



Metabolic syndrome and its association with components of sarcopenia in older community-dwelling Chinese

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Abstract

Aging and obesity contribute to muscle dysfunction. This study aimed to determine the cross-sectional associations between components of metabolic syndrome (MetS) and sarcopenia in 251 older community-dwelling Chinese. The total fat-free mass was measured by dual-energy X-ray absorptiometry, muscle strength (handgrip strength) by a handheld dynamometer, physical performance by 4-meter walk, 5-time chair stand test, and the short physical performance battery (SPPB). MetS was defined using the International Diabetes Federation (IDF) criteria. The participants with MetS had a higher appendicular skeletal muscle mass (ASM) and relative ASM (RASM). The males with MetS had higher handgrip strength, and the females with MetS had higher SPPB scores. After adjusting for age and body mass index, the participants with an increased waist circumference had a higher ASM, and those with increased diastolic blood pressure (DBP) also had higher handgrip strength. The males with elevated fasting blood glucose (FBG) levels had a lower gait speed. Components of MetS, such as DPB and FBG, were associated with muscle strength and physical performance in older adults. These results suggest that muscle strength and function should be considered in treating older adults with MetS.

Keywords: metabolic syndrome, sarcopenia, community-dwelling, older Chinese

Introduction

The term "sarcopenia" is typically used to describe age-related declines in muscle mass, strength, and physical performance^[1]. According to the definition set by the Asian Working Group for Sarcopenia (AWGS), the prevalence of sarcopenia was 12.5% in the elderly community-dwelling Chinese women and 8.2% in men^[1]. Sarcopenia contributes to several

adverse health outcomes, including infectious complications, prolonged duration of mechanical ventilation, longer hospitalization times, higher need for rehabilitation care, increased disability, and higher mortality^[2]. However, the mechanism underlying sarcopenia has not yet been clarified. In addition to aging, the potential factors associated with sarcopenia include chronic inflammation, malnutrition, lack of exercise, and hormonal dysregulation^[3]. Furthermore,

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low muscle function and mass in obese individuals is defined as sarcopenic obesity, which is associated with cardiovascular and metabolic diseases^[4].

Metabolic syndrome (MetS) arises from a cluster of risk factors (abdominal obesity, high blood pressure, high blood glucose, and blood lipid abnormalities), and may increase the incidences of type 2 diabetes and cardiovascular diseases^[5]. In Chinese adults, the prevalence of MetS has increased from 9.5% in 2002 to 18.7% in 2010–2012^[6]. As with sarcopenia, the incidence of MetS increases with age and adiposity^[7]. Several studies have revealed a relationship between MetS and sarcopenia^[8–9], but others have denied it^[10]. More importantly, the associations between sarcopenia and the components of MetS in older community-dwelling Chinese remain unclear.

In this study, we recruited community-dwelling Chinese individuals aged ≥ 60 years to investigate the associations between components of MetS and sarcopenia. We demonstrated that the components of MetS, such as blood pressure and blood glucose, were associated with muscle strength and physical performance in older adults. Muscular strength and function should be considered in the treatment of older adults with MetS.

Subjects and methods

Study participants

A total of 251 older (aged ≥ 60 years) community-dwelling Chinese men and women living in Nanjing, China were recruited. Subjects with any of the following conditions were excluded: (1) inability to complete the interview; (2) diseases that might affect muscle metabolism, such as inflammatory myopathy,

Parkinson's disease, stroke, thyroid diseases, chronic heart, liver, or renal failure; (3) currently receiving long-term steroid treatment; and (4) malignant tumors. The flowchart of study participants is shown in **Fig. 1**. The interviews with the participants were conducted in Mandarin. The participants' body mass index (BMI), waist/hip circumference, and blood pressure (BP) were measured before interviews. Blood samples were collected after the participant fasted for 10 hours, and the samples were sent to the hospital's clinical laboratory for measurement of plasma glucose, triglyceride, and cholesterol levels.

The clinical study was approved by the Ethics Committee of the First Affiliated Hospital of Nanjing Medical University, Nanjing, China (2019-NT-48), and performed in accordance with the Declaration of Helsinki. All participants gave informed consent before taking part.

MetS definition

MetS was defined according to the International Diabetes Federation criteria^[11]. MetS was defined according to central obesity (defined as an elevated waist circumference, that is ≥ 90 cm in males and ≥ 80 cm in females) and two or more of the following factors: elevated fasting blood glucose (FBG, ≥ 5.6 mmol/L or previously diagnosed diabetes and reported use of glucose-lowering drugs), elevated triglycerides (TG, ≥ 1.7 mmol/L or reported use of triglyceride-lowering drugs), high density lipoprotein cholesterol (HDL-C, <1.03 mmol/L for men and <1.29 mmol/L for women, or reported use of drugs that increase HDL-C concentrations), elevated blood pressure (BP) (systolic blood pressure [SBP] ≥ 130 mmHg or diastolic blood pressure [DBP] ≥ 85 mmHg or reported use of antihypertensive drugs).

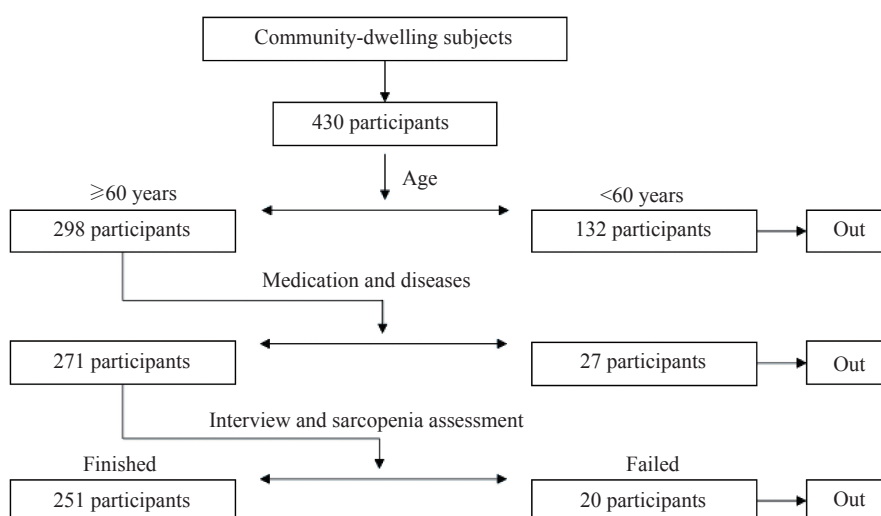


Fig. 1 Flowchart of study participants.

Muscle mass, muscle strength, and physical performance assessment

Muscle mass

All the participants underwent whole-body dual-energy X-ray absorptiometry (DXA; Hologic Inc., USA) to obtain their total fat-free mass. Five body parts, including the android, gynoid, trunk, upper limb, and lower limb, were measured. The limb fat-free mass (the sum of the lean mass of both the arms and legs) was used as a proxy for the appendicular skeletal muscle (ASM) mass. The height-adjusted relative appendicular skeletal muscle (RASM) mass was also calculated ($\text{ASM}/\text{height}^2$, kg/m^2).

Handgrip strength

Upper limb muscle strength was evaluated by measuring the hand grip strength of the subject's dominant hand. The handgrip strength was measured in kilograms using a portable hydraulic dynamometer (Jamar 5030J1, Jamar Technologies, USA). Three attempts with a 1-min interval between them were recorded, and the maximum value was used in further analyses. The measurements were performed by the same staff that performed the other tests.

Gait speed (4-meter walk)

Gait speed was evaluated by asking the participants to walk for four meters along a straight walkway on a flat floor at their usual speed. Using the same stopwatch as before, skilled staff measured the time the participants' spent in performing this task. Each participant was asked to perform this task twice, and the shorter time was recorded for further analysis.

5-time chair stand test

The chair stand test, also called the chair rise test, was used as a proxy for the measurement of leg muscle strength. Participants were asked to stand and sit in a chair five times as quickly as they could, with their arms crossed over their chest, and skilled staff measured the time they spent in performing this task using a stopwatch.

Short physical performance battery

The Short physical performance battery (SPPB) is a composite score that assesses the results of gait speed, balance, and the chair stand test^[12]. Each test was scored from 0 (worst performance) to 4 (best performance), and a total score was obtained for the entire battery of tests by taking the sum of the scores for all three tests. The total possible score ranged from 0 to 12.

Sarcopenia definition

The Asian Working Group for Sarcopenia (AWGS) 2019 consensus was used as criteria to diagnose sarcopenia. Sarcopenia was defined as low muscle mass and low muscle strength, or low physical performance; severe sarcopenia was defined as low muscle, low muscle strength, and low physical performance; low muscle mass as $\text{ASM} < 7.0 \text{ kg}/\text{m}^2$ in males and $< 5.4 \text{ kg}/\text{m}^2$ in females by DXA; low muscle strength as handgrip strength $< 28 \text{ kg}$ for males and $< 18 \text{ kg}$ for females. Criteria for low physical performance included 6-meter walk $< 1.0 \text{ m}/\text{second}$, SPPB score ≤ 9 , or 5-time chair stand test ≤ 12 seconds.

Statistical analysis

The continuous variable data were expressed as the mean \pm standard deviation (SD), and the categorical data were expressed as numbers and percentages. Comparisons between the continuous variables were performed using the Student's *t*-test. The Mann-Whitney *U* test was used for the comparisons of discontinuous variables. Pearson's correlations were used to examine the associations between the components of sarcopenia alone and between the components of sarcopenia and the MetS components. We performed multiple linear regression analyses to explore the associations between the components of MetS and sarcopenia, which were adjusted for age. All the statistical analyses were performed using SPSS software, version 25.0 (USA), and $P < 0.05$ was considered statistically significant.

Results

Characteristics of subjects according to MetS status

A total of 251 participants aged 60 years or older and living in the community of Nanjing, China, were recruited. According to the definition of sarcopenia from the AWGS, six males and seven females were diagnosed with sarcopenia, and only one female with severe sarcopenia. The prevalence of MetS was 31% in men and 49% in women. **Table 1** presents the descriptive characteristics according to the participants' MetS status. Participants with MetS had higher ASM and RASM values. The male subjects with MetS had higher handgrip strength, and the female subjects with MetS had higher SPPB scores. There were no differences in age, chair stand test, and gait speed between the participants with and without MetS.

Table 1 Characteristics of participants with and without metabolic syndrome

Parameters	Male			Female		
	MetS (n=31)	No MetS (n=69)	P-value	MetS (n=74)	No MetS (n=77)	P-value
Age (years) [#]	67.6±6.2	69.4±6.0	0.106	67.9±6.4	67.4±5.7	0.854
BMI (kg/m ²) [#]	26.3±2.1	23.6±2.2	0.000	25.5±3.1	22.7±2.2	0.000
Waist circumference (cm)	96.5±6.2	87.1±9.0	0.000	89.9±7.8	79.6±7.1	0.000
Hip circumference (cm)	100.2±5.6	94.3±7.1	0.000	97.2±5.9	93.4±4.6	0.000
Waist to hip ratio	0.96±0.05	0.92±0.07	0.006	0.93±0.07	0.85±0.07	0.000
SBP (mmHg) [#]	137.5±13.5	132.2±17.9	0.149	136.7±16.9	126.9±18.4	0.000
DBP (mmHg) [#]	82.5±7.6	79.6±10.7	0.279	78.9±9.3	75.2±8.2	0.023
FBG (mmol/L) [#]	6.1±1.5	5.2±0.8	0.001	6.0±1.6	5.2±1.1	0.000
TG (mmol/L) [#]	1.6±0.5	1.4±0.7	0.009	2.0±1.2	1.4±0.5	0.000
HDL-C (mmol/L)	1.0±0.2	1.2±0.3	0.000	1.2±0.3	1.5±0.4	0.000
LDL-C (mmol/L)	2.5±0.6	2.6±0.8	0.616	2.9±0.9	2.7±0.8	0.237
TC (mmol/L)	4.4±0.9	4.6±1.0	0.359	5.0±1.0	4.9±1.0	0.549
Muscle mass						
ASM (kg)	21.3±2.7	19.3±2.7	0.001	14.1±2.0	12.9±1.8	0.000
RASM (kg/m ²)	7.4±0.8	6.8±0.8	0.001	5.8±0.8	5.4±0.6	0.002
Muscle strength						
Handgrip strength (kg)	42.5±7.5	37.8±7.1	0.004	24.9±4.4	24.0±4.4	0.209
Chair stand test (s)	9.1±3.1	8.9±2.8	0.742	9.1±2.3	9.2±2.8	0.747
Physical performance						
Gait speed (m/s)	1.3±0.3	1.3±0.3	0.839	1.3±0.3	1.3±0.3	0.586
SPPB score [#]	11.5±0.9	11.6±1.0	0.313	11.5±0.9	11.4±1.3	0.000

[#]Mann-Whiney U test. BMI: body mass index; SBP: systolic blood pressure; DBP: diastolic blood pressure; FBG: fasting blood glucose; TG: triglycerides; HDL-C: high density lipoprotein cholesterol; LDL-C: low density lipoprotein cholesterol; TC: total cholesterol; ASM: appendicular skeletal muscle mass; RASM: relative ASM; SPPB: short physical performance battery. Bold font indicates P-value <0.05.

Associations between components of MetS and sarcopenia

The Pearson's correlation coefficients for the components of MetS and sarcopenia are shown in **Table 2**. Waist circumference was significantly positively associated with ASM and RASM in men and women. Both SBP and DBP were significantly positively associated with ASM and RASM in women. DBP also had a weakly positive association with handgrip strength in men and a positive association with gait speed in women. FBG had weakly positive associations with both ASM and RASM, and a negative association with gait speed in both men and women. FBG also had a positive association with the time measured for the chair stand test in women. TG was positively associated with ASM and RASM in women. HDL-C cholesterol was negatively associated with ASM in both men and women.

Multiple linear regression analysis of components of MetS and sarcopenia

Table 3 presents the findings from the multiple linear regression analysis comparing the components of MetS and sarcopenia after adjusting for age and BMI. The waist circumference was positively associated with ASM in both men and women. Men with elevated SBP values had longer chair stand test times. However, women with elevated DBP values had shorter chair stand test times. DBP was positively associated with ASM and handgrip strength in men and positively associated with handgrip strength and gait speed in women. Men with increased FBG levels had low gait speed. Women with raised triglycerides had longer chair stand test times, and those with increased HDL-C levels had lower handgrip strength.

Discussion

We investigated the relationship between MetS and

Table 2 Pearson's correlation coefficient between components of metabolic syndrome and sarcopenia

Pearson's correlation coefficient (*P*-value)

Parameters	WC	SBP [#]	DBP [#]	FBG [#]	TG [#]	HDL-C
Male						
ASM	0.443 (0.000)	-0.020 (0.842)	0.144 (0.156)	0.185 (0.067)	0.177 (0.080)	-0.209 (0.038)
RASM	0.392 (0.000)	-0.011 (0.911)	0.051 (0.620)	0.228 (0.023)	0.101 (0.321)	-0.176 (0.081)
Handgrip strength	0.039 (0.703)	0.066 (0.519)	0.208 (0.039)	0.007 (0.944)	0.033 (0.748)	0.076 (0.457)
Chair stand test	0.146 (0.149)	0.036 (0.720)	-0.133 (0.190)	0.021 (0.838)	0.051 (0.617)	-0.127 (0.209)
Gait speed	-0.081 (0.426)	0.104 (0.304)	0.167 (0.098)	-0.208 (0.038)	0.167 (0.099)	-0.077 (0.449)
SPPB score [#]	-0.152 (0.133)	-0.028 (0.782)	0.173 (0.086)	-0.072 (0.478)	0.008 (0.940)	0.076 (0.456)
Female						
ASM	0.408 (0.000)	0.266 (0.001)	0.282 (0.000)	0.169 (0.039)	0.235 (0.004)	-0.226 (0.005)
RASM [#]	0.397 (0.000)	0.246 (0.002)	0.213 (0.009)	0.173 (0.034)	0.163 (0.047)	-0.166 (0.101)
Handgrip strength	0.025 (0.759)	0.130 (0.114)	0.157 (0.055)	-0.051 (0.538)	0.093 (0.258)	-0.096 (0.244)
Chair stand test	0.073 (0.374)	0.044 (0.594)	-0.112 (0.173)	0.163 (0.046)	0.022 (0.785)	-0.082 (0.317)
Gait speed	-0.079 (0.336)	-0.008 (0.918)	0.180 (0.027)	-0.184 (0.024)	0.017 (0.835)	0.001 (0.990)
SPPB score [#]	-0.068 (0.406)	-0.112 (0.171)	0.131 (0.109)	-0.106 (0.197)	-0.011 (0.893)	0.076 (0.456)

[#]Spearman's correlations. WC: waist circumference; SBP: systolic blood pressure; DBP: diastolic blood pressure; FBG: fasting blood glucose; TG: triglycerides; ASM: appendicular skeletal muscle mass; RASM: relative ASM; SPPB: short physical performance battery. Bold font indicates *P*-value<0.05.

Table 3 Multiple linear regression exploring associations between components of metabolic syndrome and sarcopenia

Standardized coefficient β (*P*-value)

	WC	SBP [#]	DBP [#]	FBG [#]	TG [#]	HDL-C
Male						
ASM	0.152 (0.000)	-0.037 (0.081)	0.083 (0.025)	0.071 (0.766)	0.695 (0.217)	1.413 (0.275)
Handgrip strength	0.119 (0.175)	-0.099 (0.094)	0.315 (0.003)	0.241 (0.718)	1.226 (0.436)	6.039 (0.097)
Chair stand test	0.005 (0.892)	0.051 (0.031)	-0.084 (0.038)	0.500 (0.060)	-0.507 (0.415)	-2.229 (0.121)
Gait speed	-0.001 (0.687)	-0.001 (0.968)	0.004 (0.372)	-0.065 (0.012)	0.039 (0.520)	-0.070 (0.611)
Female						
ASM	0.065 (0.001)	0.002 (0.811)	0.035 (0.067)	-0.003 (0.979)	0.027 (0.896)	-0.977 (0.080)
Hand grip strength	-0.037 (0.423)	0.005 (0.826)	0.104 (0.025)	-0.213 (0.413)	-0.403 (0.424)	-2.814 (0.038)
Chair stand test	0.021 (0.417)	-0.003 (0.844)	-0.03 (0.241)	0.230 (0.132)	0.596 (0.037)	0.637 (0.402)
Gait speed	-0.004 (0.112)	-0.001 (0.641)	0.008 (0.003)	-0.030 (0.064)	-0.035 (0.250)	-0.148 (0.069)

[#]Non-normally distributed variable. Adjustment for age and BMI. WC: waist circumference; SBP: systolic blood pressure; DBP: diastolic blood pressure; FBG: fasting blood glucose; TG: triglycerides; ASM: appendicular skeletal muscle mass. Bold font indicates *P*-value<0.05.

the components of sarcopenia in older community-dwelling Chinese. According to our results, waist circumference was associated with ASM and RASM, and waist circumference increased ASM in both men and women. This is consistent with the results of a previous study^[13]. As the key diagnostic element of MetS, waist circumference is strongly related to visceral fat, and it reflects age-related changes in body composition^[14]. Several longitudinal studies have shown the predictive value of abdominal obesity for

disability and declines in physical function in older adults^[15-16]. In our study, the waist circumference was associated with muscle mass, but not with muscle strength or physical performance. This might be because the participants in our study had complete control over self-care. More importantly, this may suggest that increased muscle mass does not necessarily mean better physical performance in older adults with MetS; however, more assessments of muscle quality are required in this population.

Skeletal muscle tissue is vascularized by an elaborate network of arterioles and venules. During exercise, increased cardiac output and reduced vascular resistance ensure blood flow to skeletal muscle^[17]. In a condition of atherosclerosis, however, aging leads to a decline in this ability^[18]. BP is a biomarker of atherosclerosis, and may be associated with skeletal muscle tissue damage. Contrary to previous assumptions, many studies have confirmed that individuals with a high BP exhibit greater muscle strength than those with a normal BP^[19–20]. Taekema *et al*^[21] found that a higher SBP and pulse pressure were associated with higher handgrip strength after adjusting for comorbidity and medication use in the oldest. Ji *et al*^[22] also demonstrated that handgrip strength increased with DBP in both men and women. These studies show that DBP is positively associated with handgrip strength. However, the exact pathophysiological mechanisms for these findings are unclear. Increased vascular resistance during the aging process requires higher pressure to maintain tissue perfusion to prevent further ischemic end organ damage, such as those occurring in skeletal muscle^[23–24]. Due to reduced sympatholysis, peripheral vascular resistance increases with chronological age, resulting in an elevated sympathetic tone^[25].

Gait speed is a well-known indicator of the risk of functional decline and mortality in older adults^[26] and is frequently used as a quick, simple, and reliable index of estimating the functional capacity of older patients. The factors associated with gait speed are poorly understood. We observed a relationship between FBG and the components of sarcopenia, which includes gait speed. The participants with elevated FBG levels had lower gait speed ($P=0.012$ for the men and $P=0.064$ for the women). Sugimoto *et al* recently reported that gait speed increased significantly in the subgroup in which the HbA1c value decreased by 1% or more^[27]. A longitudinal study of a Korean population revealed that a high glycemic level ($HbA1c \geq 8.5\%$) in older patients with diabetes was associated with low muscle mass and quality^[28]. In addition, postprandial hyperglycemia has been suggested as an independent risk factor for lower muscle mass, weak handgrip strength, and slow gait speed^[29]. However, efficient glycemic control or insulin use exerts favorable effects on muscle mass and physical function. An increase in fat mass, inflammation and the accumulation of advanced glycation end products together lead to a decline in muscle function^[30], which may explain the relationship between poor glycemic control and sarcopenia.

To the best of our knowledge, no other studies have investigated the association between the components of MetS and sarcopenia in older community-dwelling Chinese. Our findings are noteworthy because they highlight the importance of maintaining DBP and FBG to prevent a decline in muscle function with increasing age. Increased muscle mass does not necessarily mean better physical performance in older adults with MetS. However, our study has several limitations. First, the participants were relatively young and active, which may have led to a low prevalence of sarcopenia and skewed the results of the statistical analyses. Second, it was difficult to clarify causality in a cross-sectional analysis. Last, these results may not be generalizable to a larger population because of the small sample size and difference in the health of participants.

In conclusion, our results highlight the link between the components of MetS and sarcopenia and provide evidence for screening sarcopenia in older adults with MetS.

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