JMM Journal of Menopausal Medicine
pISSN: 2288-6478, eISSN: 2288-6761
https://doi.org/10.6118/jmm.23014
J Menopausal Med 2023;29:58-65
ORIGINAL ARTICLE

Correlation of Sarcopenic Obesity on Various Cardiometabolic Risk Factors and Fracture Risk in Mid-Aged Korean Women

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Objectives: This study aimed to investigate the correlation of sarcopenic obesity with various cardiometabolic risk factors and fracture risk in middle-aged Korean women.

Methods: In this cross-sectional study, the medical records of 1,775 women who had visited Pusan National University Hospital for routine health screenings from 2010 to 2016 were reviewed. The patients were divided into four groups as follows: group 1, nonsarcopenic, nonobese (NS-NO); group 2, nonsarcopenic, obese (NS-O); group 3, sarcopenic, nonobese (S-NO); and group 4, sarcopenic, obese (S-O). Each patient was assessed based on self-reported questionnaires and individual interviews with a healthcare provider. The Fracture Risk Assessment Tool (FRAX) was used to assess bone fracture risk.

Results: Postmenopausal women accounted for 68.5% of the total patient population. The proportion of each group was as follows: NS-NO, 71.2%; NS-O, 17.9%; S-NO, 10.2%; and S-O, 0.7%. Statistical analysis of various parameters associated with metabolic and cardiovascular risks revealed that the S-O group had more patients with hypertension, diabetes, osteopenia, and metabolic syndrome. The FRAX scores were significantly higher in the S-O group than in other groups.

Conclusions: Middle-aged women with obesity and reduced muscle mass, known as sarcopenic obesity, are at increased risk of hypertension, diabetes, and metabolic syndrome. Furthermore, sarcopenic obesity, individual cardiometabolic risks, and menopause can increase the bone fracture risk.

Key Words: Bone fractures, Cardiometabolic diseases, Cardiovascular diseases, Fracture Risk Assessment Tool, Sarcopenic obesity

INTRODUCTION

The population of aging and obese patients has been increasing worldwide, and the associated health complications have drawn much scholarly attention. The decrease in basal metabolic rate associated with aging may result in weight gain and a loss of muscle mass [1,2]. Obesity and sarcopenia in the elderly are independently related to metabolic and cardiovascular morbidity and mortality [3-6].

The combination of sarcopenia and obesity, called "sarcopenic obesity," was first proposed by Baumgartner [7]. Sarcopenic obesity was associated with an increased risk of cardiovascular disease in a large cohort United Kingdom (UK) study [8]. According to a recent systematic review, sarcopenic obesity is a global health phenomenon caused by the increased aging of the population combined with the increased obesity epidemic, and it appears to increase the risk of cardiovascular disease (CVD) in older people [9]. A Korean study demonstrated a pathophysiological relationship between insulin resistance and cardiometabolic diseases in patients with sarcopenic obesity [10]. It has also been linked to deteriorating physical function and mobility,

Received: May 31, 2023 **Accepted:** August 14, 2023
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as well as an increased risk of fractures [11,12].

Menopause is associated with a decline in physical activity, an imbalance in eating habits, and a change in body composition. Consequently, menopause increases abdominal fat depots and the prevalence of cardiovascular and metabolic risks, as well as the risk of falls and fractures related to osteoporosis, which increases steadily with the duration of estrogen deficiency [13]. Recent research indicated that the earliest postmenopausal stages were followed by a considerable decrease in bone mass [14].

Therefore, it is anticipated that the coexistence of obesity and sarcopenia in middle-aged women is strongly associated with various health risks for unfavorable long-term consequences, although there are currently insufficient studies on this subject. Thus, the aim of this study was to investigate the effects of sarcopenic obesity on various cardiometabolic risk factors and fracture risk in middle-aged Korean women.

MATERIALS AND METHODS

Study population and laboratory measurements

The study was a cross-sectional study, reviewed the medical records of 1,775 female patients who had visited Pusan National University Hospital Health Promotion Center for routine health screenings from 2010 to 2016. Every patient answered a demographic survey with a healthcare provider to provide their past medical history, including any systemic disease, medication history, and/or menstrual history. Physical examination included vital signs, body weight, height, and waist circumference. Those patients taking glucocorticoids, undergoing osteoporosis management, hormone replacement therapy, or oral 25-OH vitamin D3/calcium supplementation, or with a history of fractures, unclear medical records, and/or incomplete self-reported questionnaires were excluded from the analysis. Body mass index (BMI) was analyzed as the patient's weight in kilograms (kg) divided by height in meters (m) squared. The percent total body fat and body muscle, and appendicular skeletal muscle mass (ASM) were measured by bioelectrical impedance analysis (X-SCAN PLUS II; Jawon Medical).

Blood samples were obtained from patients after eight hours of overnight fasting and included the following measurements: complete blood cell count, liver and renal biochemistry parameters, lipid profiles, hemoglobin A1c, homocysteine, and C-reactive protein levels using the Roche Modular DP with an enzymatic colorimetric method and fasting plasma glucose levels analyzed by the glucose oxidase method (LX-20; Beckman Coulter). Glomerular filtration rate was calculated using the Isotope Dilution Mass Spectrometry-Modification of Diet in Renal Disease equation established in previous literature. All patients agreed to participate in the study and provided informed consent indicating that their medical records were to be used for the study. The study was exempted from Institutional Review Board review by the Human Research Protection Committee of Pusan National University Hospital.

Patient group definitions and bone fracture assessment

The patients were divided into four groups according to the presence or absence of obesity or sarcopenia. Obesity was defined as a BMI of > 25 kg/m^2 in accordance with the guidelines of the Korean Obesity Society. Sarcopenia was defined by an ASM divided by height squared (ASM/Ht^2) of < 5.7 kg/m^2, referring to the 2019 consensus update of the Asian Working Group for Sarcopenia Group [15]. The four groups are as follows: group 1, non-sarcopenic, non-obese (NS-NO); group 2, non-sarcopenic, obese (NS-O); group 3, sarcopenic, non-obese (S-NO); and group 4, sarcopenic, obese (S-O). The Fracture Risk Assessment Tool (FRAX) was used for evaluating bone fracture risk. The tool estimates the 10-year probability of major osteoporotic fracture as a percentage. A high risk group for bone fracture was defined as those with a FRAX value of 20 or above, indicating the need for pharmacological intervention [16].

Statistical analysis

All statistical data were organized into a computerized database. An independent *t* test or Wilcoxon rank sum test was performed for continuous variables, and the chi-squared test was performed for categorical variables. Multiple group comparisons were made by one-way analysis of variance or the Kruskal-Wallis test for continuous variables or by chi-squared test or Fisher's exact test for categorical variables. Since this study was conducted on relatively healthy middle-aged women, the FRAX values were relatively low. In order to examine various factors associated with the FRAX values, logistic regression was performed using a mean FRAX value of 3.40 for all patients. In the univariate analysis, it was aimed to examine the association between FRAX scores and menopausal status, as well as

Table 1. Clinical and biochemical characteristics according to menopause

	Overall (n = 1,755)	Premenopause (n = 553)	Postmenopause (n = 1,202)	*P* value
Group 1	1,249 (71.2)	398 (72.0)	851 (70.8)	< 0.001
Group 2	314 (17.9)	79 (14.3)	235 (19.6)	-
Group 3	179 (10.2)	75 (13.6)	104 (8.7)	-
Group 4	13 (0.7)	1 (0.2)	12 (1.0)	-
Hypertension	335 (19.1)	45 (8.1)	290 (24.1)	< 0.001
Diabetes	83 (4.7)	11 (2.0)	72 (6.0)	< 0.001
Osteopenia	436 (24.8)	73 (13.2)	363 (30.2)	< 0.001
Hyperlipidemia	286 (16.3)	53 (9.6)	233 (19.4)	< 0.001
Metabolic syndrome	332 (18.9)	51 (9.2)	281 (23.4)	< 0.001
Smoking	90 (5.1)	27 (4.9)	63 (5.2)	0.841
Age (y)	55.2 ± 8.3	47.2 ± 4.8	58.8 ± 6.9	< 0.001
Body weight (kg)	57.0 ± 8.0	56.8 ± 8.8	57.0 ± 8.0	0.522
Body fat percentage	29.6 ± 4.8	28.0 ± 5.1	30.3 ± 4.5	< 0.001
Waist circumference (cm)	79.1 ± 8.4	77.3 ± 7.9	79.9 ± 8.6	< 0.001
BMI (kg/m^2)	22.8 ± 3.0	22.3 ± 2.8	23.1 ± 3.1	< 0.001
Height (cm)	157.9 ± 5.2	159.6 ± 4.9	157.2 ± 5.1	< 0.001
ASM (kg)	18.6 ± 3.8	18.8 ±3.9	18.5 ± 3.8	0.126
ASM/ht^2 (kg/m^2)	7.5 ± 1.5	7.4 ± 1.5	7.5 ± 1.5	0.167
SBP (mmHg)	117.5 ± 16.8	113.9 ± 14.7	119.2 ± 17.4	< 0.001
DBP (mmHg)	72.0 ± 10.1	70.6 ± 9.8	72.6 ± 10.2	< 0.001
Uric acid (mg/dL)	4.5 ± 1.0	4.2 ± 0.9	4.6 ± 1.1	< 0.001
Phosphate (mg/dL)	3.8 ± 0.5	3.6 ± 0.5	3.8 ± 0.5	< 0.001
Calcium (mg/dL)	9.4 ± 0.4	9.3 ± 0.4	9.5 ± 0.4	< 0.001
ALP (U/L)	82.7 ± 49.0	66.3 ± 35.5	90.3 ± 52.4	< 0.001
Total cholesterol (mg/dL)	204.3 ± 36.9	195.3 ± 32.3	208.4 ± 38.1	< 0.001
Triglyceride (mg/dL)	95.8 ± 57.8	86.4 ± 45.4	100.1 ± 62.3	< 0.001
HDL cholesterol (mg/dL)	62.0 ± 15.6	63.1 ± 15.2	61.5 ± 15.8	0.046
LDL cholesterol (mg/dL)	130.3 ± 35.3	121.4 ± 31.1	134.4 ± 36.4	< 0.001
Free fatty acid (mEq/L)	664.8 ± 309.4	610.2 ± 307.2	689.9 ± 307.2	< 0.001
Glucose (mg/dL)	89.9 ± 18.5	85.6 ± 12.5	91.9 ± 20.4	< 0.001
CRP (mg/dL)	0.1 ± 0.3	0.1 ± 0.3	0.1 ± 0.2	0.042
TSH (mg/dL)	23.6 ± 12.2	20.7 ± 10.5	24.9 ± 12.8	< 0.001
fT4 (ng/dL)	2.6 ± 2.5	2.5 ± 2.2	2.7 ± 2.6	0.172
FRAX (%)	3.8 ± 1.6	2.6 ± 0.6	4.3 ± 1.6	< 0.001
FRAX p50 ≥ 3.4%	894 (51.0)	48 (9.0)	846 (70.0)	< 0.001
High risk	41 (2.3)	0 (0.0)	41 (3.4)	< 0.001

Data are presented as number (%) or mean ± SD.
BMI: body mass index, ASM: appendicular skeletal muscle mass, SBP: systolic blood pressure, DBP: diastolic blood pressure, ALP: alkaline phosphatase, HDL: high-density lipoprotein, LDL: low-density lipoprotein, CRP: C-reactive protein, TSH: thyroid-stimulating hormone, fT4: free thyroxine, FRAX: Fracture Risk Assessment Tool.

cardiometabolic disease. In the multivariate analysis, it was adjusted for menopausal status and cardiometabolic disease to assess the association between FRAX scores and groups. R 4.1.3 was employed in the analysis process, and *P* values of < 0.05 were considered to be

Table 2. Clinical and biochemical characteristics according to the patient groups

	Overall (n = 1,755)	Group 1 (NS-NO) (n = 1,249)	Group 2 (NS-O) (n = 314)	Group 3 (S-NO) (n = 179)	Group 4 (S-O) (n = 13)	*P* value
Age (y)	55.2 ± 8.3	54.9 ± 7.9	57.2 ± 9.0	52.5± 8.7	62.3 ± 9.5	< 0.001
Menopause	1,202 (68.5)	851 (68.1)	235 (74.8)	104 (58.1)	12 (92.3)	< 0.001
Hypertension	335 (19.1)	191 (15.3)	118 (37.6)	16 (8.9)	10 (76.9)	< 0.001
Diabetes	83 (4.7)	44 (3.5)	32 (10.2)	5 (2.8)	2 (15.4)	< 0.001
Osteopenia	436 (24.8)	332 (26.6)	54 (17.2)	46 (25.7)	4 (30.8)	0.004
Hyperlipidemia	286 (16.3)	196 (15.7)	69 (22.0)	19 (10.6)	2 (15.4)	0.007
Metabolic syndrome	332 (18.9)	168 (13.5)	146 (46.5)	11 (6.1)	7 (53.8)	< 0.001
Smoking	90 (5.1)	58 (4.6)	22 (7.0)	10 (5.6)	0 (0.0)	0.341
Body weight (kg)	57.0 ± 8.0	55.4 ± 5.0	67.6 ± 8.3	48.8 ± 5.6	66.4 ± 7.1	< 0.001
Body fat percentage	29.6 [26.7, 32.6]	28.9 [26.4, 31.2]	34.9 [33.4, 36.7]	25.6 [22.9, 27.7]	38.4 [36.4, 39.7]	< 0.001
Waist circumference (cm)	78.0 [73.0, 84.0]	77.0 [73.0, 81.5]	88.0 [84.1, 93.0]	72.0 [67.5, 76.0]	93.0 [86.0, 97.0]	< 0.001
BMI, (kg/m^2)	22.5 [20.9, 24.4]	22.2 [21.0, 23.4]	26.5 [25.7, 28.3]	19.3 [18.2, 20.20]	27.2 [25.4, 27.6]	< 0.001
Height (cm)	157.9 [154.6, 161.4]	158.0 [155.0, 161.5]	157.0 [153.0, 160.3]	158.3 [154.9, 162.5]	157.7 [155.7, 159.0]	0.001
ASM (kg)	18.4 [15.9, 21.0]	18.60 [16.6, 20.5]	21.35 [17.6, 24.3]	13.1 [12.3, 14.0]	13.5 [12.5, 14.0]	< 0.001
ASM/ht^2 (kg/m^2)	7.4 [6.4, 8.4]	7.40 [6.6, 8.2]	8.7 [7.4, 9.8]	5.2 [5.0, 5.4]	5.6 [5.3, 5.6]	< 0.001
SBP (mmHg)	116.0 [106.0, 128.0]	114.0 [104.0, 125.0]	126.0 [115.0, 138.0]	110.0 [102.5, 124.0]	143.00 [113.0, 150.0]	< 0.001
DBP (mmHg)	71.0 [65.0, 78.0]	70.0 [64.0, 77.0]	77.0 [71.0, 83.0]	70.0 [64.0, 76.0]	83.00 [68.0, 91.0]	< 0.001
Uric acid (mg/dL)	4.4 [3.8, 5.1]	4.3 [3.8, 4.9]	4.7 [4.1, 5.5]	4.3 [3.6, 5.0]	5.4 [4.0, 7.0]	< 0.001
Phosphate (mg/dL)	3.7 [3.4, 4.1]	3.8 [3.4, 4.1]	3.6 [3.3, 4.0]	3.9 [3.5, 4.2]	3.7 [3.5, 4.0]	< 0.001
Calcium (mg/dL)	9.4 [9.2, 9.7]	9.4 [9.1, 9.6]	9.4 [9.2, 9.7]	9.5 [9.3, 9.8]	9.6 [9.2, 9.9]	< 0.001
ALP (U/L)	67.0 [53.0, 90.0]	66.0 [52.0, 90.0]	70.5 [56.3, 93.8]	61.0 [51.0, 84.0]	73.0 [67.0, 95.0]	0.003
Vitamin D total (ng/mL)	21.5 [13.8, 31.1]	22.0 [14.3, 32.3]	20.3 [13.2, 27.9]	21.1 [13.0, 28.4]	18.8 [12.0, 19.4]	0.028
Total cholesterol (mg/dL)	201.0 [179.0, 227.0]	200.0 [178.0, 225.0]	205.5 [180.3, 236.0]	203.0 [179.0, 228.0]	199.0 [168.0, 241.0]	0.177
Triglyceride (mg/dL)	83.0 [59.5, 115.0]	78.0 [58.0, 108.0]	103.0 [81.0, 139.8]	73.0 [57.5, 103.0]	134.0 [114.0, 171.0]	< 0.001
HDL cholesterol (mg/dL)	61.0 [51.0, 71.0]	62.0 [52.0, 72.0]	55.0 [46.0, 63.0]	66.0 [57.0, 80.0]	56.0 [53.0, 61.0]	< 0.001
LDL cholesterol (mg/dL)	127.0 [105.0, 152.0]	126.0 [105.0, 150.0]	134.0 [111.3, 163.8]	118.0 [100.5, 147.0]	129.0 [96.0, 138.0]	0.001
Free fatty acid (mEq/L)	622.0 [446.0, 821.5]	606.0 [445.0, 805.0]	643.5 [446.5, 845.8]	690.0 [427.5, 851.5]	789.0 [605.0, 1,118.0]	0.026
Glucose (mg/dL)	87.0 [81.0, 93.0]	87.0 [81.0, 93.0]	91.0 [85.0, 100.0]	86.0 [79.0, 90.0]	98.0 [84.0, 108.0]	< 0.001
CRP (mg/dL)	0.04 [0.02, 0.09]	0.04 [0.02, 0.07]	0.08 [0.04, 0.16]	0.03 [0.02, 0.07]	0.24 [0.04, 0.3]	< 0.001
TSH (uIU/mL)	2.1 [1.3, 3.2]	2.1 [1.3, 3.2]	2.0 [1.2, 3.1]	2.1 [1.3, 3.4]	2.7 [1.8, 3.8]	0.564
fT4 (ng/dL)	1.2 [1.1, 1.3]	1.2 [1.1, 1.3]	1.2 [1.1, 1.4]	1.2 [1.1, 1.3]	1.4 [1.2, 1.5]	0.135
FRAX (%)	3.4 [2.7, 4.5]	3.4 [2.7, 4.4]	3.7 [2.9, 4.9]	2.9 [2.4, 4.3]	4.3 [3.9, 5.0]	< 0.001
FRAX p50 ≥ 3.4%	894 (50.9)	625 (50.0)	185 (58.9)	72 (40.2)	12 (92.3)	< 0.001
High risk	41 (2.3)	24 (1.9)	6 (1.9)	10 (5.6)	1 (7.7)	0.015

Data are presented as mean ± SD, number (%), or median [interquartile range].
NS-NO: nonsarcopenic, nonobese, NS-O: nonsarcopenic, obese, S-NO: sarcopenic, nonobese, S-O: sarcopenic, obese, BMI: body mass index, ASM: appendicular skeletal muscle mass, SBP: systolic blood pressure, DBP: diastolic blood pressure, ALP: alkaline phosphatase, HDL: high-density lipoprotein, LDL: low-density lipoprotein, CRP: C-reactive protein, TSH: thyroid-stimulating hormone, fT4: free thyroxine, FRAX: Fracture Risk Assessment Tool.

Table 3. Logistic regression analysis of mean FRAX values

Variable	Univariate analysis		Multivariate analysis	
	OR (95% CI)	*P* value	OR (95% CI)	*P* value
Outcome: mean FRAX value ≥ 3.4%				
Group 1 (NS-NO)	Ref.		Ref.	
Group 2 (NS-O)	1.4 (1.1, 1.8)	0.005	1.3 (0.9, 1.8)	0.136
Group 3 (S-NO)	0.7 (0.5, 0.9)	0.014	0.8 (0.56, 1.2)	0.358
Group 4 (S-O)	12.0 (1.6, 92.3)	0.017	9.5 (0.8, 116.1)	0.078
Menopause	25.0 (18.1, 34.5)	< 0.001	20.8 (15.0, 28.8)	< 0.001
Hypertension	2.8 (2.1, 3.6)	< 0.001	1.5 (1.1, 2.1)	0.009
Diabetes	2.8 (1.7, 4.6)	< 0.001	1.7 (1.0, 3.1)	0.067
Osteopenia	3.2 (2.5, 4.0)	< 0.001	2.7 (2.0, 3.6)	< 0.001
Hyperlipidemia	2.3 (1.7, 3.0)	< 0.001	1.7 (1.2, 2.4)	0.001

FRAX: Fracture Risk Assessment Tool, OR: odds ratio, CI: confidence interval, NS-NO: nonsarcopenic, nonobese, NS-O: nonsarcopenic, obese, S-NO: sarcopenic, nonobese, S-O: sarcopenic, obese.

statistically significant.

RESULTS

The clinical and biochemical characteristics in the patients according to menopause are presented in Table 1. The mean age of all patients was 55.2 years, and the mean body weight was 57.0 kg. Postmenopausal women accounted for 68.5% of the total patient population. The mean age of postmenopausal women was observed to be 58.8 years, which showed a considerable difference of around 10 years from premenopausal women. Postmenopausal women were found to have a higher incidence of hypertension, diabetes, hyperlipidemia, and metabolic syndrome, along with a corresponding elevation in laboratory parameters such as total cholesterol, low-density lipoprotein (LDL)-cholesterol, fasting glucose levels, etc. Furthermore, the FRAX values, along with the prevalence of high risk, showed a significant increase in postmenopausal women as compared to premenopausal women.

Table 2 showed the prevalence of cardiometabolic diseases and biochemical characteristics among patients grouped according to the definitions established earlier. Patients were distributed as NS-NO of 71.2%, NS-O of 17.9%, S-NO of 10.2%, and S-O of 0.7%. The S-O group had a significantly higher prevalence of hypertension, diabetes, and metabolic syndrome compared to the NS-NO, NS-O, and S-NO groups. The NS-O group was the most likely to have hyperlipidemia, yet the biochemical features associated with hyperlipidemia were unfavorable in the S-O group as well as in the NS-O group. Triglyceride (TG) levels were the highest in the S-O group, and LDL-cholesterol levels in the S-O group were the second highest, following the NS-O group (TG of 134.0 mg/dL and LDL-cholesterol of 129.0 mg/dL in S-O group vs. TG of 103.0 mg/dL and LDL-cholesterol of 134.0 mg/dL in NS-O group). Moreover, diabetes was more prevalent in the S-O group than in the other three groups and the S-O group had the highest fasting glucose levels, at 98.0 mg/dL.

Osteopenia was most prevalent in the S-O group compared to the NS-NO, NS-O and S-NO groups (30.8% vs. 26.6%, 17.2% and 25.7% respectively, P = 0.004). Additionally, the FRAX scores were the highest in the S-O group and the high risk of bone fracture was most prevalent in the S-O group than the other three groups with statistical significance. As shown in Table 3, in the logistic regression analysis based on the mean FRAX value of the entire patient group, menopause was strongly positively associated with FRAX scores in both univariate and multivariate analyses. Hypertension, osteopenia, and hyperlipidemia were also positively associated with FRAX values. While the S-O group showed a strong association with FRAX values, it did not demonstrate statistical significance in the multivariate analysis.

DISCUSSION

The prevalence of cardiovascular diseases is higher in postmenopausal women compared to premenopausal

women. The underlying mechanisms remain either unclear, however, decreased estrogen are thought to plays a crucial role in this regard [17,18]. The estrogen deficiency that occurs after menopause leads to relative androgen excess, decreased sex hormone-binding globulin, changes in body composition, increased visceral fat, and decreased high-density lipoprotein cholesterol. Obesity, which increases after menopause, also contributes to an elevated risk of cardiovascular disease. Moreover, obesity imposes limitations on physical activity and diminishes the desire for exercise, leading to a reduction in overall physical activity levels. This decline in physical activity further worsens the progression of sarcopenia, creating a vicious cycle where sarcopenia restricts physical activity, leading to the development of obesity [2]. Sarcopenia and obesity have been recognized as independent risk factors for metabolic disease. And when sarcopenia and obesity coexist in sarcopenic obesity, they have a synergistic effect on metabolic and cardiovascular diseases [2,19,20].

In this study, it was established that postmenopausal women had a high prevalence of cardiometabolic diseases. The prevalence of sarcopenic obesity varies by study, gender, and race. In this study, it was 0.7% in women with an mean age of 55.1, it was 5.7% at an mean age of 63.1 in one Korean study and it was 13.59% in women aged 75 to 84 years in recent Korean study [21-23]. The prevalence of sarcopenic obesity will gradually increase with age, and this could have a more negative impact on women after menopause [24]. The hypertension, diabetes and metabolic syndrome were most prevalent in the S-O group, and hyperlipidemia was most prevalent in the NS-O group. Even though biochemical characteristics associated with hyperlipidemia were insufficient for diagnosis, they were unfavorable in the S-O group as well as the NS-O group. FRAX values were significantly highest in the S-O group. Additionally, menopause and the presence of cardiometabolic diseases were positively correlated with higher FRAX values.

Similarly, according to a UK cohort study conducted on 450,000 people in 2019, the S-O group had the highest risk of CVD events, including diabetes, coronary heart disease, and stroke, and S-O individuals had high estimated risks for CVD mortality outcomes [8]. A United States (US) study reported that older adults with S-O were more likely to have hypertension, metabolic syndrome, and type 2 diabetes compared to those with NS-NO, S-NO, or NS-O [20]. Although the mean age of participants in the UK and US studies was in the late 50s and late 60s, respectively, and a significant number of male participants was included, these studies identified a higher prevalence of cardiometabolic diseases in S-O group, similar to our research. Consequently, hormonal changes during menopause lead to alterations in women's body composition, resulting in an accumulation of abdominal fat that significantly elevates their susceptibility to cardiometabolic diseases. Furthermore, as women continue to age, the co-occurrence of sarcopenia and obesity further amplifies the prevalence of cardiometabolic diseases.

Women experience a rapid bone loss before and after menopause, which increases their vulnerability to osteoporosis and fractures in later life [25]. When sarcopenic obesity, which have association with poor balance, high serum parathyroid hormone levels, and low vitamin D levels is added, it is expected to further elevate the risk of osteoporosis and fractures and few studies have reported in this regard [26]. A Korean study reported that there was a correlation between an elevated fat mass and insufficient muscle mass, which was associated with the occurrence of osteoporosis and therefore S-O was more closely associated with osteoporosis than any other group [21]. In a recent study that focused on Chinese patients aged 60 and above, the S-O group had a higher risk of osteoporotic vertebral fractures [27]. Also, there was a report indicating that postmenopausal women with sarcopenic obesity experienced an increased risk of falls related to balance destabilization [11]. Sarcopenic obesity is associated not only with cardiometabolic diseases but also with an increased prevalence of osteoporosis and an elevated risk of fractures.

The strength of the study is that it was the first study related to sarcopenic obesity and its comorbidity in middle-aged women in South Korea. However, limitations still exist and should be considered. First, this was a single-center study and could not represent the general population. Since this study focused on patients who underwent health medical examinations conducted by patients who exhibited a relatively high interest in their health, the proportion in the sarcopenic obesity group was found to be low. Further nationwide and multicentered studies are required. Second, sarcopenia was defined using only muscle mass, in this study. The methods for diagnosing sarcopenia include muscle mass, muscle strength, and physical performance. Therefore, further research is needed to define sarcope-

nia, including muscle strength or physical performance. When combined with obesity and reduced muscle mass, known as sarcopenic obesity, middle-aged women were an increased risk for hypertension, diabetes, and metabolic syndrome. Regarding bone fracture risk, sarcopenic obesity as well as individual cardiometabolic risks and menopause increased the fracture risk.

FUNDING

This work was supported by clinical research grant from Pusan National University Hospital in 2023.

CONFILCT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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