The Relationship Between Anthropometric and Ultrasonographic Muscle and Subcutaneous Fat Thickness Measurements and Osteoporosis in Male Patients

Erkek Hastalarda Antropometrik ve Ultrasonografik Kas ve Deri Altı Yağ Kalınlığı Ölçümleri ile Osteoporoz Arasındaki İlişki

 Bilinç Doğruöz Karatekin, Erkan Mesci*, Afitap İçağasioğlu*

İstanbul Göztepe Prof. Dr. Süleyman Yalçın City Hospital, Clinic of Physical Medicine and Rehabilitation, İstanbul, Turkey
*İstanbul Medeniyet University Faculty of Medicine, Department of Physical Medicine and Rehabilitation, İstanbul, Turkey

Abstract

Objective: In this study, the relationship between osteoporosis severity and fat and muscle mass and strength in osteoporotic men was compared with anthropometric and ultrasonographic measurements.

Materials and Methods: Forty-three osteoporotic men who applied to the physical medicine and rehabilitation outpatient clinic were evaluated as follows: osteoporosis severity by dual energy X-ray absorbtiometry T-scores and bone mineral densities (BMD), muscle strength by Jamar Hand Dynanometer, muscle mass by anthropometric mid arm muscle circumference (MAMC) and ultrasonographic mid-upper arm muscle thickness, subcutaneous fat thickness by triceps skinfold thickness caliper and ultrasonographic triceps subcutaneous fat thickness. The smoking use of the patients was noted and their physical activity levels were evaluated with the international physical activity questionnaire.

Results: A statistically significant correlation was found with MAMC and femur neck T-score, femur total T-score, femur total BMD, mid-upper arm muscle thickness and triceps skinfold thickness caliper ($p<0.05$, $r=0.391$, $r=0.358$, $r=0.319$, $r=0.352$, $r=0.440$, respectively). A statistically significant correlation was found with mid-upper arm muscle thickness and femur neck T-score, femur neck BMD, femur total T-score and hand grip strength ($p<0.05$, $r=0.500$, $r=0.315$, $r=0.396$, $r=0.407$, respectively). Triceps skinfold measurement was significantly correlated with ultrasonographic triceps subcutaneous fat thickness, MAMC and hand grip strength ($p<0.01$, $r=0.502$, $r=0.440$, $r=0.413$, $r=0.352$, $r=-0.440$, respectively).

Conclusion: MAMC and ultrasonographic mid-upper arm muscle thickness measurements are associated with the severity of osteoporosis. Simple and rapid ultrasonographic and anthropometric measurements can provide information about osteoporosis and sarcopenia in men.

Keywords: Osteoporosis, male, ultrasonography, anthropometric, muscle thickness

Öz

Amaç: Bu çalışmada 50 yaş üzeri osteoporotik erkeklerde osteoporoz şiddeti ile yağ ve kas kütlesi ve kuvveti arasındaki ilişki antropometrik ve ultrasonografik ölçümlerle karşılaştırıldı.

Gereç ve Yöntem: Fiziksel tıp ve rehabilitasyon polikliniğine başvuran 43 osteoporotik erkekte, dual enerji X-ışını absorbtiyometri T-skorları ve kemik mineral yoğunlukları (KMY) ile osteoporoz şiddeti, Jamar Hand Dynanometer ile el kavrama kuvveti, antropometrik orta kol kas çevresi (MAMC) ve ultrasonografik orta-üst kol kas kalınlığı ölçümü ile kas kütlesi, triseps skinfold kalınlığı kaliper ve ultrasonografik triseps deri altı yağ kalınlığı ölçümü ile deri altı yağ kalınlığı değerlendirildi. Hastaların sigara kullanımı not edildi ve uluslararası fiziksel aktivite anketi ile fiziksel aktivite düzeyleri değerlendirildi.

Bulgular: MAMC ile femur boyun T-skoru, femur total T-skoru, femur total KMY, ultrasonografik orta-üst kol kas kalınlığı ve triseps skinfold kalınlığı ile istatistiksel olarak anlamlı korelasyon saptandı ($p<0,05$, $r=0,391$, $r=0,358$, $r=0,319$, $r=0,352$, $r=0,440$, sırasıyla). Ultrasonografik orta-üst kol kas kalınlığı ile femur boyun T-skoru, femur boyun KMY, femur total T-skoru ve el kavrama kuvveti ile istatistiksel olarak anlamlı korelasyon saptandı ($p<0,05$, $r=0,500$, $r=0,315$, $r=0,396$, $r=0,407$, sırasıyla). Triseps skinfold ölçümü triseps subkütan yağ kalınlığı ile, MAMC ile ve el kavrama kuvveti ile anlamlı korele saptandı ($p<0,01$, $r=0,502$, $r=0,440$, $r=0,413$, $r=0,352$, $r=-0,440$, sırasıyla).

Sonuç: MAMC ve ultrasonografik orta-üst kol kas kalınlığı ölçümü osteoporoz şiddeti ile ilişkilidir. Basit ve hızlı ultrasonografik ve antropometrik ölçümler erkeklerde osteoporoz ve sarkopeni ile ilgili bilgi verebilir.

Anahtar kelimeler: Osteoporoz, erkek, ultrasonografi, antropometri, kas kalınlığı

Turk J Osteoporos
2023;29:150-5

Doğruöz Karatekin et al.
Anthropometric and Ultrasonographic Measurements in Male Osteoporosis **151**

Introduction

Osteoporosis is described as a 'silent disease' because although it does not cause obvious symptoms when uncomplicated, it can cause a serious disease burden due to fragility fractures (1). In the FRACTURK study, it is estimated that there were 1,045,000 individuals with osteoporosis in 2010, and the figures will increase by 64% to reach 870,000 men and 1,841,000 women in 2035 (2).

Several studies have been published on the links between bone, muscle, and adipose tissue, and to better reveal the common mechanisms in the etiopathogenesis of osteoporosis and sarcopenia (3,4). Previous studies have shown that bone mass is more closely related to muscle mass in men than in women (5-7). This situation is explained by gender specific sex hormone differences. Differences in bone and muscle properties in men are controlled by testosterone and IGF-1 levels, and an increase in these hormones causes an elevation in muscle mass and strength, while an elevation in estrogen levels in women causes an increase in bone mass more than muscle (5).

Muscle plays a critical role in regulating bone mass. Relationships between body composition, bone mineral density (BMD) and osteoporosis have been reported in clinical studies (8,9). In the studies of Gjesdal et al. (8), it is demonstrated that lean muscle mass is more strongly associated with BMD of the femoral neck in middle-aged and older men and women compared to fat mass, while fat mass is a much stronger indicator of BMD among women.

Muscle-bone relationship is reported to be best observed in the non-weight-bearing and non-dominant upper limbs, which are not subjected to higher than normal mechanical loads. In their study, Klein et al. (10) reported that the age-related decrease in muscle cross sectional area (CSA) was more pronounced in the arm than in the forearm and the decrease in muscle size and strength with age contributes significantly to the decrease in bone cortical area.

Among studies investigating the relationship between muscle characteristics and osteoporosis, there is little information about the relationship between upper extremity anthropometry and osteoporosis. An emerging anthropometric measurement in recent years, mid-arm muscle circumference (MAMC) has been shown to be a marker of muscle mass, with a significantly inverse relationship between MAMC and mortality in older men (11). MAMC is an practical and convenient bedside anthropometric measurement and recently be reported as a marker for osteoporosis in male population (12).

In addition to clinical and anthropometric measurements, real time ultrasonography (USG) is a proposed method that is accurate in determining size, location and texture of soft tissue structures and is easily accessible, low-cost and suitable for daily practice. There are studies reported that muscle ultrasonographic evaluation may be a reliable tool in estimating muscle mass (13,14). However, no study evaluating anthropometric measurements and ultrasonographic measurements together and investigating their relationship with osteoporosis in adult men is found within our knowledge.

In this study, the relationship between osteoporosis and muscle strength, ultrasonographic measurement of upper arm muscle thickness and MAMC were investigated in osteoporotic adult men.

Materials and Methods

A cross-sectional study conducted to investigate the relationship between mid upper arm muscle thickness and subcutaneous fat thicknesses measured ultrasonographically, anthropometric measurements and femoral neck and total bone mineral densities in adult osteoporotic men. Forty-three osteoporotic men who applied to the physical medicine and rehabilitation outpatient clinic between February and December 2021 were included.

Men with a T-score of -2.5 and below in dual energy X-ray absorbtiometry according to the World Health Organization criteria and diagnosed with osteoporosis were included in the study (15).

Patients diagnosed with secondary osteoporosis and patients with malignancy, thyroid/parathyroid disease, diabetes mellitus, cardiovascular disease, and patients using antiepileptics, antiandrogenic medications or steroids were excluded.

Ethics committee approval for the study was obtained from İstanbul Medeniyet University Göztepe Training and Research Hospital Clinical Research Ethics Committee (decision no: 2020/0089, date: 19.02.2020). The study was conducted in accordance with the Declaration of Helsinki according to the STROBE checklist and all participants gave written consent before the study.

Demographic Data

Age, smoking status and daily activity levels of the patients were recorded as demographic parameters. The activity of the participants during a day was evaluated with international physical activity questionnaire (IPAQ) short form (16). Physical activity scores noted as MET minutes a week and dividen into 3 categories as low/moderate/high activity levels.

Anthropometric Measurements

Anthropometric measurements were made using a tape measure and skinfold caliper by the same researcher.

Body mass index was calculated as body weight in kilogram and the square of the height in meters (kg/m^2).

Triceps skinfold (TS) thickness: The measurement was made with a skinfold thickness caliper. During the measurement, the subject was standing with his arms hanging freely to the sides without straining and the person taking the measurement is behind the subject. The measurement was taken over the triceps muscle at the back of the upper arm and in the middle of the upper arm (middle between the acromion and the olecranon points). The skin lifted between the fingers was be perpendicular to the ground.

152 Doğruöz Karatekin et al.
Anthropometric and Ultrasonographic Measurements in Male Osteoporosis

Turk J Osteoporos
2023;29:150-5

Mid upper arm circumference (MUAC): The arm is bent 90º from the elbow, the midpoint between the acromial protrusion on the shoulder and the olecranon protrusion on the elbow is marked, and the circumference is measured with a non-flexible measuring tape to estimate muscle mass.

MAMC (cm): MAMC was calculated as: MUAC (cm) - 0.3142 x TS thickness (mm) (17).

Hand Grip Strength

Hand grip strength was measured using Jamar Hand Dynamometer (manufactured by Patterson Medical) following published procedures (32). Measurements were made while the individual was in an upright sitting position (without arm support on the sitting surface), the arm was kept in a free position, the knee angle was 90 degrees, the elbow angle was 90 degrees, and the wrist was kept without deviation and the dynamometer was held in an upright position. The measurement was performed for both hands 3 times with an interval of 10 seconds and the average of the 3 measurements was taken. The highest force (in kg) was taken for the dependent variable.

Ultrasound Measurements

A B-mode ultrasound device (Toshiba Aplio SSA-770A™) with a 7.5 MHz linear transducer was used. The ultrasound examination of all subjects was performed by the same experienced musculoskeletal sonographer. In order to eliminate changes in muscle thickness and muscle echo intensity, attention was paid to apply minimum and equal pressure to the probe during ultrasound scans. By applying water-based gel to the probe, surface tension formation was prevented by preventing air from remaining between the probe and the skin. The transducer was held perpendicular to the skin, and the depth was adjusted to visualize the humerus.

The patients were positioned in an upright position standing with the elbows 90° flexed. A mark was made on the skin at the midpoint between the tip of the acromion and the olecranon process. Thickness of the mid upper arm muscle was measured from the subcutaneous adipose tissue to humerus and thickness of triceps subcutaneous fat thickness was measured from dermis to muscle (Figure 1).

This examination was performed 3 times, and the average of 3 measurements was noted.

Statistical Analysis

Before the study, power analysis was performed using the G power program to determine the number of samples. When the correlation analysis coefficient was taken as 0.3, the effect size was calculated as 0.55. When alpha 0.05 and 1-beta 0.99 were accepted, the number of samples to be included in the study was found to be 39. All data were evaluated using the IBM SPSS Statistics (Statistical Package for Social Sciences, version 22.0, IBM, USA) program. Shapiro-Wilk test was used to determine whether the quantitative variables were suitable for normal distribution. Descriptive statistics of quantitative variables were given as mean ± standard deviation and as frequency for
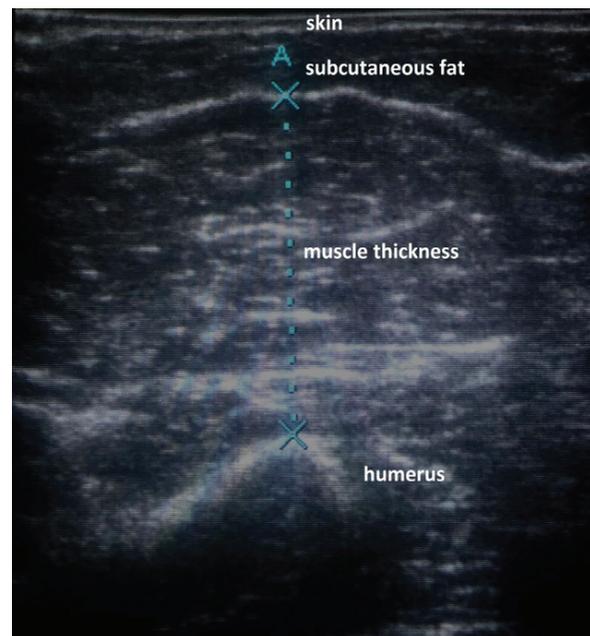
Figure 1. Ultrasonographic assessment of mid upper arm muscle thickness

categorical variables. Spearman and Pearson correlation analysis was applied to determine whether there was a relationship between quantitative variables. Cohen's classification was used for the effect size of the relationship is the correlation coefficient (18). For all tests, the statistical significance level was accepted as 0.05 or 0.01.

Results

Demographic and clinical data of the participants are given in Table 1.

Correlation analysis between anthropometric, ultrasonographic measurements and BMD, T-score measurements are given in Table 2.

When the correlation of ultrasonographic mid upper arm muscle thickness measurement and osteoporosis parameters was examined; Large statistically significant relationship between muscle thickness and femur neck T-score (p<0.01, r=0.500), moderate statistically significant relationship between muscle thickness and femoral neck BMD (p<0.05, r=0.315) and moderate statistically significant relationship between muscle thickness and femur total T-score (p<0.01, r=0.396) was found. No statistically significant relationship was found between smoking status and femoral neck and femoral total BMD (r=-0.130, p=0.406; r=-0.209, p=0.179, respectively). But statistically significant medium relationship was found between smoking status and MAMC (r=-0.346, p=0.023).

No statistically significant relationship was found between IPAQ score and femoral neck and femoral total BMD (r=0.194, p=0.213; r=0.286, p=0.063, respectively). No statistically significant medium relationship was found between IPAQ score and MAMC (r=-0.182, p=0.244).

Turk J Osteoporos
2023;29:150-5

Doğruöz Karatekin et al.
Anthropometric and Ultrasonographic Measurements in Male Osteoporosis **153**

Table 1. Characteristics of the participants (n=43)	
Age (years), mean ± SD	64.06±7.38
BMI (kg/m²), mean ± SD	26.72±4.25
Femur neck T-score, mean ± SD	-1.59±0.77
Femur neck BMD, mean ± SD	0.90±0.16
Femur total T-score, mean ± SD	-2.17±0.47
Femur total BMD, mean ± SD	0.80±0.11
Hand grip strength (n), mean ± SD	46.74±11.99
Mid upper arm circumference (cm), mean ± SD	31.00±4.47
Mid arm muscle circumference (cm), mean ± SD	30.56±4.41
Triceps skinfold thickness caliper (mm), mean ± SD	13.95±3.66
Triceps subcutaneous fat thickness USG (mm), mean ± SD	8.73±3.03
Mid upper arm muscle thickness USG (mm), mean ± SD	30.06±6.85
IPAQ score (MET), mean ± SD	248.37±271.27
IPAQ category, n (%)	
Minimally active	10 (23.3)
Inactive	33 (76.7)
Smoking status, n (%)	
Yes	15 (34.9)
No	28 (65.1)
SD: Standard deviation, USG: Ultrasonography, BMD: Bone mineral density, IPAQ: International physical activity questionnaire, BMI: Body mass index	

Correlation analysis between anthropometric, ultrasonographic measurements and hand grip strength are given in Table 3.

Intraclass correlation coefficients (ICC) were calculated to evaluate intra-rater reliability of muscle and fat thickness measurements by ultrasound.

The ICC value was 0.997 [95% confidence interval (CI) 0.992 to 0.999] for mid upper arm muscle thickness USG, and 0.992 (95% CI 0.980 to 0.997) for triceps subcutaneous fat thickness USG.

Discussion

In this study, the relationship between osteoporosis severity and muscle mass and strength in osteoporotic men was compared with anthropometric and ultrasonographic measurements.

Osteoporosis is considered a primarily female disease, therefore male osteoporosis is underestimated, underdiagnosed and undertreated. However, studies have reported a significant risk of fragility fracture of 13% in a 50-year-old man and 25% in an 80-year-old man (19,20).

A relationship between BMD and muscle mass and muscle strength in elderly people has been reported in the literature (21). There is an increasing number of publications showing that this muscle-bone relationship is more prominent in men.

Table 2. Correlation analysis between anthropometric, ultrasonographic measurements and bone mineral density, T-score measurements (n=43)		Femur neck T-score	Femur neck BMD	Femur total T-score	Femur total BMD
MUAC	rho	0.398**	0.241	0.367*	0.330*
	p	0.008	0.120	0.015	0.031
MAMC	rho	0.391**	0.233	0.358*	0.319*
	p	0.009	0.132	0.018	0.037
USG fat	rho	-0.195	-0.184†	-0.226	-0.234
	p	0.210	0.238	0.145	0.131
USG mus	rho	0.500**	0.315†*	0.396**	0.170
	p	0.001	0.039	0.009	0.275
TST caliper	rho	0.168	0.124	0.084	0.066
	p	0.281	0.427	0.594	0.673

*p<0.05, **p<0.01, †Pearson correlation test
MUAC: Mid upper arm circumference, MAMC: Mid arm muscle circumference, USG: Ultrasonography, TST: Triceps skinfold thickness, BMD: Bone mineral density

In a study conducted on a group of male osteoporotic patients over the age of 65 with a very high sample size, sarcopenia was reported to be a predictor of risk of fracture independent of BMD (6). Also in another study conducted in a cohort of 4000 Chinese men and women aged 65 and over, sarcopenia was found to be significantly associated with all fractures in men, but not in women (7).

In this study, ultrasonographic measurement of mid-upper arm muscle thickness was found to be significantly correlated with femoral neck T-score, femoral neck BMD and femur total T-score. MAMC measurement was also found to be significantly correlated with femur total T-score and BMD and femur neck T-score. Significant correlation was revealed between the two measurements (MAMC and ultrasonographic measurement of mid-upper arm muscle thickness). MAMC has been previously reported as a muscle mass marker in evaluation of sarcopenia (22). Cano et al. (11) reported MAMC as an indicator of mortality in elderly men. Kuo et al. (23) reported in their study on 731 community-dwelling adults aged 65 and older that the relationship between sarcopenia and osteoporosis was more pronounced in males. Chao et al. (12) recently reported that MAMC may be an indicator of osteoporosis in men, but not in women, in their study of a large population of 10,000 people. Similar to Chao et al. (12), in this study, MAMC was associated with osteoporosis in men. While MAMC can be used to estimate muscle mass and screening osteoporosis in clinical practice, it can also be estimated more precisely with a cost-free and bedside ultrasonographic mid upper arm muscle thickness measurement.

Baek et al. (24) compared ultrasonographic measurements of certain muscle groups according to gender in the estimation of appendicular skeletal muscle mass in sarcopenia screening, and

154 Doğruöz Karatekin et al.
Anthropometric and Ultrasonographic Measurements in Male Osteoporosis

Turk J Osteoporos
2023;29:150-5

Table 3. Correlation analysis between anthropometric, ultrasonographic measurements and hand grip strength (n=43)

		Hand grip strength	MAMC	TST caliper	USG fat	USG mus
Hand grip strength	rho	1	-0.022	-0.413[**]	-0.292	0.407[**]
	p	-	0.890	0.006	0.058	0.007
MAMC	rho	-	1	0.440[**]	0.160	0.352[*]
	p	-	-	0.003	0.306	0.021
TST caliper	rho	-	-	1	0.502[**]	0.028
	p	-	-	-	0.001	0.858
USG fat	rho	-	-	-	1	-0.225
	p	-	-	-	-	0.147
USG mus	rho	-	-	-	-	1
	p	-	-	-	-	-

[*]p<0.05, [**]p<0.01
MAMC: Mid arm muscle circumference, USG: Ultrasonography, TST: Triceps skinfold thickness

showed the relationship of biceps, triceps and rectus femoris muscles with sarcopenia in men. These results show that muscle USG is a method that can be easily used in sarcopenia screening and measurements of various muscles can be used in sarcopenia screening. Klein et al. (10) reported a greater reduction in age-related muscle CSA in the arm than in the forearm. Since MUAC is measured in the calculation of MAMC, the measurement of the same region provides standardization, due to proposition of Klein et al. (10), and the convenience of measuring the same area for the clinician, mid upper arm muscle measurement was used in this study.

While no correlation was found between TS thickness and osteoporosis, TS thickness was positively correlated with ultrasonographic triceps subcutaneous fat thickness and MAMC, and negatively correlated with hand grip strength. The MAMC as muscle mass indicator and hand grip strength as indicator of muscle strength are included in the sarcopenia diagnostic criteria. Although the severity of osteoporosis cannot be estimated by measuring subcutaneous fat thickness with a skinfold caliper or USG, it seems to be useful in sarcopenia screening.

In this study, no relationship was found between smoking status, physical activity level and the severity of osteoporosis. However, a relationship was found between smoking status and MAMC. It is known that smoking and sedentary life are important risk factors for osteoporosis (25). Chao et al. (12) also found correlation between smoking and MAMC tertiles in their study and included them in the modeling, and they found a relationship between the included model and osteoporosis. In the Framingham Heart Study, Visser et al. (26) reported that smoking and reduced physical activity were associated with lower BMD in elderly men and women. In this study, participants did not show a homogeneous distribution in terms of physical activity levels. With the small sample size of the study, the fact that 80% of them are physically inactive may be the reason for this result.

This is the first study to investigate the relationship between anthropometric and ultrasonographic muscle and fat thickness measurements and osteoporosis in men to our best knowledge.

Study Limitations

However, the study has some limitations. The small sample size of the study is the primary limitation. Since the study sample was not homogeneously distributed in terms of physical activity level, no relationship was found between physical activity, MAMC and osteoporosis severity. This relationship may be demonstrated in a more homogeneous group.

Conclusion

In conclusion, MAMC, an anthropometric measurement, and ultrasonographic mid upper arm muscle thickness measurement were found to be associated with the severity of osteoporosis. Secondly, it can be suggested that the measurement of TS thickness can be used in screening for sarcopenia. Simple and rapid ultrasonographic measurements can provide information about osteoporosis and sarcopenia in men.

Ethics

Ethics Committee Approval: Ethics committee approval for the study was obtained from İstanbul Medeniyet University Göztepe Training and Research Hospital Clinical Research Ethics Committee (decision no: 2020/0089, date: 19.02.2020).

Informed Consent: All participants gave written consent before the study.

Peer-review: Externally peer-reviewed.

Authorship Contributions

Concept: B.D.K., E.M., A.İ., Design: B.D.K., E.M., A.İ., Data Collection or Processing: B.D.K., E.M., A.İ., Analysis or Interpretation: B.D.K., E.M., A.İ., Literature Search: B.D.K., E.M., A.İ., Writing: B.D.K., E.M.

Conflict of Interest: No conflict of interest was declared by the authors.

Turk J Osteoporos
2023;29:150-5

Doğruöz Karatekin et al.
Anthropometric and Ultrasonographic Measurements in Male Osteoporosis **155**

References

1. Rinonapoli G, Ruggiero C, Meccariello L, Bisaccia M, Ceccarini P, Caraffa A. Osteoporosis in Men: A Review of an Underestimated Bone Condition. Int J Mol Sci 2021;22:2105

2. Tuzun S, Eskiyurt N, Akarirmak U, Saridogan M, Senocak M, Johansson H, et al. Incidence of hip fracture and prevalence of osteoporosis in Turkey: the FRACTURK study. Osteoporos Int 2012;23:949-55.

3. Edwards MH, Gregson CL, Patel HP, Jameson KA, Harvey NC, Sayer AA, et al. Muscle size, strength, and physical performance and their associations with bone structure in the Hertfordshire Cohort Study. J Bone Miner Res 2013;28:2295-304.

4. Tagliaferri C, Wittrant Y, Davicco MJ, Walrand S, Coxam V. Muscle and bone, two interconnected tissues. Ageing Res Rev 2015;21:55-70.

5. Žofková I. Hormonal aspects of the muscle-bone unit. Physiol Res. 2008;57 Suppl 1:S159-69.

6. Yu R, Leung J, Woo J. Incremental predictive value of sarcopenia for incident fracture in an elderly Chinese cohort: results from the Osteoporotic Fractures in Men (MrOs) Study. J Am Med Dir Assoc 2014;15:551-8.

7. Yu R, Leung J, Woo J. Sarcopenia combined with FRAX probabilities improves fracture risk prediction in older Chinese men. J Am Med Dir Assoc 2014;15:918-23.

8. Gjesdal CG, Halse JI, Eide GE, Brun JG, Tell GS. Impact of lean mass and fat mass on bone mineral density: The Hordaland Health Study. Maturitas 2008;59:191-200.

9. Bakker I, Twisk JW, Van Mechelen W, Kemper HC. Fat-free body mass is the most important body composition determinant of 10-yr longitudinal development of lumbar bone in adult men and women. J Clin Endocrinol Metab 2003;88:2607-13.

10. Klein CS, Allman BL, Marsh GD, Rice CL. Muscle size, strength, and bone geometry in the upper limbs of young and old men. J Gerontol A Biol Sci Med Sci 2002;57:M455-9.

11. Cano NJ, Miolane-Debouit M, Léger J, Heng AE. Assessment of body protein: energy status in chronic kidney disease. Semin Nephrol 2009;29:59-66.

12. Chao YP, Kao TW, Chen WL, Peng TC, Wu LW. Mid-arm muscle circumference as an indicator of osteoporosis in community-dwelling older men. Arch Gerontol Geriatr 2020;87:103998.

13. Takai Y, Ohta M, Akagi R, Kato E, Wakahara T, Kawakami Y, et al. Applicability of ultrasound muscle thickness measurements for predicting fat-free mass in elderly population. J Nutr Health Aging 2014;18:579-85.

14. Li S, Li H, Hu Y, Zhu S, Xu Z, Zhang Q, et al. Ultrasound for Measuring the Cross-Sectional Area of Biceps Brachii Muscle in Sarcopenia. Int J Med Sci 2020;17:2947-53.

15. Kanis JA, McCloskey EV, Johansson H, Oden A, Melton LJ 3rd, Khaltaev N. A reference standard for the description of osteoporosis. Bone 2008;42:467-75.

16. Lee PH, Macfarlane DJ, Lam TH, Stewart SM. Validity of the International Physical Activity Questionnaire Short Form (IPAQ-SF): a systematic review. Int J Behav Nutr Phys Act 2011;8:115.

17. Weber JR, Kelley JH. Health assessment in nursing: 5th ed. 2013. p. 1-912.

18. Cohen J. Statistical power analysis for the behavioral sciences. 2nd ed. ed. Hillsdale, N.J: L. Erlbaum Associates; 1988.

19. Nguyen TV, Eisman JA, Kelly PJ, Sambrook PN. Risk factors for osteoporotic fractures in elderly men. Am J Epidemiol 1996;144:255-63.

20. Bliuc D, Nguyen ND, Milch VE, Nguyen TV, Eisman JA, Center JR. Mortality risk associated with low-trauma osteoporotic fracture and subsequent fracture in men and women. JAMA 2009;301:513-21.

21. Proctor DN, Melton LJ, Khosla S, Crowson CS, O'Connor MK, Riggs BL. Relative influence of physical activity, muscle mass and strength on bone density. Osteoporos Int 2000;11:944-52.

22. Akın S, Mucuk S, Öztürk A, Mazıcıoğlu M, Göçer Ş, Arguvanlı S, et al. Muscle function-dependent sarcopenia and cut-off values of possible predictors in community-dwelling Turkish elderly: calf circumference, midarm muscle circumference and walking speed. Eur J Clin Nutr 2015;69:1087-90.

23. Kuo YH, Wang TF, Liu LK, Lee WJ, Peng LN, Chen LK. Epidemiology of Sarcopenia and Factors Associated With It Among Community-Dwelling Older Adults in Taiwan. Am J Med Sci 2019;357:124-33.

24. Baek SH, Sung JH, Park JW, Son MH, Lee JH, Kim BJ. Usefulness of muscle ultrasound in appendicular skeletal muscle mass estimation for sarcopenia assessment. PLoS One 2023;18:e0280202.

25. Curtis E, Litwic A, Cooper C, Dennison E. Determinants of Muscle and Bone Aging. J Cell Physiol 2015;230:2618-25.

26. Visser M, Kiel DP, Langlois J, Hannan MT, Felson DT, Wilson PW, et al. Muscle mass and fat mass in relation to bone mineral density in very old men and women: the Framingham Heart Study. Appl Radiat Isot 1998;49:745-7.