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Association Between Grip Strength-to-Body Weight Ratio and Cardiometabolic Multimorbidity: A Cross-Sectional Study from CHARLS

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Research Article

Keywords: Grip strength, Body weight ratio, Cardiometabolic multimorbidity, Cross-sectional study, CHARLS

Posted Date: November 19th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11153751/v1

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Additional Declarations: No competing interests reported.

Abstract

Background

Cardiometabolic multimorbidity (CMM), defined as the coexistence of two or more cardiometabolic diseases, represents a growing public health challenge among aging populations. Grip strength relative to body weight may serve as a more equitable indicator of muscular fitness across different body sizes. Grip strength-to-body weight ratio (GWR) may be a simple marker for assessing cardiometabolic risk.This study aimed to investigate the association between GWR and CMM in middle-aged and older Chinese adults.

Methods

We conducted a cross-sectional analysis using data from the China Health and Retirement Longitudinal Study (CHARLS), including 18,184 participants aged 45 years and older. GWR was calculated as the ratio of grip strength (kg) to body weight (kg). To facilitate interpretation, we multiplied the original GWR by 10 to create GWR10. Thus, each unit increase in GWR10 corresponds to a 0.1-unit increase in the original GWR ratio. CMM was defined as the presence of two or more conditions among hypertension, diabetes, heart disease, stroke, and dyslipidemia. Multivariable logistic regression models were constructed to examine the association between GWR and CMM.

Results

The prevalence of CMM was 20.3% (n = 3,700). Higher GWR was markedly associated with lower odds of CMM (adjusted OR = 0.79, 95% CI: 0.76–0.81, P < 0.001) per unit increase. This finding is notable. Compared with the lowest quartile (Q1), the highest quartile (Q4) showed a 72% reduction in CMM odds (adjusted OR = 0.28, 95% CI: 0.24–0.33, P < 0.001). A significant age-stratified interaction was observed (P for interaction = 0.001), with the strongest inverse association in the 55–64 age group (OR = 0.74, 95% CI: 0.71–0.78). A nonlinear relationship was observed between GWR and CMM (P for nonlinearity < 0.001), with a breakpoint at GWR10 = 3.459 (corresponding to original GWR = 0.3459). Subgroup analyses showed consistent associations across sex, education, marital status, rural/urban residence, smoking, drinking, and physical activity groups (all P for interaction > 0.05).

Conclusions

Higher GWR was significantly associated with lower odds of CMM in a nonlinear manner and independently associated with reduced odds of CMM in middle-aged and older Chinese adults, with a significant age-modifying inverse association. GWR may serve as a practical clinical indicator for identifying individuals at risk for cardiometabolic multimorbidity.

Introduction

Cardiometabolic multimorbidity (CMM), defined as the coexistence of at least two cardiometabolic conditions including diabetes, hypertension, and cardiovascular disease, represents a growing public health challenge worldwide [1, 2]. The prevalence of CMM has increased substantially over the past decades, driven by population aging, urbanization, and the global epidemic of obesity and metabolic syndrome [3]. In China, the rapid epidemiological transition has led to a dramatic rise in the burden of chronic non-communicable diseases, with CMM becoming particularly prevalent among middle-aged and older adults [4]. The co-occurrence of multiple cardiometabolic conditions not only increases the risk of adverse cardiovascular events, disability, and mortality but also imposes substantial economic burden on healthcare systemswith single-disease states [5]. Understanding the risk factors and developing effective prevention strategies for CMM are therefore of paramount importance for public health. Metabolic dysfunction has been increasingly recognized as a central pathway linking various chronic diseases, highlighting the need for integrated approaches to assess and manage metabolic risk [6].

Grip strength, a simple and reliable measure of overall muscular fitness, has emerged as an important predictor of cardiovascular and metabolic health outcomes [7, 8]. Previous studies have demonstrated that low grip strength is associated with increased risk of cardiovascular disease, diabetes, and all-cause mortality [9, 10]. However, grip strength alone may not fully capture the metabolic health status of individuals, as it is influenced by body size and composition. The grip strength-to-body weight ratio (GWR), which adjusts grip strength for body weight, has been proposed as a more informative marker that reflects relative muscular strength and metabolic fitness [11, 12]. Emerging evidence suggests that GWR may be associated with cardiometabolic risk factors and multimorbidity. A recent study from the China Health and Retirement Longitudinal Study (CHARLS) reported that visceral adiposity index and handgrip strength were independently associated with CMM among middle-aged and older Chinese adults [13]. Another study found that handgrip strength was associated with morbidity and mortality of CMM [14]. Furthermore, relative muscle strength, as measured by grip strength adjusted for body weight, has been linked to cardiometabolic multimorbidity in Chinese populations [15]. Despite these advances, the specific association between GWR and CMM, including dose-response relationships and potential thresholds, remains inadequately characterized.

Several limitations in the existing literature warrant further investigation. First, most previous studies have examined grip strength or muscle strength in isolation, without considering the combined effect of muscular strength and body weight. Second, the dose-response relationship between GWR and CMM, including potential nonlinear associations and threshold effects, has not been thoroughly explored. Third, few studies have conducted comprehensive subgroup analyses to assess the consistency of associations across different demographic and lifestyle characteristics. Fourth, the impact of unmeasured confounding on the observed associations has not been systematically evaluated. To address these gaps, we conducted a large cross-sectional study using data from CHARLS to investigate the association between GWR and CMM among middle-aged and older Chinese adults. Specifically, we aimed to: (1) examine the overall association between GWR and CMM; (2) explore potential nonlinear dose-response relationships using restricted cubic splines; (3) identify potential thresholds through segmented regression analysis; (4) assess the consistency of associations across subgroups; and (5) evaluate the clinical utility of GWR for predicting CMM.

Methods

Study Design and Population

This cross-sectional study utilized data from the China Health and Retirement Longitudinal Study (CHARLS), a nationally representative survey of Chinese adults aged 45 years and older. CHARLS employed a multi-stage stratified probability sampling design, covering 28 provinces, 150 counties, and 450 communities across mainland China. The current analysis included participants from Waves 1–3 (2011–2015) who had complete data for grip strength, body weight, and CMM assessment. Of 57,417 records from Waves 1–3, we excluded participants aged less than 45 years (n = 2,273), those with missing grip strength data (n = 14,077), missing body weight data (n = 317), missing CMM data (n = 2,177), and extreme GWR values below the 1st percentile or above the 99th percentile (n = 386). For participants with multiple waves of data, we selected the most recent wave to ensure one record per individual. The final analytic sample comprised 18,184 participants. (Fig. 1).This study was conducted in accordance with the ethical principles of the Declaration of Helsinki. All data analyzed in this study were retrieved from publicly available databases, where all personal identifiable information had been completely de-identified prior to public release. Therefore, individual informed consent was not required for this secondary retrospective analysis.

Exposure: Grip Strength-to-Body Weight Ratio

Grip strength was measured using a hand-held dynamometer. Participants were instructed to squeeze the dynamometer with maximum effort while seated with the elbow flexed at 90 degrees. This finding is notable. Two measurements were taken for each hand, and the maximum value from the dominant hand was recorded in kilograms [16]. Body weight was measured to the nearest 0.1 kg using a calibrated scale. GWR was calculated as grip strength (kg) divided by body weight (kg). For categorical analyses, participants were divided into quartiles based on GWR distribution.For ease of interpretation, the original GWR was multiplied by 10 to create the variable GWR10. Accordingly, each 1-unit increase in GWR10 represents a 0.1-unit increase in the original grip strength-to-body weight ratio

Outcome: Cardiometabolic Multimorbidity

CMM was defined as the coexistence of two or more of the following five cardiometabolic conditions: (1) hypertension, defined as systolic blood pressure > = 140 mmHg or diastolic blood pressure > = 90 mmHg or self-reported physician diagnosis or current antihypertensive medication use; (2) diabetes mellitus, defined as fasting glucose > = 126 mg/dL or self-reported physician diagnosis or current hypoglycemic medication use; (3) heart disease, defined as self-reported physician diagnosis; (4) stroke, defined as self-reported physician diagnosis; and (5) dyslipidemia, defined as total cholesterol > = 240 mg/dL or self-reported physician diagnosis or current lipid-lowering medication use [17].

Covariates

Demographic variables included age, gender, education level, marital status, and residential area. Lifestyle factors included smoking status, current drinking status, and physical activity level. Anthropometric measurements included body mass index (BMI), waist circumference, systolic blood pressure, and diastolic blood pressure [18]. Laboratory variables comprised C-reactive protein (CRP), white blood cell count (WBC), platelet count (PLT), mean corpuscular volume (MCV), blood urea nitrogen (BUN), creatinine, cystatin C, estimated glomerular filtration rate (eGFR), uric acid, hemoglobin A1c (HbA1c), fasting glucose, triglycerides, high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), and total cholesterol.

Statistical Analysis

Continuous variables were expressed as mean ± standard deviation (SD) or median (interquartile range, IQR) as appropriate. Categorical variables were presented as frequencies and percentages. Differences across GWR quartiles were compared using one-way analysis of variance (ANOVA) for normally distributed continuous variables, Kruskal-Wallis test for non-normally distributed variables, and chi-square test for categorical variables.

Multivariable logistic regression models were used to assess the association between GWR and CMM. Three models were constructed: Model 1 (crude), Model 2 (adjusted for age and sex), Model(adjusted for age and sex, education, marital status, rural/urban residence, smoking, drinking, physical activity)and Model4 (further adjusted for age and sex, education, marital status, rural/urban residence, smoking, drinking, physical activity, and clinical variables). Restricted cubic splines with 4 knots at the 5th, 35th, 65th, and 95th percentiles were used to explore potential nonlinear dose-response relationships.

Subgroup analyses were performed stratified by age, sex, education, marital status, rural/urban residence, smoking, drinking, and physical activity. Interaction terms were included to test for heterogeneity across subgroups. Segmented regression was used to identify breakpoints in the dose-response relationship. Net reclassification improvement (NRI) and integrated discrimination improvement (IDI) were calculated to assess model improvement. E-values were calculated to assess the potential impact of unmeasured confounding. .

Statistical analyses were performed using R4.2.2 (http://www.R-project.org, The R Foundation) and Free Statistics software version 2.5.1. A two-sided P value < 0.05 was considered statistically significant.

Results

Baseline Characteristics

A total of 18,184 participants (mean age 59.4 ± 9.3 years; 47.8% male) were included in the final analysis. The prevalence of CMM was 20.3% (n = 3,700). Participants in higher GWR quartiles were more likely to be younger, male, urban residents, non-smokers, and non-drinkers (all P < 0.001). (Table 1).

Table 1
Baseline Characteristics of Participants by Grip Strength-to-Body Weight Ratio (GWR) Quartiles

Variables	Total (n = 18184)	1 (n = 5255)	2 (n = 4630)	3 (n = 4456)	4 (n = 3843)	p	statistic
Age, n (%)						< 0.001	796.307
45–54 years	5265 (29.0)	1065 (20.3)	1302 (28.1)	1432 (32.1)	1466 (38.1)		
55–64 years	6443 (35.4)	1690 (32.2)	1675 (36.2)	1632 (36.6)	1446 (37.6)		
65–74 years	4361 (24.0)	1496 (28.5)	1133 (24.5)	1009 (22.6)	723 (18.8)		
≥75 years	2115 (11.6)	1004 (19.1)	520 (11.2)	383 (8.6)	208 (5.4)		
Gender, n (%)						< 0.001	4324.637
Female	9494 (52.2)	4199 (79.9)	2983 (64.4)	1728 (38.8)	584 (15.2)		
Male	8690 (47.8)	1056 (20.1)	1647 (35.6)	2728 (61.2)	3259 (84.8)		
Edu_Cat, n (%)						< 0.001	581.91
Primary school or below	12445 (68.4)	4191 (79.8)	3215 (69.4)	2838 (63.7)	2201 (57.3)		
Secondary school or above	5739 (31.6)	1064 (20.2)	1415 (30.6)	1618 (36.3)	1642 (42.7)		
Married, n (%)						< 0.001	267.405
Unmarried	3521 (19.4)	1370 (26.1)	918 (19.8)	711 (16)	522 (13.6)		
Married	14663 (80.6)	3885 (73.9)	3712 (80.2)	3745 (84)	3321 (86.4)		
Rural, n (%)						0.001	15.564
Urban	7192 (39.6)	2073 (39.4)	1917 (41.4)	1772 (39.8)	1430 (37.2)		
Rural	10992 (60.4)	3182 (60.6)	2713 (58.6)	2684 (60.2)	2413 (62.8)		
Smoking, n (%)						< 0.001	2397.427
Non-smoker	10194 (56.1)	3965 (75.5)	3063 (66.2)	2105 (47.2)	1061 (27.6)		
Smoker	7990 (43.9)	1290 (24.5)	1567 (33.8)	2351 (52.8)	2782 (72.4)		
Drinking, n (%)						< 0.001	1485.629
Non-drinker	11905 (65.5)	4239 (80.7)	3346 (72.3)	2620 (58.8)	1700 (44.2)		
Drinker	6279 (34.5)	1016 (19.3)	1284 (27.7)	1836 (41.2)	2143 (55.8)		
TotalAct4, n (%)						< 0.001	25.171
Low	11137 (61.2)	3363 (64)	2799 (60.5)	2646 (59.4)	2329 (60.6)		
High	7047 (38.8)	1892 (36)	1831 (39.5)	1810 (40.6)	1514 (39.4)		
Waist, Mean ± SD	85.7 ± 12.9	89.9 ± 12.6	86.9 ± 11.9	84.3 ± 12.3	80.0 ± 12.8	< 0.001	504.943
SBP, Mean ± SD	128.9 ± 21.0	132.1 ± 22.1	128.8 ± 20.5	127.7 ± 20.7	125.7 ± 19.7	< 0.001	77.101
DBP, Mean ± SD	75.7 ± 12.5	76.1 ± 12.5	75.3 ± 12.4	75.9 ± 12.6	75.3 ± 12.3	< 0.001	5.426
CRP3, n (%)						< 0.001	546.06
Low	14220 (78.2)	3556 (67.7)	3668 (79.2)	3672 (82.4)	3324 (86.5)		
High	3964 (21.8)	1699 (32.3)	962 (20.8)	784 (17.6)	519 (13.5)		
TC, Mean ± SD	186.8 ± 37.4	190.2 ± 38.1	188.7 ± 38.3	184.0 ± 35.1	182.6 ± 37.2	< 0.001	32.983
WBC, Mean ± SD	6.0 ± 1.8	6.1 ± 1.6	6.0 ± 1.6	6.0 ± 1.7	6.1 ± 2.3	0.007	4.009
PLT, Mean ± SD	205.4 ± 65.5	210.8 ± 69.1	206.5 ± 64.9	202.4 ± 65.6	200.2 ± 60.2	< 0.001	23.917

Note. GWR indicates grip strength-to-body weight ratio (GWR10 = grip strength / body weight × 10); CMM, cardiometabolic multimorbidity; SBP, systolic blood pressure; DBP, diastolic blood pressure; CRP, C-reactive protein; TC, total cholesterol; WBC, white blood cell count; PLT, platelet count; HGB, hemoglobin; HCT, hematocrit; MCV, mean corpuscular volume; BUN, blood urea nitrogen; eGFR, estimated glomerular filtration rate. Data are presented as n (%) for categorical variables and mean ± SD or median (IQR) for continuous variables.

Variables	Total (n = 18184)	1 (n = 5255)	2 (n = 4630)	3 (n = 4456)	4 (n = 3843)	p	statistic
HGB, Mean ± SD	13.8 ± 1.8	13.4 ± 1.7	13.6 ± 1.8	14.1 ± 1.9	14.4 ± 1.7	< 0.001	299.361
HCT, Mean ± SD	41.4 ± 5.8	40.3 ± 5.5	40.9 ± 5.8	42.2 ± 6.0	42.8 ± 5.8	< 0.001	147.031
MCV, Mean ± SD	91.3 ± 8.0	90.7 ± 8.0	91.0 ± 8.1	91.5 ± 8.0	92.4 ± 7.9	< 0.001	26.857
BUN, Mean ± SD	15.7 ± 4.2	15.5 ± 4.3	15.7 ± 4.6	15.7 ± 4.0	16.0 ± 3.9	< 0.001	11.307
Creatinine, Mean ± SD	0.8 ± 0.3	0.8 ± 0.3	0.8 ± 0.3	0.8 ± 0.2	0.9 ± 0.2	< 0.001	72.234
CystatinC, Mean ± SD	0.9 ± 0.2	0.9 ± 0.3	0.9 ± 0.2	0.9 ± 0.2	0.9 ± 0.2	< 0.001	27.86
eGFR, Mean ± SD	104.0 ± 26.9	109.3 ± 29.3	106.9 ± 28.1	100.8 ± 25.5	97.0 ± 20.6	< 0.001	197.683
UricAcid, Mean ± SD	4.9 ± 1.2	4.7 ± 1.2	4.8 ± 1.2	5.0 ± 1.3	5.1 ± 1.2	< 0.001	71.857
HbA1c, Mean ± SD	5.8 ± 0.9	6.0 ± 1.0	5.9 ± 1.0	5.8 ± 0.8	5.7 ± 0.7	< 0.001	81.939
Glucose, Mean ± SD	105.6 ± 37.3	108.9 ± 41.4	106.6 ± 40.3	103.4 ± 32.4	102.3 ± 31.6	< 0.001	23.468
TG, Median (IQR)	112.4 (81.4, 166.4)	127.4 (90.3, 179.6)	115.9 (84.1, 169.0)	107.1 (78.8, 161.9)	95.6 (71.7, 140.5)	< 0.001	392.129
HDL, Mean ± SD	51.3 ± 12.6	50.0 ± 11.7	50.8 ± 11.9	51.5 ± 12.7	53.8 ± 14.1	< 0.001	56.334
LDL, Mean ± SD	106.0 ± 31.2	108.5 ± 31.5	107.6 ± 31.8	103.9 ± 29.6	102.8 ± 31.3	< 0.001	26.662
GWR10, Mean ± SD	5.0 ± 1.7	3.1 ± 1.1	4.7 ± 0.3	5.7 ± 0.3	7.2 ± 0.7	< 0.001	29106.806
CMM, n (%)						< 0.001	598.959
0	14484 (79.7)	3679 (70)	3616 (78.1)	3742 (84)	3447 (89.7)		
1	3700 (20.3)	1576 (30)	1014 (21.9)	714 (16)	396 (10.3)		

Note. GWR indicates grip strength-to-body weight ratio (GWR10 = grip strength / body weight × 10); CMM, cardiometabolic multimorbidity; SBP, systolic blood pressure; DBP, diastolic blood pressure; CRP, C-reactive protein; TC, total cholesterol; WBC, white blood cell count; PLT, platelet count; HGB, hemoglobin; HCT, hematocrit; MCV, mean corpuscular volume; BUN, blood urea nitrogen; eGFR, estimated glomerular filtration rate. Data are presented as n (%) for categorical variables and mean ± SD or median (IQR) for continuous variables.

Association Between GWR and CMM

In the fully adjusted model (Model4), each unit increase in GWR10 was associated with 21% lower odds of CMM (OR = 0.79, 95% CI: 0.76–0.81). Compared with the lowest quartile (Q1), the highest quartile (Q4) had 72% lower odds of CMM (OR = 0.28, 95% CI: 0.24–0.33). A significant nonlinear relationship was observed (P for nonlinearity < 0.001), with a breakpoint at GWR10 = 3.459 (corresponding to original GWR = 0.3459). Below this breakpoint, the association was weaker (OR = 1.10, 95% CI: 1.00-1.20), while above it, the association was stronger (OR = 0.69, 95% CI: 0.65–0.72). (Table 2). (Fig. 2).

Table 2
Multivariable Logistic Regression Analyses of the Association Between GWR and Cardiometabolic Multimorbidity

Variable	n.total	n.event_%	model1.OR (95%CI)	model1.P value	Model2.OR (95%CI)	Model2.P value	Model3.OR (95%CI)	Model3.P value	Model4.OR (95%CI)	Model4.P value
GWR10										
GWR10	18184	3700 (20.3)	0.77 (0.75 ~ 0.79)	< 0.001	0.78 (0.76 ~ 0.8)	< 0.001	0.77 (0.75 ~ 0.79)	< 0.001	0.79 (0.76 ~ 0.81)	< 0.001
GWR10q4										
q1	4546	1394 (30.7)	1(Ref)		1(Ref)		1(Ref)		1(Ref)	
q2	4543	1030 (22.7)	0.66 (0.6 ~ 0.73)	< 0.001	0.68 (0.61 ~ 0.74)	< 0.001	0.66 (0.6 ~ 0.72)	< 0.001	0.68 (0.61 ~ 0.76)	< 0.001
q3	4549	787 (17.3)	0.47 (0.43 ~ 0.52)	< 0.001	0.47 (0.42 ~ 0.52)	< 0.001	0.46 (0.41 ~ 0.51)	< 0.001	0.47 (0.42 ~ 0.54)	< 0.001
q4	4546	489 (10.8)	0.27 (0.24 ~ 0.31)	< 0.001	0.27 (0.23 ~ 0.3)	< 0.001	0.26 (0.23 ~ 0.3)	< 0.001	0.28 (0.24 ~ 0.33)	< 0.001
Trend.test	18184	3700 (20.3)	0.66 (0.64 ~ 0.68)	< 0.001	0.66 (0.63 ~ 0.68)	< 0.001	0.65 (0.62 ~ 0.68)	< 0.001	0.67 (0.63 ~ 0.7)	< 0.001

Note. GWR indicates grip strength-to-body weight ratio (GWR10 = grip strength / body weight × 10); OR, odds ratio; CI, confidence interval. Model 1: crude; Model 2: adjusted for age and gender; Model 3: adjusted for age, gender, education, marital status, rural/urban residence, smoking, drinking, physical activity, Model4:adjusted for age, gender, education, marital status, rural/urban residence, smoking, drinking, physical activity,systolic blood pressure, diastolic blood pressure, C-reactive protein, total cholesterol, white blood cell count, platelet count, mean corpuscular volume, cystatin C, uric acid, blood urea nitrogen, and estimated glomerular filtration rate.

Age-Stratified Analysis

A significant interaction between age and GWR was observed (P for interaction = 0.001; Table 3). In age-stratified analyses, the protective association between GWR and CMM was strongest in the 55–64 age group (adjusted OR = 0.74, 95% CI: 0.71–0.78), followed by the 45–54 age group (adjusted OR = 0.79, 95% CI: 0.74–0.84), the 65–74 age group (adjusted OR = 0.80, 95% CI: 0.76–0.85), and was weakest in the > = 75 age group (adjusted OR = 0.87, 95% CI: 0.80–0.94). No significant interactions were observed for other subgroup variables. (Fig. 3). (Fig. 6).

Table 3
Subgroup Analyses of the Association Between GWR and CMM

Subgroup	n	CMM, n (%)	Adjusted OR (95% CI)	P	P for Interaction
Age 45–54	5,265	641 (12.2)	0.79 (0.74–0.84)	< 0.001	0.001
Age 55–64	6,443	1,356 (21.0)	0.74 (0.71–0.78)	< 0.001	
Age 65–74	4,361	1,170 (26.8)	0.80 (0.76–0.85)	< 0.001	
Age > = 75	2,115	533 (25.2)	0.87 (0.80–0.94)	0.001	
Male	9,494	2,092 (22.0)	0.80 (0.77–0.83)	< 0.001	0.477
Female	8,690	1,608 (18.5)	0.77 (0.74–0.81)	< 0.001	
Urban	7,192	1,773 (24.7)	0.78 (0.74–0.82)	< 0.001	0.752
Rural	10,992	1,927 (17.5)	0.79 (0.76–0.82)	< 0.001	

Note. GWR indicates grip strength-to-body weight ratio (GWR10 = grip strength / body weight × 10); OR, odds ratio; CI, confidence interval. Adjusted for age, gender, education, marital status, rural/urban residence, smoking, drinking, physical activity, systolic blood pressure, diastolic blood pressure, C-reactive protein, total cholesterol, white blood cell count, platelet count, mean corpuscular volume, cystatin C, uric acid, blood urea nitrogen, and estimated glomerular filtration rate.

Dose-Response and Inflection Point Analysis

Segmented regression analysis identified a significant inflection point at GWR = 3.46 (95% CI: 3.34–3.58; Table 4). Below this threshold, the association between GWR and CMM was borderline significant (OR = 1.10, 95% CI: 1.00-1.20, P = 0.049). Above this threshold, each unit increase in GWR was associated with a 31% reduction in CMM odds (OR = 0.69, 95% CI: 0.65–0.72, P < 0.001). The likelihood ratio test confirmed a significant non-linear relationship (P < 0.001). (Fig. 7).

Table 4
Segmented Regression Analysis for GWR and CMM Association

Item	n	Breakpoint/OR (95% CI)	P value
Inflection point	13,931	3.46 (3.34–3.58)	NA
Below inflection	2,140	1.10 (1.00-1.20)	0.049
Above inflection	11,791	0.69 (0.65–0.72)	< 0.001
Likelihood ratio test			< 0.001
Non-linear test			< 0.001

Note. GWR indicates grip strength-to-body weight ratio (GWR10 = grip strength / body weight × 10); OR, odds ratio; CI, confidence interval. Segmented regression was used to identify breakpoints in the dose-response relationship. The breakpoint of 3.459 in GWR10 corresponds to 0.3459 in the original GWR.

Model Performance and Sensitivity Analyses

ROC curve analysis demonstrated that the full model including GWR achieved superior discriminative performance compared with the model without GWR. Adding GWR significantly improved model classification, with a categorical NRI of 0.050 (95% CI: 0.034–0.065, P < 0.001), continuous NRI of 0.289 (95% CI: 0.253–0.325, P < 0.001), and IDI of 0.015 (95% CI: 0.013–0.017, P < 0.001). (Fig. 4). E-value analysis yielded an E-value of 1.85 for the point estimate and 1.77 for the lower confidence limit, suggesting that an unmeasured confounder would need to be associated with both GWR and CMM by a risk ratio of at least 1.85-fold each to explain away the observed association. (Fig. 5).

Discussion

In this large cross-sectional study of 18,184 middle-aged and older Chinese adults, we found a significant nonlinear inverse association between GWR10 and CMM. Each unit increase in GWR10 was associated with 21% lower odds of CMM (OR = 0.79, 95% CI: 0.76–0.81) after adjusting for potential confounders. The dose-response analysis revealed a nonlinear relationship, with a breakpoint at GWR10 = 3.459 (corresponding to original GWR = 0.3459). Below this threshold, the association between GWR and CMM was weaker, while above it, the inverse association became stronger. Subgroup analyses demonstrated consistent associations across age, sex, education, marital status, rural/urban residence, smoking, drinking, and physical activity groups, with no significant interactions. Furthermore, the addition of GWR to the model significantly improved discrimination and reclassification for CMM, and E-value analysis suggested that unmeasured confounding alone was unlikely to explain the observed association. (Fig. 3).

Our findings are consistent with several previous studies that have examined the relationship between muscle strength and cardiometabolic health. A recent study from CHARLS reported that handgrip strength was associated with cardiometabolic multimorbidity among middle-aged and older Chinese adults [9]. Similarly, another study found that handgrip strength was associated with morbidity and all-cause mortality of CMM [10]. Furthermore, relative muscle strength, as measured by grip strength adjusted for body weight, has been linked to cardiometabolic multimorbidity in Chinese populations [11]. Our study extends these findings by demonstrating that GWR, a simple and accessible measure of relative muscular strength, is inversely associated with CMM in a nonlinear manner. The identification of a threshold effect at GWR10 = 3.459 provides clinically relevant information for risk stratification and intervention targeting. However, some studies have reported conflicting results. For instance, a study by Zhang et al. found that the association between muscle strength and CMM was attenuated after adjusting for body composition [12]. This discrepancy may be explained by differences in study design, population characteristics, and the specific measures of muscle strength used.

Several biological mechanisms may be related to the association between GWR and CMM. First, skeletal muscle plays a critical role in glucose metabolism and insulin sensitivity, with muscle mass and function being key determinants of metabolic health [19, 20]. Low GWR may reflect reduced muscle mass or function, which is associated with impaired glucose uptake, insulin resistance, and ultimately metabolic dysfunction [21]. Second, muscle strength is closely related to inflammatory status, with reduced muscle function being associated with chronic low-grade inflammation, a hallmark of cardiometabolic diseases [22, 23]. Third, the relationship between muscle strength and cardiovascular health is bidirectional, with poor cardiovascular health leading to reduced muscle perfusion and function, while low muscle strength may be associated with cardiovascular risk through impaired vascular function and endothelial health [24]. Fourth, the nonlinear relationship observed in our study may reflect threshold effects in the pathophysiological pathways linking muscle strength to cardiometabolic risk, with the inverse association becoming stronger above a certain level of relative muscular strength [25].

Several limitations should be acknowledged. First, the cross-sectional design precludes causal inference, and we cannot determine whether low GWR precedes or results from CMM. Longitudinal studies are needed to establish temporal relationships. Second, although we adjusted for a wide range of confounders, residual confounding cannot be excluded. However, E-value analysis suggested that unmeasured confounding alone is unlikely to fully explain the observed association. Third, grip strength measurements may be influenced by factors such as time of day, fatigue, and measurement technique, which could introduce measurement error. Fourth, our study population consisted of Chinese adults, which may limit generalizability to other populations with different ethnic, cultural, or healthcare characteristics. Fifth, we did not have data on body composition,

which would allow for more precise assessment of the relative contributions of muscle mass versus muscle quality to the observed associations. Sixth, the definition of CMM used in our study may not capture the full spectrum of cardiometabolic disease burden.

conclusion

In conclusion, this study found a significant nonlinear inverse association between GWR and CMM among middle-aged and older Chinese adults, with a breakpoint at GWR10 = 3.459. GWR may serve as a simple and accessible marker for identifying individuals at risk of CMM. These findings have important clinical implications, as GWR can be easily measured in clinical settings and may help guide prevention and intervention strategies. Future prospective studies are needed to confirm these findings and determine whether GWR can be used as a clinical tool for risk stratification and to evaluate the potential benefits of interventions targeting relative muscular strength for the prevention of CMM.

Declarations

Funding

This work was supported by the Natural Science Foundation of Inner Mongolia Autonomous Region (Grant No. 2023LHMS08050).

Conflict of Interest

The authors declare no conflicts of interest.

Author Contributions

Anming Li: Conceptualization, Methodology, Formal analysis, Writing - Original Draft. Xue Bai: Data curation, Investigation, Visualization. Xuchen Han: Resources, Writing - Review & Editing. Shiping Chen: Supervision, Project administration, Writing - Review & Editing. All authors reviewed and approved the final manuscript.Anming Li and Xue Bai contributed equally to this work.

Acknowledgments

The authors would like to express our sincere gratitude to the clinical scientist team for their invaluable guidance and expertise throughout this research. We are particularly grateful to Dr. Jie Liu for his insightful contributions and unwavering support. We also thank all participants and staff of the China Health and Retirement Longitudinal Study (CHARLS) for their contributions to this study.

Human Ethics and Consent to Participate declarations:

The original China Health and Retirement Longitudinal Study (CHARLS) was approved by the Institutional Review Board of Peking University (approval number: IRB00001052-11015). All participants of CHARLS provided written informed consent before participation. The present study is a secondary analysis of publicly available, de-identified CHARLS data.

Human ethics and participation consent statement: Not applicable

Clinical trial registration number: Not applicable

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Figures



Figure 1

Study flowchart showing participant selection from the China Health and Retirement Longitudinal Study (CHARLS). From 57,417 records across Waves 1-3, 24,958 unique participants were identified. After excluding those aged <45 years (n = 2,273), with missing grip-strength data (n = 14,077), missing body-weight data (n = 317), missing CMM-related variables (n = 2,177), and extreme outlier values (n = 386), the final analytical sample included 18,184 participants.

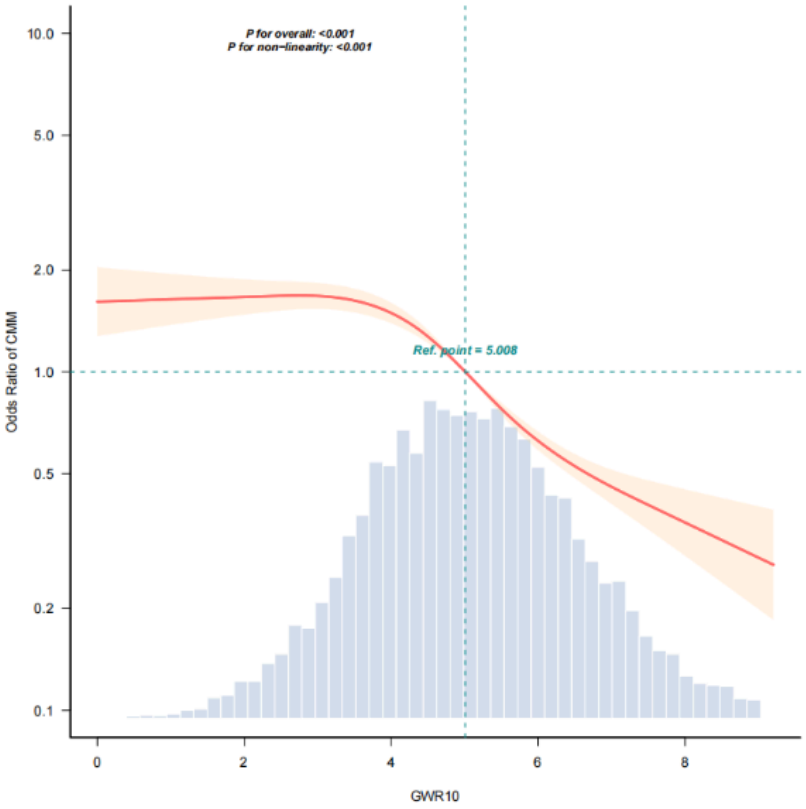


Figure 2

Restricted cubic spline regression for the association between grip strength-to-body weight ratio (GWR) and cardiometabolic multimorbidity (CMM). The curve shows a nonlinear relationship (P for overall <0.001, P for non-linearity <0.001). The reference point was set at GWR = 50.08 (corresponding to original GWR = 5.008). Adjusted for age, gender, education, marital status, rural/urban residence, smoking, drinking, physical activity, systolic blood pressure, diastolic blood pressure, C-reactive protein, total cholesterol, white blood cell count, platelet count, mean corpuscular volume, cystatin C, uric acid, blood urea nitrogen, and estimated glomerular filtration rate.

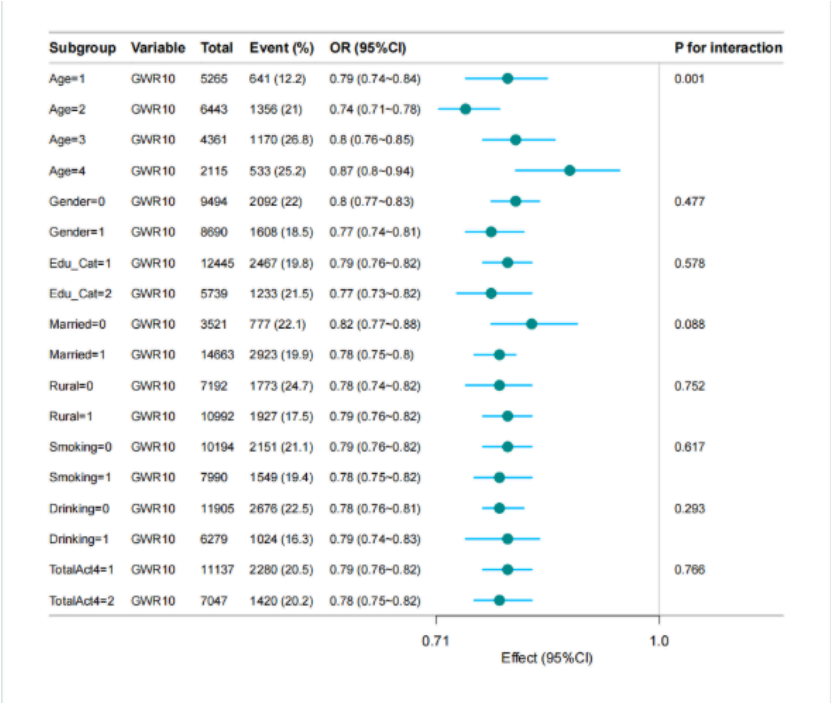


Figure 3

Forest plot showing subgroup analyses of the association between GWR and CMM across different demographic and lifestyle subgroups. Adjusted odds ratios (ORs) with 95% confidence intervals (CIs) are shown. P for interaction values indicate no significant heterogeneity across subgroups (all P >0.05).

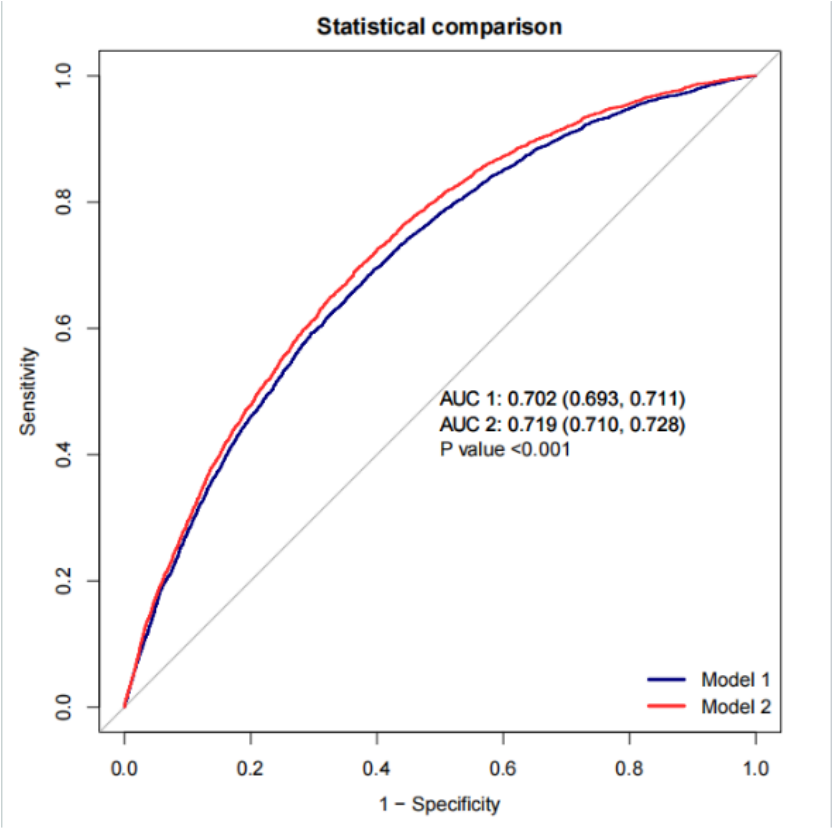


Figure 4

Receiver operating characteristic (ROC) curves comparing the discriminatory ability of two models for CMM. Model 1 (AUC = 0.702, 95% CI: 0.693-0.711) included demographic factors. Model 2 (AUC = 0.719, 95% CI: 0.710-0.728) included additional clinical variables. The difference in AUCs was statistically significant (P <0.001).

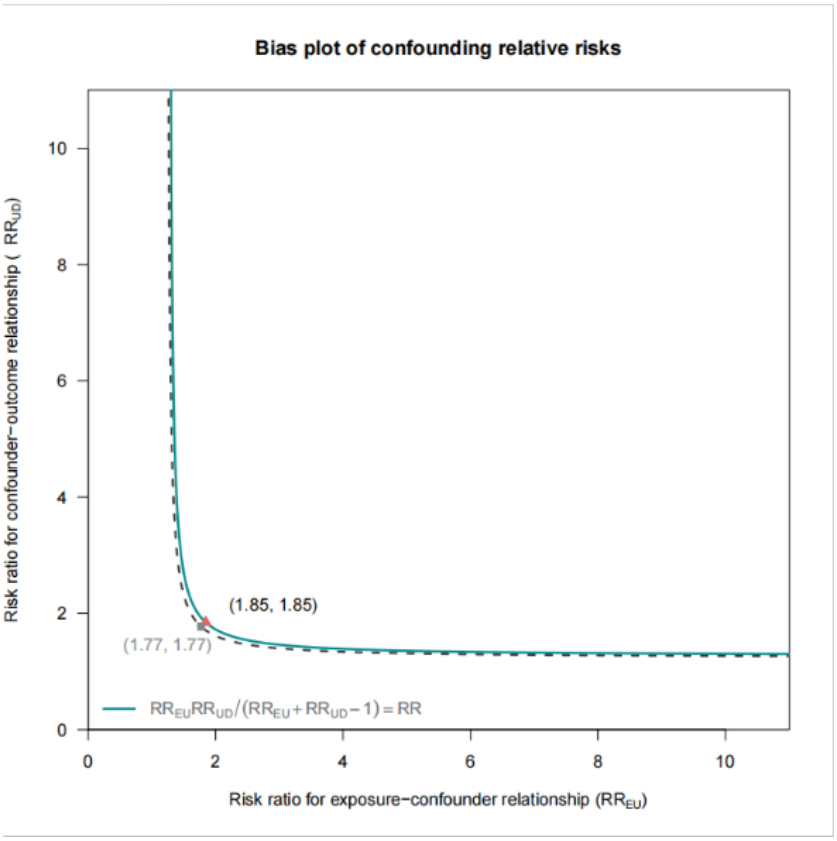


Figure 5

E-value bias plot assessing the potential impact of unmeasured confounding on the observed association between GWR and CMM. The E-value of 1.85 indicates that an unmeasured confounder would need to be associated with both GWR and CMM by a risk ratio of at least 1.85 each to explain away the observed association. (Figure 5).

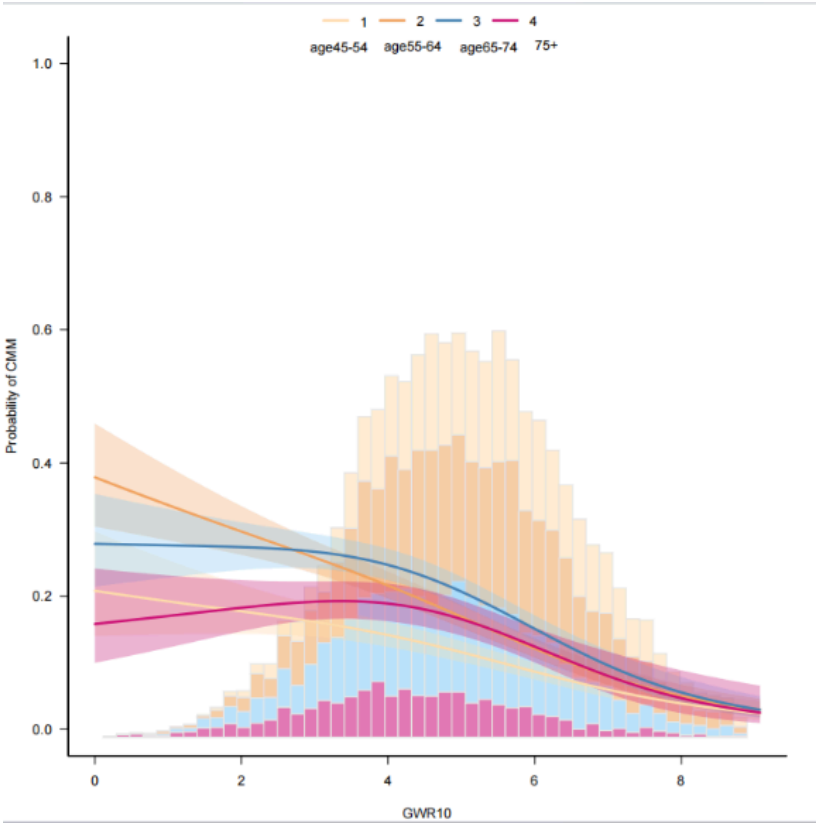


Figure 6

Age-stratified dose-response curves for the association between GWR and probability of CMM across four age groups (45-54, 55-64, 65-74, and ≥75 years).

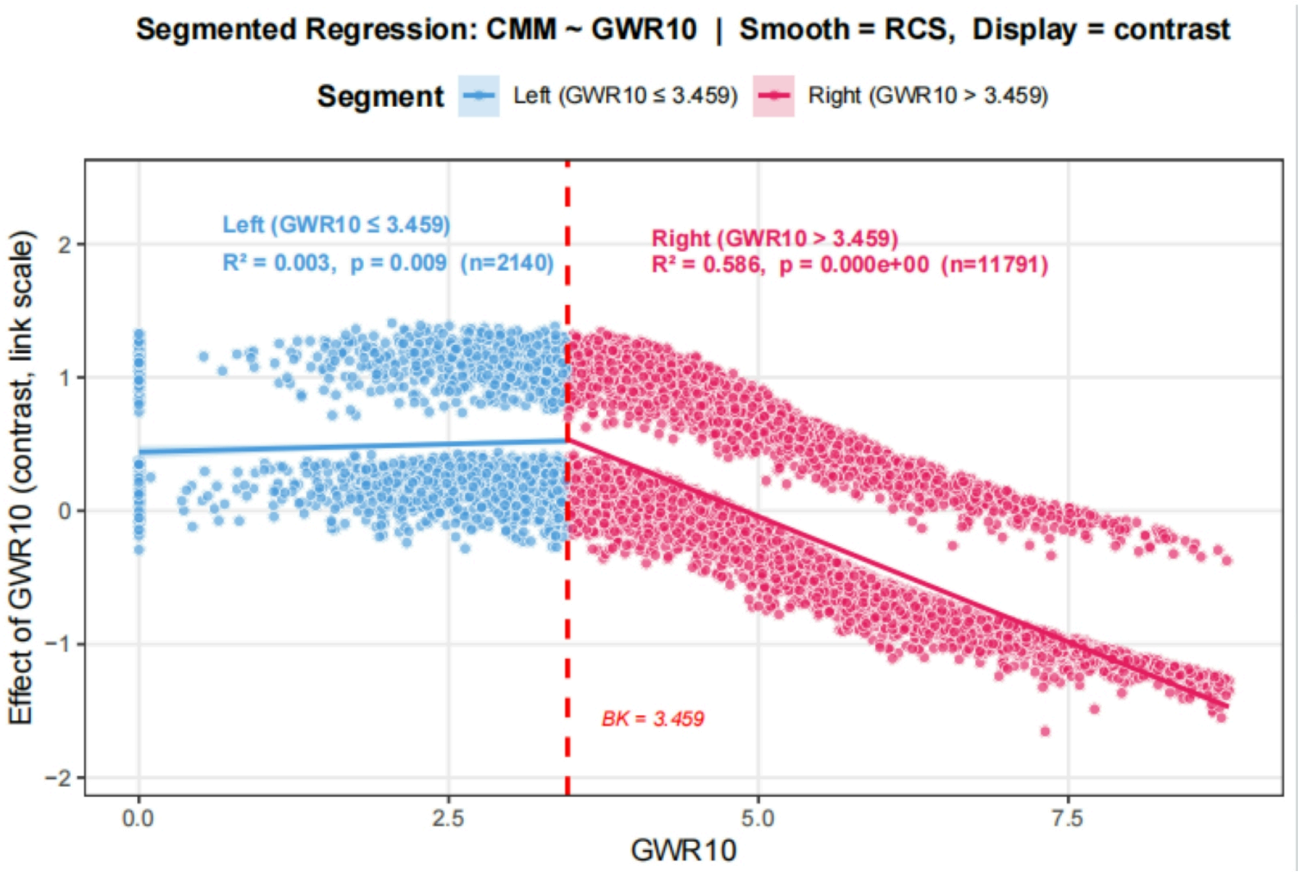


Figure 7

Segmented regression analysis showing the relationship between GWR and CMM with a breakpoint at 3.459 (corresponding to original GWR = 0.3459). Left segment (GWR10 ≤3.459): R^2 = 0.003, P = 0.009 (n = 2,140). Right segment (GWR10 >3.459): R^2 = 0.586, P <0.001 (n = 11,791).

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SupplementaryTable.docx