performed in future study. Also, we were unable to investigate handgrip strength in relation to cause-specific death, which can be addressed in further investigations.

5. Conclusion

In conclusion, the current study suggested that handgrip strength was negatively associated with all-cause mortality, with the association remaining significant across multiple adjustments for confounding factors. Handgrip strength could represent an essential measure in comprehensive physical assessments and a predictor of all-cause mortality. Therefore, improving this daily behavior would contribute to substantial public health implications, especially for middle-aged and older adults. Further research to elucidate related mechanism are warranted.

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Data availability statement

The data that support the findings of this study are openly available in CHARLS at [http://charls.pku.edu.cn/en], reference number [NA].

Sponsor's role

No sponsor had any role in study design, data analysis and interpretation, or manuscript preparation.

Impact statement

We certify that this work is novel of recent novel prospective observational study.

Our finding is that improving handgrip strength, an easily accessible daily behavior, would reduce the risk of all-cause mortality among middle-aged and older adults, thus having potential public health implications.

Credit authorship contribution statement

Yang Liu did the statistical analysis supervised by Yanan Ma. Yuhan Wang and Yang Liu wrote the paper supervised by Yanan Ma, Wanshui Yang, and Naihui Sun. All authors contributed to the data interpretation, revised each draft for important intellectual content, and read and approved the final manuscript. Yuhan Wang, Yang Liu, and Jiajin Hu contributed equally as the first author. Yanan Ma, Wanshui Yang, and Naihui Sun contributed equally as the corresponding co-author.

Declaration of Interest Statement

The results presented in this manuscript have not been considered for publication elsewhere. None of the manuscript's contents have been previously published or posted on the internet. The authors do not have any conflicts of interest to disclose. All of the authors have read and approved the final version of this manuscript.

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Appendix A. Supplementary data

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References

1. Muntaner C, Hadden WC, Kravets N. Social class, race/ethnicity and all-cause mortality in the US: longitudinal results from the 1986-1994 National Health Interview Survey. *Eur J Epidemiol* 2004;19(8):777-784.
2. Wang W, Yin P, Wang LJ et al. Analysis on all-cause mortality rate and life expectancy in China, 2005-2018. *Zhonghua Liu Xing Bing Xue Za Zhi* 2021;42(8):1420-1428.

3. Hahn P, Spies C, Unglaub F et al. Grip strength measurement : significance and boundaries. *Orthopade* 2018;47(3):191-197.
4. Ling CH, Taekema D, de Craen AJ et al. Handgrip strength and mortality in the oldest old population: the Leiden 85-plus study. *Cmaj* 2010;182(5):429-435.
5. Labott BK, Bucht H, Morat M et al. Effects of exercise training on handgrip strength in older adults: a meta-analytical review. *Gerontology* 2019;65(6):686-698.
6. 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.
7. Bae EJ, Park NJ, Sohn HS et al. Handgrip strength and all-cause mortality in middle-aged and older Koreans. *Int J Environ Res Public Health* 2019;16(5).
8. Germain CM, Vasquez E, Batsis JA et al. Sex, race and age differences in muscle strength and limitations in community dwelling older adults: data from the Health and Retirement Survey (HRS). *Arch Gerontol Geriatr* 2016;65:98-103.
9. Fang EF, Xie C, Schenkel JA et al. A research agenda for ageing in China in the 21st century (2nd edition): focusing on basic and translational research, long-term care, policy and social networks. *Ageing Res Rev* 2020;64:101174.
10. Mallah MA, Liu M, Liu Y et al. Association of handgrip strength with the prevalence of hypertension in a Chinese Han population. *Chronic Dis Transl Med* 2019;5(2):113-121.
11. Feng Q, Jiang C, Wang M et al. Association between relative handgrip strength and hypertension in Chinese adults: an analysis of four successive national surveys with 712,442 individuals (2000-2014). *PLoS One* 2021;16(10):e0258763.
12. Zhao Y, Hu Y, Smith JP et al. Cohort profile: the China Health and Retirement Longitudinal Study (CHARLS). *Int J Epidemiol* 2014;43(1):61-68.
13. 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(43):3232-3240.
14. Craig CL, Marshall AL, Sjöström M et al. International physical activity questionnaire: 12-country reliability and validity. *Med Sci Sports Exerc* 2003;35(8):1381-1395.
15. Li X, Zhang W, Zhang W et al. Level of physical activity among middle-aged and older Chinese people: evidence from the China health and retirement longitudinal study. *BMC Public Health* 2020;20(1):1682.
16. Spruit MA, Sillen MJ, Groenen MT et al. New normative values for handgrip strength: results from the UK Biobank. *J Am Med Dir Assoc* 2013;14(10). 775.e5–11.
17. 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(9990): 266-273.
18. Kawamoto R, Kikuchi A, Akase T et al. Thigh circumference and handgrip strength are significantly associated with all-cause mortality: findings from a study on Japanese community-dwelling persons. *Eur Geriatr Med* 2021;12(6):1191-1200.
19. Cooper R, Kuh D, Hardy R. Objectively measured physical capability levels and mortality: systematic review and meta-analysis. *Bmj* 2010;341:c4467.
20. Katzmarzyk PT, Craig CL. Musculoskeletal fitness and risk of mortality. *Med Sci Sports Exerc* 2002;34(5):740-744.
21. 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(1):201.
22. Ruiz JR, Sui X, Lobelo F et al. Association between muscular strength and mortality in men: prospective cohort study. *Bmj* 2008;337(7661):a439.
23. McPhee JS, French DP, Jackson D et al. Physical activity in older age: perspectives for healthy ageing and frailty. *Biogerontology* 2016;17(3):567-580.
24. Pan Z, Chang C. Gender and the regulation of longevity: implications for autoimmunity. *Autoimmun Rev* 2012;11(6–7):A393-A403.
25. Morley JE. Sarcopenia in the elderly. *Fam Pract* 2012;29(Suppl 1). i44-i8.
26. Rantanen T, Guralnik JM, Sakari-Rantala R et al. Disability, physical activity, and muscle strength in older women: the Women's Health and Aging Study. *Arch Phys Med Rehabil* 1999;80(2):130-135.
27. Meyer HE, Tverdal A, Falch JA et al. Factors associated with mortality after hip fracture. *Osteoporos Int* 2000;11(3):228-232.
28. Ferrannini E, Haffner SM, Mitchell BD et al. Hyperinsulinaemia: the key feature of a cardiovascular and metabolic syndrome. *Diabetologia* 1991;34(6):416-422.
29. Gao K, Cao LF, Ma WZ et al. Association between sarcopenia and cardiovascular disease among middle-aged and older adults: findings from the China health and retirement longitudinal study. *EClinicalMedicine* 2022;44:101264.
30. Abizanda P, Navarro JL, García-Tomás MI et al. Validity and usefulness of hand-held dynamometry for measuring muscle strength in community-dwelling older persons. *Arch Gerontol Geriatr* 2012;54(1):21-27.