Diabetes, Metabolic Syndrome and Obesity

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ORIGINAL RESEARCH

Importance of Assessing Sarcopenia in Patients with Type 2 Diabetes Mellitus Based on Body Fat Percentage Measured by Dual-Energy X-Ray Absorptiometry in Different Genders

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Background: Growing evidence indicates that there is a close relationship between type 2 diabetes mellitus (T2DM) and sarcopenia, and T2DM patients are often accompanied by obesity. However, research exploring the connection between body fat percentage (BFP) and sarcopenia is currently limited.

Methods: This was a cross-sectional study that included 676 patients with T2DM over 50 years old. The appendicular skeletal muscle mass index (ASMI), handgrip strength, and 5-time chair stand test (5-TCST) were measured, and sarcopenia was diagnosed according to the Asian Working Group on Sarcopenia (AWGS). Spearman's coefficient was used to evaluate the correlation of BFP and body mass index (BMI) with the diagnostic elements of sarcopenia, and BFP and other relevant covariates were included in the binary logistic regression model. The subgroup performed an interaction test for statistically significant population baseline information.

Results: The prevalence of sarcopenia was 18.0% in males and 11.6% in females. Spearman correlation analysis showed that BFP was positively correlated with ASMI in women (R=0.107, P=0.029), but not in men. BFP was negatively correlated with grip strength (male: R= −0.187, P=0.003; female: R=−0.108, P=0.029). There was a positive correlation between BFP and 5-TCST (male: R=0.199, P=0.001; female: R=0.144, P=0.003). After adjusting for confounding factors, BFP was an independent risk factor for sarcopenia (men, OR: 1.33, 95% CI: 1.15–1.54; women, OR: 1.26, 95% CI: 1.13–1.41). This correlation was generally consistent, as demonstrated in further subgroup analyses.

Conclusion: High BFP was significantly associated with sarcopenia risk, and this association was independent of gender, age, and BMI.

Keywords: body fat percentage, diabetes, sarcopenia, body mass index, obesity

Introduction

Statistics indicate a current global diabetes prevalence of 10.5%, and projections suggest that the number of patients will reach 643 million by 2030, with more than 90% being diagnosed with type 2 diabetes mellitus (T2DM). This escalation is attributed to the continuous improvement of living standards, along with the sedentary lifestyle and unhealthy dietary habits prevalent in modern society, rendering T2DM and its complications a pervasive global health issue endangering human well-being.[1] T2DM is not only associated with complications such as cardiovascular disease and kidney disease but also has a close relationship with sarcopenia,[2] a geriatric syndrome characterized by age-related loss of muscle mass, muscle strength, and/or physical function.[3] Skeletal muscle is one of the largest organs in the body. It plays an important role in glucose metabolism as it controls the consumption and storage of glucose.[4] Their quantity and quality decrease

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with age. The mass of skeletal muscle also differs between the sexes.[3] Previous studies have shown that it is associated with increased secretion of inflammatory cytokines and insulin resistance.[5] Therefore, reduced skeletal muscle mass disturbs normal glucose metabolism and affects insulin sensitivity and blood sugar levels. Sarcopenia is considered to be a novel complication observed in the middle-aged and elderly population with T2DM and has received increasing attention in recent years.[6] Systematic analyses report that the global prevalence of sarcopenia in the elderly is about 10% to 16% using different classifications and cutoff points. The prevalence of sarcopenia was higher in patients compared to the general population, and the prevalence of sarcopenia varied from 18% in patients with diabetes to 66% in patients with unresectable esophageal cancer.[7]

T2DM patients are usually accompanied by overweight or obesity, and the excessive accumulation of certain nutrients and metabolites causes insulin resistance, macrophage dysfunction, and the destruction of the metabolic balance of the microbiota-gut-brain axis, etc., which leads to systemic inflammation and further aggravates immunometabolism disorders, resulting in accelerated loss of β cell function and gradual increase of blood glucose.[8] Body mass index (BMI) is a commonly used clinical indicator to reflect whether a patient is obese. Studies have reported that BMI is a protective factor for sarcopenia, possibly because a high BMI reflects a good nutritional status.[9] However, BMI cannot reflect the proportion of body composition, and high body fat mass and low muscle mass can also increase the risk of sarcopenia.[10] In a study of healthy elderly human body composition analysis results show that BMI and fat mass tend to increase with age overall, and decrease slightly over the age of 75 years. Lean body mass also reduced with age, especially in men.[11] BMI alone may be an insufficient nutritional assessment method in the elderly as it may mask muscle mass loss. Multiple studies have suggested that excess body fat increases all-cause mortality and people with low lean mass have been found to have higher death rates,[12,13] strengthening the notion that the optimal body composition to balance fat and lean mass is an essential component of healthy aging. According to Hong SH et al, the increase in body fat percentage (BFP) is closely related to the decline of muscle mass and function, which is especially obvious in patients with diabetes. Patients with T2DM have hyperinsulinemia caused by insulin resistance, which promotes the synthesis of fat and inhibits the decomposition of fat. The increase in body fat will encourage the secretion of various cytokines and accelerate the catabolism of muscle, leading to sarcopenia. The reduction of muscle mass will lead to the weakening of the response of target tissues to insulin and aggravate insulin resistance, forming a continuous vicious circle, and leading to the occurrence of adverse clinical outcomes.[14]

However, there is very minimal data on the effect of fat mass on sarcopenia in T2DM patients to date. Therefore, an in-depth exploration of the relationship between BFP and sarcopenia in T2DM is of great significance for the development of more effective prevention and treatment strategies.

Materials and Methods

Study Population

This study was a cross-sectional observational study, including 676 inpatients diagnosed with T2DM in the Department of Endocrinology of the Second People's Hospital of Hefei from December 2020 to August 2023. Patients over 50 years of age without acute complications of diabetes who underwent dual-energy X-ray absorptiometry(DXA) were prospectively enrolled; exclusion criteria were: a. Patients with severe systemic diseases (severe infection, heart, kidney, liver, and other diseases, mental disorders, malignant tumors, and connective tissue diseases, etc); b. with hyperthyroidism and hypothyroidism; c. with chronic gastrointestinal diseases such as malabsorption; d. Disability and poor cognitive function. All patients were informed and signed an informed consent form, and the hospital ethics committee approved the study. The research process complies with the Helsinki Declaration.

Parameters

Outcome Variables

The outcome variable of this study was the presence or absence of sarcopenia, which was recorded in the database as a dichotomous variable (yes or no). The skeletal muscle mass of the patient's extremities was measured using DXA and the appendicular skeletal muscle mass index (ASMI) was calculated using: [skeletal muscle mass of the extremities (kg)/height

(m^2)]. Patients' dominant handgrip strength was measured two times using an electronic grip strength meter (Xiangshan EH101) with an interval of at least 1 minute and the maximum value was selected. Patients sat in a 46cm high chair without arms crossed their arms in front of their chest and completed five sit-to-stand movements as fast as possible. The time of completion was recorded, which was called the 5-time chair stand test (5-TCST). The AWGS 2019 cutoffs for low muscle mass in sarcopenia diagnosis are as follows: ASMI <7.0 kg/m^2 in men and <5.4 kg/m^2 in women; low muscle strength is defined as handgrip strength <28 kg for men and <18 kg for women; criteria for low physical performance are 5-TCST ≥12 seconds. Sarcopenia is a disease characterized by a loss of muscle mass accompanied by a decline in muscle strength, physical function, or both.[3]

Independent Variables

The independent variable in this study was BFP, which was recorded as a continuous variable in the database.

Covariates

We collected patient information including age, sex, BMI, and duration of diabetes. Early morning venous blood samples were collected from all enrolled patients after 10 hours of fasting. Triglyceride (TG), total cholesterol (TC), high-density lipoprotein cholesterol (HDL), low-density lipoprotein cholesterol (LDL), glycosylated hemoglobin (HbA1c), fasting C-peptide (F-CP), blood calcium, blood phosphorus, hemoglobin, prealbumin, albumin, alanine aminotransferase (ALT), aspartate aminotransferase (AST), blood urea nitrogen (BUN). Urine samples were collected in the morning and urine albumin/creatinine ratio (UACR) was measured. Bone mineral density (BMD) was measured by DXA. According to the diagnostic criteria of diabetic complications in the Chinese Guidelines for the Prevention and Treatment of Type 2 diabetes,[15] diabetic retinopathy (DR), diabetic nephropathy (DN), diabetic peripheral neuropathy (DPN), and diabetic peripheral vascular disease (PAD) were screened according to fundus photography, UACR, electro neurophysiology examination, carotid, and lower extremity arterial ultrasound.

Statistical Analysis

Since the distribution of body composition, such as fat and muscle mass, was different between men and women, it was intended that the analysis be performed separately for men and women. For continuous variables, the data was represented as mean ± SD or median (interquartile range). Categorical variables were reported as frequencies. The Student's *t*-test, Kruskal–Wallis H-test, or Chi-square test was used for comparisons between variables where appropriate. Spearman's coefficient was used to analyze the correlation of BFP and BMI with each component of sarcopenia. In the analysis of factors associated with sarcopenia, significant variables in the univariate analysis as well as independent variables were included in the binary logistic regression model. Data analyses and plotting in this study were performed using Empower (R) (www.empowerstats.com), R (www.R-project.org), and Graph Prism (ver. 9.5; San Diego, USA). Statistical significance was defined as a two-sided p-value less than 0.05.

Results

Comparison of Demographic Baseline and Clinical Data Between the Sarcopenia Group and Control Group

Table 1 presents the baseline characteristics of the subjects. A total of 676 participants with T2DM (male, n=261; female, n=415) were included in this study. In both males and females, compared with the non-sarcopenia group, the incidence of sarcopenia increased significantly with age, BMI decreased significantly, and UACR was higher in the sarcopenia group. The male sarcopenia group had lower prealbumin, and the female sarcopenia group had a longer duration of diabetes, lower hemoglobin, ALT, AST, and TG, more severe osteopenia, and a higher incidence of diabetic peripheral neuropathy. Table 2 presents the factors used to diagnose sarcopenia. The ASMI and grip strength of the sarcopenia group were lower than those of the non-sarcopenia group and higher than the non-sarcopenia group in 5-TCST.

Table 1 Participant Characteristics According to Sex and Sarcopenia Status

	Male			Female		
	Non-Sarcopenia (n=214)	**Sarcopenia (n=47)**	**P-value**	**Non-Sarcopenia (n=367)**	**Sarcopenia (n=48)**	**P-value**
Age(years)	60.70 ± 7.09	68.55 ± 7.85	<0.001	63.38 ± 8.16	70.19 ± 8.87	<0.001
BFP(%)	27.80 ± 5.15	29.27 ± 4.38	0.070	36.85 ± 5.15	36.54 ± 5.05	0.690
BMI(kg/m^2)	25.31 ± 2.91	23.89 ± 1.98	0.002	24.81 ± 3.51	22.07 ± 2.93	<0.001
Diabetes duration(years)	10.00 (3.25–14.00)	12.00 (8.00–16.00)	0.090	10.00 (5.00–15.00)	12.00 (8.00–18.25)	0.012
HBA1c(%)	8.53 ± 2.12	8.59 ± 1.66	0.860	8.58 ± 2.05	8.82 ± 2.10	0.457
F-CP(ng/mL)	1.69 (1.22–2.48)	1.51 (0.93–1.98)	0.073	1.75 (1.12–2.46)	1.86 (1.33–2.74)	0.404
UACR(mg/g.cr)	13.30 (7.80–30.95)	24.50 (11.55–228.85)	0.027	18.20 (10.95–30.80)	24.45 (17.08–114.70)	<0.001
Uric acid (mmol/L)	332.81 ± 82.68	335.19 ± 94.46	0.862	291.89 ± 78.92	300.96 ± 93.23	0.465
BUN(mmol/L)	6.15 ± 2.15	6.40 ± 1.77	0.450	5.65 ± 1.87	6.21 ± 2.49	0.061
Hemoglobin (g/L)	140.05 ± 15.06	136.91 ± 12.50	0.185	126.38 ± 11.97	120.15 ± 13.30	<0.001
Prealbumin (mmol/L)	249.00 ± 51.12	214.14 ± 51.05	<0.001	226.63 ± 47.91	219.20 ± 66.92	0.337
Albumin (mmol/L)	40.16 ± 4.11	38.95 ± 3.57	0.062	39.83 ± 3.56	39.07 ± 3.63	0.167
ALT (U/L)	18.00 (14.00–25.00)	17.00 (13.00–26.50)	0.415	16.00 (13.00–23.00)	14.00 (11.75–18.00)	0.006
AST (U/L)	18.00 (16.00–22.00)	19.00 (16.00–26.50)	0.461	19.00 (16.00–23.00)	17.00 (15.00–21.00)	0.046
Blood calcium (mmol/L)	2.30 ± 0.10	2.28 ± 0.17	0.290	2.31 ± 0.17	2.30 ± 0.10	0.935
Blood phosphorus (mmol/L)	1.17 ± 0.18	1.23 ± 0.30	0.081	1.28 ± 0.20	1.24 ± 0.19	0.236
TG(mmol/L)	1.44 (0.98–2.17)	1.22 (0.91–1.95)	0.143	1.43 (1.04–1.98)	1.15 (0.84–1.51)	0.008
TC (mmol/L)	4.21 ± 1.15	4.13 ± 1.19	0.673	4.44 ± 1.18	4.32 ± 1.38	0.514
HDL(mmol/L)	1.13 ± 0.33	1.15 ± 0.36	0.790	1.32 ± 0.48	1.36 ± 0.54	0.555
LDL(mmol/L)	2.59 ± 0.94	2.57 ± 1.03	0.907	2.70 ± 1.01	2.58 ± 1.01	0.434
BMD			0.862			0.012
Normal	82 (38.32%)	19 (40.43%)		66 (17.98%)	5 (10.42%)	
Decreased Bone mass	98 (45.79%)	22 (46.81%)		140 (38.15%)	11 (22.92%)	
Rarefaction of bone	34 (15.89%)	6 (12.77%)		161 (43.87%)	32 (66.67%)	
DR			0.441			0.929
No	152 (71.03%)	36 (76.60%)		285 (77.66%)	37 (77.08%)	
Yes	62 (28.97%)	11 (23.40%)		82 (22.34%)	11 (22.92%)	
DN			0.065			0.101
No	172 (80.37%)	32 (68.09%)		284 (77.38%)	32 (66.67%)	
Yes	42 (19.63%)	15 (31.91%)		83 (22.62%)	16 (33.33%)	

(*Continued*)

Table 1 (Continued).

	Male			Female		
	Non-Sarcopenia (n=214)	**Sarcopenia (n=47)**	**P-value**	**Non-Sarcopenia (n=367)**	**Sarcopenia (n=48)**	**P-value**
DPN			0.244			0.041
No	43 (20.09%)	6 (12.77%)		76 (20.71%)	4 (8.33%)	
Yes	171 (79.91%)	41 (87.23%)		291 (79.29%)	44 (91.67%)	
PAD			0.208			0.054
No	55 (25.70%)	8 (17.02%)		136 (37.06%)	11 (22.92%)	
Yes	159 (74.30%)	39 (82.98%)		231 (62.94%)	37 (77.08%)	

Abbreviations: BFP, body fat percentage; BMI, body mass index; HbA1c, glycosylated hemoglobin; F-CP, fasting C-peptide; UACR, urinary albumin/creatinine ratio; BUN, blood urea nitrogen; ALT, alanine transaminase; AST, aspartate aminotransferase TG, triglycerides; TC, total cholesterol; HDL, high-density lipoprotein; LDL, low-density lipoprotein; BMD, bone mineral density; DR, diabetes retinopathy; DN, diabetes nephropathy; DPN, diabetic peripheral neuropathy; PAD, diabetic peripheral angiopathy.

Table 2 Diagnostic Factors for Sarcopenia

	Male			Female		
	Non-Sarcopenia (n=214)	**Sarcopenia (n=47)**	**P-value**	**Non-Sarcopenia (n=367)**	**Sarcopenia (n=48)**	**P-value**
ASMI(kg/m^2)	7.456 ± 0.858	6.315 ± 0.646	<0.001	6.178 ± 0.792	4.890 ± 0.491	<0.001
Handgrip strength(kg)	35.78 ± 8.06	25.14 ± 5.88	<0.001	35.78 ± 8.06	25.14 ± 5.88	<0.001
5-TCST(seconds)	7.42 ± 2.38	10.77 ± 2.57	<0.001	7.42 ± 2.38	10.77 ± 2.57	<0.001

Abbreviations: ASMI, appendicular skeletal muscle mass index; 5-TCST, 5-time chair stand test.

Correlation of BFP and BMI with Each Component of Sarcopenia

BMI was positively correlated with ASMI in both sexes (male: R=0.536, $P < 0.001$; female: R= 0.589, $P < 0.001$), and BFP was negatively correlated with grip strength (male: R= −0.187, P=0.003; female: R=−0.108, P=0.029). There was a positive correlation between BFP and the 5-TCST (male: R=0.199, P=0.001; female: R=0.144, P=0.003). BFP was positively correlated with ASMI in females (R=0.107, P=0.029). However, no significant associations were found between BMI and muscle strength in either sex or between BMI and 5-TCST. As shown in Figure 1.

Univariate and Multivariate Binary Logistic Regression Analysis of Sarcopenia

The logistic regression models for the association between BF% and sarcopenia for both sexes are shown in Table 3. The results showed that in models after adjusting for all other covariates, a higher BF% was still associated with an increased risk of sarcopenia in both sexes (men, OR: 1.33, 95% CI: 1.15–1.54; women, OR: 1.26, 95% CI: 1.13–1.41), and advanced age was associated with an increased risk of sarcopenia (men, OR: 1.17, 95% CI: 1.09–1.25; women, OR: 1.11, 95% CI: 1.05–1.18), while higher BMI was associated with reduced risk of sarcopenia (men, OR: 0.73, 95% CI: 0.61–0.88; women, OR: 0.67, 95% CI: 0.57–0.78) . In males, osteoporosis was significantly associated with sarcopenia (OR: 0.14, 95% CI: 0.03–0.64). In females, hemoglobin and TG were protective factors for sarcopenia (OR: 0.95, 95% CI: 0.91–0.99; OR: 0.63, 95% CI: 0.41–0.97).

Subgroup Analyses and Interactions

Further subgroup analysis (Figure 2) showed that the prevalence of sarcopenia in either gender was significantly associated with BFP in both older and younger age classes, overweight, normal, and emaciated populations, and the interaction test showed no significant difference ($P > 0.05$).

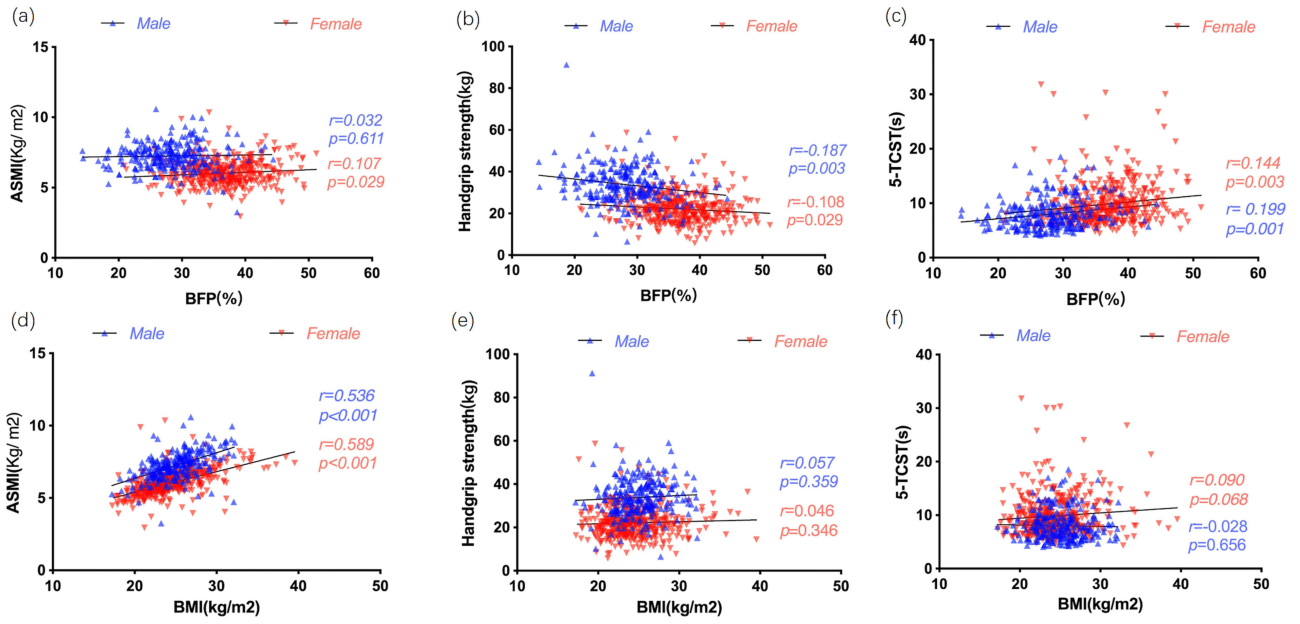

Figure 1 Correlation between BFP, BMI, and components of sarcopenia. **(a-c)** The correlation of BFP and ASMI, handgrip strength, 5-TCST. **(d-f)** The correlation of BMI and ASMI, handgrip strength, 5-TCST.

Abbreviations: BFP, body fat percentage; BMI, body mass index; ASMI, appendicular skeletal muscle mass index; 5-TCST, 5-time chair stand test.

Discussion

Body fat increases with age until the seventh decade of life and then decreases,[16,17] while compression of the vertebral body results in decreased height,[18] which affects anthropometric measures such as BMI. However, the muscle mass of

Table 3 Multiple Logistic Regression Analysis of Objective Variables of Sarcopenia

Exposure	Male		Female	
	Non-adjusted	Adjust	Non-adjusted	Adjust
Age	1.15 (1.09, 1.20) <0.001	1.17 (1.09, 1.25) <0.001	1.10 (1.06, 1.15) <0.001	1.11 (1.05, 1.18) <0.001
BMI	0.82 (0.73, 0.93) 0.002	0.73 (0.61, 0.88) 0.001	0.73 (0.64, 0.82) <0.001	0.67 (0.57, 0.78) <0.001
Diabetes duration	1.06 (1.02, 1.10) 0.006	1.02 (0.96, 1.08) 0.497	1.05 (1.01, 1.09) 0.015	0.99 (0.94, 1.04) 0.667
UACR	1.00 (1.00, 1.00) 0.781	1.00 (1.00, 1.00) 0.664	1.00 (1.00, 1.00) 0.021	1.00 (1.00, 1.00) 0.021
Hemoglobin	0.99 (0.96, 1.01) 0.185	1.02 (0.98, 1.06) 0.269	0.96 (0.94, 0.98) 0.001	0.95 (0.91, 0.99) 0.007
Prealbumin	0.99 (0.98, 0.99) <0.001	0.99 (0.98, 1.00) 0.022	1.00 (0.99, 1.00) 0.336	1.00 (0.99, 1.01) 0.489
ALT	0.99 (0.97, 1.02) 0.438	1.00 (0.94, 1.06) 0.959	0.96 (0.92, 1.00) 0.033	1.00 (0.94, 1.07) 0.938
AST	1.01 (0.97, 1.05) 0.650	0.99 (0.88, 1.12) 0.881	0.97 (0.93, 1.01) 0.145	0.97 (0.90, 1.05) 0.425
TG	0.75 (0.53, 1.07) 0.110	0.67 (0.40, 1.12) 0.128	0.77 (0.54, 1.10) 0.146	0.63 (0.41, 0.97) 0.037
BMD				
Normal	Reference	Reference	Reference	Reference
Decreased Bone mass	0.97 (0.49, 1.91) 0.927	0.88 (0.35, 2.20) 0.783	1.04 (0.35, 3.11) 0.948	0.45 (0.12, 1.70) 0.239
Rarefaction of bone	0.76 (0.28, 2.07) 0.594	0.14 (0.03, 0.64) 0.011	2.62 (0.98, 7.03) 0.055	0.91 (0.26, 3.27) 0.890

(*Continued*)

Table 3 (Continued).

Exposure	Male		Female	
	Non-adjusted	Adjust	Non-adjusted	Adjust
DPN				
No	Reference	Reference	Reference	Reference
Yes	1.72 (0.69, 4.31) 0.249	2.20 (0.60, 8.10) 0.238	2.87 (1.00, 8.24) 0.05	1.44 (0.41, 5.06) 0.567
BFP	1.06 (0.99, 1.13) 0.072	1.33 (1.15, 1.54) <0.001	0.99 (0.93, 1.05) 0.689	1.26 (1.13, 1.41) <0.001

Abbreviations: BMI, body mass index; UACR, urinary albumin/creatinine ratio; ALT, alanine transaminase; AST, aspartate aminotransferase; TG, triglycerides; BMD, bone mineral density; DPN, diabetic peripheral neuropathy; BFP, body fat percentage.

the human body starts to lose gradually from the age of 40, so the weight of middle-aged and elderly people is mainly increased in the form of fat rather than muscle.

In China, BMI ≥24 indicates overweight, especially in patients with diabetes, and dietary guidance is often provided to reduce weight. However, there is concern that providing weight loss guidance without considering patient characteristics leads to reduced muscle mass and increases the risk of patients developing sarcopenia. In this cross-sectional study, we evaluated factors associated with the risk of sarcopenia in the group of T2DM patients over 50 years of age. Based on the results of the body composition analysis, the prevalence of sarcopenia decreased with increasing BMI levels. Although with higher BMI than sarcopenia alone, sarcopenic obesity(SO) patients had a high risk of physical disability, as well as more metabolic issues, which may induce poor clinical outcomes.[19] The comorbid state of obesity and sarcopenia is described SO, its current diagnostic criteria are likely inaccurate, because the concurrent loss of muscle and gain in fat could bring little or zero net change in weight or BMI.[20] Previous studies have shown a strong positive association between BMI and BFP,[21] but our main findings showed that high levels of BFP were associated with an increased risk of sarcopenia in both men and women, highlighting the importance of assessing BFP rather than BMI alone in managing sarcopenia in T2DM.

In this study, the prevalence of sarcopenia in male patients with type 2 diabetes was higher than that in female patients, with 18.0% in males and 11.6% in females, which was consistent with the data reported by the ASWG 2019 that the prevalence of males was 5.1–21.0% and the prevalence of females was 4.1%-16.3%.[3] Sarcopenia is more common in

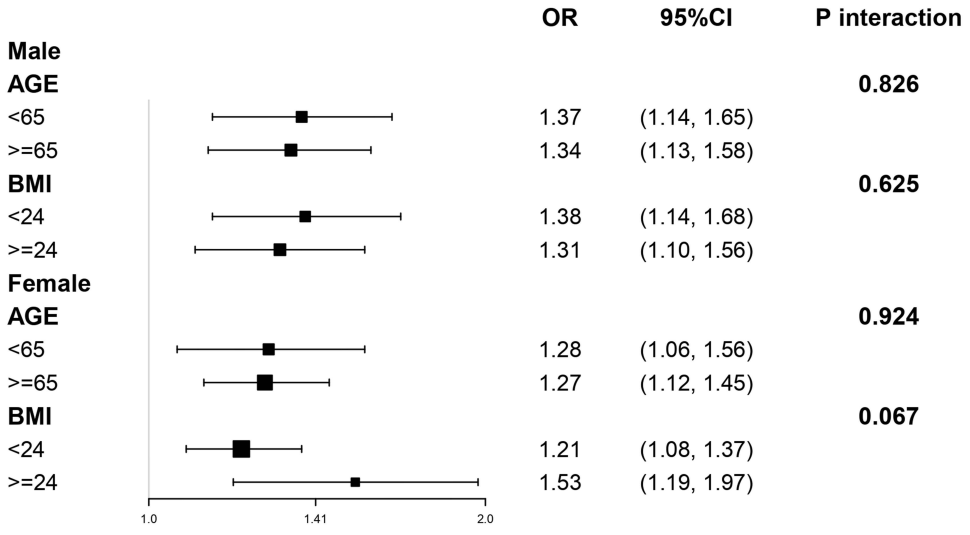

Figure 2 Subgroup analyses and interactions.
Abbreviation: BMI, body mass index.

the male population, and the main explanations for this phenomenon are the following: As men age, their testosterone levels decrease. Testosterone is essential for maintaining muscle mass and strength. A decrease in its level may lead to a decrease in muscle mass and function,[22] thereby increasing the risk of sarcopenia. In addition, unhealthy lifestyles, such as unhealthy eating habits and tobacco and alcohol intake, may lead to obesity and muscle mass loss,[23,24] which may be more common in men. Obesity can cause low-grade inflammation and insulin resistance, which further affects muscle metabolism.

We found a positive correlation between BFP and ASMI in women, and an upward trend in BFP in men, although not related to ASMI, which is consistent with the findings of Lina Sun et al,[25] suggesting that BFP may be more related to muscle or physical function rather than muscle mass. In both men and women, BFP was negatively correlated with muscle strength and positively correlated with the 5-CTST. A possible explanation for these findings is that obesity leads to intermuscular and intramuscular adipose tissue infiltration, accumulation of lipids and their derivatives within and between muscle cells, induction of mitochondrial dysfunction, interference with fatty acid β-oxidation, and enhanced reactive oxygen species production. This leads to lipotoxicity and insulin resistance, as well as enhanced secretion of some proinflammatory cytokines, resulting in muscle atrophy and impaired muscle function.[26,27] There has been evidence from pre-clinical studies indicating that the fat mass in muscle increased not only worsens the muscle metabolism ability but also leads to muscle fibrosis and work of the mismatch between oxygen supply and demand, affecting the muscle contraction.[28,29]

Hemoglobin and albumin can reflect the nutritional status of the human body. Sung-Hua Tseng et al found that higher hemoglobin level was associated with faster walking speed and stronger grip strength,[30] while anemia (low hemoglobin level) was significantly associated with sarcopenia, which is consistent with our results.

The modulatory effect that plasma TG produced by omega-3 fatty acids could mitigate muscle loss is supported by previous study.[31] Among the different lipid Parameters, it has been found that medium-chain triglycerides (MCTs) may be an important sarcopenia nutrient because MCTs can enhance muscle growth by activating ghrelin and thus stimulating growth hormone release.[32] However, MCTs supplementation may lead to a small increase in serum TG.[33] Of the 2613 subjects who were in a survey of skeletal muscle mass and blood lipid levels in the study showed less muscle disease onset and negatively correlated with TG,[34] which is consistent with our observations. Nevertheless, other research has indicated a significant positive correlation between TG levels and muscle atrophy.[35] As one of the three major energy substances, the appropriate intake of lipids is essential for maintaining the normal physiological function of muscles, but excess adipose tissue damages muscle homeostasis, in turn, destroys muscle function.[29] At present, the results of studies on the correlation between lipoprotein subfractions and muscle mass and function are very different. Whether serum TG is a risk factor or a protective factor for sarcopenia is still unclear, and further studies are needed to clarify the relationship between them and the underlying biological mechanism.

In the multivariate logistic regression analysis, our results showed that osteoporosis was associated with a lower incidence of sarcopenia in men, which was inconsistent with the results of previous studies.[10] With the increase of age, male androgen levels decrease, and androgen not only promotes muscle synthesis but also has important benefits in stimulating periosteal bone formation and cortical bone expansion.[36] Sarcopenia and osteoporosis share many common pathophysiological mechanisms, such as changes in hormone levels, effects of cellular aging, and increased levels of chronic inflammation.[37] At the same time, the decrease in muscle strength will reduce the mechanical stimulation to the bone, leading to disuse osteoporosis.[38] The explanation for the inconsistent results of our study may be due to the following reasons: the population selected in this study included middle-aged people, the prevalence of osteoporosis in men was relatively low, and there were few positive samples, which may lead to bias in the results. On the other hand, the study of bone mass in this study selected categorical variables and lacked the analysis of relevant continuous variables. In the future, more detailed research is needed to conduct dual analysis to verify the reliability of the results.

Our study has several strengths, such as the analysis of different genders and the use of reliable instruments for body composition assessment. We used interaction tests to test the robustness of our results. However, it cannot be denied that this study does have some limitations. Although the multiple regression analysis was adjusted, some other confounding factors, such as the use of glucose-lowering drugs and inflammatory markers, were not included in the model. Our study

was a cross-sectional study, and we could only observe associations and could not determine causality. Therefore, future clinical studies with higher levels of evidence in larger populations are warranted to validate our findings.

Conclusion

In Conclusion, our study showed that higher BFP was associated with an increased risk of sarcopenia in middle-aged and elderly patients with T2DM, and this relationship was independent of gender, age, and BMI. Therefore, we should not control the weight of diabetic patients based on BMI alone but should consider body composition to develop personalized diagnosis and treatment programs for patients, which can help prevent sarcopenia, and improve the quality of life of patients.

Ethics Statement

Ethics Committee approval was released from the Second People's Hospital of Hefei. Date 25.10.2019 and number 2019-research-084.

Informed Consent

An informed consent form was obtained from the patients before participating in the study.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

References

1. Sun H, Saeedi P, Karuranga S, et al. IDF Diabetes Atlas: global, regional and country-level diabetes prevalence estimates for 2021 and projections for 2045. *Diabet Res Clin Pract*. 2022;183:109119. doi:10.1016/j.diabres.2021.109119
2. Bellary S, Kyrou I, Brown JE, Bailey CJ. Type 2 diabetes mellitus in older adults: clinical considerations and management. *Nat Rev Endocrinol*. 2021;17(9):534–548. doi:10.1038/s41574-021-00512-2
3. Chen LK, Woo J, Assantachai P, et al. Asian working group for sarcopenia: 2019 consensus update on sarcopenia diagnosis and treatment. *J Am Med Directors Assoc*. 2020;21(3):300–307.e2. doi:10.1016/j.jamda.2019.12.012
4. Mizgier ML, Casas M, Contreras-Ferrat A, Llanos P, Galgani JE. Potential role of skeletal muscle glucose metabolism on the regulation of insulin secretion. *Obes Rev*. 2014;15(7):587–597. doi:10.1111/obr.12166
5. Park JH, Lee MY, Shin HK, Yoon KJ, Lee J, Park JH. Lower skeletal muscle mass is associated with diabetes and insulin resistance: a cross-sectional study. *Diabetes Metab Res Rev*. 2023;39:e3681. doi:10.1002/dmrr.3681
6. Sinclair AJ, Abdelhafiz AH, Rodríguez-Mañas L. Frailty and sarcopenia - newly emerging and high impact complications of diabetes. *J Diabetes Complications*. 2017;31(9):1465–1473. doi:10.1016/j.jdiacomp.2017.05.003
7. Yuan S, Larsson SC. Epidemiology of sarcopenia: prevalence, risk factors, and consequences. *Metabolism*. 2023;144:155533. doi:10.1016/j.metabol.2023.155533
8. Gao D, Jiao J, Wang Z, et al. The roles of cell-cell and organ-organ crosstalk in the type 2 diabetes mellitus associated inflammatory microenvironment. *Cytokine Growth Factor Rev*. 2022;66:15–25. doi:10.1016/j.cytogfr.2022.04.002
9. Xiu S, Sun L, Mu Z, Fu J. Low prealbumin levels are associated with sarcopenia in older men with type 2 diabetes mellitus: a cross-sectional study. *Nutrition*. 2021;91–92:111415. doi:10.1016/j.nut.2021.111415

10. Fukuoka Y, Narita T, Fujita H, et al. Importance of physical evaluation using skeletal muscle mass index and body fat percentage to prevent sarcopenia in elderly Japanese diabetes patients. *J Diabetes Invest*. 2019;10(2):322–330. doi:10.1111/jdi.12908
11. Malczyk E, Dzięgielewska-Gęsiak S, Fatyga E, Ziółko E, Kokot T, Muc-Wierzgon M. Body composition in healthy older persons: role of the ratio of extracellular/total body water. *J Biol Regul Homeost Agents*. 2016;30(3):767–772.
12. Winter JE, MacInnis RJ, Wattanapenpaiboon N, Nowson CA. BMI and all-cause mortality in older adults: a meta-analysis. *Am J Clin Nutr*. 2014;99 (4):875–890. doi:10.3945/ajcn.113.068122
13. Lee DH, Keum N, Hu FB, et al. Predicted lean body mass, fat mass, and all cause and cause specific mortality in men: prospective US cohort study. *BMJ*. 2018;362:k2575. doi:10.1136/bmj.k2575
14. Hong SH, Choi KM. Sarcopenic obesity, insulin resistance, and their implications in cardiovascular and metabolic consequences. *Int J Mol Sci*. 2020;21(2):494. doi:10.3390/ijms21020494
15. Chinese Elderly Type 2 Diabetes Prevention and Treatment of Clinical Guidelines Writing Group, Geriatric Endocrinology and Metabolism Branch of Chinese Geriatric Society, Geriatric Endocrinology and Metabolism Branch of Chinese Geriatric Health Care Society, Geriatric Professional Committee of Beijing Medical Award Foundation, National Clinical Medical Research Center for Geriatric Diseases (PLA General Hospital). 中国老年2型糖尿病防治临床指南(2022年版) [Clinical guidelines for prevention and treatment of type 2 diabetes mellitus in the elderly in China (2022 edition)]. *Zhonghua Nei Ke Za Zhi*. 2022;61(1):12–50. Chinese. doi:10.3760/cma.j.cn112138-20211027-00751
16. Heo M, Faith MS, Pietrobelli A, Heymsfield SB. Percentage of body fat cutoffs by sex, age, and race-ethnicity in the US adult population from NHANES 1999–2004. *Am J Clin Nutr*. 2012;95(3):594–602. doi:10.3945/ajcn.111.025171
17. Flegal KM, Shepherd JA, Looker AC, et al. Comparisons of percentage body fat, body mass index, waist circumference, and waist-stature ratio in adults. *Am J Clin Nutr*. 2009;89(2):500–508. doi:10.3945/ajcn.2008.26847
18. Xu W, Perera S, Medich D, et al. Height loss, vertebral fractures, and the misclassification of osteoporosis. *Bone*. 2011;48(2):307–311. doi:10.1016/j.bone.2010.09.027
19. Roh E, Choi KM. Health consequences of sarcopenic obesity: a narrative review. *Front Endocrinol*. 2020;11:11. doi:10.3389/fendo.2020.00332
20. Li CW, Yu K, Shyh-Chang N, et al. Pathogenesis of sarcopenia and the relationship with fat mass: descriptive review. *J Cachex Sarcop Muscl*. 2022;13(2):781–794. doi:10.1002/jcsm.12901
21. He J, Zhang B, Fan Y, et al. Comparison of bioelectrical body and visceral fat indices and anthropometric measures in relation to type 2 diabetes by sex among Chinese adults, a cross-sectional study. *Front Public Health*. 2023;11:1001397. doi:10.3389/fpubh.2023.1001397
22. Martín AI, Priego T, López-Calderón A. Hormones and Muscle Atrophy. *Adv Exp Med Biol*. 2018;1088:207–233. doi:10.1007/978-981-13-1435-3_9
23. Locquet M, Bruyère O, Lengelé L, Reginster JY, Beaudart C. Relationship between smoking and the incidence of sarcopenia: the SarcoPhAge cohort. *Public Health*. 2021;193:101–108. doi:10.1016/j.puhe.2021.01.017
24. Xia X, Xiang S, Hua L, Sun Q, Wang R. The relationship between lifestyles and sarcopenia-related traits: a two-sample Mendelian randomization study. *Arch Gerontol Geriatr*. 2024;116:105169. doi:10.1016/j.archger.2023.105169
25. Sun L, Fu J, Mu Z, Duan X, Chan P, Xiu S. Association between body fat and sarcopenia in older adults with type 2 diabetes mellitus: a cross-sectional study. *Front Endocrinol*. 2023;14:1094075. doi:10.3389/fendo.2023.1094075
26. Batsis JA, Villareal DT. Sarcopenic obesity in older adults: aetiology, epidemiology and treatment strategies. *Nat Rev Endocrinol*. 2018;14 (9):513–537. doi:10.1038/s41574-018-0062-9
27. Axelrod CL, Dantas WS, Kirwan JP. Sarcopenic obesity: emerging mechanisms and therapeutic potential. *Metab Clin Exp*. 2023;146. doi:10.1016/j.metabol.2023.155639
28. Hill C, James RS, Cox VM, Tallis J. Does dietary-induced obesity in old age impair the contractile performance of isolated mouse soleus, extensor digitorum longus and diaphragm skeletal muscles? *Nutrients*. 2019;11(3):505. doi:10.3390/nu11030505
29. Messa GAM, Piasecki M, Hurst J, Hill C, Tallis J, Degens H. The impact of a high-fat diet in mice is dependent on duration and age, and differs between muscles. *J Exp Biol*. 2020;223(Pt 6):jeb217117. doi:10.1242/jeb.217117
30. Tseng SH, Lee WJ, Peng LN, Lin MH, Chen LK. Associations between hemoglobin levels and sarcopenia and its components: results from the I-Lan longitudinal study. *Exp Gerontol*. 2021;150:111379. doi:10.1016/j.exger.2021.111379
31. Buoite Stella A, Gortan Cappellari G, Barazzoni R, Zanetti M. Update on the impact of omega 3 fatty acids on inflammation, insulin resistance and sarcopenia: a review. *Int J Mol Sci*. 2018;19(1):218. doi:10.3390/ijms19010218
32. Abe S, Ezaki O, Suzuki M. Medium-chain triglycerides (8:0 and 10:0) are promising nutrients for sarcopenia: a randomized controlled trial. *Am J Clin Nutr*. 2019;110(3):652–665. doi:10.1093/ajcn/nqz138
33. McKenzie KM, Lee CM, Mijatovic J, Haghighi MM, Skilton MR. Medium-Chain triglyceride oil and blood lipids: a systematic review and meta-analysis of randomized trials. *J Nutr*. 2021;151(10):2949–2956. doi:10.1093/jn/nxab220
34. Wang N, Chen M, Fang D. Relationship between serum triglyceride to high-density lipoprotein cholesterol ratio and sarcopenia occurrence rate in community-dwelling Chinese adults. *Lipids Health Dis*. 2020;19(1):248. doi:10.1186/s12944-020-01422-4
35. Gong H, Liu Y, Lyu X, Dong L, Zhang X. Lipoprotein subfractions in patients with sarcopenia and their relevance to skeletal muscle mass and function. *Exp Gerontol*. 2022;159:111668. doi:10.1016/j.exger.2021.111668
36. Almeida M, Laurent MR, Dubois V, et al. Estrogens and androgens in skeletal physiology and pathophysiology. *Physiol Rev*. 2017;97(1):135–187. doi:10.1152/physrev.00033.2015
37. Laurent MR, Dedeyne L, Dupont J, Mellaerts B, Dejaeger M, Gielen E. Age-related bone loss and sarcopenia in men. *Maturitas*. 2019;122:51–56. doi:10.1016/j.maturitas.2019.01.006
38. Wang L, You X, Zhang L, Zhang C, Zou W. Mechanical regulation of bone remodeling. *Bone Res*. 2022;10(1):1–15. doi:10.1038/s41413-022-00190-4