

# Relationship Between Body Composition and Hypertension in Postmenopausal Women with Osteoporosis—A Single-Center Cross-Sectional Study

Shu Jiang<sup>1,\*</sup>, Yu Fu<sup>2,\*</sup>, Lu Chen<sup>2</sup>, Yi Qiu<sup>2</sup>

<sup>1</sup>Department of Echocardiography and Cardiology, The First People's Hospital of Changzhou, Changzhou, Jiangsu Province, 213003, People's Republic of China; <sup>2</sup>Department of Clinical Nutrition, The First People's Hospital of Changzhou, Changzhou, Jiangsu Province, 213003, People's Republic of China

\*These authors contributed equally to this work

Correspondence: Lu Chen; Yi Qiu, Email cl2324@czfph.com; 13685275829@163.com

**Objective:** To research the association among body composition and the presence or absence of comorbid hypertension in postmenopausal women with osteoporosis.

**Methods:** Postmenopausal osteoporosis sufferers according to whether they are combined with hypertension or not were divided into two groups: hypertension-negative group and hypertension-positive group. Compare the indicators of the two groups, find out the independent influencing factors, and test the test effect of influencing factors. Establish a prediction model and analyse the relationship between the prediction model and blood pressure.

**Results:** There were statistical differences in age, 25-hydroxyvitamin D, uric acid, homocysteine, history of diabetes, high-density lipoprotein cholesterol, body mass index (BMI), waist circumference (WC), body fat mass (BFM), body fat percentage (PBF) and visceral fat area (VFA) between two groups. Logistic analysis showed that BFM and VFA were independent influencing factors for hypertension, with for BFM (OR, 0.46; 95% CI, 0.24–0.90;  $p=0.024$ ) and VFA (OR, 1.06; 95% CI, 1.01–1.13;  $p=0.031$ ). Based on the body composition parameters of BMI, WC, BFM, PBF and VFA, the area under the curve of the prediction model for detecting hypertension was 0.694 by receiver-operating characteristic test ( $p < 0.001$ ). Using generalized additive model, the predictor were found to have a significant dose-response relationship with systolic blood pressure (SBP), but not with diastolic blood pressure.

**Conclusion:** BFM and VFA are independent influencing factors for hypertension in postmenopausal osteoporosis patients. In postmenopausal osteoporosis patients, the predictive model composed of body composition related parameters has certain significance in predicting whether postmenopausal osteoporosis is complicated with hypertension. The effect of the prediction model on blood pressure was mainly reflected in SBP.

**Keywords:** body composition, osteoporosis, hypertension, body fat mass, visceral fat area

## Background

Osteoporosis can occur at all ages, with postmenopausal women and the elderly being the most prevalent groups. 2021 data from the 7th China Population Survey showed that older people ranked first in the world, with 264 million (18.7%) people aged 60+, and with over 190 million in the 65+ age group. With the increasing trend of population ageing, the incidence of osteoporosis is rapidly rising in China and has become a public health challenge that cannot be ignored. A comprehensive analysis of 5097 postmenopausal women in Morocco showed that the prevalence of osteoporosis in this group was 32%.<sup>1</sup> This condition is closely linked to the decline in oestrogen levels in women after menopause, as well as increasing the risk of developing hypertension. The large-scale cross-sectional study of the NHANES (National

Health and Nutrition Examination Survey) from 1999–2018 confirmed that the risk of osteoporosis in patients with hypertension is 1.69 folds greater compared to those without hypertension.<sup>2</sup> It has also been noted that patients with osteoporosis have a markedly greater prevalence of hypertension and coronary heart disease.<sup>3</sup>

Currently, most studies have focused on osteoporosis. In this paper, postmenopausal women with osteoporosis were selected to study the risk of hypertension in this population. From the perspective of nutrition and body composition, the effect of body composition on whether postmenopausal women with osteoporosis complicated with hypertension was studied. And how to carry out reasonable lifestyle intervention to prevent the occurrence of hypertension was explored.

## Methods

### Study Population

During 6/2020 to 6/2023, 164 hospitalised patients with osteoporosis were selected as study subjects in the First People's Hospital of Changzhou. All of them were postmenopausal women. The bone mineral density of the patients was measured by dual-energy X-ray bone densitometry according to the criteria of the Chinese Guidelines for the Diagnosis and Treatment of Primary Osteoporosis (2022 edition). The clinical diagnosis of osteoporosis was confirmed if the patient's bone mineral density T value was lower than  $-2.5$ . Subsequently, the patients were categorised into a non-hypertensive group (negative group) and a hypertensive group (positive group) according to whether they were accompanied by hypertension or not. The diagnosis of hypertension was based on the Chinese Guidelines for the Prevention and Control of Hypertension 2024 (Revised), which were as follows (in the absence of antihypertensive medication): three in-office blood pressure measurements on non-simultaneous days were  $\geq 140/90$  mmHg; or the average of home self-measurement of blood pressure for five to seven consecutive days was  $\geq 135/85$  mmHg; or the results of 24-hour ambulatory blood pressure monitoring showed an average value of  $\geq 130/80$  mmHg. Patients with a history of hypertension and currently taking antihypertensive medication were classified as hypertensive even if their blood pressure was below the above criteria.

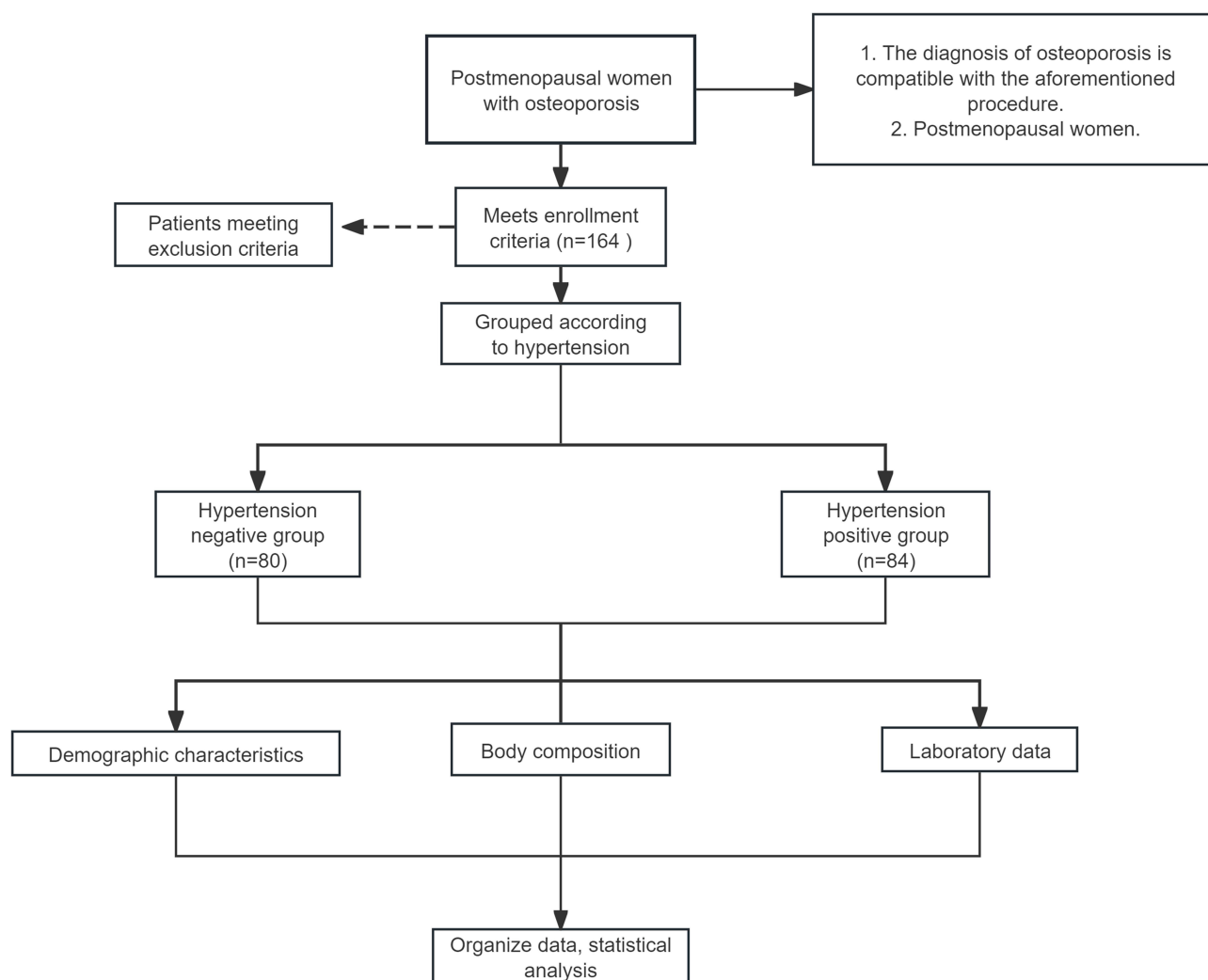
Inclusion criteria were: (1) postmenopausal women, age ranged from 45 to 85 years; (2) patients with a clear diagnosis of osteoporosis; (3) patients with a body composition analysis; (4) the data were complete. Exclusion criteria were: (1) serious underlying diseases; (2) secondary hypertension; (3) thyroid and parathyroid diseases; (4) gastrointestinal and renal diseases affecting calcium and vitamin D absorption and metabolism; (5) malignancies; (6) had taken or were taking drugs affecting bone metabolism; (7) secondary osteoporosis and osteoporotic fractures. Figure 1 presents the flowchart for this study. This study was approved by the Ethics Committee of the First People's Hospital of Changzhou, and the approval number was (2024) Department 167. The study was carried out in accordance with the guidelines of the Declaration of Helsinki.

### Data Collection

General information: Age, past medical history, personal habits, and blood pressure indicators were collected and recorded for all patients.

Laboratory tests: were performed in our hospital and all blood samples were centrifuged, separated to be analysed within one hour of collection. The following indices were measured by colorimetric method: serum uric acid (UA), total cholesterol (TC), triglycerides (TG), low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), apolipoprotein A1, apolipoprotein B, and homocysteine (HCY).

Bone metabolism index measurement: Four millilitres of venous blood was drawn early in the morning on an empty stomach and centrifuged at  $4000 \times g$  for 5 minutes and the supernatant was taken. Roche Electrochemiluminescence Immunoassay Analyser and its accompanying kit were used to detect procollagen type I N-terminal propeptide, type I collagen C-terminal cross-linking peptide, parathyroid hormone and osteocalcin. Dual-energy X-ray bone densitometry (Hologic Discovery, USA) was used to measure the bone density of the lumbar spine (L1-4), the left femoral neck, and the femoral trochanter, and to correct for osteophytes. Before the examination, subjects were asked to remove any high-density items they were wearing and to measure their height and weight. Bone density measurements were performed by the same technician to ensure data consistency.



**Figure 1** Flow chart of the study population.

**Body composition analysis:** Body composition analyser (Biospace Co., Ltd., Korea, Inbody 770 model) was used to measure in fasting state, including: body mass index (BMI), waist circumference (WC), hip circumference, muscle circumference of the upper arm, whole body water, intracellular water, extracellular water, minerals, protein content, bone mineral content, fat-free volume, muscle volume, limb skeletal muscle mass, body fat mass (BFM), percentage body fat (PBF), Inbody score, visceral fat area (VFA), and cell counts were recorded.

## Statistical Analysis

Data are presented as  $\bar{x} \pm s$  or as medians with interquartile ranges for continuous variables, while categorical variables are presented as frequencies and percentages. To assess statistical differences in means and proportions between the two groups, the Mann–Whitney *U*-test and chi-square test were employed. A multivariate logistic regression model was constructed to investigate the association between hypertension and various parameters. Additionally, multivariate logistic regression analysis was conducted to explore the link between body composition parameters and hypertension, with significant predictors being retained in the model. The diagnostic accuracy of these predictors for hypertension was evaluated using receiver operating characteristic (ROC) curves. Furthermore, generalized additive models were applied to examine the dose-response relationship between the predictors and systolic blood pressure (SBP) as well as diastolic blood pressure (DBP). All statistical analyses were performed using R software and EmpowerStats (<http://www.empowerstats.com>, X&Y Solutions, Inc., Boston, MA), with a two-sided significance level of 0.05 used to determine statistical significance.

## Results

### Baseline Data

These 164 patients were included in this study and they were categorised into hypertension negative group (n=80) and hypertension positive group (n=84) according to whether they had hypertension. Table 1 and Table 2 show the comparison of each parameter between the two groups. There were significant differences in age, history of diabetes, 25-hydroxyvitamin D, UA, HDL-C and HCY. In addition, in terms of body composition, the two groups showed significant differences in BMI, WC, BFM, PBF, and VFA.

**Table 1** Subgroups Based on the Presence or Absence of Hypertension and Comparison of Baseline Data Between the Two Groups

	Hypertension Negative	Hypertension Positive	p-value
N	80	84	
Age (year)	66.2 ± 8.9	70.5 ± 7.8	0.001
Diabetes (%)	7 (8.8%)	18 (21.4%)	0.024
Smoking (%)	0(0.0%)	2(2.4%)	0.165
Drinking alcohol (%)	1(1.2%)	2(2.4%)	0.589
25-hydroxyvitamin D (ng/mL)	25.2 ± 10.3	21.6 ± 8.0	0.014
UA (umol/L)	270.8 ± 58.5	303.3 ± 62.8	<0.001
PTH (pg/mL)	48.4 ± 20.4	46.2 ± 21.7	0.516
OC (ng/mL)	13.2 ± 5.9	15.4 ± 9.1	0.084
PINP (ng/mL)	35.0 (23.8–46.0)	41.2 (24.9–65.0)	0.159
CTX (pg/mL)	281.9 (192.8–387.8)	353.0 (180.9–675.9)	0.074
TC (mmol/L)	5.4 ± 0.9	5.7 ± 3.3	0.486
TG (mmol/L)	1.3 (0.9–1.7)	1.4 (1.0–2.2)	0.249
HDL-C (mmol/L)	1.6 ± 0.5	1.4 ± 0.4	0.016
LDL-C (mmol/L)	2.9 ± 0.7	3.0 ± 0.9	0.824
ApoA (g/L)	1.6 ± 0.3	1.5 ± 0.3	0.093
ApoB (g/L)	1.0 ± 0.3	1.1 ± 0.3	0.43
HCY (umol/L)	10.0 ± 2.4	12.5 ± 6.3	0.005
FFA (mmol/L)	0.6 ± 0.2	0.6 ± 0.3	0.309
Cone BMD (g/cm <sup>2</sup> )	0.7 ± 0.1	0.7 ± 0.1	0.81
Hip BMD (g/cm <sup>2</sup> )	0.7 ± 0.1	0.7 ± 0.3	0.914
Femoral neck BMD (g/cm <sup>2</sup> )	0.6 ± 0.1	0.6 ± 0.1	0.36

**Notes:** Reference value: 25-hydroxyvitamin D >30ng/mL, UA 155–357umol/L, PTH 12.19–87.19pg/mL, OC 8.9–29.1ng/mL, PINP 21.3–112.7ng/mL, CTX 130–900pg/mL, TC 2.9–5.68 mmol/L, TG 0.23–1.23 mmol/L, HDL-C 0.9–2.19 mmol/L, LDL-C <3.36 mmol/L, ApoA 1.2–1.6g/L, ApoB 0.6–1.1g/L, HCY <20 umol/L, FFA 0.2–0.9mmol/L.

**Abbreviations:** UA, Uric acid; PTH, Parathyroid hormone; OC, Osteocalcin; PINP, procollagen type I N-propeptide; CTX, C-terminal crosslinking telopeptide of type I collagen; TC, Total cholesterol; TG, Triglyceride; HDL-C, High density lipoprotein cholesterol; LDL-C, Low-density lipoprotein cholesterol; ApoA, Apolipoprotein A1; ApoB, Apolipoprotein B; HCY, Homocysteine; FFA, Free fatty acids; BMD, bone mineral density.

**Table 2** Comparison of Body Composition Parameters Between the Two Groups According to Whether They Were Divided Into Groups with or without Hypertension

	Hypertension Negative	Hypertension Positive	p-value
BMI (kg/m <sup>2</sup> )	21.1 ± 3.0	22.4 ± 3.5	0.012
WC (cm)	77.8 ± 7.8	80.7 ± 8.7	0.028
HC (cm)	88.6 ± 4.4	89.4 ± 5.5	0.343
AMC (cm)	23.3 ± 1.9	23.7 ± 2.4	0.223
TBW (L)	26.8 ± 2.8	26.3 ± 4.0	0.305
ICW (L)	16.4 ± 1.8	16.0 ± 2.5	0.232
ECW (L)	10.4 ± 1.1	10.3 ± 1.5	0.463
Minerals (kg)	2.6 ± 0.2	2.5 ± 0.3	0.314
Protein (kg)	7.1 ± 0.8	6.9 ± 1.1	0.252
BM (kg)	2.1 ± 0.2	2.1 ± 0.3	0.392
FFM (kg)	36.5 ± 3.8	35.7 ± 5.4	0.291
Muscle mass	19.4 ± 2.3	18.8 ± 3.3	0.246
SMME (kg)	5.7 ± 0.6	5.6 ± 0.9	0.433
BFM (kg)	16.3 ± 5.6	18.2 ± 6.1	0.043
PBF (%)	30.2 ± 7.2	32.9 ± 7.6	0.019
Inbody score	70.4 ± 4.3	69.5 ± 5.2	0.248
VFA (cm <sup>2</sup> )	83.1 ± 33.2	98.1 ± 37.8	0.008
Amount of body cells	23.5 ± 2.5	22.9 ± 3.6	0.248

**Abbreviations:** BMI, Body mass index; WC, Waist circumference; HC, Hip circumference; AMC, Arm muscle circumference; TBW, Total body water; ICW, Intracellular water; ECW, Extracellular water; BM, Bone mineral; FFM, Fat Free Mass; SMME, Skeletal muscle mass of the extremities; BFM, Body Fat Mass; PBF, Percent Body Fat; VFA, Visceral fat area.

## Relationship Between the Variables and Hypertension

Binary logistic regression was carried out with hypertension as the dependent variable and age, diabetes, UA, 25-hydroxyvitamin D, HCY, TG, TC, LDL-C, HDL-C, BMI, WC, BFM, PBF and VFA as the independent variable. The results are shown in Table 3. BFM and VFA were independent influencing factors for hypertension. In Figure 2, the risk ratios of each factor are presented in the form of forest plots.

**Table 3** Multivariate Logistic Regression Results

	z value	exp(coef)	95% CI low	95% CI upp	p-value
Age	0.549	1.02	0.955	1.086	0.583
25-hydroxyvitamin D	-0.988	0.98	0.933	1.023	0.323
UA	1.162	1.00	0.997	1.012	0.245

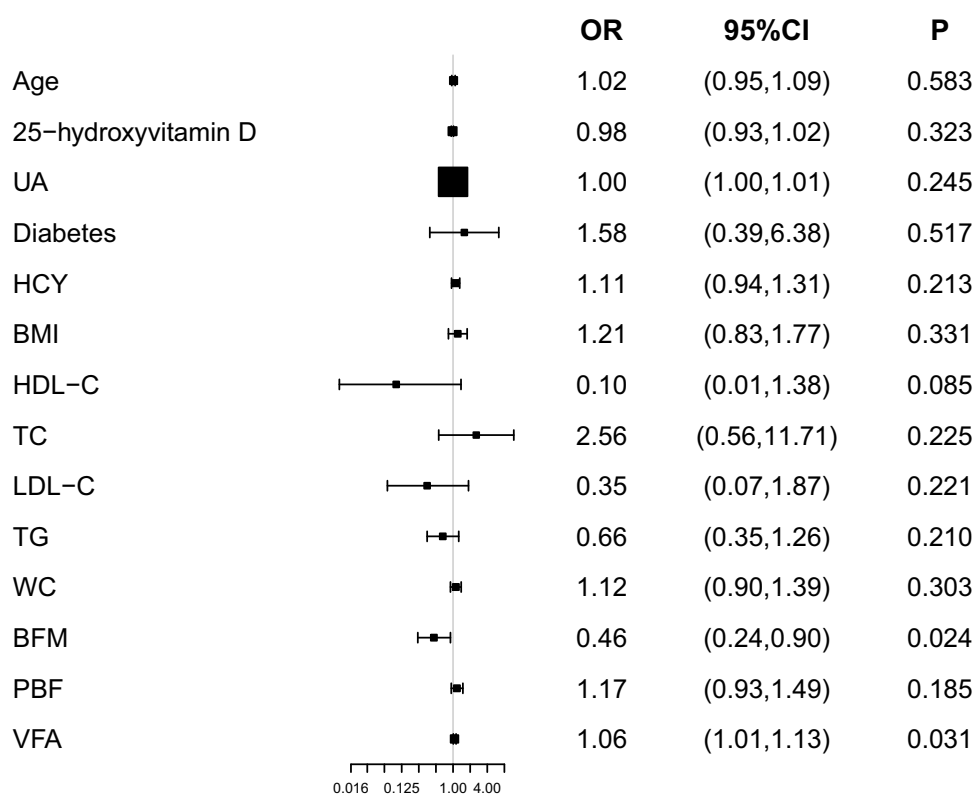
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**Table 3** (Continued).

	z value	exp(coef)	95% CI low	95% CI upp	p-value
Diabetes	0.648	1.58	0.394	6.383	0.517
HCY	1.245	1.11	0.942	1.309	0.213
BMI	0.972	1.21	0.826	1.765	0.331
HDL-C	-1.722	0.10	0.007	1.378	0.085
TC	1.213	2.56	0.560	11.709	0.225
LDL-C	-1.223	0.35	0.066	1.873	0.221
TG	-1.255	0.66	0.349	1.260	0.210
WC	1.030	1.12	0.903	1.387	0.303
BFM	-2.260	0.46	0.235	0.902	0.024
PBF	1.326	1.17	0.926	1.488	0.185
VFA	2.163	1.06	1.006	1.126	0.031

**Abbreviations:** UA, Uric acid; HCY, Homocysteine; BMI, Body mass index; HDL-C, High density lipoprotein cholesterol; TC, Total cholesterol; LDL-C, Low-density lipoprotein cholesterol; TG, Triglyceride; WC, Waist circumference; BFM, Body Fat Mass; PBF, Percent Body Fat; VFA, Visceral fat area.

The results of binary logistic regression with hypertension as the dependent variable and BMI, WC, BFM, PBF, VFA as the independent variables in body composition are shown in Table 4. The predictive indicator composed of BMI, WC, BFM, PBF and VFA were saved (formula =  $0.256\text{BMI} + 0.135\text{WC} - 0.772\text{BFM} + 0.161\text{PBF} + 0.058\text{VFA}$ ). The predictive

**Figure 2** Risk ratios for factors associated with hypertension in postmenopausal women with osteoporosis.

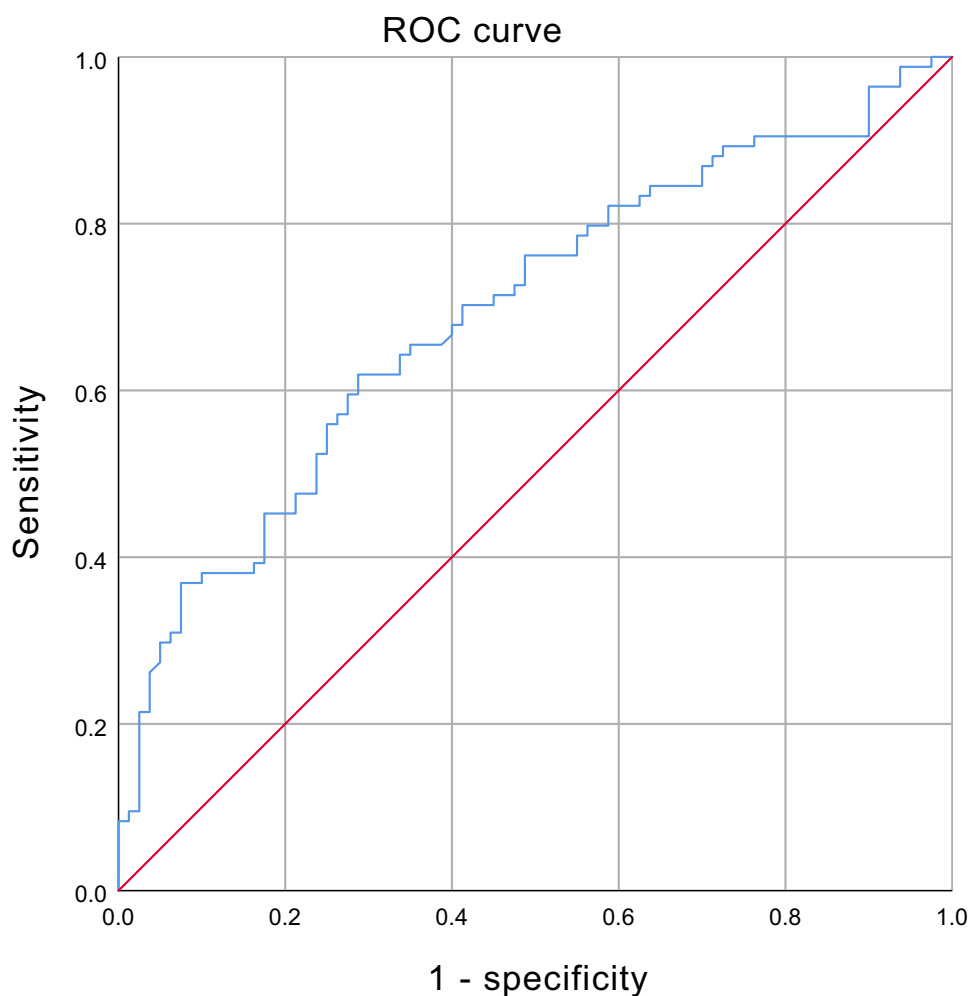
**Abbreviations:** OR, Odds ratios; UA, Uric acid; HCY, Homocysteine; BMI, Body mass index; TC, Total cholesterol; TG, Triglyceride; HDL-C, High density lipoprotein cholesterol; LDL-C, Low-density lipoprotein cholesterol; WC, Waist circumference; BFM, Body Fat Mass; PBF, Percent Body Fat; VFA, Visceral fat area.

**Table 4** Logistic Regression with the Presence or Absence of Hypertension as the Dependent Variable and Parameters Related to Body Composition as Independent Variables

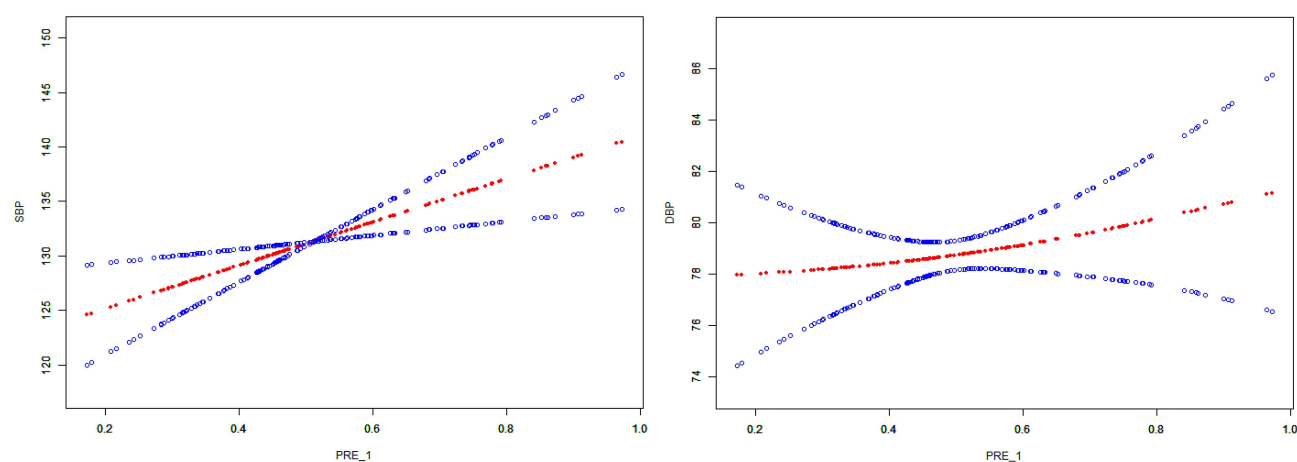
	<b>B</b>	<b>Standard Error</b>	<b>Wald</b>	<b>p-value</b>	<b>Exp(B)</b>
BMI	0.256	0.134	3.665	0.056	1.292
WC	0.135	0.075	3.215	0.073	1.145
BFM	-0.772	0.229	11.377	0.001	0.462
PBF	0.161	0.083	3.797	0.051	1.175
VFA	0.058	0.021	7.88	0.005	1.06

**Abbreviations:** BMI, Body mass index; WC, Waist circumference; BFM, Body Fat Mass; PBF, Percent Body Fat; VFA, Visceral fat area.

indicator was analyzed by logistic regression. After adjusting for Age, Diabetes, UA, 25-hydroxyvitamin D, HCY, and HDL-C, the predictive indicator was found to be independent risk factors for hypertension. In Figure 3 ROC curve analysis of the predictors showed that the area under the curve for predicting hypertension was 0.694 ( $p < 0.001$ ).



**Figure 3** Test of the predictive value of the predictor composed of body composition parameters for whether postmenopausal women with osteoporosis have hypertension.



**Figure 4** Examined dose-response relationships of the predictor with SBP and DBP using generalized additive models. The red dotted line corresponds to the smooth curve between the variables. Age, 25-hydroxyvitamin D, UA, Diabetes, HCY, HDL-C, TC, TG, LDL-C were adjusted.

**Abbreviations:** SBP, Systolic blood pressure; DBP, Diastolic blood pressure; PRE\_1, predictor composed of body composition parameters.

## Dose-Response Association Between Body Composition Predictor and SBP, DBP

The dose-response relationship between body composition predictors and SBP was investigated using a generalised additive model, and Figure 4 demonstrates the existence of a dose-response relationship between the two ( $p=0.004$ ). However, there was no statistically significant relationship with DBP ( $p=0.488$ ). With the increase of body composition predictor, SBP also increased, while DBP did not change significantly. Even so, it can be seen from the curve fitting that DBP showed an overall upward trend.

## Discussion

This study used a cross-sectional investigation, aiming at postmenopausal women with osteoporosis, which is special compared with the general population. Past researches found that hypertension prevalence was higher in osteoporosis patients than in non-osteoporosis patients.<sup>2</sup> Similarly, in our study the prevalence of combined hypertension in patients with osteoporosis was about 51.2%, 24 of them were diagnosed after hospitalization, accounting for 28.6% of hypertensive patients. This indicates that many patients do not have the awareness of monitoring blood pressure, so they lack of timely and effective treatment for hypertension. Elevated blood pressure can induce structural or functional alterations in the arterial vascular system and its supply organs, ultimately resulting in target organ damage and subsequent cardiovascular and cerebrovascular events, which may lead to organ failure, including that of the heart and kidneys. A prospective observational study involving 61 populations globally (encompassing nearly 1 million individuals aged 40–89 years)<sup>4</sup> revealed that both SBP and DBP exhibit a consistent, independent, and directly proportional relationship with the risk of stroke, coronary heart disease events, and cardiovascular mortality. Consequently, the accurate diagnosis and effective management of hypertension are of paramount importance.

A study conducted previously among Asian women revealed an association between reduced bone mineral density and the incidence of atherosclerotic cardiovascular events.<sup>5</sup> High blood pressure is also prone to osteoporosis, the pathophysiological mechanisms underlying osteoporosis in hypertensive patients may involve the following interrelated pathways. Primary Mechanism: Hyperactivation of the renin-angiotensin-aldosterone system (RAAS) elevates circulating angiotensin II levels, which promotes accelerated bone remodeling. This enhanced bone turnover disrupts the balance between bone resorption and formation, ultimately leading to progressive reduction in bone mineral density.<sup>2,6,7</sup> Secondary Mechanism: Chronic hypertension promotes renal calcium wasting through pressure natriuresis, thereby disrupting calcium homeostasis and triggering compensatory secondary hyperparathyroidism. The resultant elevation of parathyroid hormone (PTH) levels stimulates bone resorption through increased osteoclastic activity while simultaneously enhancing renal  $1\alpha$ -hydroxylase activity to amplify calcium reabsorption - a paradoxical response that exacerbates skeletal calcium depletion.<sup>8</sup> In this study, it was found that age, 25-hydroxyvitamin D, UA, HCY, history



of diabetes, and HDL-C were statistically different between the two groups of women with and without hypertension. It is well established that UA is associated with the metabolic syndrome, and therefore has an effect on blood pressure.<sup>9</sup> Wu et al discovered that postmenopausal women diagnosed with osteoporosis typically exhibited low levels of 25-hydroxyvitamin D. After in-depth discussion of hypertensive patients with osteoporosis, it was concluded that when 25-hydroxyvitamin D content was below 42 nmol/L, blood pressure increased significantly with the decrease of 25-hydroxyvitamin D content, but when it was above 42 nmol/L, 25-hydroxyvitamin D had no such effect on blood pressure.<sup>10</sup>

Postmenopausal women experience a range of body composition changes, including increased fat mass, redistribution of adipose tissue to visceral regions, and accelerated declines in muscle mass and strength.<sup>11,12</sup> It is well known that fat, muscle, and bone tissues are anatomically and functionally closely related, and all are influenced by common factors.<sup>13</sup> In the field of body composition analysis, a study involved 1285 patients found that osteoporosis was significantly associated with sarcopenia. In the non-obese sarcopenic population, the highest prevalence of osteoporosis was found at the lumbar spine, full hip, and femoral neck locations, while total adiposity was positively correlated with bone mineral density at the hip and femoral neck.<sup>14</sup> What's more, scholars have subdivided adiposity levels by location, with high leg fat levels independently associated with lower risk of hypertension and cardiovascular-metabolic disease.<sup>15</sup> Yang et al showed that for every unit increase in leg fat levels, the prevalence of osteoporosis was reduced by 36.9%.<sup>16</sup>

In this study, BFM and VFA were identified as independent predictors of whether patients with osteoporosis had comorbid hypertension after controlling for other potential confounders. A large cohort study in Iran explored the relationship between body composition and hypertension and found that high PBF had been related to increased risk of new-onset hypertension.<sup>17</sup> Previous studies have confirmed this finding that VFA was statistically significant ( $p < 0.05$ ) in a comparison of body composition between healthy women and hypertensive female patients.<sup>18</sup>

Given the results of the NHANES study, which showed a nonlinear correlation between visceral adiposity index (VAI) and skeletal muscle loss, a VAI value of 1.51 was identified as the critical tipping point, and there was a significant positive association per unit increase in VAI with the likelihood of skeletal muscle loss (OR, 2.54; 95% CI, 1.74–3.79).<sup>19</sup>

One noteworthy finding of this study is that, in the univariate analysis, both BFM and VFA were identified as risk factors. However, following the multifactorial logistic regression analysis, it was observed that BFM acted as a protective factor, while VFA was identified as a risk factor. The reason for this condition may be that fat is divided into visceral fat and subcutaneous fat. The inclusion of both variables in the logistic regression analyses yielded disparate results from those observed in the univariate analyses, which can be attributed to the influence of subcutaneous fat. Many studies have shown that visceral fats are a risk factor for cardiovascular disease, whereas subcutaneous fat has been shown to exert a protective effect.<sup>20–22</sup>

The Obesity Paradox: Previous studies have demonstrated that obesity is a risk factor for the onset of disease, but that when the disease manifests, obesity becomes a protective factor.<sup>23,24</sup> Fat distribution is different between men and women, in women have relatively less visceral fat and more subcutaneous fat. Excess visceral fat has been linked to the development of metabolic syndrome. People with more subcutaneous fat have a lower risk of cardiovascular disease regardless of whether they have excessive visceral fat.<sup>25</sup> This is associated with the adipokines and pro-inflammatory cytokines produced by visceral fat, such as tumour necrosis factor and interleukin-6.<sup>26</sup>

Subcutaneous fat, on the other hand, is a lower-grade inflammatory state. A retrospective study comprising 1102 participants conducted by Kim et al revealed that subcutaneous fat area is an independent prognostic indicator for femur fractures in the elderly. In addition, studies have shown that the greater the area of subcutaneous fat, the better the prognosis for elderly patients with proximal femur fractures.<sup>27</sup> The redistribution of body fat with age reduces the amount of subcutaneous fat, which functions as a leptin-producing agent. Since leptin improves glucagon sensitivity and regulates sugar-lipid measurement and immune response, this may be the reason why subcutaneous fat reduces mortality and increases healthy longevity.<sup>28</sup>

This paper presents a study of the predictors of blood pressure in postmenopausal osteoporotic populations, with a focus on the role of body composition. The analysis revealed that predictors comprising BMI, WC, BFM, PBF, and VFA had a significant impact on SBP. There was no such effect on DBP. Kaess et al conducted a cross-sectional investigation (Framingham Heart Study 3223 participants) showing a significant correlation between visceral fat-

subcutaneous fat ratio and SBP, DBP ( $p < 0.001$ ).<sup>29</sup> A correlation between hypertension and visceral fat-subcutaneous fat ratio was observed in a 625-participant study in China ( $r = 0.255$ ).<sup>21</sup> In the animal experiments of Nazari et al rats were fed with a moderate amount of high-fat chow and male rats were obtained to show a gradual increase in body weight, plasma triglycerides, and SBP at weeks 2, 4, and 5 of feeding, respectively.<sup>30</sup> A cohort of specialised occupational pilots revealed a statistically significant inverse correlation between BMI, WC, PBF and SBP, DBP, mean arterial pressure ( $p < 0.001$ ).<sup>31</sup>

The results of this study have implications for nutritional interventions. In older women, diets rich in meat, vegetables, dairy products, fruit and eggs have been linked to increased bone mineral density, whereas beverages and fried foods have been associated with decreased L1–4.<sup>32</sup> In a Japanese study related to dietary intervention for visceral fat in male patients, it was found that Optimized Nutri-Dense Meals without strict control of total energy, limiting saturated fatty acids only to 6.2 grams per two meals is beneficial for visceral fat reduction.<sup>33</sup> And the intake of polyphenol-rich foods has a role in controlling blood pressure in the postmenopausal female population.<sup>34</sup> Although flaxseed is known to exert effect in lowering blood lipids, its effect on reducing volatile fatty acids remains to be demonstrated.<sup>35</sup> In terms of probiotics, there are also studies in Poland showing that consuming the probiotic *Lactobacillus acidophilus* for 12 weeks can lead to significant reductions in body fat and visceral fat.<sup>36</sup> Meanwhile the results of sedentary lifestyles on blood pressure were inconsistent, with women perhaps benefiting from exercise in comparison.<sup>37</sup> Studies in the type 2 diabetes mellitus population have found aerobic or combined exercise to be more effective in reducing VFA, and there was no difference in visceral fat reduction with long-term interventions (>12 weeks) compared to short-term interventions.<sup>38</sup>

## Conclusions

BFM and VFA are independent influencing factors for hypertension in postmenopausal osteoporosis patients. In postmenopausal osteoporosis patients, the predictive model composed of body composition related parameters has certain significance in predicting whether postmenopausal osteoporosis is complicated with hypertension. The effect of the prediction model on blood pressure was mainly reflected in SBP.

A limitation of this study is that it was a single-center retrospective study with a small sample size, which may have been influenced by selection bias and unmeasured confounding variables. Further validation through prospective cohort studies with rigorously controlled covariates is warranted to confirm the generalisability of these findings and mitigate confounding effects.

## Data Sharing Statement

Raw data can be obtained upon request from the corresponding author.

## Ethics Statement

This study was approved by the Ethics Committee of the First People's Hospital of Changzhou, and the approval number was (2024) Department 167. Since our study was a retrospective observational study, the informed consent form was exempted from signing after approval from the Ethics Committee of The First People's Hospital of Changzhou. All data were anonymized using unique study IDs, with access restricted to authorized researchers only. Original medical records remained securely stored in the hospital's encrypted database.

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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. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

## Disclosure

The authors report no conflicts of interest in this work.

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