SOCIEDADE BRASILEIRA DE ORTOPEDIA E TRAUMATOLOGIA

RBO REVISTA BRASILEIRA DE ORTOPEDIA

www.rbo.org.br

Original Article

Relationship between obesity, sarcopenia, sarcopenic obesity, and bone mineral density in elderly subjects aged 80 years and over☆

Vanessa Ribeiro dos Santos[a], *Diego Giulliano Destro Christofaro*[b], *Igor Conterato Gomes*[c], *Ismael Forte Freitas Júnior*[b], *Luís Alberto Gobbo*[b,*]

[a] *Programa de Pós-Graduação em Ciências da Motricidade, Instituto de Biociências, Universidade Estadual Paulista (UNESP), Rio Claro, SP, Brazil*

[b] *Departamento de Educação Física, Faculdade de Ciências e Tecnologia, Universidade Estadual Paulista (UNESP), Presidente Prudente, SP, Brazil*

[c] *Departamento de Educação Física, Faculdade Maurício de Nassau, Natal, RN, Brazil*

ARTICLE INFO

Article history:
Received 3 March 2017
Accepted 2 May 2017
Available online 22 September 2017

Keywords:
Body composition
Osteoporosis
Aged 80 years and over

ABSTRACT

Objective: This study sought to analyze the relationship between the components and aggravations of body composition (obesity, sarcopenia, and sarcopenic obesity) and bone mineral density in elderly subjects aged ≥80 years.

Methods: A cross-sectional study design was utilized to assess 128 subjects aged between 80 and 95 years. Body composition and bone mineral density were measured by dual energy X-ray absorptiometry. Gait speed was assessment by walking test. The statistical analyses included Spearman's correlation, one-way analysis of variance, the chi-squared test, and binary logistic regression analysis.

Results: The elderly subjects with sarcopenia had lower bone mineral density compared to the obesity group, with higher risk for presence of osteopenia/osteoporosis in the spine (OR: 2.81; CI: 1.11–7.11) and femur (OR: 2.75; CI: 1.02–7.44). Obesity was shown to be a protective factor for osteopenia/osteoporosis in the spine (OR: 0.43; CI: 0.20–0.93) and femur (OR: 0.27; CI: 0.12–0.62).

Conclusion: It was found that lean mass is more directly related to bone mineral density (total, femur, and spine) and sarcopenia is associated with osteopenia/osteoporosis. Obesity represents a possible protective factor for osteopenia/osteoporosis in elderly subjects aged 80 years and over.

☆ Work done in the Departamento de Educação Física, Escola de Tecnologia e Ciências, Universidade Estadual Paulista (UNESP), Presidente Prudente, SP, Brazil.

* *Corresponding author.*
E-mail: luisgobbo@fct.unesp.br (L.A. Gobbo).

https://doi.org/10.1016/j.rboe.2017.09.002

Relação entre obesidade, sarcopenia, obesidade sarcopênica e densidade mineral óssea em idosos com 80 anos ou mais

Palavras-chave:
Composição corporal
Osteoporose
Idosos 80 anos ou mais

RESUMO

Objetivo: O objetivo do presente estudo foi analisar a relação entre os componentes e agravos da composição corporal (obesidade, sarcopenia e obesidade sarcopênica) com a densidade mineral óssea em idosos com idade ≥ 80 anos.
Métodos: Estudo com delineamento transversal que avaliou 128 sujeitos com idade entre 80 e 95 anos. A composição corporal e densidade mineral óssea foram mensuradas por meio da técnica de absorciometria de raios X de dupla energia. A velocidade de caminhada foi avaliada pelo teste de caminhada usual. Para análise estatística foram realizados os testes de correlação de Spearman, análise de variância com um fator, teste qui-quadrado e análise de regressão logística binária.
Resultados: Os idosos com sarcopenia apresentaram valores menores de DMO quando comparados com o grupo obesidade com maior chance de risco para a presença de osteopenia/osteoporose na coluna (OR: 2,81; IC: 1,11-7,11) e fêmur (OR: 2,75 IC: 1,02-7,44). Obesidade apresentou fator de proteção para osteopenia/osteoporose na coluna (OR: 0,43; IC: 0,20-0,93) e fêmur (OR: 0,27; IC: 0,12-0,62).
Conclusão: Observou-se que a massa magra está diretamente relacionada com a DMO (total, fêmur e coluna) e que a sarcopenia está associada à osteopenia/osteoporose em idosos com 80 anos ou mais.

Introduction

The prevalence of osteoporosis is high in the elderly. This disease damages functional capacity in this population,[1] since it may increase the prevalence of falls and fractures[2] and lead to dependency in performing activities of daily living (ADL), for example, standing up, sitting and climbing a flight of stairs, among others.

Bone mineral density (BMD) is determined by the amount of mineral content in the bone area, and may be influenced by several factors, among them, body composition.[3] Some studies have investigated the individual relationships between BMD and its components (body fat and lean mass). Genaro et al.[4] observed that lean mass is more associated with BMD in osteoporotic postmenopausal women than body fat, on the other hand Bleicher et al.[5] suggested that the loss of body fat is more associated with BMD in men aged over 70 years.

There is an assumption that both components (body fat and lean mass) could contribute to the maintenance of BMD, by generating a mechanical overload on the bones[6,7] favoring the absorption of calcium, however, recent evidence has shown that excess body fat is not a protective factor for BMD in older individuals.[8,9] In relation to lean mass, studies show that this variable is directly associated with bone mass[10,11] and a decrease in the quantity and quality of both is related to aging. This marked decrease in muscle mass that occurs with aging, associated with low muscle strength or low physical performance, is defined as sarcopenia[12] and, in the event that this condition coexists with excess body fat, it is called sarcopenic obesity.[13]

There is a gap in the literature with regard to the investigation of such aspects in elderly subjects aged 80 years and over. Thus, the aim of this study was to analyze the relationship between the components of body composition and aggravations (obesity, sarcopenia and sarcopenic obesity) with BMD in elderly subjects aged 80 years and over.

Methods

Sample characteristics

This was a cross-sectional study with a convenience sample, conducted between October 2009 and May 2010 in the city of Presidente Prudente (~210,000 habitants), located in the southeastern region of Brazil.

Elderly residents aged 80 years and over of both sexes, were invited to participate in the study. The Presidente Prudente municipal health department provided the names, addresses and telephone numbers of individuals who used the public health service of the city. The invitation was made by telephone and the survey was also publicized in the media. A total of 135 subjects responded to the invitations. Individuals who were unable to walk, bedridden, residents of rural areas, institutionalized, those with pacemakers and individuals with incomplete data in the database were excluded. Thus, the sample consisted of 128 subjects.

The objectives and methodology used for data collection were explained and the subjects were informed that they could withdraw from the study at any time. Only those who signed the “Informed Consent” were included in the sample. All protocols were reviewed and approved by the Research

Ethics Committee of the University Estadual Paulista (Case number 26/2009).

Body composition

For body composition analysis Dual Energy X-ray Absorptiometry (DXA) equipment of the Lunar brand, model DPX-MD, software 4.7 was used. Data were transmitted to a device connected to a computer on which the results of lean mass, body fat and bone mineral density (BMD) were recorded. For analysis of the BMD, total proximal femur, lumbar spine (L1–L4) and total whole-body BMD were assessed. The examinations were performed following the manufacturer's recommendations.

Definition of groups (obesity, sarcopenia and sarcopenic obesity)

The sample was divided into four groups: (i) normal group (NG): subjects who were not obese or sarcopenic; (ii) obesity group (OG): subjects classified with a fat percentage above the 60th percentile (33.9% and 43.6%) for men and women, respectively, according to the recommendations of Baumgartner et al.[14]; (iii) sarcopenia group (SG): subjects with low muscle mass and gait speed were classified as sarcopenic. For muscle mass classification, the appendicular lean mass (ALM) index was used (upper limb + lower limb lean mass [kg]/stature [m]^2), being that low muscle mass was considered as present in individuals with an ALM index below 7.59 kg/m^2 and 5.57 kg/m^2 for men and women, respectively. The adoption of these cutoff points was based on 2 standard deviations below the mean of a reference group of young adults ($n = 60$; 25 men and 35 women) aged between 20 and 30 years, as suggested by Baumgartner et al.[15] Individuals with a gait speed below 0.8 m/s, in a 3 m walking test, were considered as having low gait speed, according to Cruz-Jentoft et al.[12]; (iv) sarcopenic obesity group (SOG): subjects who presented both obesity and sarcopenia conditions.

Osteopenia/osteoporosis

Elderly subjects were classified as having osteopenia or osteoporosis according to the criteria established by the World Health Organization.[3]

Gait speed

Gait speed was defined by the performance achieved in a 3 m walking test.[16] Subjects were instructed to walk naturally, and the lowest time (in seconds) obtained from two attempts was recorded.

Anthropometric measurements

Body weight was measured by an electronic scale and height was measured by a fixed stadiometer. These measurements were used for calculating BMI [weight (kg)/height (m)^2], and were performed following the procedures described by Freitas Júnior.[17]

Smoking

Smoking was referred by elderly subjects through interviews. The questions and answers options are described below:

i) Do you currently smoke?
ii) Have you smoked before?

Statistical analysis

Descriptive statistics consisted of mean and standard deviation. The average values for each variable were compared between the groups, using the analysis of variance (ANOVA) followed by the One-way post hoc Tukey test. Spearman's correlation was used to analyze the relationship between BMD and body composition. To compare BMD between the groups (NG, OG, SG, SOG) the one-way analysis of variance (ANOVA) test followed by the post hoc Tukey test were used. The chi-square test was used to analyze the association between obesity, sarcopenia, sarcopenic obesity and the presence of osteopenia/osteoporosis. Binary logistic regression analysis was used to express the magnitude of associations in values of odds ratio (OR) and their confidence intervals, 95%. Statistical analysis was performed using SPSS software (SPSS Inc., Chicago, IL), version 17.0 and the significance level was set at 5%.

Results

The participation of women in the study was higher compared to men (63% vs. 37%), most of elderly subjects were aged between 80 and 84 years (78% vs. 22%) and (38%) of sample were smokers or currently smoke.

Table 1 presents the general characteristics of the sample and comparison analysis according to the groups. There was no difference between the groups for height and total lean mass. The OG presented lower age compared to the SOG ($p = 0.024$). The SG group presented lower weight compared to the OG and SOG groups ($p \leq 0.001$), lower BMI compared to the other three groups ($p \leq 0.001$) and lower appendicular lean mass compared to the NG and OG groups ($p = 0.007$). The OG e OSG groups presented higher fat mass compared to the NG e SG groups ($p \leq 0.001$).

Table 2 presents the values of the Spearman correlations between the variables of body composition and femur, spine, and total BMD. FM showed correlations of 0.39, 0.32 and 0.41 ($p \leq 0.001$) with total proximal femur, spine and total BMD, respectively, lean mass showed correlations of 0.55, 0.52 and 0.67 ($p \leq 0.001$) and ALM of 0.53, 0.42, 0.62 ($p \leq 0.001$).

Fig. 1 shows the comparison of BMD between the four groups investigated. The mean of total proximal femur and total whole-body BMD of the OG (0.87 g/cm^2 and 1.06 g/cm^2, respectively) was different to the NG (0.78 g/cm^2 and 1.00 g/cm^2) and SG (0.75 g/cm^2 and 0.98 g/cm^2) groups.

Table 3 shows the association between the presence of osteopenia/osteoporosis (spine and total proximal femur) and obesity, sarcopenia and sarcopenic obesity. Obesity was shown to be a protective factor for osteopenia/osteoporosis in the spine, as well as in the total proximal femur. The elderly

Table 1 – Sample characteristics and comparisons according to group.

Variables	Normal ($n=57$) Mean ± SD	Obesity ($n=38$) Mean ± SD	Sarcopenia ($n=20$) Mean ± SD	Sarcopenic obesity ($n=13$) Mean ± SD	p
Age (years)	83.3 ± 3.1[a,b]	82.5 ± 1.8[a]	84.2 ± 3.0[a,b]	84.8 ± 2.7[b]	0.024
Weight (kg)	59.8 ± 13.3[ac]	73.1 ± 12.3[b]	54.2 ± 10.2[a]	67.5 ± 12.5[b,c]	≤0.001
Height (cm)	155.9 ± 11.0	155.1 ± 9.1	157.8 ± 9.0	156.6 ± 7.7	0.794
BMI (kg/m^2)	24.3 ± 3.1[a]	30.2 ± 3.2[b]	21.7 ± 3.1[c]	27.4 ± 3.5[d]	≤0.001
Fat mass (kg)	18.369 ± 6.6[a]	31.114 ± 6.9[b]	15.199 ± 4.8[a]	27.008 ± 6.0[b]	≤0.001
Lean mass (kg)	36.914 ± 12.6	37.791 ± 9.5	35.589 ± 7.4	37.295 ± 8.2	0.903
ALM (kg/m^2)	6.9 ± 1.1[a]	6.8 ± 1.0[a]	6.1 ± 0.8[b]	6.4 ± 1.1.0[a,b]	0.007

SD, standard deviation; BMI, body mass index; ALM, appendicular lean mass.
[a,b,c,d] Different letters are used to identify differences among groups (normal, obesity, sarcopenia and sarcopenic obesity).

Table 2 – Correlation between variables of body composition and bone mineral density in the elderly aged 80 years and over.

Composition	Density (g/cm^2)					
	Femur		Spine		Total	
	r	p	r	p	r	p
FM total (kg)	0.39	$p \leq 0.001$	0.32	$p \leq 0.001$	0.41	$p \leq 0.001$
LM total (kg)	0.55	$p \leq 0.001$	0.52	$p \leq 0.001$	0.67	$p \leq 0.001$
ALM (kg/m^2)	0.53	$p \leq 0.001$	0.42	$p \leq 0.001$	0.62	$p \leq 0.001$

Femur, total proximal femur; FM, fat mass; LM, lean mass; ALM, appendicular lean mass.

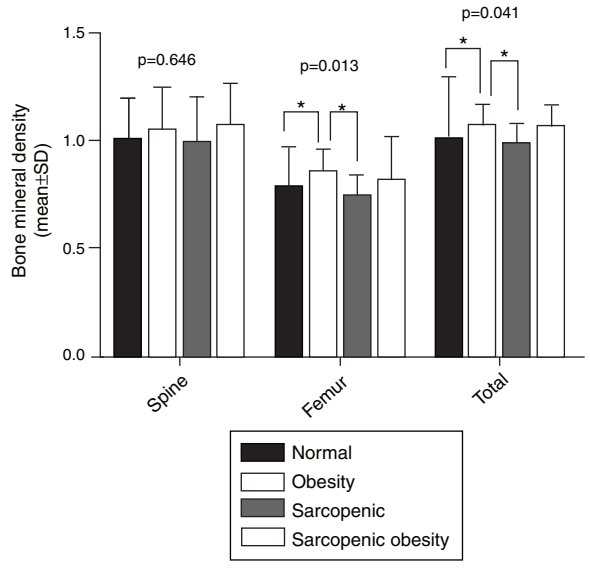

Fig. 1 – Comparison of mean and standard deviation of the bone mineral density (spine, total proximal femur and spine) between the normal, obesity, sarcopenic and sarcopenic obesity groups.

participants with sarcopenia had more chances of presenting osteopenia/osteoporosis in the femur and spine, independent of age and smoking.

The variable sex showed statistical significance in model regard to the association between obesity and osteopenia/osteoporosis in the femur (OR: 0.21; 95CI% 0.08–0.57), indicating protection for women. It also statistically significant in models regarding the association between sarcopenia and osteopenia/osteoporosis in the femur (OR: 0.29; 95CI% 0.11–0.78), indicating protection for women and in spine (OR: 2.78; 95CI% 1.09–7.19), in this case, with higher chance of risk for women.

Discussion

The present study observed that lean mass is more directly related to BMD (total, femur and spine) and the aggravation of body composition, sarcopenia, may be related to low BMD and the presence of osteoporosis in sites femur and spine of the human body.

The direct association between lean mass and bone mineral density found in the present study corroborates the findings previously published in the scientific literature.[18,19] One of the physiological factors that seems to contribute to this relationship is the fact that muscles also have an endocrine function, producing bioactive molecules, which may contribute to the homeostatic regulation of both masses (muscle and bone).[20] Regarding the relationship between sarcopenia and osteoporosis, recent studies have indicated this link[10,11,21–23] and it is suggested that further, more detailed investigations into this aspect are carried out, considering that the presence of these two conditions is the leading cause of disability, hospitalization and health care costs in the elderly.[24,25] The results of this study demonstrated that elderly subjects with sarcopenia have approximately four times more chances of having osteopenia/osteoporosis in the femur. Similar to our findings, Go et al.[22] observed that men over 50 years of age, with osteopenia and osteoporosis have more chance of presenting sarcopenia. Verschueren et al.[18] found that middle-aged and elderly men aged 40–79 years were three times more likely to have osteoporosis. Sjoblom et al.[21] investigated a group of postmenopausal women, aged 65–72 years, and observed that women with sarcopenia had 12.9 and 2.7 times more chances of having osteoporosis and fractures, respectively, and a 2.1 times higher risk of having had a fall in the preceding 12 months compared to their peers without sarcopenia. Our findings show that the chances of an elderly person aged over 80 years with sarcopenia presenting osteoporosis is greater compared to younger subjects.

Research indicates that sarcopenia and osteoporosis are associated clinical conditions and have the same etiology

Table 3 – Association between the presence of osteopenia/osteoporosis and obesity, sarcopenia and sarcopenic obesity in the elderly aged 80 years and over.

Groups	Spine		
	n (%)	OR (CI 95%)	AOR (CI 95%)
Obesity			
No	41 (53.2)	1.00	1.00
Yes	18 (35.3)	0.48 (0.23–0.99)	0.43 (0.20–0.93)
Sarcopenia			
No	39 (41.9)	1.00	1.00
Yes	20 (57.1)	1.87 (0.84–4.00)	2.81 (1.11–7.11)
Sarcopenic obesity			
No	52 (45.6)	1.00	1.00
Yes	7 (50.0)	1.66 (0.50–5.48)	1.84 (0.53–6.40)
Groups	Femur		
	n (%)	OR (CI 95%)	AOR (CI 95%)
Obesity			
No	53 (68.8)	1.00	1.00
Yes	20 (39.2)	0.29 (0.14–0.61)	0.27 (0.12–0.62)
Sarcopenia			
No	46 (49.5)	1.00	1.00
Yes	27 (77.1)	3.45 (1.42–8.38)	2.75 (1.02–7.44)
Sarcopenic obesity			
No	64 (56.1)	1.00	1.00
Yes	09 (64.3)	1.79 (0.52–6.16)	0.90 (0.23–3.49)

Femur, total proximal femur; AOR, adjusting for gender, age and smoking.

(inflammation, hormonal and nutritional deficiencies, and physical inactivity) and the same risk factors for musculoskeletal injuries.[26] An increase in muscle mass causes elongation of collagen fibers and periosteum at the interface, resulting in stimulation of bone growth at the site. In addition, higher blood flow to the bone can lead to an increase in bone strength, and as the increase of blood flow in the limbs is proportional to the quantity of muscle mass, its decrease in these locations can lead to osteoporosis.[7]

Recent evidence has indicated that obesity is not a protective factor for osteoporosis and fractures in older individuals[8,9,27] due to the adverse effects caused by adipose tissue such as oxidative stress and the synthesis of pro-inflammatory adipocytokines that affect bone metabolism.[6,28] However, in our study involving elderly subjects over 80 years of age, the results revealed that in this age group obesity is a protective factor for osteopenia/osteoporosis in the spine and femur. Our findings corroborate with those found by Marwaha et al.[29] in adults of both sexes and by Yang et al.[30] in women aged over 50 years and support the traditional conclusion that obesity is beneficial to bone health because of the well-established positive effect of mechanical loading conferred by body weight on bone formation, since mechanical loading stimulates bone formation by decreasing apoptosis and increasing proliferation and differentiation of osteoblasts and osteocytes.[28] It is noteworthy that the full effects of excess body fat on BMD have not yet been elucidated and may vary according to the type and distribution of fat (subcutaneous and visceral).[29]

When comparing the mean values of BMD, the values for the elderly subjects with sarcopenic obesity were similar to those of the obesity group (Fig. 1); however, when analyzing the association between sarcopenic obesity and osteoporosis, although there was no statistical significance. This result indicates that the chance of osteoporosis in the elderly subjects with sarcopenic obesity is lower than for those with only sarcopenia, because it seems to be alleviated by excess body fat, but the association between obesity and sarcopenia does not eliminate the chance caused by sarcopenia of osteoporosis in the femur. These results are similar to those reported by Beck et al.[31] in postmenopausal women, who observed that, in absolute terms, BMD and femoral geometric strength are greater in those with a higher BMI, however, this increase in BMD and geometric strength varies with the proportion of muscle mass and not with the body weight or fat mass, showing that lean mass exerts great influence on this relationship.

As a caveat, it is worth noting that the cross-sectional design of this study does not establish a causality relationship, however, a limited number of studies have aimed to verify such aspects in the elderly aged over 80 years. Another factor was the analysis of bone mineral density which was performed by DXA, the gold standard equipment for this type of diagnosis.

Conclusion

In summary, lean mass is more directly related to BMD (total, femur and spine) and sarcopenia is associated to

osteopenia/osteoporosis. Obesity represents a possible protective factor for osteopenia/osteoporosis in elderly subjects aged 80 years and over. Preventive measures such as physical activity throughout life can help to maintain muscle and bone mass thereby reducing the risk of sarcopenia, sarcopenic obesity and osteoporosis in older subjects.

Conflicts of interest

The authors declare no conflicts of interest.

Acknowledgements

We acknowledge support from Conselho Nacional de Desenvolvimento Científico e Tecnológico do Brasil.

REFERENCES

1. Di Monaco M, Castiglioni C, Vallero F, Di Monaco R, Tappero R. Men recover ability to function less than women do: an observational study of 1094 subjects after hip fracture. Am J Phys Med Rehabil. 2012;91(4):309–15.
2. Frost M, Wraae K, Abrahamsen B, Høiberg M, Hagen C, Andersen M, et al. Osteoporosis and vertebral fractures in men aged 60–74 years. Age Ageing. 2012;41(2):171–7.
3. Prevention and management of osteoporosis. World Health Organ Tech Rep Ser. 2003;921:1–164.
4. Genaro PS, Pereira GA, Pinheiro MM, Szejnfeld VL, Martini LA. Influence of body composition on bone mass in postmenopausal osteoporotic women. Arch Gerontol Geriatr. 2010;51(3):295–8.
5. Bleicher K, Cumming RG, Naganathan V, Travison TG, Sambrook PN, Blyth FM, et al. The role of fat and lean mass in bone loss in older men: findings from the CHAMP study. Bone. 2011;49(6):1299–305.
6. Bhupathiraju SN, Dawson-Hughes B, Hannan MT, Lichtenstein AH, Tucker KL. Centrally located body fat is associated with lower bone mineral density in older Puerto Rican adults. Am J Clin Nutr. 2011;94(4):1063–70.
7. Kaji H. Linkage between muscle and bone: common catabolic signals resulting in osteoporosis and sarcopenia. Curr Opin Clin Nutr Metab Care. 2013;16(3):272–7.
8. Nielson CM, Srikanth P, Orwoll ES. Obesity and fracture in men and women: an epidemiologic perspective. J Bone Miner Res. 2012;27(1):1–10.
9. Tanaka S, Kuroda T, Saito M, Shiraki M. Overweight/obesity and underweight are both risk factors for osteoporotic fractures at different sites in Japanese postmenopausal women. Osteoporos Int. 2013;24(1):69–76.
10. Di Monaco M, Vallero F, Di Monaco R, Tappero R. Prevalence of sarcopenia and its association with osteoporosis in 313 older women following a hip fracture. Arch Gerontol Geriatr. 2011;52(1):71–4.
11. Di Monaco M, Castiglioni C, Vallero F, Di Monaco R, Tappero R. Sarcopenia is more prevalent in men than in women after hip fracture: a cross-sectional study of 591 inpatients. Arch Gerontol Geriatr. 2012;55(2):e48–52.
12. Cruz-Jentoft AJ, Baeyens JP, Bauer JM, Boirie Y, Cederholm T, Landi F, et al. Sarcopenia: European consensus on definition and diagnosis: Report of the European Working Group on Sarcopenia in Older People. Age Ageing. 2010;39(4):412–23.
13. Zamboni M, Mazzali G, Fantin F, Rossi A, Di Francesco V. Sarcopenic obesity: a new category of obesity in the elderly. Nutr Metab Cardiovasc Dis. 2008;18(5):388–95.
14. Baumgartner RN, Wayne SJ, Waters DL, Janssen I, Gallagher D, Morley JE. Sarcopenic obesity predicts instrumental activities of daily living disability in the elderly. Obes Res. 2004;12(12):1995–2004.
15. Baumgartner RN, Koehler KM, Gallagher D, Romero L, Heymsfield SB, Ross RR, et al. Epidemiology of sarcopenia among the elderly in New Mexico. Am J Epidemiol. 1998;147(8):755–63. Erratum in: Am J Epidemiol 1999;149(12):1161.
16. Guralnik JM, Simonsick EM, Ferrucci L, Glynn RJ, Berkman LF, Blazer DG, et al. A short physical performance battery assessing lowerb extremity function: association with self-reported disability and prediction of mortality and nursing home admission. J Gerontol. 1994;49(2):M85–94.
17. Freitas Júnior IF. Medidas: estatura, peso, comprimento dos segmentos. In: Padronização de técnicas antropométricas. Cultura Acadêmica: Presidente Prudente (SP); 2009. p. 23–5.
18. Verschueren S, Gielen E, O'Neill TW, Pye SR, Adams JE, Ward KA, et al. Sarcopenia and its relationship with bone mineral density in middle-aged and elderly European men. Osteoporos Int. 2013;24(1):87–98.
19. Cheng Q, Zhu X, Zhang X, Li H, Du Y, Hong W, et al. A cross-sectional study of loss of muscle mass corresponding to sarcopenia in healthy Chinese men and women: reference values, prevalence, and association with bone mass. J Bone Miner Metab. 2014;32(1):78–88.
20. Karasik D, Kiel DP. Evidence for pleiotropic factors in genetics of the musculoskeletal system. Bone. 2010;46(5):1226–37.
21. Sjöblom S, Suuronen J, Rikkonen T, Honkanen R, Kröger H, Sirola J. Relationship between postmenopausal osteoporosis and the components of clinical sarcopenia. Maturitas. 2013;75(2):175–80.
22. Go SW, Cha YH, Lee JA, Park HS. Association between sarcopenia, bone density, and health-related quality of life in Korean men. Korean J Fam Med. 2013;34(4):281–8.
23. Miyakoshi N, Hongo M, Mizutani Y, Shimada Y. Prevalence of sarcopenia in Japanese women with osteopenia and osteoporosis. J Bone Miner Metab. 2013;31(5):556–61.
24. Janssen I, Shepard DS, Katzmarzyk PT, Roubenoff R. The healthcare costs of sarcopenia in the United States. J Am Geriatr Soc. 2004;52(1):80–5.
25. Carlos F, Clark P, Galindo-Suárez RM, Chico-Barba LG. Health care costs of osteopenia, osteoporosis, and fragility fractures in Mexico. Arch Osteoporos. 2013;8:125.
26. Ferrucci L, Baroni M, Ranchelli A, Lauretani F, Maggio M, Mecocci P, et al. Interaction between bone and muscle in older persons with mobility limitations. Curr Pharm Des. 2014;20(19):3178–97.
27. Tang X, Liu G, Kang J, Hou Y, Jiang F, Yuan W, et al. Obesity and risk of hip fracture in adults: a meta-analysis of prospective cohort studies. PLoS ONE. 2013;8(4):e55077.
28. Cao JJ. Effects of obesity on bone metabolism. J Orthop Surg Res. 2011;6:30.
29. Marwaha RK, Garg MK, Tandon N, Mehan N, Sastry A, Bhadra K. Relationship of body fat and its distribution with bone mineral density in Indian population. J Clin Densitom. 2013;16(3):353–9.
30. Yang S, Nguyen ND, Center JR, Eisman JA, Nguyen TV. Association between abdominal obesity and fracture risk: a prospective study. J Clin Endocrinol Metab. 2013;98(6):2478–83.
31. Beck TJ, Petit MA, Wu G, LeBoff MS, Cauley JA, Chen Z. Does obesity really make the femur stronger? BMD, geometry, and fracture incidence in the women's health initiative-observational study. J Bone Miner Res. 2009;24(8):1369–79.