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Association between grip strength level and fall experience among older Chinese adults: a cross-sectional study from the CHARLS

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Abstract

Objectives To explore the dose-response relationship between levels of grip strength and the fall experience among older adult Chinese.

Methods This study used data from the 2015 China Health and Retirement Longitudinal Study (CHARLS), including 5,486 older Chinese adults aged 60 and above. Grip strength was measured with a dynamometer, and falls were recorded via questionnaire. Logistic regression and restricted cubic spline (RCS) tests assessed the relationship between grip strength and fall experience. Additionally, disparities across different genders, age, and residential areas were explored.

Results After adjusting for confounding factors, compared to the lowest quartile of grip strength, the fall experience of older men decreased by 39% (OR = 0.61, 95% CI = 0.45–0.84, p = 0.002) in the third quartile and 42% (OR = 0.58, 95% CI = 0.42–0.80, p < 0.001) in the highest quartile, the fall experience of older women decreased by 33% (OR = 0.67, 95% CI = 0.51–0.88, p = 0.004) in highest quartile. Restricted cubic spline analysis indicated a negative dose-response relationship between grip strength levels and fall experience among older Chinese adults. Subgroup analyses revealed that the negative dose - response relationship between grip strength levels and fall experience was absent among the elderly aged 75 and above, as well as among rural - dwelling females.

Conclusion This cross-sectional study utilizing CHARLS data reveals a significant negative dose-response relationship between grip strength and falls among Chinese older adults aged 60 to 75 years living in urban areas and Chinese older men of the same age group residing in rural areas. Within this demographic, grip strength can be preliminarily

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used to estimate the likelihood of falls, enabling the early implementation of preventive interventions to reduce the personal and societal impacts associated with fall-related injuries.

Clinical trial number Not applicable.

Keywords Grip strength, Fall experience, Dose-response relationship, Logistic regression, Restricted cubic spline

Introduction

Falls represent a significant challenge for older adults, posing a serious health risk that can reduce life expectancy and becoming a major public health concern worldwide. According to the World Health Organization, approximately 35% of individuals aged 60 and older experience at least one fall annually. The fall experiences increases with age: 32–42% of those over 70 experience falls, and this percentage rises to 50% among those over 80 [1], making falls the second leading cause of accidental injury and death worldwide, following road traffic accidents [2]. Falls not only lead to severe physical injuries, such as fractures and head traumas [3], but also strip older adults of their independence [4]. This increases their reliance on societal support, leading to economic burdens and psychological issues, such as depression and anxiety, which further degrade their quality of life [5, 6]. Therefore, mitigating fall experience in older adults is a critical issue that needs urgent attention in the public health domain.

Investigating physiological markers related to falls in older adults can help identify relevant factors and devise preventive strategies. Although evidence suggests a relationship between muscle reduction and weakness and the fall experience [7–9], there is a growing recognition of the importance of specific and objective physical markers in identifying fall experience. Grip strength is an effective and widely used measure of muscle function and strength [10], offering a simple, efficient, and rapid method for assessment [11]. Grip strength has been demonstrated to be closely associated with successful aging [12]. However, due to differences in muscle mass and strength among populations [13], Asians typically have weaker grip strength and are more likely to be classified as having muscle reduction and weakness [14]. The relationship between falls and successful aging is not always consistent. Therefore, the dose-response relationship between grip strength levels and fall experience among Asians warrants further investigation. Previous study based on China Health and Retirement Longitudinal Study (CHARLS) data explored the relationship between grip strength and the risk of falls among middle-aged and older adults aged 45 and above in China finding a significant negative correlation between the two [15]. However, with 57.8% of the study's participants aged between 45 and 60, the excessive number of middle-aged individuals may influence the outcomes for the older adults. Therefore, further research focusing on individuals over 60 is necessary.

In a population of non-institutionalized older Chinese adults, although falls are associated with insufficient grip strength [16], the relationship between various levels of grip strength and falls is not well-defined. Given China's rapid demographic changes and the growing number of older adults [17], exploring the quantitative relationship between different grip strength level and falls could help identify falls and facilitate effective interventions. Therefore, this study aims to clarify the association between grip strength and falls using data from Wave 3 (2015) of the CHARLS. Our primary objective is to explore the correlation between grip strength levels and the fall experience among older adults residing in Chinese communities, specifically delineating the dose-response relationship. This will enable the identification of older adults at high risk of falls through grip strength assessment, improving early intervention strategies.

Materials and methods

Participants

The China Health and Retirement Longitudinal Study (CHARLS) is a nationally representative survey of middle-aged and older adults in China. This survey is conducted by the National School of Development (CNDI) and the Chinese Social Science Research Center (CSRC) at Peking University [18]. It employs a stratified, multistage, probability sampling method proportional to population size, surveying individuals aged 45 and above from 150 counties and 450 communities (villages) across 28 provinces (autonomous regions, municipalities) [18]. The aim is to collect demographic and health-related data of middle-aged and older adults. The data collection for CHARLS was ethically approved by the Biomedical Ethics Review Committee of Peking University, with the approval number IRB00001052-11015, and is open to the academic community without the need for additional ethical approval [18].

This study is a cross-sectional analysis based on the 2015 CHARLS data. Based on the definition of the older adults in China, we included the participants aged 60 years or older, excluding those under 60 or with missing data on grip strength and fall experience. The study subjects were required to have complete data on grip strength, gender, age, drinking status, smoking status, residency, education level, comorbidities status, activities of daily living (ADL), and fall status. The initial sample consisted of 14,294 individuals aged 45 and older. Of these, 7,337 were excluded due to being under the age of 60, and 1,471 were excluded due to missing data on grip strength and status of falls, leaving a final sample of 5,486 participants for analysis (Fig. 1). Among these, there were 267 missing data points on covariates such as residence, smoking status, and alcohol consumption, which were imputed using the K-Nearest Neighbors (KNN) imputation method (with $k = 10$).

This study analyzed males and females separately, using fall status as the dependent variable and grip strength level as the independent variable, incorporating additional covariates in the regression model to assess their relationship.

Grip strength

Grip strength was measured using the Yuejian™ WL-1000 dynamometer (Nantong Yuejian Physical Measurement Instrument Co., Ltd., Nantong, China), with measurements in kilograms [18]. CHARLS testers instructed participants to stand, hold the dynamometer at a 90° angle, and squeeze the handle for 3–5 s. Each participant performed two measurements on both the left and right hands, for a total of 4 measurements. Participants were encouraged to exert maximum effort during the measurements with verbal encouragement [19]. We used the maximum value from the four measurements, whether it was from the left or right hand. Additionally, considering the influence of body weight on grip strength, we also considered the relative grip strength level (defined as maximum grip strength divided by body weight) as a supplementary analysis. Grip strength levels were categorized using quartiles for analysis. Given the substantial differences in grip strength between men and women, gender was treated as a distinguishing factor. Specifically, the quartiles for male grip strength were as follows: $Q1 \leq 29$ kg, $29 \text{ kg} < Q2 \leq 34.5$ kg, $34.5 \text{ kg} < Q3 \leq 39.5$ kg, $Q4 > 39.5$ kg; and female grip strength quartiles were: $Q1 \leq 18.5$ kg, $18.5 \text{ kg} < Q2 \leq 22.5$ kg, $22.5 \text{ kg} < Q3 \leq 27$ kg, $Q4 > 27$ kg. The quartiles for male relative grip strength were as follows: $Q1 \leq 0.48$, $0.48 < Q2 \leq 0.57$, $0.57 < Q3 \leq 0.66$, $Q4 > 0.66$, and female relative grip strength quartiles were: $Q1 \leq 0.35$, $0.35 < Q2 \leq 0.42$, $0.42 < Q3 \leq 0.50$, $Q4 > 0.50$.

Fall

Fall status were based on self-reports from participants, assessed using the question, "Have you fallen in the past two years?". If a participant answered "yes", he/she was defined as someone who had fallen [16].

Covariates

This study included multiple covariates related to the falls in older adults. Age, residency (urban and rural), marital status (married with spouse present, divorced/ never married, widowed, and others), education level (illiteracy, primary, secondary, and high school and above), health behaviors (alcohol and smoking status), ADL, and comorbidities status were selected as covariates for analysis in this study [15]. The ADL assessment is categorized into two domains: Basic Activities of Daily Living (BADL) and Instrumental Activities of Daily Living (IADL) [20]. BADL includes fundamental tasks such as eating, bathing, dressing, transferring in and out of bed, toileting, and defecation. IADL encompasses more complex activities, including housework, shopping, cooking, medication management, and financial management. Participants were asked whether they encountered difficulties performing these activities, with response options ranging from "no trouble" to "unable to perform the task." Individuals were classified as having an ADL disability if they reported difficulties with any of the 12 items [21]. Comorbidities status summarizes several comorbidities (arthritis, congestive heart failure, coronary heart disease, angina pectoris, heart attack, stroke, diabetes,

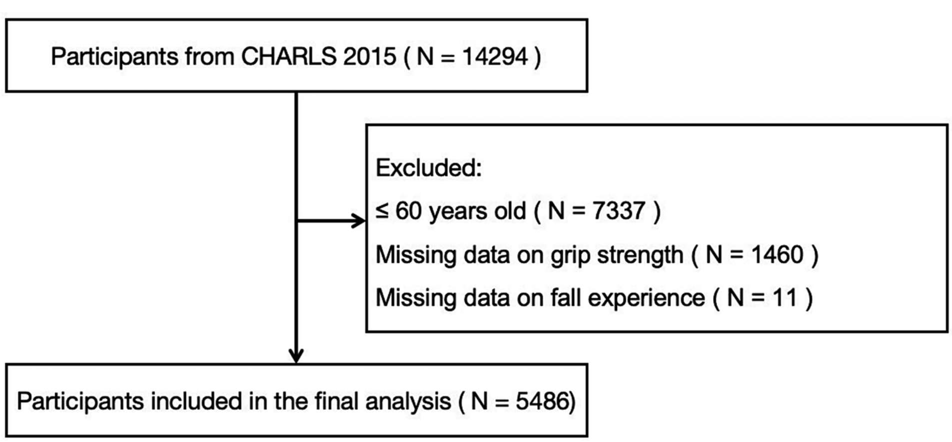

Fig. 1 Flow chart of sample selection from CHARLS 2015

asthma, chronic back pain, chronic lung disease, hypertension, and visual impairment) common among older adults. Having one or more of these diseases is defined as "yes", while no disease is defined as "no".

Data analysis

In this study, all data processing and analysis were conducted using R 4.2.2 software. Measurement variables were presented as mean ± standard deviation (mean ± SD), count data were expressed as percentages, and categorical variables were shown as frequencies and percentages. Kolmogorov-Smirnov tests were used to examine if the data were normally distributed. Group comparisons were performed using the χ^2 test or Fisher's exact test. Considering the large differences in grip strength between men and women, our initial analysis differentiated by gender. To examine the association between various levels of grip strength, relative grip strength, and fall experience among older adults, we used logistic regression: Model 1 included no variable adjustments; Model 2 adjusted for demographic characteristics (age, residence, marital status, and educational level); Model 3 further adjusted for health behaviors (smoking and drinking status), ADL, and comorbidities status. Restricted cubic spline (RCS) analysis was used to determine the dose-response relationship between grip strength and fall experience. Additionally, we carried out sensitivity analyses to validate the stability of our results. Specifically, subgroup analyses were conducted based on intrinsic factors (age) and extrinsic factors (residence) to assess differences across subgroups. Concurrently, we also adopted a sequential approach of eliminating covariates one after another to examine whether there were confounding factors and to assess the stability of the model. The outcomes were presented as odds ratios (ORs) and 95% confidence intervals (CIs), with a *p*-value below 0.05 indicated statistical significance for observed differences.

Results

Baseline characteristics of study participants

Table 1 shows baseline characteristics for 5,486 older adult participants, with an average age of 68.44 ± 6.89 years. Of these participants, 2,739 were male and 2,747 were female. 4,416 (83.01%) were aged 60–75, and 1,070 (16.99%) were aged 75 and above. Of all participants, 1086 had experienced falls, accounting for 19.80% of the total. There was a statistically significant correlation between the fall experience and the variables of gender, residency, education level, smoking status, drinking status, ADL, comorbidities status, grip strength level, and related grip strength level ($p \leq 0.004$). The Kolmogorov-Smirnov tests indicated that the distributions of grip strength, relative grip strength, and ADL data do not conform to a normal distribution ($p < 0.05$). However, histograms and Q-Q plots suggest that the data distributions closely approximate normality. It should be noted that a large sample size may result in excessively small p-values.

Logistic regression analysis of grip strength and fall experience

For older Chinese men, in the unadjusted Model 1, grip strength demonstrated a significant negative association with the fall experience (OR = 0.97, 95% CI = 0.95–0.98). After systematically adjusting for various confounding factors, the fully adjusted Model 3 continued to show a statistically significant negative association between grip strength and the experience of falls (OR = 0.98, 95% CI = 0.96–0.99). To further explore the relationship between grip strength and the experience of falls, grip strength was categorized into quartiles. In both unadjusted and adjusted models, participants in higher quartiles of grip strength exhibited significantly reduced fall experience compared to those in the lowest quartile. Specifically, in the unadjusted analysis, the second, third, and fourth quartiles of grip strength were associated with reductions in fall experience of 25% (OR = 0.75, 95% CI = 0.57–0.98, $p = 0.030$), 46% (OR = 0.54, 95% CI = 0.40–0.72, $p < 0.001$), and 50% (OR = 0.50, 95% CI = 0.37–0.67, $p < 0.001$), respectively. After adjusting for confounders, these reductions were 18% (OR = 0.82, 95% CI = 0.62–1.09, $p = 0.164$), 39% (OR = 0.61, 95% CI = 0.45–0.84, $p = 0.002$), and 42% (OR = 0.58, 95% CI = 0.42–0.80, $p < 0.001$) for the third and fourth quartiles, respectively (Table 2).

For older Chinese women, to further explore the relationship between grip strength and the experience of falls, grip strength was categorized into quartiles. In both unadjusted and adjusted models, participants in higher quartiles of grip strength exhibited significantly reduced fall experience compared to those in the lowest quartile. Specifically, in the unadjusted analysis, the second, third, and fourth quartiles of grip strength were associated with reductions in fall experience of 18% (OR = 0.82, 95% CI = 0.64–1.03, $p = 0.089$), 30% (OR = 0.69, 95% CI = 0.54–0.88, $p = 0.003$), and 43% (OR = 0.57, 95% CI = 0.44–0.73, $p < 0.001$), respectively. After adjusting for confounders, these reductions were 11% (OR = 0.89, 95% CI = 0.70–1.13, $p = 0.336$), 20% (OR = 0.80, 95% CI = 0.62–1.03, $p = 0.080$), and 33% (OR = 0.67, 95% CI = 0.51–0.88, $p = 0.004$) for the third and fourth quartiles, respectively (Table 3).

RCS analysis demonstrated a negative dose-response relationship between grip strength levels and fall experience in older men and older women ($p \leq 0.019$, Fig. 2), higher grip strength levels were associated with fewer falls.

Table 1 Baseline characteristics of study participants

Variables	Total ($n=5486$)	NO-fall ($n=4400$)	Fall ($n=1086$)	χ^2	*p* - value
Age (year)				2.98	0.084
60–75	4416	3,562 (80.7%)	854 (18.3%)		
75+	1070	838 (78.3%)	232 (21.7%)		
Residency				8.30	0.004
Urban	2098	1,724 (82.2%)	374 (17.8%)		
Rural	3388	2,676 (79.0%)	712 (21.0%)		
Educational level				29.64	< 0.001
Illiteracy	3034	2,365 (77.9%)	669 (22.1%)		
Primary school	1415	1,149 (81.2%)	266 (18.8%)		
Secondary school	670	579 (86.4%)	91 (13.6%)		
High school and above	367	307 (83.7%)	60 (16.3%)		
Gender				59.90	< 0.001
Female	2747	2,089 (76.0%)	658 (24.0%)		
Male	2739	2,311 (84.4%)	428 (15.6%)		
Marital status				2.36	0.501
Married with spouse present	4182	3,359 (80.3%)	823 (19.7%)		
Divorced/ never married	79	64 (81.0%)	15 (19.0%)		
Widowed	1057	836 (79.1%)	221 (20.9%)		
Others	168	141 (83.9%)	27 (16.1%)		
Drinking status				8.73	0.003
No	3688	2,917 (79.1%)	771 (20.9%)		
Yes	1798	1,483 (82.5%)	315 (17.5%)		
Smoking status				26.78	< 0.001
No	3931	3,084 (78.5%)	847 (21.5%)		
Yes	1555	1,316 (84.6%)	239 (15.4%)		
Comorbidities				32.26	< 0.001
No	876	757 (86.4%)	119 (13.6%)		
Yes	4610	3,643 (79.0%)	967 (21.0%)		
ADL				130.36	< 0.001
Normal	3912	3,290 (84.1%)	622 (15.9%)		
Disability	1574	1,110 (70.5%)	464 (29.5%)		
Grip strength level				46.84	< 0.001
Q1	1370	991 (72.3%)	379 (27.7%)		
Q2	1362	1,067 (78.3%)	295 (21.7%)		
Q3	1332	1,100 (82.6%)	232 (17.4%)		
Q4	1422	1,242 (87.3%)	180 (12.7%)		
Relative grip strength level				86.65	< 0.001
Q1	1372	998 (72.7%)	374 (27.3%)		
Q2	1371	1,079 (78.7%)	292 (21.3%)		
Q3	1371	1,147 (83.7%)	224 (16.3%)		
Q4	1372	1,176 (85.7%)	196 (14.3%)		

Note ADL, activities of daily living; Q quartiles; Q1 was used as the reference; Categorical variables were presented as numbers (percentage)

A, dose-response relationship between grip strength level and the fall experience in the older men; B, dose-response relationship between grip strength level and the fall experience in the older women; The RCS curves were adjusted for age, marital status, residency, education level, smoking status, drinking status, ADL and comorbidities status; The solid blue lines represented the ORs of fall accidents, the blue region indicated corresponding 95% CIs; The short dashed black lines indicated the reference value; ORs below 1.0 indicates reduced odds of falls, while ORs above 1.0 suggests increased odds.

Logistic regression analysis of relative grip strength and fall experience

In women, the dose-response relationship between relative grip strength levels and the occurrence of falls is similar to that observed with absolute grip strength levels. However, in men, no significant dose-response

Table 2 Logistic regression analysis of the relationship between different grip strength level and fall experience in older Chinese men

Variables	Model 1		Model 2		Model 3	
	OR (95%CI)	*p* - value	OR (95%CI)	*p* - value	OR (95%CI)	*p* - value
Q1	REF		REF		REF	
Q2	0.75 (0.57, 0.98)	0.034	0.74 (0.56, 0.97)	0.032	0.82 (0.62, 1.09)	0.164
Q3	0.54 (0.40, 0.72)	< 0.001	0.52 (0.38, 0.71)	< 0.001	0.61 (0.45, 0.84)	0.002
Q4	0.50 (0.37, 0.67)	< 0.001	0.48 (0.35, 0.66)	< 0.001	0.58 (0.42, 0.80)	< 0.001
p for trend		< 0.001		< 0.001		0.002

Note Data are presented as odds ratio (95% confidence interval); SD standard deviation, Q quartiles, REF, reference; Model 1 did not adjust for confounders; Model 2 adjusted for age, marital status, residency, education level; Model 3 adjusted for age, marital status, residency, education level, smoking status, drinking status, ADL, comorbidities

Table 3 Logistic regression analysis of the relationship between different grip strength level and fall experience in older Chinese women

Variables	Model 1		Model 2		Model 3	
	OR (95%CI)	*p* - value	OR (95%CI)	*p* - value	OR (95%CI)	*p* - value
Q1	REF		REF		REF	
Q2	0.82 (0.64, 1.03)	0.089	0.83 (0.66, 1.06)	0.134	0.89 (0.70, 1.13)	0.336
Q3	0.69 (0.54, 0.88)	0.003	0.72 (0.56, 0.93)	0.011	0.80 (0.62, 1.03)	0.080
Q4	0.57 (0.44, 0.73)	< 0.001	0.59 (0.45, 0.78)	< 0.001	0.67 (0.51, 0.88)	0.004
p for trend		< 0.001		0.001		0.032

Note Data are presented as odds ratio (95% confidence interval); SD standard deviation, Q quartiles, REF, reference; Model 1 did not adjust for confounders; Model 2 adjusted for age, marital status, residency, education level; Model 3 adjusted for age, marital status, residency, education level, smoking status, drinking status, ADL, comorbidities

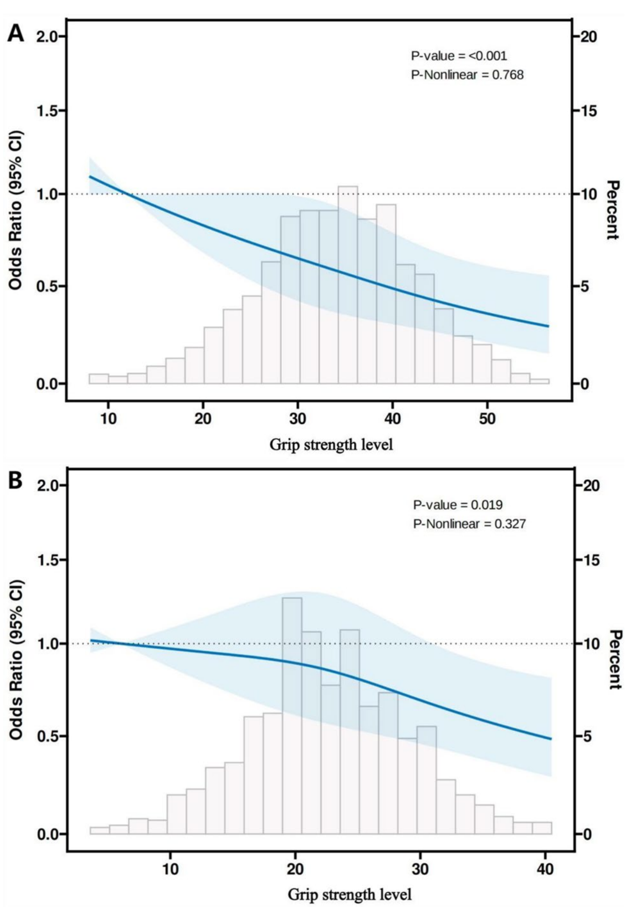

Fig. 2 Dose-response relationship between grip strength level and the fall experience in the older adults

relationship exists between relative grip strength levels and falls. Detailed results can be found in Supplementary Materials, Tables S1-S2 and Figures S1-S2.

Subgroup analyses

In terms of age, compared to the first quartile grip strength level, males aged 60–75 had a significant 39% lower fall experience at the third quartile grip strength level (OR = 0.61, 95% CI = 0.43–0.86, $p = 0.005$), had a significant 44% lower fall experience, at the fourth quartile grip strength level (OR = 0.56, 95% CI = 0.40–0.80, $p = 0.001$). No significant reduction in fall experience was observed for second quartile levels in males. In contrast, females aged 60–75 had a significant 34% lower fall experience at the fourth quartile grip strength level (OR = 0.66, 95% CI = 0.49–0.89, $p = 0.007$). No significant reduction in fall experience was observed for other quartile levels in females. For individuals aged over 75, no significant reduction in fall experience was observed for either gender at any quartile level compared to the first quartile grip strength levels ($p > 0.05$). Results are shown in Table 4.

Regarding extrinsic factors (residential environment) affecting fall experiences in older adults, for men, urban males with grip strength at Q3 and Q4 levels were significantly negatively associated with fall experiences (Q3: OR = 0.53, $p = 0.026$; Q4: OR = 0.50, $p = 0.018$), with a significant overall trend (p for trend = 0.010). Rural males at Q3 and Q4 levels also showed a significant negative association (Q3: OR = 0.67, $p = 0.036$; Q4: OR = 0.63, $p = 0.022$), although the overall trend was not significant

Table 4 Logistic regression analysis of the relationship between different grip strength level and fall experience in man and woman at different ages subgroups

Subgroup	Variables	*N*	OR (95%CI)	*p* - value
Age group of men (years)				
60–75	Q2	523	0.88 (0.63, 1.22)	0.428
	Q3	584	0.61 (0.43, 0.86)	0.005
	Q4	651	0.56 (0.40, 0.80)	0.001
	p for trend			0.002
75+	Q2	140	0.57 (0.31, 1.05)	0.072
	Q3	69	0.72 (0.33, 1.58)	0.415
	Q4	31	1.22 (0.45, 3.29)	0.691
	p for trend			0.239
Age group of women (years)				
60–75	Q2	550	0.86 (0.64, 1.14)	0.297
	Q3	635	0.77(0.58, 1.03)	0.074
	Q4	590	0.66 (0.49, 0.89)	0.007
	p for trend			0.050
75+	Q2	167	0.97 (0.61, 1.52)	0.885
	Q3	64	0.93 (0.49, 1.77)	0.833
	Q4	44	0.70 (0.31, 1.62)	0.409
	p for trend			0.869

Note Data are presented as odds ratio (95% confidence interval); Q quartiles; Q1 was used as the reference; model were adjusted for residency, marital status, education level, smoking status, drinking status, ADL, comorbidities status

Table 5 Logistic regression analysis of the relationship between different grip strength level and fall experience in different residential subgroups

Subgroup	Variables	*N*	OR (95%CI)	*p* - value
Residency (man)				
Urban	Q2	231	1.04 (0.64, 1.70)	0.860
	Q3	261	0.53(0.30, 0.93)	0.026
	Q4	319	0.50 (0.29, 0.89)	0.018
	p for trend			0.010
Rural	Q2	432	0.71 (0.50, 1.01)	0.056
	Q3	392	0.67 (0.46, 0.97)	0.036
	Q4	363	0.63 (0.43, 0.94)	0.022
	p for trend			0.065
Residency (woman)				
Urban	Q2	284	1.00 (0.66, 1.52)	0.993
	Q3	308	0.77(0.49, 1.20)	0.242
	Q4	268	0.61 (0.39, 0.98)	0.048
	p for trend			0.116
Rural	Q2	433	0.83 (0.62, 1.12)	0.215
	Q3	391	0.81 (0.59, 1.11)	0.185
	Q4	366	0.70 (0.50, 0.99)	0.041
	p for trend			0.214

Note Data are presented as odds ratio (95% confidence interval); Q quartiles; Q1 was used as the reference; model was adjusted for age, marital status, education level, smoking status, drinking status, ADL, comorbidities status

(p for trend = 0.065). For women, urban females only at the Q4 level of grip strength were significantly negatively associated with fall experiences (OR = 0.61, $p = 0.048$), while rural females also showed a significant negative association only at the Q4 level (OR = 0.70, $p = 0.041$). Results are shown in Table 5.

Furthermore, RCS analysis was used to investigate the dose-response relationship between grip strength and fall experience in various subgroups. There exists a negative dose - response relationship between grip strength levels and falls among older adults aged 60–75. However, this relationship is not observed in those aged 75 and above. Among different subgroups, grip strength levels demonstrate a negative dose - response relationship with fall experience in urban males and females, as well as rural males. The only exception is rural females, among whom such a relationship is absent. The results are shown in Supplementary material Figures S3 - S10.

Sensitivity analysis by sequentially removing covariates

We adopted a sequential approach of eliminating covariates one after another to examine whether there were confounding factors and to assess the stability of the model. The results indicate that there were no confounders in the covariates and that grip strength remains strongly associated with fall experience (refer to Supplementary material Tables S3-S4).

Discussion

The data was derived from a nationally representative sample of older adults, encompassing a broad data collection scope across 150 counties and 450 communities in 28 provinces [18]. This extensive coverage facilitates a comprehensive analysis of the relationship between grip strength and fall experience within this population. Overall, the results indicate a negative dose-response relationship between grip strength and the fall experience among the older adults, both male and female. Subgroup analyses suggest that the relationship between levels of grip strength and the fall experience in the older adults varies by age and place of residence.

Muscle mass and strength are significant factors influencing the fall experience [9], and can be represented by grip strength [10]. However, there are differences in muscle mass and strength between Asian and Western populations [14], leading to varying standards for grip strength levels [13]. Despite these differences, this study found a negative dose-response relationship between grip strength and fall experience among older Chinese adults, with higher grip strength associated with lower fall experience compared to lower grip strength. This correlation aligns with findings from other international populations [22–24], indicating that the relationship between grip strength and fall experience may not affected by ethnicity.

The weakening of grip strength is frequently regarded as one of the indicators of functional decline in the elderly [16]. It also serves as a crucial criterion for diagnosing sarcopenia [10]. As a surrogate marker of muscle strength [25], the attenuation of grip strength may signify a general decrease in overall muscle strength [26], particularly the decline of limb muscles. The weakening of hand muscle strength often heralds systemic muscle deterioration, subsequently affecting the strength and coordination of the lower extremities. Moreover, the decline in grip strength may be associated with the deterioration of neurological function. The degeneration of the nervous system reduces the ability to control muscles [27]. An important cause of falls is the inability of neuromuscular function to meet the requirements for body posture adjustment. Therefore, to a certain extent, grip strength can reflect the likelihood of falls.

Subgroup analyses revealed that the dose-response relationship between grip strength levels and fall experience in older adults is influenced by intrinsic physiological factors such as age. Among individuals aged 60–75, a exists between grip strength levels and falls. However, this relationship appears to break down in those aged 75 and above. With increasing age, declines in vision, hearing, cognitive abilities, and an increase in illnesses significantly elevate fall experience [28, 29]. As these factors become more pronounced with age, they overshadow the relationship between grip strength and falls. Consequently, grip strength loses its efficacy as a reliable forecaster of fall incidents in this particular age group [30].

The dose - response relationship between levels of grip strength and the fall experience among the older adults is also influenced by external environmental factors of their residence. Rural - dwelling females did not exhibit such a negative dose - response relationship between grip strength levels and fall experience. On the one hand, postmenopausal declines in estrogen levels in older women adults lead to increased risks of muscle mass reduction and osteoporosis [31, 32]. Women also tend to experience more severe musculoskeletal pain and joint degeneration [33]. These adverse factors render older women adults more susceptible to falls under conditions of high exposure, whereas older men adults are less affected by increased exposure [34]. On the other hand, rural communities often have less developed infrastructure and more complex environments (e.g., uneven roads, insufficient lighting), which increase the fall experience for the older adults [35, 36]. Moreover, rural areas generally have poorer medical facilities and fewer opportunities for the older adults to receive health education and interventions [37]. These two sets of factors may lead to a higher fall experience among rural older women. This means that even if their grip strength levels are high, it doesn't manifest as a lower fall experience. As a result, the correlation of the dose - response relationship between grip strength levels and the fall experience of elderly rural women is reduced.

This study has several limitations. Firstly, it is a cross-sectional study, with data sourced from 5486 respondents surveyed in 2015, lacking longitudinal data over multiple years, thus precluding any inference of a causal relationship between grip strength levels and fall experience, and failed to include past fall history data in the analysis. Isolated incidents may occur accidentally, and the failure to study recurrent falls might lead to the possibility of overestimating the fall risk. Additionally, there may also be the possibility of reverse causation, whereby an individual may become incapacitated as a result of a fall, causing their grip strength to become weaker. Secondly, reports of falls and other covariates analyzed in this study relied on self-reports from participants or their family members. Participant had to recall falls in two years period and the potential for an underestimated fall count due to this long time period. The influence of illiteracy could result in inaccuracies and biases into fall outcomes, potentially underestimating the true relationship between grip strength and falls. Additionally, among the eligible population categorized by age, 1471 individuals (21.1%) were excluded due to the absence of critical data necessary for analysis, which may also introduce bias into the results. Thirdly, the study primarily targets older Chinese adults aged 60 and above, so the findings and conclusions may not be generalizable to other countries. Fourthly, although the analysis adjusted for several significant factors, there may still be confounding factors not considered that could affect the results. Future research should aim to confirm causal relationships and explore underlying mechanisms to solidify the foundation for predicting and preventing falls among the older adults.

This cross-sectional study using CHARLS data highlights the strong correlation between grip strength levels and fall experience. Among the older adults in China, compared to relative grip strength, absolute grip strength demonstrates a stronger dose-response relationship with fall experience across all genders. A negative dose-response relationship exists between absolute grip strength and fall experience among both men and women, but this relationship is only significant in the age group of 60 to 75 years. Furthermore, this relationship is not observed among rural - dwelling females. Therefore, under specific conditions (age between 60 and 75, urban - residents, and rural - dwelling males), absolute grip strength can preliminarily be used to estimate the likelihood of falls, enabling early implementation of preventative interventions to reduce the personal and societal impacts of fall-related injuries.

Supplementary Information

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Supplementary Material 1

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Author contributions
GD conceptualized and designed the study. YG and YZ collected and analyzed the data. GD and YG drafted the manuscript. DB, JZ, ZH and JT revised and reviewed the final approval of the manuscript. All authors have reviewed and approved the final manuscript.

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Data availability
The datasets supporting the study are publicly available on the CHARLS website (http://charls.pku.edu.cn).

Declarations

Ethics approval and consent to participate
The original CHARLS was approved by the ethics review committee of Peking University, and all participants gave written informed consent at the time of participation. This research followed the guidance of the Declaration of Helsinki.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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