Association of Sarcopenic Obesity and Body Composition With Metabolically Unhealthy Overweight/Obese Phenotypes Among Iranian Women: A Cross-Sectional Study

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Research note

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Abstract

Objectives

Obesity is a major risk factor for metabolic syndrome, with its prevalence has increased over the past decade. Major changes in body composition with aging have a significant effect on many clinical outcomes. Sarcopenic obesity consists of both the presence of abnormal adipose tissue with a deficit of muscle mass.

Results

Of the 241 subjects in this study (average age 35.32 years), 176 (73.03%) were classified as MUO phenotype. Based on this study, the prevalence of sarcopenic obesity was 7.88%. We found that high fat-free mass was more strongly and significantly associated with MUO phenotype. Furthermore, we found that individuals with high fat-free mass and high skeletal muscle mass had a significantly low prevalence of MUO phenotype. A significant positive correlation between metabolic phenotypes and sarcopenic obesity was also observed after all potential covariates were adjusted for. These results of this study suggest that increased adiposity and decreased skeletal muscle mass are associated with unfavorable metabolic traits among overweight and obese Iranian women. SO was also found to be associated with a greater risk of developing MUO phenotype.

Introduction

Obesity is an abnormal accumulation of fat that affects health negatively [1] with its prevalence having doubled since 1980 in middle-aged and older adults [2]. Previous studies reported 16.5% of Iranian subjects older than 18 years [3] and 24.8% of women aged 30 years and above as obese [4]. Obese subjects have been reported to have heterogeneous phenotypes with different degrees of metabolic risk [5]. A sub-group of obese individuals without associated metabolic complications have been phenotypically described as metabolically healthy obese (MHO) individuals [6, 7]. On the other hand is the metabolically unhealthy obese (MUO) individuals characterized by obesity-related metabolic complications [8]. Previous studies have reported MHO phenotype to be associated with a healthy metabolic profile, characterized by a lower amount of visceral adipose tissue (VAT) and liver fat [9], favorable lipid profile, high insulin sensitivity, and low pro-inflammatory cytokine levels in plasma [9, 10] than MUO subjects.

Major changes associated with aging in body composition include a decline in both fat-free mass and muscle strength referred to as sarcopenia [11]; and, an increase in body fat and a decline in skeletal muscle referred to as sarcopenic obesity (SO) [12]. Numerous studies have reported a significantly higher risk of mortality [13] worse cardiovascular risk profiles including hyperglycemia, hypertension, dyslipidemia, insulin resistance, and lower cardiorespiratory fitness [14–16] in sarcopenic obese individuals compared to non-sarcopenic or non-obese subjects.

Previous reports indicate a 9.9% prevalence of SO among Tehranian overweight/obese women [17], while a 10.9% and a 7.2% prevalence of MUO and MHO phenotypes respectively in Iranian adult population [18]. The aim of this study therefore was to determine the association of sarcopenic obesity and body composition with metabolically unhealthy overweight/obese phenotypes among Iranian women.

Methods

Study design and Population

This cross-sectional study was conducted among 241 women referred to health centers affiliated to Tehran University Medical Science (TUMS) in Iran. Subjects were registered by the use of multistage cluster random sampling method. Inclusion criteria were age 18–48 years and being overweight/obese. Exclusion criteria included having; an acute or chronic inflammatory disease, regular use of medication, history of hypertension, cardiovascular disease, diabetes mellitus, impaired renal and liver function, intake of alcohol or drug abuse, smoking, thyroid disease, malignancies, pregnancy, and lactation. All participants were informed about the study aims and procedures and provided written informed consent. The Medical Research Ethics Committee of TUMS approved the study with the following identification IR.TUMS.VCR.REC.1398.692.

Measurements

Dietary Assessment

A semi-quantitative food frequency questionnaire (FFQ) with 147 food items was applied to evaluate the usual dietary intake. Predictable average daily intakes of food parameters were computed using NUTRITIONIST IV software (version 7.0; N-Squared Computing, Salem, OR), modified for Iranian foods.

Measurement of blood samples

Blood samples were collected following overnight fasting. Fasting blood sugar, triglyceride, total cholesterol, high-density lipoprotein (HDL), low-density lipoprotein (LDL), and high-sensitive C-reactive protein (hs-CRP) were assessed using a package from Randox Laboratories (Hitachi 902).

Body composition and anthropometric measurements assessment

Bioelectrical impedance analyzer (BIA) (InBody 720, South Korea) was used to assess body composition indicators, including body fat-free mass and fat mass. Anthropometric measurements such as weight, height, waist circumference, and hip circumference were performed on all participants. BMI was then calculated by dividing the weight (kg) by the square of the height (m).

Assessment of blood pressure

The blood pressure was assessed after the participants rested for 10 minutes. Hypertension was defined as blood pressure > 130/85 mmHg. This category includes patients taking antihypertensive medicines, even if treatment achieves a blood pressure level that is within the target range.

The HOMA-IR calculation

The insulin resistance homeostatic model assessment (HOMA-IR) was based on the following equation: [fasting plasma glucose (mmol/l) × fasting plasma insulin (mIU/l)]/22.5 [19].

Definition of metabolic health and sarcopenic obesity

The Karelis criteria were used because all inflammation criteria are tested. The existence of four or more of the following five is described as metabolic abnormality according to the requirements of Karelis, composition: TG 1.7 mmol/l, HDL 1.3 mmol/l, without treatment; LDL 2.6 mmol/l, without treatment, 3.0 mg/l hs-CRP and 2.7 HOMA-IR [20]. We assessed SO as two lower quintiles of SMM and two highest quintiles of FM [21] using BIA.

Other baseline measurements

The socio-demographic characteristics assessed by questionnaire included age, gender, educational level attained, physical activity status, and smoking habits. The validated International Physical Activity Questionnaire (short form) was used to assess the level of physical activity.

Statistical Analysis

All statistical analyses were performed using the IBM SPSS software version 25.0 (SPSS, Chicago, IL, USA), and *p*-values less than 0.05 were considered statistically significant. Normal distribution of data was checked by the Kolmogorov-Smirnov test. Continuous variables were represented as mean ± standard deviations (SDs), and categorical variables represented as percentages and numbers. An independent sample t-test (continuous variables) and a chi-square (χ^2) tests (categorical variables) were used to assess differences between the study groups. Spearman bivariate correlation between body composition variables and sarcopenic obesity was performed. Association between metabolic healthy statuses with measures of body composition and sarcopenic obesity were assessed using Binary logistic regression.

Results

General characteristics of study participants

The general characteristics of the study subjects are shown in Table 1. In total, 241 women (35.32 ± 8.68 years) participated in our study. The prevalence of SO was 7.88%. Subjects in the MUO group had a significantly higher body weight, BMI, WC, BFM, and VFA compared to subjects in the MHO group ($p < 0.001$). The FFM ($p = 0.004$), FMI ($p = 0.001$), and SMM ($p = 0.002$) were significantly higher in the MUO group. TG, LDL, and total cholesterol were significantly higher ($p < 0.001$) in the unhealthy group, while the levels of HDL were significantly higher ($p < 0.001$) in the healthy group. A significant difference was also

observed among the groups base on HOMA-IR ($p < 0.001$) and insulin level ($p = 0.001$). A significantly higher diastolic blood pressure and mean hs-CRP level were observed among the unhealthy group ($p < 0.001$).

Table 1
General characteristics of study participants

variables	Metabolically Healthy (mean ± SD)	Metabolically Unhealthy	P- value*	P- value ^{†**}
Demographic characteristic				
Age (year) ^a	35.92 ± 7.55	36.32 ± 8.68	0.74	0.84
Marital status ^b	17 (34.0)	33 (66.0)	0.21	0.80
Single (%)	47 (25.0)	141 (75.0)		
Married (%)				
Education ^b	1 (33.3)	2 (66.7)	0.57	0.73
Illiterate (%)	4 (16.0)	21 (84.0)		
Under diploma (%)	24 (26.1)	68 (73.9)		
Diploma (%)	35 (27.7)	83 (70.3)		
Bachelor and above (%)				
Economic status ^b	6 (19.4)	25 (80.6)	0.02	0.16
Low class (%)	20 (48.8)	21 (51.2)		
Middle class (%)	7 (29.2)	17 (70.8)		
High class (%)				
Sarcopenic obesity ^b	61 (27.5)	161 (72.5)	0.06	0.04
Non-sarcopenic obese (%)				
Sarcopenic obese (%)	4 (21.1)	15 (78.9)		
Anthropometry and Body Composition				
Weight (kg) ^a	74.89 ± 8.71	81.03 ± 11.02	< 0.001	< 0.001
Height (cm) ^a	161.09 ± 5.18	161.51 ± 5.83	0.06	0.92
BMI (kg/m ²) ^a	28.75 ± 2.86	31.11 ± 3.64	< 0.001	< 0.001
WC (cm) ^a	93.38 ± 7.01	99.64 ± 9.27	< 0.001	< 0.001
Body fat mass (kg) ^a	29.76 ± 5.96	34.03 ± 7.34	< 0.001	< 0.001

variables	Metabolically Healthy (mean ± SD)	Metabolically Unhealthy	P- value*	P- value ^{†**}
Visceral fat area(cm ²) ^a	14.04 ± 2.89	15.72 ± 3.25	< 0.001	0.001
Fat-free mass (kg) ^a	44.84 ± 4.68	47.10 ± 5.57	0.004	0.01
Skeletal muscle mass (kg) ^a	24.42 ± 2.69	25.89 ± 3.32	0.002	0.008
Fat free mass index (kg) ^a	17.26 ± 1.21	18.75 ± 9.88	0.23	0.27
Fat mass index (kg) ^a	11.65 ± 2.62	13.06 ± 2.78	0.001	< 0.001
Blood Parameters				
FBG (mg/dL) ^a	4.68 ± 0.40	4.86 ± 0.49	0.05	0.03
TG (mg/dL) ^a	0.90 ± 0.28	1.52 ± 0.82	< 0.001	< 0.001
HDL (mg/dL) ^a	1.34 ± 0.24	1.14 ± 0.26	< 0.001	< 0.001
LDL (mg/dL) ^a	2.19 ± 0.50	2.53 ± 0.62	< 0.001	0.001
Total cholesterol (mg/dL) ^a	4.37 ± 0.74	4.89 ± 0.93	< 0.001	0.003
Insulin (mIU/l)	1.13 ± 0.24	1.24 ± 0.22	0.001	0.01
HOMA index ^a	2.47 ± 0.85	3.66 ± 1.24	< 0.001	< 0.001
Blood Pressure				
SBP (mmHg) ^a	109.01 ± 12.44	112.66 ± 13.92	0.06	0.18
DBP (mmHg) ^a	73.74 ± 8.29	79.39 ± 10.05	< 0.001	0.007
Inflammatory parameter and other variables				
Hs-CRP (mg/L) ^a	1.33 ± 1.18	5.37 ± 4.91	< 0.001	< 0.001
Physical activity (MET min/week) ^a	989.33 ± 1078.53	1304.14 ± 2404.33	0.33	0.29
SD, standard deviation; BMI, body mass index; WC, waist circumference; FBG, fasting blood glucose; TG, triglyceride; HDL, high-density lipoprotein; LDL, low-density lipoprotein; hs-CRP, High sensitive c-reactive protein; SBP, systolic blood pressure; DBP, diastolic blood pressure.				

variables	Metabolically Healthy	Metabolically Unhealthy	P- value*	P- value ^{†**}
	(mean ± SD)			
Data are presented as mean ± standard deviation (SD) or percent.				
‡Collinear variables did not enter into the model and this P-value obtained from ANCOVA analysis				
*p-value obtained from independent T-test				
** p-value obtained from ANCOVA test, variable adjust for age, physical activity, energy intake, and BMI				
Chi-square and analysis of variance were used for qualitative and quantitative variables respectively, and the p-value was set to < 0.05.				
^a Mean ± SD				
^b Sample size (%)				

Dietary intake of study subjects according to metabolic statuses

As shown in Table 2, the food groups, mean dietary intakes, and the mean nutrient intakes of the study participants were not statistically significantly different between the MHO and MUO groups even after controlling for potential confounding variables ($p > 0.05$).

Table 2
Dietary intake of study subjects according to metabolic statuses

Dietary intake of study subjects according to metabolic statuses						
Variables	Metabolic healthy		Metabolic unhealthy		P-value*	P-value**
	Mean	SD	Mean	SD		
Food groups						
Fruits (g/d)	508.45	373.30	505.83	352.66	0.96	0.34
Vegetables(g/d)	379.99	227.11	387.94	248.29	0.82	0.12
Cereal(g/d)	422.18	195.27	427.86	226.56	0.86	0.61
Whole grains(g/d)	58.64	53.41	65.77	62.43	0.42	0.31
Refined grains(g/d)	363.54	203.95	362.45	211.23	0.97	0.43
Nuts(g/d)	15.23	16.91	19.06	28.03	0.96	0.67
Legumes(g/d)	51.64	55.38	48.23	34.54	0.57	0.62
Red meat (g/d)	21.61	17.70	22.53	19.75	0.74	0.60
White meat(g/d)	38.34	32.02	47.34	42.68	0.12	0.54
Salt and salty snacks(g/d)	36.79	38.78	41.18	47.54	0.51	0.99
Dairy(g/d)	274.24	234.54	301.84	214.28	0.39	0.70
Tea(g/d)	637.96	463.59	793.25	912.36	0.19	0.19
Dietary intake						
Energy intake (kcal/d)	2505.26	727.89	2615.62	754.66	0.31	-
Carbohydrate (g/d)	362.65	126.42	370.55	117.74	0.65	0.20
Carbohydrate (% energy)	57.16	6.58	56.57	6.64	0.54	0.44
Protein (g/d)	83.30	26.04	89.26	28.26	0.14	0.58

MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid; SFA, Saturated fatty acid

Data are presented as mean $\pm$ standard deviation (SD).

^a Calculated by analysis of variance and p-value < 0.05 indicates a significant level.

*Obtained from Independent T-test

**Obtained from ANCOVA analysis

Food group adjusted by age, BMI, physical activity, and energy intake (Kcal)

Dietary intake (macronutrient and micronutrient) adjusted by energy intake (Kcal)

Variables	Metabolic healthy		Metabolic unhealthy		P-value*	P-value**
	Mean	SD	Mean	SD		
Protein (% energy)	13.43	2.61	13.75	2.33	0.36	0.64
Fat (g/d)	88.66	27.49	94.91	33.61	0.18	0.33
Fat (% energy)	32.38	5.79	32.75	6.66	0.82	0.62
MUFA (g/d)	28.93	8.47	31.39	11.69	0.12	0.24
PUFA(g/d)	18.84	6.71	20.12	9.06	0.30	0.64
SFA (g/d)	25.99	9.76	28.43	11.60	0.13	0.14
Fiber (g/d)	45.18	20.05	44.30	17.86	0.74	0.15
Nutrients						
Vitamin A (RAE)	729.58	351.47	795.26	428.82	0.27	0.84
Thiamine (mg/d)	2.01	0.65	2.05	0.63	0.63	0.39
Riboflavin (mg/d)	2.05	0.71	2.23	0.84	0.14	0.30
Niacin (mg/d)	23.59	7.09	25.25	9.30	0.19	0.74
Vitamin B6 (mg/d)	2.06	0.67	2.17	0.72	0.28	0.80
Folic acid (µg/d)	585.20	181.26	606.54	171.92	0.40	0.66
Vitamin B12 (µg/d)	3.99	2.00	4.47	2.36	0.15	0.29
Vitamin C (mg/d)	190.26	124.40	195.71	132.75	0.77	0.19
Vitamin E (mg/d)	15.91	6.73	17.32	9.28	0.26	0.37
Vitamin D (µg/d)	2.05	1.73	1.87	1.47	0.44	0.22
Iron (mg/d)	18.28	6.03	18.63	5.90	0.68	0.14

MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid; SFA, Saturated fatty acid

Data are presented as mean ± standard deviation (SD).

^a Calculated by analysis of variance and p-value < 0.05 indicates a significant level.

*Obtained from Independent T-test

**Obtained from ANCOVA analysis

Food group adjusted by age, BMI, physical activity, and energy intake (Kcal)

Dietary intake (macronutrient and micronutrient) adjusted by energy intake (Kcal)

Variables	Metabolic healthy		Metabolic unhealthy		P-value*	P-value**
	Mean	SD	Mean	SD		
Selenium (µg/d)	114.81	36.86	119.67	42.80	0.42	0.95
Zinc (mg/d)	12.33	4.13	13.12	4.30	0.20	0.94
Magnesium (mg/d)	443.71	144.98	463.73	150.39	0.36	0.65
Calcium (mg/d)	1117.99	423.03	1158.55	410.52	0.50	0.82
Potassium (mg/d)	4208.43	1662.90	4345.83	1538.23	0.55	0.44
Caffeine (g/d)	147.13	105.55	157.53	178.52	0.66	0.72
MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid; SFA, Saturated fatty acid						
Data are presented as mean ± standard deviation (SD).						
a Calculated by analysis of variance and p-value < 0.05 indicates a significant level.						
*Obtained from Independent T-test						
**Obtained from ANCOVA analysis						
Food group adjusted by age, BMI, physical activity, and energy intake (Kcal)						
Dietary intake (macronutrient and micronutrient) adjusted by energy intake (Kcal)						

Correlation of main variables with sarcopenic obesity

Additional file 1: **Table S1** contains the correlation between sarcopenic obesity with the variables of interest in this study. A simple correlation revealed a significant inverse associations between sarcopenic obesity with FFM ($r = -0.30$, $p = < 0.001$) and FFMI ($r = -0.12$, $p = 0.01$), while significant positive correlations were observed between sarcopenic obesity with BFM ($r = 0.27$, $p = < 0.001$) and FMI ($r = 0.33$, $p = < 0.001$).

Association between obesity statuses with measures of body composition

Association of SO with body composition are presented in Table 3. In the crude model, participants with MUO had 0.27 folds increased odds of FFM compared to than the MHO subjects ($p = 0.001$). However, after controlling for potential confounders (age, total energy intake, and physical activity level), the MUO groups had 0.29 folds decreased odds of FFM compared to the MHO group ($p = 0.008$). In the crude model, participants with MUO were observed to be positively associated with greater odds of increasing BFM than those with MHO phenotype ($p = 0.01$). The observed association between metabolic health statuses and BFM remained significant even after controlling for all potential confounders. Subjects with MUO phenotype in the crude model were observed to have a 0.87 kg lower SMM compared with the MHO subjects ($p = 0.006$). After age, total energy intake, and physical activity had been controlled for, the MUO

participants had a 0.83 lower SMM compared with the MHO subjects ($p = 0.01$). Furthermore, after additional adjustment for weight and economic status, the association remained significant ($p = 0.03$). The control of all potential confounders revealed a 4.21 fold greater odds of sarcopenic obesity among MUO subjects ($p = 0.02$).

Table 3

Association between metabolic healthy statuses with measures of body composition and sarcopenic obesity

Variables		β	OR (95% CI)	P-value
Fat-Free Mass				
Crude	MUO	0.76	0.27 (0.13,0.56)	0.001
	MHO	Ref	Ref	
Model 1	MUO	-0.89	0.29 (0.13,0.62)	0.008
	MHO	Ref	Ref	
Model 2	MUO	-0.55	0.26 (0.11,0.59)	0.07
	MHO	Ref	Ref	
Body Fat Mass				
Crude	MUO	1.31	3.73 (1.27, 10.91)	0.01
	MHO	Ref	Ref	
Model 1	MUO	1.49	4.44 (1.31, 15.00)	0.01
	MHO	Ref	Ref	
Model 2	MUO	0.95	2.60 (1.39, 17.20)	0.02
	MHO	Ref	Ref	
Skeletal Muscle Mass				
Crude	MUO	-0.87	0.50 (0.27, 0.90)	0.006
	MHO	Ref	Ref	
Model 1	MUO	-0.83	0.46 (0.22, 0.84)	0.01
	MHO	Ref	Ref	
Model 2	MUO	-0.73	0.47 (0.24, 0.94)	0.03

MUO; metabolic unhealthy obese, MH; metabolic obese

P-values are reported base on the Binary logistic regression test and are considered significant at ≤ 0.05

Healthy obese is a reference group

Model 1: Adjusted for age, kcal, and physical activity

Model 2: Model 1 confounders with further adjustment with weight and economic status

Variables		β	OR (95% CI)	P-value
	MHO	Ref	Ref	
Sarcopenic obesity				
Crude	MUO	0.35	1.42 (0.45, 4.45)	0.54
	MHO	Ref	Ref	
Model 1	MUO	0.42	1.52 (0.40, 5.70)	0.53
	MHO	Ref	Ref	
Model 2	MUO	1.43	4.21 (1.28, 62.26)	0.02
	MHO	Ref	Ref	
MUO; metabolic unhealthy obese, MH; metabolic obese				
P-values are reported base on the Binary logistic regression test and are considered significant at ≤ 0.05				
Healthy obese is a reference group				
Model 1: Adjusted for age, kcal, and physical activity				
Model 2: Model 1 confounders with further adjustment with weight and economic status				

Discussion

This study was conducted among overweight and obese Iranian women between the ages of 18–50 years, with a BMI ≥ 25 kg/m². The metabolic risk was assessed according to Karelis criteria and subjects classified as either MHO or MUO. Of the 241 subjects, 73.03% were classified as MUO with 7.88% as SO. We found that individuals with high FFM and high SMM to have a significantly low risk of MUO phenotype. We also found a significant positive correlation between sarcopenic obesity and MUO phenotype after all potential covariates were controlled.

This study's MUO phenotypes showed a significantly higher BFM, VFM, FFM, SMM, and FMI than the MHO group. Previous studies have found that MUO women had significantly higher BFM, VFM, and muscle mass than MHO women [21] and healthy obese people [29].

Despite the fact that some studies [6, 22, 23] have observed a non-significant difference in the measures of adiposity in “healthy” and “unhealthy” phenotypes, in line with other previous studies [7, 24], we observed a significant increase in BFM in the MUO phenotype even after all potential confounders were controlled for. BFM has been reported as an independent predictor of insulin resistance and dyslipidemia [25] among postmenopausal women. Higher BFM has also been reported as an increased risk factor for type 2 diabetes [26, 27], as well as increase metabolic risk and the risk of cardiovascular disease [28, 29]

in both gender. Furthermore, researches have shown increasing BFM to be correlated with an increase in FBG, triglyceride, LDL, and total cholesterol, and a decrease in HDL cholesterol [30, 31].

There have also been conflicting results regarding SMM accumulation among the metabolic phenotypes. While in some studies no significant differences in SMM indices between metabolic phenotypes of either obese or non-obese postmenopausal women [23] were found, some studies have reported SMM to significantly increase in the MUO phenotype of postmenopausal women [8, 32], and significantly decrease in the metabolic non-obese phenotype of young women (5). Estrella *et al.*, [33] among Hispanic/Latino women found higher SMM to be independently associated with a lower prevalence of the MHO phenotype. In our study, each increase of 1-SD in skeletal muscle mass was associated with a lower prevalence of the MUO phenotype. Our result is in line with the fourth and fifth Korean National Health and Nutrition Examination Survey which reported a protective association of muscle mass with metabolic syndrome [34]. Additionally, in a 7-year retrospective cohort study, Kim and colleagues [35] found that an increase in relative skeletal muscle mass over time has a potential preventive effect on developing metabolic syndrome, independently of baseline skeletal muscle mass and glycometabolic parameters. In a nationally representative sample of 4,449 US adults aged 50 years and older from the NHANES surveys, Li and associates [36] found that only participants with low muscle mass but without metabolic syndrome had a significantly increased risk of all-cause mortality.

After we adjusted for all potential confounders, each increase of 1-SD in sarcopenic obesity was observed to be associated with a higher prevalence of MUO phenotype in the current study. In line with previous epidemiological studies, reports have shown that the odds of metabolic syndrome was 6 to 8 times higher in postmenopausal Korean women, elderly Korean men and women, and adult Caucasian subjects with sarcopenic obesity (SO) compared to those without sarcopenic obesity [14, 37–39]. Furthermore, Kim *et al.*, [40] reported an increased risk of metabolic syndrome in subjects with sarcopenic obesity. In their study, compared with normal subjects, they found that SO subjects had significantly higher values for a number of metabolic syndrome components. Furthermore, they found SO to be independently associated with metabolic syndrome among women after adjustment for age.

Conclusion

In conclusion, increased adiposity and decreased skeletal muscle mass was associated with unfavorable metabolic traits among overweight and obese Iranian women. SO was also found to be associated with a greater risk of developing MUO phenotype after controlling for potential confounders.

Limitations

The cross-sectional nature of this study does not permit the assessment of causality. Also, we used BIA in order to assess body composition but not dual X-ray absorptiometry which is considered the gold standard method. However, BIA is also a validated and reliable method for the measurement of body

composition [41]. Furthermore, the result of the current study cannot be generalized since only females were included in the study.

Abbreviations

BC body composition; **BFM**:body fat mass; **BIA**:Bioelectrical impedance analyzer **BMI**:body mass index; **CI**:confidence intervals; **DBP**:diastolic blood pressure; **DXA**:dual X-ray absorptiometry; **FBS**:fasting blood sugar; **FFM**:fat-free mass; **FFMI**:fat-free mass index; **FFQ**:food frequency questionnaire; **FM**:fat mass; **FMI**:fat mass index; **HC**:hip circumference; **HDL**:high-density lipoprotein; **HOMA-IR**:homeostatic model assessment of insulin resistance; **hs-CRP**:high-sensitive C-reactive protein; **IPAQ**:International Physical Activity Questionnaire; **LDL**:low-density lipoprotein; **MET**:metabolic equivalent; **MHO**:metabolically healthy obese; **MUO**:metabolically unhealthy obese; **OR**:odds ratios; **SBP**:systolic blood pressure; **SDs**:standard deviations; **SE**:standard errors; **SMM**:skeletal muscle mass; **SO**:sarcopenic obesity; **T-cho**:Total cholesterol; **TG** triglyceride; **TNF**:tumor necrosis factor; **VAT**:visceral adipose tissue; **WC**:waist circumference; **WHR**:waist-to-hip ratio;

Declarations

Ethical approval

This study was approved by the ethics committee of Tehran University of Medical Sciences (TUMS) with the following identification IR.TUMS.VCR.REC.1398.692.

Consent for publication

Not applicable.

Availability of data and materials

Participants of this study did not agree for their data to be shared publicly, so supporting data is not available.

Competing interests

All authors declared that they have no competing interests

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Author's contributions

ATJ wrote the article, AM and NR revised the article, FSH performed the statistical analyses, KhM had full access to all of the data in the study and took responsibility for the integrity and accuracy of the data. All authors read and approved the final manuscript.

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