Association Among Calf Circumference, Physical Performance, and Depression in the Elderly Chinese Population: A Cross-Sectional Study

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Abstract

Background: Depression and sarcopenia are common diseases in the elderly population. However, the association between them is controversial. Based on the Chinese Longitudinal Healthy Longevity Survey (CLHLS) database, a cross-sectional study was conducted to explore the relationship between calf circumference, physical performance, and depression.

Methods: From the 8th wave of CLHLS conducted in 2018, data on calf circumference, physical performance, depressive symptoms, and demographic, socioeconomic, and health-related characteristics were collected. A statistical analysis was conducted to explore the relationship between calf circumference, physical performance, and depressive symptoms. Confounding factors were adjusted for in the multiple logistic regression analysis.

Results: A total of 12,227 participants, including 5689 (46.5%) men and 6538 (53.5%) women (mean age, 83.4 years), were included in this study. After adjusting for confounding factors, the association between calf circumference and depression disappeared (odds ratio [OR] = 1.04, 95% confidence interval [CI]: 0.92–1.17, $p = 0.58$). However, a significant inverse correlation persisted between physical performance and depressive symptoms (OR = 1.16, 95% CI: 1.13–1.20, $p < 0.001$). The subgroup analysis revealed a significant association of calf circumference (OR = 1.3, 95% CI: 1.04–1.62, $p = 0.02$) and physical performance (OR = 1.15, 95% CI: 1.08–1.22, $p < 0.001$) with depression in the regular exercise group.

Conclusions: Physical performance was significantly associated with depression in the elderly Chinese population. Attention should be paid to assess depressive symptoms in patients with poor muscle condition.

Background

Depression, the most common type of mood disorder, is characterized by significant and persisting sadness [1]. According to a statistical analysis by the World Health Organization, depression is the leading cause of disability [2]. Depressive symptoms are common in later life, affecting approximately 10% of the elderly population [3].

Sarcopenia is characterized by age-related loss of skeletal muscle mass and function [4]. Its prevalence ranges from 5.5–25.7% in Asian countries [4] and may be underestimated in the elderly population [5]. The pathophysiology of sarcopenia includes oxidative stress, chronic inflammation, hormonal deficiency, physical inactivity, and malnutrition [6], which may also be involved in the pathogenesis of depression [7–11].

Exercise can improve mood in patients with depression and strengthen muscles, thus improving physical performance. In a randomized controlled trial, exercise intervention using a physical activity program positively affected the depressive status. Moreover, muscles are the largest group of tissues involved in

exercise and endocrine metabolism. Therefore, many studies have investigated the relationship between sarcopenia and depression [12–17].

However, none of the studies considered a large sample size of the elderly Chinese population. Therefore, the aim of the present study was to investigate the relationship between muscle condition and depression in the elderly Chinese population utilizing the Chinese Longitudinal Healthy Longevity Survey (CLHLS) database, a nationally representative sample.

Methods

Study population

Data from the 8th wave of the CLHLS conducted in 2018/2019 were utilized. In CLHLS, the trained staff had collected data from the elderly Chinese population through face-to-face interviews. The information included demographic, socioeconomic, lifestyle-related, and health-related characteristics. Detailed information of the CLHLS has been previously reported [18, 19].

We collected information on calf circumference and physical performance from the 2018 wave of the CLHLS and assessed depressive symptoms based on the Center for Epidemiologic Studies Depression Scale (CES-D). After excluding 3,560 individuals with missing data on calf circumference and CES-D, 87 individuals aged below 65 years, a total of 12,227 participants were included in this study (Figure 1).

Measurements

The questionnaire in the 2018 wave of the CLHLS included calf circumference measured in cm. According to previous studies and the Asian Working Group for Sarcopenia (AWGS) 2019 consensus [4], calf circumference was used as a measure of muscle mass. The muscle mass is considered low when the calf circumference $\leq$ 34 cm in men and $\leq$ 33 cm in women [4, 20–22].

The questionnaire in the 2018 wave of the CLHLS assessed physical performance on a four-item scale. Muscle strength was assessed using the question “Are you able to lift 5 kg of weight?” Walking ability was assessed using the question “Are you able to walk 1 km?” The strength of the lower extremities was assessed using the question “Are you able to crouch and stand three times?” Finally, core strength was assessed using the question “How do you stand up after sitting in a chair?” The respondents were requested to choose from responses “without problem,” “with problem,” and “not able to,” which were assigned scores of 0, 1, and 2 points, respectively. The total score ranged from 0 to 8 points. A higher score indicated low physical performance.

The 10-item CES-D-10 was used to assess depressive symptoms, as reported previously [23]. The options were “rarely,” “some days,” “occasionally,” and “most of the time,” which were assigned scores of 0, 1, 2, and 3 points, respectively. There were two positive questions: “Do you feel as happy as you did when you were young?” and “Are you full of hope for the future?” The results of these two questions were reversely

coded before summation. The total score ranged from 0 to 30 points. A higher score indicated greater severity of depressive symptoms. A score ≥ 10 in the CES-D-10 was considered to indicate depression, as validated by previous studies [24].

Potential confounding factors

The accuracy of results was improved by adjusting for confounding factors, including demographic characteristics (age and sex), socioeconomic characteristics (residence, education, marital status, and retirement status), lifestyle- and health-related behaviors (smoking status, drinking status, activities of daily living [ADL]), social and leisure activity index, travel in the past two years, regular dietary intake of vegetables/fruits/meat/fish/milk products/food made from beans/eggs/nuts, regular tea drinking, and exercise), and health status (body mass index [BMI], cognitive function, and medical history).

The educational level was dichotomized according to the number of years of schooling (0 and ≥ 1 year). ADL ability was assessed on an eight-item scale. ADL disability was defined as the need for an assistant to perform one or more of the five activities (bathing, dressing, toileting, indoor transferring, and feeding) or being incontinent. The social and leisure activity index was calculated using questions on gardening, *tai chi chuan*, square dancing, reading, raising animals/pets, playing *mah-jongg*/cards, watching television/listening to the radio, and participating in social activities. The options were “almost every day,” “sometimes,” and “never,” which were assigned scores of 1, 2, and 3 points, respectively. The total score ranged from 8 to 24 points. A higher score indicated lack of social and leisurely activities.

The Chinese version of the 30-point Mini-Mental State Examination (MMSE) was used for cognitive function assessment. Cognitive impairment was defined as a total score < 24 on MMSE [25]. The questionnaire included 14 self-reported medical conditions. Chronic inflammatory disorder was defined as the presence of one or more of the following ten conditions: heart disease, stroke, diabetes, gastritis, pneumonia, cholecystitis, arthritis, rheumatism, nephritis, and hepatitis.

Statistical analysis

The data were statistically analyzed using the chi-square test, Student's *t* test, or Mann–Whitney U test, as appropriate. Multiple logistic regression was used to calculate the odds ratio (OR) of depressive symptoms for muscle condition. To clarify the effects of muscle condition on depression, a stepwise approach was used to adjust for different sets of confounding factors. Model 1 included muscle mass and physical performance. Model 2 was adjusted for socioeconomic characteristics. Model 3 was additionally adjusted for lifestyle- and health-related behaviors. Model 4 was additionally adjusted for the health status.

Subgroup analyses were conducted to examine the association between muscle condition and depression by age, sex, cognitive function, exercise, ADL ability, and medical history. All subgroup analyses were performed on model 4. The data were analyzed using IBM SPSS Statistics version 20.0 for Windows (SPSS Inc., Chicago, IL). Two-tailed *p*-value < 0.05 was considered statistical significance.

Results

General characteristics

This study involved 12,227 participants (mean age: 83.4 years), including 4,904 aged 65–79 years and 7,323 aged ≥ 80 years (Table 1). The mean CES-D-10 score was 7.4 ± 4.5 (95% confidence interval [CI]: 7.31–7.47). A CES-D-10 score ≥ 10 , indicating depression, was found in 3,335 (27.3%) participants (95% CI: 26.5%–28.1%). Low calf circumference was found in 7,680 (62.8%) participants (95% CI: 61.9%–63.7%), including 3192 (41.6%) men and 4,488 (58.4%) women. Low calf circumference was significantly associated with older age, separated or never-married marital status, regular alcohol consumption, rural residence, and retirement without pension. Further, it was associated with lesser participation in social and leisurely activities, ADL disability, relatively unhealthy diet, relatively less physical activity, depressive symptoms, chronic inflammatory disorders, and poor physical performance and cognitive function.

Association between muscle condition and depressive symptoms

Table 2 shows the results of the multiple logistic regression. In model 1, muscle mass (OR = 1.16, 95% CI: 1.06–1.26, $p = 0.001$) and physical performance (OR = 1.18, 95% CI: 1.16–1.20, $p < 0.001$) were significantly associated with depressive symptoms, supporting the hypothesis that poor muscle condition increases the likelihood of depression in the elderly population. In model 2, which was adjusted for demographic characteristics, the impact of muscle mass attenuated (OR = 1.12, 95% CI: 1.01–1.24, $p = 0.03$), while that of physical performance strengthened (OR = 1.22, 95% CI: 1.20–1.25, $p < 0.001$). In models 3 and 4, which were adjusted for lifestyle- and health-related behaviors and health status, only the association between physical performance and depressive symptoms persisted (OR = 1.16, 95% CI: 1.13–1.20, $p < 0.001$).

After adjusting for confounding factors, depressive symptoms were associated with younger age, lesser educational level, separated or never-married marital status, less participation in social and leisurely activities, lesser frequency of travel, lower intake of fruits, vegetables, and eggs, lesser exercise, and presence of chronic inflammatory disorders. In the subgroup analysis (Table 3), the association between physical performance and depressive symptoms was consistent and more pronounced in the young-old population (65–80 years), men, participants not exercising regularly, and participants with cognitive impairment or chronic inflammatory disorders. In the regular exercise group, the association between muscle mass (OR = 1.3; 95% CI: 1.04–1.61; $p < 0.05$), physical performance (OR = 1.15, 95% CI: 1.08–1.22, $p < 0.001$), and depressive symptoms was significant.

Discussion

Utilizing a nationally representative large-scale survey of the elderly (aged ≥ 65 years) Chinese population, a cross-sectional study was conducted to investigate the relationship between muscle condition and depression. The association between physical performance and depression was found to be pronounced, consistent with previous studies(26-29). Physical inactivity was a common risk factor for

sarcopenia and depression and could mediate the relationship between them(31). Furthermore, muscle condition and depression share common pathogenesis(32). Contracting skeletal muscles secrete neurotrophic factors, which play a role in mood. Neurotrophins, such as brain-derived neurotrophic factor and neurotrophin-3, which promote neuronal differentiation, survival, and synaptic potentiation, are produced by both the brain and skeletal muscle and are associated with mood and muscle regeneration(33). This may be the potential mechanism underlying the association between sarcopenia and mental illness, as decreased neurotrophic support of the brain is associated with depression and anxiety(34). Chronic low-grade inflammation and oxidative stress, which are associated with both depression and sarcopenia, may be another possible mechanism(7, 35). The relationship between sarcopenia and depression may result from physical activity and brain plasticity and inflammation. Potential intervention of these factors might not only relieve depression but also improve sarcopenia.

In this study, people with larger calf circumferences were less likely to have depressive symptoms. Further, after adjusting for potential confounding factors, the impact of calf circumference attenuated, consistent with previous studies(27, 36). However, unlike previous studies, the regular exercise group showed an inverse association between muscle mass and depression. A European consensus indicates that age-related changes in fat deposits and loss of skin elasticity can lead to estimation errors of the calf circumference in the elderly population(37). Therefore, calf circumference may not be a good predictor of muscle mass in that population. In the regular exercise group, age-related changes may have been attenuated. Thus, the association between calf circumference and depression became significant. Furthermore, in the group that did not exercise regularly, individuals may have developed sarcopenic obesity, which can result in a reduced predictive value of the calf circumference for muscle mass.

Some similar previous studies have been conducted in ethnic groups other than the Chinese. An English study showed that reduction in grip strength is associated with a higher risk of depressive symptoms in participants with obesity(38). A Japanese cross-sectional study found a significant association between sarcopenia and depression in elderly male patients with diabetes, measured by “Strength, assistance with walking, rising from a chair, climbing stairs, and falls” (SARC-F) and CES-D questionnaires(39). A Korean study found that the coexistence of low muscle mass and low muscle function is significantly associated with an increased risk of depressive symptoms(40). Because of the complexity of sarcopenia diagnosis, many studies have shown a correlation with one component of its diagnostic criteria, insufficient to prove a link between muscle condition (muscle mass, muscle strength, or physical performance) and depression. More prospective and large-scale studies are required to clarify the relationship between muscle condition and depression.

The advantage of our study was the use of a large sample size of the elderly Chinese population. To obtain robust results, we adjusted for many confounding factors. However, the study has some limitations should be acknowledged. Firstly, we selected four questions in the questionnaire to evaluate participants’ physical performance by reference to SARC-F, which was recommended to screening sarcopenia by AWGS 2019 Consensus(3). However, the evaluation efficiency of the questionnaire composed of these four questions has not been tested. So the results of the present study may lack

universality. Second, due to the cross-sectional study design, the causal relationship between muscle condition and depression could not be clarified. Prospective studies are required to address this limitation.

Conclusions

Depression and sarcopenia are common diseases in the elderly population. This study showed a strong association between physical performance and depression. Future studies should focus on comorbidities of depression and sarcopenia in the elderly population and the effect of regular exercise on depressive mood.

Abbreviations

CLHLS: Chinese Longitudinal Healthy Longevity Survey; OR: Odds ratio; CI: Confidence interval; CES-D: Center for Epidemiologic Studies Depression Scale; AWGS: Asian Working Group for Sarcopenia; ADL: Activities of daily living; BMI: Body mass index; MMSE: Mini-Mental State Examination;

Declarations

Ethics approval and consent to participate: This study was carried out in accordance with the Declaration of Helsinki as revised 1989. The 2018 wave of CLHLS study was approved by the Biomedical Ethics Committee of Peking University (IRB00001052–13074). All participants or their legal representatives signed written consent forms in the baseline and follow-up surveys.

Consent for publication: Not applicable

Availability of data and materials: The data that support the findings of this study are available in <https://opendata.pku.edu.cn/dataverse/CHADS> [41].

Competing interests: Not applicable

Funding: Not applicable

Authors' contributions: JYT and TQ designed the research. JYT, TQ and MN wrote the manuscript and analyzed the data. JYT, QLZ, MN and YXZ contributed to the data collection. All authors have read and approved the manuscript.

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Tables

Table 1. Characteristics of the entire study population and subgroups based on the type of muscle mass

Variables/Subgroups	Total sample	Low muscle mass	Normal muscle mass	<i>p</i> -value
Total sample	12,227	7,680 (62.8%)	4,547 (37.2%)	
Age (years)	83.4 ± 11.0	85.9 ± 10.9	79.1 ± 9.8	0.001
Female	6,538 (53.5%)	4,488 (58.4%)	2,050 (45.1%)	0.001
Rural residence	5,327 (43.6%)	3,584 (46.7%)	1,743 (38.3%)	0.001
Educated	5,857 (55.8%)	3,096 (47.3%)	2,761 (69.8%)	0.001
Living with a spouse	5,417 (44.3%)	2,832 (37.3%)	2,585 (57.3%)	0.001
Retired with pension	3,452 (28.2%)	1,669 (22.5%)	1,783 (40.4%)	0.001
Current smoker	1,964 (16.1%)	1,199 (15.9%)	765 (17.1%)	0.089
Current alcohol drinker	1,856 (15.2%)	1,042 (13.9%)	814 (18.3%)	0.001
ADL disability	2,226 (18.2%)	1,645 (22%)	581 (13.3%)	0.001
Social and leisure activity index	20.9 ± 2.4	21.4 ± 2.2	20.2 ± 2.5	0.001
Have traveled in the past 2 years	1,659 (13.6%)	727 (9.6%)	932 (20.7%)	0.001
Regular intake of				
Vegetables	8,045 (65.8%)	4,874 (63.6%)	3,171 (69.9%)	0.001
Fruits	2,765 (22.6%)	1,478 (19.3%)	1,287 (28.4%)	0.001
Meat	4,999 (41.3%)	3,114 (41.1%)	1,885 (41.8%)	0.441
Fish	1,156 (9.5%)	643 (8.5%)	513 (11.4%)	0.001
Milk products	2,886 (23.9%)	1,610 (21.3%)	1,276 (28.3%)	0.001
Food made from beans	1,506 (12.5%)	865 (11.4%)	641 (14.2%)	0.001
Eggs	4,663 (38.6%)	2,721 (35.9%)	1,942 (43.1%)	0.001

Nuts	810 (6.6%)	379 (5%)	431 (9.6%)	0.001
Tea	2,185 (17.9%)	1,122 (15%)	1,063 (23.8%)	0.001
Regular exercise	4,174 (34.1%)	2,214 (29.2%)	1,960 (43.7%)	0.001
CES-D-10				
Total score (points)	7.4 ± 4.5	7.7 ± 4.4	6.9 ± 4.5	0.001
Total score ≥ 10	3,335 (27.3%)	2,274 (29.6%)	1,061 (23.3%)	0.001
BMI (kg/m ²)	22.4 ± 8.0	21.1 ± 8.4	24.7 ± 6.7	0.001
Physical performance index (points)	1 (0, 4)	2 (0, 5)	0 (0, 3)	0.001
Cognitive impairment	2,050 (16.8%)	1,605 (25.2%)	445 (11%)	0.001
Chronic inflammatory disorders	5,540 (45.3%)	3,217 (41.9%)	2,323 (51.1%)	0.001

Data are expressed as number (frequency) unless otherwise specified. Abbreviations: ADL: activities of daily living; CES-D-10: 10-item Center for Epidemiological Studies; BMI: body mass index

Table 2. Multiple logistic regression analysis of the association between muscle condition and depression

	Model 1		Model 2		Model 3		Model 4	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Low muscle mass	1.16**	1.06–1.26	1.12**	1.01–1.24	1.05	0.94–1.18	1.04	0.92–1.17
Physical performance	1.18***	1.16–1.20	1.22***	1.20–1.25	1.19***	1.15–1.22	1.16***	1.13–1.20
Age			0.97***	0.97–0.98	0.97***	0.96–0.98	0.97***	0.97–0.98
Female			1.08	0.98–1.20	1.06	0.93–1.18	1.01	0.88–1.15
Rural residence			0.98	0.89–1.09	0.98	0.82–1.02	0.95	0.84–1.07
Educated			0.75***	0.67–0.84	0.85**	0.75–0.96	0.84**	0.74–0.97
Living with a spouse			1.23***	1.10–1.38	1.21**	1.07–1.36	1.19**	1.04–1.36
Retired with pension			1.22***	1.10–1.40	0.91	0.78–1.03	1.02	0.85–1.15
Current smoker					1.00	0.85–1.16	1.03	0.87–1.21
Current alcohol drinker					0.83**	0.71–0.97	0.86*	0.72–1.02
ADL disability					0.98	0.84–1.13	1.16	0.97–1.37
Social and leisure activity index					1.06***	1.03–1.09	1.06***	1.02–1.09
Have traveled in the past 2 years					0.78**	0.66–0.94	0.79**	0.67–0.96
Regular intake of								
Vegetables					1.43***	1.29–1.60	1.49***	1.32–1.68
Fruits					1.41***	1.22–1.63	1.31**	1.11–1.52
Meat					1.07	0.96–1.17	1.07	0.95–1.21
Fish					0.80**	0.67–0.96	0.81**	0.68–1.00

Milk products	1.02	0.89– 1.16	1.01	0.86– 1.16
Food made from beans	1.09	0.93– 1.29	1.10	0.91– 1.31
Eggs	1.50***	1.34– 1.68	1.51***	1.31– 1.70
Nuts	1.14	0.90– 1.43	1.13	0.88– 1.44
Tea	1.13	0.97– 1.30	1.14	0.97– 1.32
Regular exercise	1.41***	1.25– 1.59	1.49***	1.31– 1.69
BMI			1.00	1.00– 1.01
Cognitive impairment			0.75***	0.65– 0.87
Chronic inflammatory disorders			0.58***	0.52– 0.65

* $p \leq 0.01$; ** $p \leq 0.05$; *** $p \leq 0.001$

Abbreviations: OR: odds ratio; CI: confidence interval; ADL: activities of daily living; BMI: body mass index;

Model 1 included muscle mass and physical performance.

Model 2 was adjusted for socioeconomic characteristics, including residence, education, marital status, and retirement status.

Model 3 was additionally adjusted for lifestyle- and health-related behaviors (smoking, alcohol consumption, activities for daily living ability, social and leisure activity index, travel, regular dietary intake, tea drinking, and exercise).

Model 4 was additionally adjusted for the health status, including the body mass index, cognitive function, and medical history.

Table 3. Subgroup analysis of the association between muscle condition and depression

	Muscle mass		Physical performance	
	OR	95% CI	OR	95% CI
By age				
< 80	1.16	0.97–1.38	1.21 ^{***}	1.14–1.28
≥ 80	0.93	0.79–1.11	1.15 ^{***}	1.11–1.19
By sex				
Male	1.01	0.84–1.22	1.21 ^{***}	1.15–1.27
Female	1.05	0.88–1.24	1.14 ^{***}	1.09–1.18
By cognitive function				
Impaired	0.83	0.62–1.11	1.17 ^{***}	1.10–1.24
Not impaired	1.08	0.95–1.24	1.16 ^{***}	1.12–1.21
Physical activity				
Regular	1.30 ^{**}	1.04–1.62	1.15 ^{***}	1.08–1.22
Not regular	0.94	0.81–1.09	1.17 ^{***}	1.13–1.21
ADL disability				
Yes	0.98	0.72–1.33	1.15 ^{***}	1.07–1.24
No	1.04	0.91–1.19	1.17 ^{***}	1.13–1.21
Chronic inflammatory disorders				
Yes	1.09	0.92–1.29	1.17 ^{***}	1.12–1.22
No	0.99	0.82–1.19	1.16 ^{***}	1.11–1.21

* $p \leq 0.1$; ** $p \leq 0.05$; *** $p \leq 0.001$

Abbreviations: OR: odds ratio; CI: confidence interval; ADL: activities of daily living

Subgroup analyses were performed on model 4.

Figures

Figure 1

Flowchart of the selection of study population from participants of the Chinese Longitudinal Healthy Longevity Survey