CHARACTERISTICS OF FAT MASS, LEAN MASS, AND BONE MINERAL DENSITY BY *DUAL-ENERGY* X-RAY ABSORPTIOMETRY IN PEOPLE OVER 40 YEARS OLD WITH METABOLIC SYNDROME

Ngo Thi Thu Thuy[1], Nguyen Ngoc Chau[2], Pham Van Thuc[3]

SUMMARY

Objectives: To determine the composition of lean mass (LM), fat mass (FM), and bone mineral density by *Dual-energy* X-ray absorptiometry (DXA) in people over 40 years old with metabolic syndrome (MetS). ***Subjects and methods*:** A cross-sectional study on 199 subjects with or without MetS (defined by the 2005 update NCEP ATP III criteria) who were examined and treated at Hai Phong Medical University Hospital from 2017 to 2022. The composition of LM, FM and bone mineral density were measured using DXA. ***Results:*** Total *FM*, total LM in individuals with MetS were higher than those in non-MetS ($p < 0.01$). FM regions (trunks, android, arms) and A/G FM ratio, LM regions (trunks, android, gynoid), and FM% regions (trunks, android) of MetS subjects were higher than those without MetS ($p < 0.01$). Nevertheless, legs FM, l*egs FM%*, arms FM%, *gynoid FM%,* total FM %, legs LM, and arms LM were not different between both groups ($p > 0.05$). The bone mineral density (BMD) of people with MetS was higher than that of subjects without MetS ($p < 0.05$) at several positions: ribs and arms, however, stratified by BMI, there was no significant difference in BMD ($p > 0.05$). ***Conclusion:*** Total *LM* and total FM in MetS subjects were higher than in non-MetS. FM regions (*arms, android*, trunks) and *A/G FM ratio, LM regions (*trunks, android, gynoid)*, and FM% regions (trunks, android)* of MetS subjects were higher than those without MetS. Total and regional *BMD* (*ribs*, *arms)* of MetS subjects were higher than those without MetS. However, there was no difference in BMD *stratified* by *BMI* between the two groups.

* *Keywords: Dual-energy X-ray absorptiometry (DXA); Fat mass; Lean mass; Metabolic syndrome (MetS).*

[1]Hai Phong Medical Hospital

[2]108 Military Central Hospital

[3]Hai Phong University of Medicine and Pharmarcy

Corresponding author: Ngo Thi Thu Thuy (thuybvdhy@gmail.com)

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INTRODUCTION

Metabolic syndrome (MetS) is a major cause of type 2 diabetes and cardiovascular diseases, which is one of the major challenges faced by public health worldwide. Obesity plays an important role in the pathogenesis of MetS. However, some obese people have a high sensitivity to insulin, thus helping to protect them from metabolic disorders [1]. More and more studies provide evidence that fat distribution is an even better predictor of FM in understanding the association between obesity and metabolic disorders [2]. BMI is a simple tool to assess obesity, but it cannot accurately measure FM and LM (LM) [1]. Recently, surveying the distribution of FM and LM by DXA is a useful tool to understand the role of adipose and lean tissue with MetS. [3 4. Therefore, we study this topic: *To determine the composition of LM, FM, and bone mineral density by DXA in people over 40 years old with metabolic syndrome.*

SUBJECTS AND METHODS

1. Subjects

A total of 199 subjects were examined and treated at Hai Phong Medical University Hospital from 2017 to 2022. These patients were divided into two groups: 128 individuals with MetS (NCEP/ATP-III) and 73 people without MetS, all over 40 years old. People in the two groups had similar average age and male/female ratio.

* *Exclusion criteria:* People with one of the following problems: autoimmune disease, patients with cirrhosis of the liver, kidney failure, tuberculosis; chronic arthritis, hyperthyroidism, primary hyperparathyroidism, Cushing's syndrome, chronic liver disease, multiple myeloma, prolonged immobilization, patients on hormone replacement therapy, women who had been removed ovaries, history and current treatment with long-term corticosteroid therapy.

2. Methods

* *Study design:* Cross-sectional study, descriptive statistics, analysis, systematic random sampling.

* *Study information collection:* History of treatment for diabetes, hypertension, dyslipidemia, and other chronic diseases.

- Anthropometric measures: waist circumference, weight, height, Body mass index (BMI - total body mass as kg/m^2), and blood pressure. The blood samples were used to estimate plasma fasting blood glucose and serum was used for estimating of triglycerides, total cholesterol, low and high-density lipoproteins.

- The Whole-body dual-energy X-ray absorptiometry (DXA) was used to measure total body mass, total body FM, total body LM, regional distribution of fat and LMes, and percentage of FM, for total and regional distributions, total BMD, and regional BMD (head, spines, ribs, arms, legs, pelvis) by Primus - Osteosys (Korea), DXA was done at the Department of Diagnostic Imaging, Viet Tiep Hospital.

The 2005 updated *NCEP/ATP III* criteria for the *diagnosis* of *metabolic syndrome.*

* *Data processing:* Using SPSS 23.0 software.

RESULTS

Table 1: General characteristics of the study subjects.

Characteristics		Non-MetS (n = 71)	MetS (n = 128)	p
Gender	Female (n, %)	60 (84.5%)	103 (80.5%)	0.48*
	Male (n, %)	11 (15.5%)	25 (19.5%)	
Age (year) ($\overline{X}$ ± SD)		58.17 ± 7.01	59.99 ± 6.59	0.07**
Waist circumference (cm)		78 (76 - 80)	85 (81 - 88)	< 0.001***
Central obesity (n, %)		17 (23.9%)	95 (74.2%)	< 0.001*
Waist-to-hip ratio		0.87 (0.83 - 0.91)	0.92 (0.89 - 0.95)	< 0.001***

(χ^2, **T-test, ***Mann - Whitney test)*

There was no significant difference in the age average and sex distribution between the group with and without MetS ($p > 0.05$).

Anthropometric indices, *including waist circumference* (WC), waist-to-hip, and the ratio of MetS individuals were higher than those of non-MetS with $p < 0.001$. The central obesity rate (%) of MetS individuals was higher than that of non-MetS with $p < 0.001$.

Table 2: Characteristics of FM and LM among the study subjects.

Sites	FM (kg)		p*	LM (kg)		p**
	Non-MetS (n = 71)	MetS (n = 128)		Non-MetS (n = 71)	MetS (n = 128)	
Trunk	6.60 ± 2.80	8.50 ± 2.77	< 0.001	17.15 (15.19 - 18.97)	18.34 (16.87 - 20.23)	0.001
Android	1.34 ± 0.55	1.76 ± 0.57	< 0.001	1.87 (1.70 - 2.07)	2.02 (1.82 - 2.29)	0.001
Android/ Gynoid	0.53 ± 0.14	0.63 ± 0.16	< 0.001	0.44 (0.42 - 0.47)	0.44 (0.42 - 0.47)	0.84
Arm	1.79 ± 0.78	2.15 ± 9.6	0.007	3.33 (2.70 - 3.70)	3.47 (3.03 - 3.99)	0.05
Gynoid	2.54 ± 0.86	2.85 ± 0.92	0.02	4,19 (3.87 - 4.55)	4,59 (4.10 - 5.13)	< 0.001
Leg	5.56 ± 2.16	5.75 ± 1.94	0.51	10.28 (8.96 - 11.68)	10.90 (9.55 -12.20)	0.05
Total	15.14 ± 5.68	17.86 ± 5.53	0.001	33.42 (31.00-36.84)	35.56 (32.57 - 39.76)	0.003

*(*T-test, **Mann - Whitney test)*

The subjects with MetS had higher FM than those without MetS. The most obvious difference was observed in the positions of arms, trunk, android, and Android/gynoid (A/G) FM ratio ($p < 0.001$), the total FM of the group with MetS was higher than that without MetS ($p < 0.01$). The gynoid FM in the group with MetS was higher than the group without MetS ($p < 0.05$). LM of the MetS group was significantly higher than that of the group without MetS at the trunk, android, gynoid ($p < 0.01$), and total LM ($p < 0.01$).

Table 3: Fat percentage of the study subjects.

Sites		Non-MetS (n = 71)	MetS (n = 128)	P*
		Median (KTPV)	Median (KTPV)	
Trunk (%)	Left	28.2 (22.3 - 33.2)	31.8 (25.9 - 35.7)	0.009
	Right	27.9 (21.9 - 33.5)	31.5 (25.9 - 35.9)	0.005
Android (%)		42.9 (31.7 - 47.8)	46.9 (41.0 - 51.0)	0.003
Arm (%)	Left	35.6 (20.9 - 41.9)	37.1 (28.1- 44.2)	0.15
	Right	37.4 (23.4 - 43.2)	37.4 (29.8 - 44.5)	0.49
Leg (%)	Left	34.7 (25.7 - 42.1)	34.7 (26.8 - 39.7)	0.53
	Right	35.4 (27.3 - 41.8)	35.1 (28.0 - 40.4)	0.75
Gynoid (%)		38.6 (28.7 - 43.8)	38.7 (32.2 - 42.4)	0.94
Total body (%)		31.7 (23.1 - 36.8)	33.3 (26.7 - 37.5)	0.17

*(*Mann - Whitney test)*

A*ndroid* FM% and *trunk FM % of* MetS *subjects were higher than those of controls* ($p < 0.01$). However, there was no difference in leg fat, gynoid, and *total fat % between the two groups* ($p > 0.05$).

Table 4: BMD characteristics of the study subjects.

Sites		Non-MetS (n = 71)	MetS (n = 128)	P*
		$\overline{X} \pm SD$	$\overline{X} \pm$ **SD**	
Head		1.98 ± 0.34	2.02 ± 0.29	0.35
Spines		0.73 ± 0.14	0.77 ± 0.15	0.05
Rib	left	0.51 ± 0.08	0.54 ± 0.08	0.005
	right	0.54 ± 0.07	0.57 ± 0.07	0.003
Arm	left	0.71 ± 0.12	0.76 ± 0.12	0.006
	right	0.74 ± 0.12	0.80 ± 0.14	0.005
Leg	left	0.99 ± 0.13	1.02 ± 0.12	0.13
	right	1.00 ± 0.13	1.03 ± 0.12	0.14
Pelvis		0.88 ± 0.15	0.92 ± 0.14	0.07
Total		0.97 ± 0.12	1.00 ± 0.11	0.04

*(*T - test)*

Total and regional *BMD* (*total body*, *ribs*, *arms)* of non-MetS were lower than MetS group ($p < 0.05$).

Table 5: Bone mineral density stratified according to BMI.

BMI / Sites	BMI < 23		P*	BMI ≥ 23		p*
	Non-MetS (n = 54)	MetS (n = 60)		Non-MetS (n = 17)	MetS (n = 68)	
Head	1.97 ± 0.34	1.98 ± 0.29	0.81	2.03 ± 0.31	2.06 ± 0.29	0.67
Spine	0.72 ± 0.14	0.74 ± 0.15	0.45	0.75 ± 0.14	0.80 ± 0.15	0.27
Left rib	0.50 ± 0.08	0.52 ± 0.08	0.27	0.55 ± 0.06	0.57 ± 0.07	0.28
Right rib	0.53 ± 0.07	0.55 ± 0.07	0.12	0.58 ± 0.06	0.59 ± 0.07	0.49
Left arm	0.69 ± 0.12	0.72 ± 0.12	0.13	0.78 ± 0.09	0.80 ± 0.12	0.66
Right arm	0.72 ± 0.12	0.75 ± 0.13	0.25	0.80 ± 0.07	0.84 ± 0.14	0.28
Left leg	0.98 ± 0.14	0.99 ± 0.12	0.68	1.03 ± 0.11	1.04 ± 0.11	0.60
Right leg	0.99 ± 0.13	0.99 ± 0.12	0.76	1.04 ± 0.11	1.06 ± 0.11	0.62
Pelvis	0.85 ± 0.14	0.88 ± 0.14	0.38	0.95 ± 0.18	0.95 ± 0.13	0.98
Total	0.95 ± 0.12	0.97 ± 0.11	0.38	1.02 ± 0.11	1.03 ± 0.11	0.58

*(*T - test)*

There was no significant difference in BMD between group with and without MetS group ($p > 0.05$).

DISCUSSION

General characteristics of the study subjects

There was no significant difference in the age average and sex distribution between the group with and without MetS ($p > 0.05$). Anthropometric indices, *including waist circumference* (WC), waist-to-hip, and the ratio of MetS individuals were higher than those of non-MetS with $p < 0.001$. The central obesity rate (%) of MetS individuals was higher than that of non-MetS with $p < 0.001$.

The pathogenesis of metabolic syndrome is complex and still not well understood, but obesity, especially central obesity is believed to play an important role.

Fat distribution characteristics of study subjects

There was increasing evidence supporting that the role of fat distribution was more important than total body fat in the development of MetS. *Abdominal obesity* is a higher risk of *metabolic disorders and cardiovascular risks than fat storage in regions of the hip and thigh.* Fat accumulation in android compartments may confer increased metabolic risk. Measurement of android fat may provide a more complete understanding of the metabolic risk associated with variations in fat distribution [5]. Body mass index (BMI) has long been widely used *for measuring obesity;* however, it is limited by an inability to differentiate between FM and LM. Moreover, the BMI does *not* provide information on the distribution of *lean* and *adipose tissue mass* [6]. *The study results* showed high reliability in measuring body composition parameters using the DXA method. Thus, it is rapidly *becoming* more *popular* as a technique to monitor body composition as well as to distribute lean and FM in the MetS population.

In our study, the FM of the subjects with MetS was higher than that of those without MetS in several locations. The most obvious difference was in the positions of arms FM, trunk FM, android FM, and A/G fat ratio ($p < 0.001$). The body FM of the MetS group was higher than that of the group without MetS ($p < 0.01$). This is similar to the gynoid FM but with $p < 0.05$. There was no difference in leg FM between the groups ($p > 0.05$). Body fat and android percentages of METs subjects were higher than non-MetS ($p < 0.01$). Leg FM%, arms FM%, gynoid FM%, and total FM% were not different between the two groups ($p > 0.05$). This finding is consistent with Xiaomin Zhang's (2013). After adjusting for covariates including age, gender, and trunk FM or trunk FM%, higher leg FM and leg FM% were, in general, correlated favorably with adiposity-related risk factors and associated with lower odds of MetS in all ethnicities, including non-Hispanic whites and blacks and Hispanic groups. In addition, in all multivariate-adjusted models, leg/whole and leg/trunk ratios were strongly associated with lower levels of most risk factors and decreased odds of MetS in these ethnicities (all odds ratios comparing extreme quintiles < 0.1) [2]. These results show that fat accumulation tends to be concentrated in the upper body of the group with MetS, especially the android position. Fat distribution is mainly in the upper

body (apple-shaped obesity or male obesity). It has been reported that a greater increase in android fat over gynoid fat (large A/G ratio) is associated with such conditions as insulin resistance and an increased risk of cardiovascular events.

Lean distribution characteristics of the study subjects: The LM of the group with MetS was significantly higher than that of the group without MetS at the trunk, android, gynoid, and total LM ($p < 0.05$). Thus, in the present study, we observed that patients with MetS had a high FM and LM phenotype. Excessive fat accumulation associated with a higher risk of MetS regardless of muscle mass was also observed in Kyuwoong Kim's study (2018): After adjustment for potential confounders, high muscle/low fat was associated with significantly lower insulin resistance ($p < 0.001$) compared to low muscle/low fat. Low muscle/high fat (IRR: 1.90; 95% confidence interval [CI]:1.44-2.50, $p < 0.001$) and high muscle/high fat (IRR: 2.30; 95% CI:1.76-3.00, $p < 0.001$) were significantly associated with the prevalence of metabolic syndrome. The study suggests that the protective association of muscle mass with metabolic syndrome is attenuated by high FM in Korean adults [1].

Bone mineral density characteristics of the study subjects: BMD of the ribs and arms, BMD of the total body were lower than those of the control group ($p < 0.05$), but when stratified by BMI, there was no difference in BMD between 2 groups ($p > 0.05$). This result shows that BMI has a great influence on the association between BMD and MetS. The impact of BMI and body weight is known to be one of the important factors that stimulate bone growth to adapt to its function of supporting the body. This situation has also been observed in diverse studies in different populations of races and ethnicities around the world. In a study by Kok-Yong Chin (2020), subjects with MetS had higher BMD compared to those without MetS in models unadjusted for BMI (spine $p = 0.008$; hip $p < 0.001$). This difference was attenuated with BMI adjustment (spine $p = 0.625$; hip $p = 0.478$) [3]. Muraduzzaman, M. (2021 in *multivariate* regression analysis, considering BMD at the lumbar spine, right femoral neck or left femoral neck as the dependent variable and age, body mass index (BMI), and MS as independent variables, β values for MS with BMD were -0.041 ($p = 0.184$), 0.002 ($p = 0.938$), 0.011 ($p = 0.688$) and with T-score were -0.330 ($p = 0.241$), -0.005 ($p = 0.984$), 0.151 ($p = 0.599$) at the lumbar spine and

right femoral neck and left femoral neck, respectively [4].

Conversely, some studies have found a relationship between MetS and bone health. Weida Liu has summarized the research results from reports (2021). In seven studies (10 datasets), the summarized ORs of osteoporosis for MetS were 0.72 (95% CI: 0.52 - 0.99). Subgroup analyses by gender showed that significant inverse associations were observed only in men (OR = 0.72, 95% CI: 0.55 - 0.96) but not in women (OR = 0.70, 95% CI: 0.41 - 1.22). The definition of MetS, the source of the study population, and the adjustment of covariates affected the estimates. In two studies (4 datasets), there was no evidence for an association between MetS and decreased BMD [8]. Bagherzadeh, M. (2020): in the adjusted multivariable model including BMI, a statistically significant association between MetS and BMD at all sites was observed in men ($p < 0.01$) and lumbar spine BMD in women ($p = 0.003$), the prevalence of osteoporosis (based on BMD) was significantly lower in that with MetS than those without MetS in both sexes, even after full adjustments (women, OR = 0.707, p-value = 0.013; men, OR = 0.563, p-value = 0.001) [9]. Thus, it can be seen that there are differences in findings on the relationship between MetS and BMD. Accordingly, positive, negative, and unrelated relationships between the two conditions were reported. This difference is explained by the fact that MetS and osteoporosis are two diseases with complex pathogenesis and multifactorial etiology, including genetic, environmental, and possible interactions between obesity and osteoporosis. The MetS covers several independent criteria and has its own independent effects on bone metabolism, and even a single disease can have opposite effects on bone metabolism. Mechanistically, each component of the MetS affects bone separately, forming a complex network of interactions that affect the skeleton. Furthermore, related to study design, sample structure, MetS model, and even the choice of variables in the multivariable regression model can also lead to different results.

CONCLUSION

Total *LM* and total FM in MetS subjects were higher than in non-MetS. FM regions (*arms, android*, trunks) and *A/G FM ratio, LM regions (*trunks, android, gynoid)*, and FM% regions (trunks, android)* of MetS subjects were higher than those without MetS. Total and regional *BMD* (*ribs*, *arms)* of MetS subjects were higher than those without MetS. However, the two groups had no difference in BMD *stratified* by *BMI*.

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