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Impact of First 10 Years of Post Menopause on Muscle Function, Muscle Mass and Bone Mineral Density in Adult Women

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Abstract

Background: Previous studies suggested that the early identification of risk factors for the development of osteoporosis should reduce medical complications, which are associated with increased morbidity and mortality in older women.

Purpose: The present study had the objective to identify the relationship between Bone Mineral Density (BMD), anthropometric characteristics, years of post-menopause, strength, muscle mass and the performance on functional tests in up 10 years postmenopausal women.

Methods: Participated of the study fifty-eight post menopause women who were assessed by dual-energy X-ray absorptiometry (DXA) of femoral neck and whole-body to determine BMD and relative skeletal muscle index (RSMI). Also, the muscle strength was assessed by handgrip strength test (HGS) and two functional tests were performed: Timed Up-and-Go (TUG) and Five-Times-Sit-To-Stand (FTSTS).

Results: The results shown a positive correlation between BMD and weight (r = 0.54, p < 0.05), BMD and BMI (r = 0.56, p < 0.05), BMD and RSMI (r = 0.38, p < 0.05).

Conclusions: The findings of the present study demonstrated a correlation between muscle mass and BMD and also shown that anthropometric characteristics, such as higher weight and BMI were correlated with higher BMD and muscle mass in up 10 years postmenopausal women.

Keywords: Metabolic bone diseases; Muscle strength; Sarcopenia; Body mass index

Introduction

Age-related changes affect the muscle-skeletal system resulting in decline of muscle and bone mass, especially in women and the bone decline may result in a metabolic bone disease called osteoporosis. Osteoporosis is a common and costly disease, characterized by the decline of bone mineral density and changes on bone microarchitecture, which leads to weakness on the resistance of bones and higher risk of fractures in older women [1-3].

The main cause of osteoporosis are changes on hormonal system function, which results in decline on blood levels of oestrogen, and it may be or not associated with low ingestion of calcio on daily diet [2,4-6]. Beyond the bone mass decline, decrements on blood levels of oestrogen also may cause age-related muscle mass loss [1,3,7,8]. According to previous studies the relative muscle skeletal index (RMSI) reduces approximately 1.1 kg/decade [9]. And, functionally, the handgrip strength (HGS) and mobility performance (Timed-up-Go, TUG) reduces significantly in women over 50 years.

Previous studies suggested that the early identification of risk factors for the development of osteoporosis should reduce medical complications, which are associated with increased morbidity and mortality in older women [1-3]. With respect of this, investigations focused on find out how the aging, postmenopausal changes, muscle and bone loss may be associated and how these factors interfere on functional performance and strength are important to reduce the risk of falls, bone fractures and incapacity in older women [10]. Thus, the present study had the objective to identify the relationship among BMD, anthropometric characteristics, years of postmenopausal, strength, muscle mass and the performance on functional tests in up 10 years postmenopausal women.

Methods

Participants

Fifty-nine postmenopausal women up to 10 years since the last menstruation, all sedentary (no moderate-to-vigorous physical exercise practised more than once per week) and not under hormonal treatment participated of this study. Menopause was confirmed after cessation of menstrual cycles for more than 12 months, according to the recommendations of the World Health Organization (WHO). One woman was excluded because was diagnosed with osteoporosis.

All volunteers were recruited from the community of Ribeirão Preto/ Brazil. The study was approved by the local Ethics Committee (protocol

number 174.828) and all the volunteers signed the consent form. The non-inclusion criteria were having: neurological, cardiorespiratory or rheumatic diseases, diabetes mellitus, smoking, vestibulopathy, history of bone fractures, orthopaedical illness and the score in Mini-Mental State Examination less than 23.

Procedures

All women underwent bone densitometry examination of femoral neck and whole-body by dual-energy X-ray absorptiometry – DXA (Discovery, Hologic Inc., Bedford, MA, USA) by a trained radiologic technician. The whole-body evaluation allowed to determine the RMSI, which was calculated by dividing appendicle skeletal muscle mass by height squared. The sarcopenia cut-off for women proposed by Baumgartner et al of 5.45 Kg/m^2 was considered [5-7].

Strength was assessed by a handgrip (HGS, Jamar Hand Dynamometer) [4,10,11]. For the strength assessment the volunteers stood in upright position with their elbow flexed to 90° to perform maximum grip by right and left sides [4,10,11]. The test was performed three times for each side with 30-second rest interval between the trials. The average of all trials was considered. To avoid any influence of the circadian cycle on the data collection all tests were performed in the morning.

For the functional and mobility assessment the timed-up-go test (TUG) was performed [4]. For the TUG, the subjects had to stand up from a chair, walk 3 meters, turn around, return and sit down again on the chair [12,13]. Also, the five-time-sit-to-stand test (FTSTS) was performed [14,15]. For the FTSTS, the subjects were seated on a chair with their hips and knees flexed at 90 degrees. Thus, the subjects were instructed to cross their arms in front of the trunk. Upon hearing a verbal command, the subjects had to stand up and sit down five times, consecutively, as quickly as possible. TUG and FTSTS were performed three times, and the average of all trials were considered

Statistical analysis

For the statistical analysis the Shapiro-Wilk's test was used to verify the normality, for the comparison between groups for used t-student test and Mann-Whitney test were used, and to correlate the variables the Pearson test and multiple regression analyses were conducted. The statistical package PASW (SPSS Inc., USA) was used for all statistical analyses. The significant level was set at $p < 0.05$.

Results

The average age, BMI, post menopause time, and BMD of the sample were 53.8 ± 4,17 yr, 28,99 ± 4,93 kg.m^{-2}, 38,03 ± 16,91 months, and 0,78 ± 0,54 g.cm^{-2}. Table 1 shows the characteristics of the sample.

The results demonstrated that was a positive correlation between BMD and weight (r = 0.54, p < 0.05), BMD and BMI (r = 0.56, p < 0.05), BMD and RSMI (r = 0.38, p < 0.05). Weight was positively correlated with RSMI, HGS and BMI. BMI and RSMI was correlated (r = 0.71). Table 2 shows these results.

Discussion

Highlight the mechanisms that predispose older postmenopausal women at risk of fractures may corroborate to create more efficient preventive strategies to prevent this. Although, aging is one of the most important risk factors for osteoporosis, recent studies have demonstrated that the most fractures in postmenopausal women occur in subjects with normal BMD or osteopenia [16,6]. With respect

Variables	Participants (n = 58)
BMD femoral neck (g.cm^{-2})	0,78 ± 0,54
T-Valor	-0,9 ± 0,58
Age (years)	53,8 ± 4,17
Weight (Kg)	71,3 ± 13,08
Height (cm)	156,69 ± 6,88
BMI (Kg/cm²)	28,99 ± 4,93
Normal weight (n / %)	9 15, 51%
Overweight (n / %)	27 46, 55%
Obesity (n / %)	22 37, 93%
Post menopause time (month)	38,03 ± 16,91
RSMI	6,91 ± 0,83
HGS (Kgf) Right	25,4 ± 4,77
HGS (Kgf) Left	24,61 ± 4,47
TUG (seconds)	6,34 ± 0,76
FTSTS (seconds)	10,99 ± 1,93

Group 1 = Women with normal BMD; Group 2 = Women with osteopenia; BMI = Body Mass Index; RSMI = Relative Skeletal Muscle Index; HGS = Handgrip Strength; TUG = Timed Up-and-Go test; FTSTS = Five-Times-Sit-to-Stand test

Table 1: Characteristics of the study sample, regarding clinical tests: HGS, TUG and FTSTS.

of this, the present study evaluated the relationship between BMD, anthropometric characteristics, years of postmenopausal, strength, muscle mass and the performance on functional tests in up 10 years postmenopausal women.

The osteoporosis is a multi-factorial bone diseases and it is controversial in the literature what are the anthropometric and physical characteristics that most influence BMD [10,17]. The mechanical load may lead to bone strengthening with mobility-induced weight-bearing stress [3]. Thus, our results are in accordance to previous studies that demonstrated that weight loss may increase the bone turnover, suggesting that body weight enhances the differentiation of osteoblasts and increase osteoblastic bone formation besides attenuates osteoclastic activity [13,14,15,18].

Previous studies suggested that low weight or BMI might be an important risk factor for lower BMD [2,4,10,16,17,19], pelvis and femur fractures [6] and the correlation is stronger over time for non-hispanic whites [18]. In this context, the femoral neck BMD varies each 0.16% per kilogramme change in weight [2]. Thus, the prevalence of osteoporosis for postmenopausal women decreases from 50% for BMI < 20 km/cm² to 29.8% for BMI > 25 km/cm² [20].

In addition, previous studies suggested that fat mass is associated with whole body BMD in older women, independent of lean mass [15]. The relationship between body composition and endocrine control is related to the production of peripheral gonadal hormones by adipose tissue. With respect to this, in obese subjects this hormonal changes may affect bone turnover and BMD, protecting the adverse effects of estrogen deficiency after menopause [3,10,14] and attenuating the bone loss. The leptins, the adipokine most studied in relation to bone, increase proliferation and differentiation of osteoblasts and they also regulate osteoclast development. Additionally, the secretion of bone-active pancreatic beta cell hormones like insulin, indirectly, amylin and preptin also seems more prevalent in obesity and they are direct stimulators to osteoblast growth and inhibiting osteoclastic bone resorption [10,21].

Other authors suggest that the weight body is significantly correlated with skeletal muscle mass because heavier subjects require greater

Correlations		All Sample (n = 58)	
		r	P value
BMD	T-Valor	0.868	0.000*
BMD	Age (years)	0.086	0.521
BMD	PMT (month)	0.035	0.792
BMD	Weight (Kg)	0.535	0.000*
BMD	Height (cm)	0.76	0.568
BMD	BMI (Kg/cm²)	0.557	0.000*
BMD	RSMI (Kg/m²)	0.379	0.003*
BMD	HGS (Kgf) R	0.153	0.252
BMD	HGS (Kgf) L	0.166	0.214
BMD	TUG (seconds)	0.009	0.948
BMD	FTSTS (seconds)	0.206	0.121
Age (years)	PMT (month)	0.235	0.076
Age (years)	Weight (Kg)	0.051	0.704
Age (years)	Height (cm)	0.022	0.871
Age (years)	BMI (Kg/cm²)	0.038	0.775
Age (years)	RSMI (Kg/m²)	-0.029	0.828
Age (years)	HGS (Kgf) R	-0.044	0.742
Age (years)	HGS (Kgf) L	-0.159	0.234
Age (years)	TUG (seconds)	0.158	0.235
Age (years)	FTSTS (seconds)	-0.176	0.185
PMT (years)	Weight (Kg)	0.015	0.913
PMT (years)	Height (cm)	0.210	0.113
PMT (years)	BMI (Kg/cm²)	-0.085	0.528
PMT (years)	RSMI (Kg/m²)	-0.141	0.293
PMT (years)	HGS (Kgf) R	0.085	0.527
PMT (years)	HGS (Kgf) L	-0.010	0.942
PMT (years)	TUG (seconds)	-0.030	0.820
PMT (years)	FTSTS (seconds)	-0.171	0.200
Weight (Kg)	Height (cm)	0.421	0.001*
Weight (Kg)	BMI (Kg/cm²)	0.874	0.000*
Weight (Kg)	RSMI (Kg/m²)	0.661	0.000*
Weight (Kg)	HGS (Kgf) R	0.365	0.005*
Weight (Kg)	HGS (Kgf) L	0.185	0.163
Weight (Kg)	TUG (seconds)	0.012	0.928
Weight (Kg)	FTSTS (seconds)	0.175	0.188
BMI (Kg/cm²)	Height (cm)	-0.068	0.614
BMI (Kg/cm²)	RSMI (Kg/m²)	0.711	0.000*
BMI (Kg/cm²)	HGS (Kgf) R	0.163	0.221
BMI (Kg/cm²)	HGS (Kgf) L	-0.002	0.988
BMI (Kg/cm²)	TUG (seconds)	0.044	0.741
BMI (Kg/cm²)	FTSTS (seconds)	0.151	0.258
RSMI (Kg/m²)	Height (cm)	0.064	0.635
RSMI (Kg/m²)	HGS (Kgf) R	0.368	0.004*
RSMI (Kg/m²)	HGS (Kgf) L	0.259	0.049*
RSMI (Kg/m²)	TUG (seconds)	-0.027	0.840
RSMI (Kg/m²)	FTSTS (seconds)	0.156	0.243

Group 1 = Women with normal BMD; Group 2 = Women with osteopenia

PMT = Post-Menopausal Time; RSMI = Relative Skeletal Muscle Index; HGS = Handgrip Strength; TUG = Timed Up-and-Go Test; FTSTS = Five-Times-Sit-to-Stand Test; * significant association, p < 0.05.

Table 2: Analyses of multiple linear regressions (Pearson test).

muscle mass for movement and would be expected to have more muscle [9,19]. Our findings demonstrated that there is a moderate correlation between weight and RSMI, and a strong relation between BMI and RSMI. Consistent with the statement that lower strength or low muscle mass or RSMI may induce a lower contraction and mechanical stress

on bone, a lower osteogenic stimulus in osteocytes resulting in a lower BMD development and possible higher risk of osteoporotic fracture in elderly people [4, 6,13,22- 24].

With respect to this, our results demonstrated that weight; BMI and RSMI have a moderate positive correlation with BMD in adult women. In this context, some authors reported that age, RSMI and fat mass collectively explained 38% variance of femoral neck BMD [6]. In addition previous observational data suggested that increasing lean mass could constitute a preventive measure against bone loss and possibly musculoskeletal aging [2,13].

Additionally it is unclear which measure should be used to sarcopenia [7,22], associated to the fact that decrease of muscle mass by itself seems an inconsistent predictor of mobility limitation [7] or functional ability [25]. The present study did not find correlation between physical performance and RMSI. Also, similarly to previous studies our finding did not find association between handgrip strength, FTSTS and TUG score with BMD in women [22].

Also, we found a weak correlation between RSMI and HGS. Consistent with some authors, modest reductions in skeletal muscle mass with aging do not cause functional impairment and disability [26], however others have demonstrated the clinical risk factors as a indicate of low BMD and fracture [27].

Our sample showed approximately 21% lower strength for right side and 17% for left side considering the values reported by Bohannon et al. [11], but the HGS were higher than 20 kgf, a cut off value that represents a good muscle strength condition in the clinical practice [7]. Regarding TUG test, the results are similar to those expected for the same age [12]. In the FTSTS, no volunteer spent more than 15 seconds to performance the FTSTS, which is considered a cut off value to double the risk of recurrent falls [15]. These functional performance results may be explained by the fact that the evaluated women did not present sarcopenia.

Our sample did not meet the muscle mass criteria below 5.45 kg/m2 [6] for sacopenia, which may be explained because the cut-off reference value was not appropriate for the Brazilian population [28], or for adult post-menopausal population, or because early stage of sarcopenia are undetectable [7]. Previous studies supported the idea that intervention strategies designed to preserve muscle mass should be initiated by the fifth decade of life, because although the prevalence of sarcopenia increased from the third to sixth decades of life, it remained relatively constant thereafter [29]. Additionally, according to the European Working Group on Sarcopenia in Older People criteria also, a cohort Finnish study with 70–80 year-old home dwelling showed that 36% has osteopenia and only 0,9% of women has sarcopenia [30], while in osteoporotic Brazilian woman (69.7 ± 6.4 years), only 21% of sample is below criteria of sarcopenia [31].

Our data corroborate the studies about the effect of weight and BMI on BMD, however it is important to emphasize that higher BMI is significantly associated with a number of comorbidities, including asthma, emphysema, diabetes, reduced physical activity, co-medications, increased risk of falls, higher morbidity and economic costs associated with fractures because of a greater risk of non-union, postoperative complications, comorbidities, and slower rehabilitation [3,24,32,]. Furthermore, the BMI and hip fracture seems to have nonlinear correlation. Although the lower BMI is a higher risk factor for fracture, the higher BMI not seems a higher protect factor comparing with normal BMI, thus obesity should not be a protective factor for hip fracture risk [33]. Additionally, the increased prevalence

of overweight in older US women appears unlikely to be accompanied by a significant reduction in osteoporosis prevalence [26] suggesting that protective factors to avoid BMD decrease should be further studied and recommendations on the benefits of BMI should be cautious for post-menopausal women.

Finally, the screening and prevention of bone loss and a specific orientation about weight body in younger postmenopausal women may be an effective way to prevent or delay fractures in postmenopausal women. Although the menopause occurs around 50 years old and the rate of BMD loss accelerates in the peri-menopause and in the first yeas after menopause [10], the women before 60 or 65 years old do not meet current national guidelines for osteoporosis treatment [10,34-38]. Additionally, recent studies have demonstrated that over 50% of postmenopausal women with incident fractures have a BMD higher than the diagnostic of osteoporosis and a substantial proportion of women with low-trauma fractures also have normal BMD [16]. Understanding the influence of different body composition on BMD or on fractures, as well as the importance of increasing lean mass as a strategy for preventing bone loss seem relevant.

Limitations of this study include the fact that we chose to use HGS, TUG and FTSTS tests to measure respectively muscle strength and performance because they could be easily applied in clinical practice. However, we do not know whether these results would be similar if we had used different evaluation methods to measure muscle strength and performance such as isokinetic or isometric strength tests for lower limb muscles, self-reference gait speed or power stair climbing test.

Based on the results, in the first 10 years of post-menopause, there was not a direct association between the decrease of BMD and sarcopenia in adult postmenopausal women. Despite the significant correlations among weight, BMI, RSMI and HGS were found it could not be proven that it is independently correlated with BMD. With respect to this, the most important finding of the present study is that it demonstrated that weight was the only factor to affect the BMD for enrolled post-menopause women.

References

1. Lim LS, Hoeksema LJ, Sherin K, ACPM Prevention Practice Committee (2009) Screening for osteoporosis in the adult U.S. population: ACPM position statement on preventive practice. Am J Prev Med 36: 366-375.

2. Zhai G, Hart DJ, Valdes AM, Kato BS, Richards JB, et al. (2008) Natural history and risk factors for bone loss in postmenopausal Caucasian women: A 15-year follow-up population-based study. Osteoporos Int 19: 1211-1217.

3. Sirola J, Kröger H (2011) Similarities in acquired factors related to postmenopausal osteoporosis and sarcopenia. J Osteoporos 2011: 536735.

4. Marin RV, Pedrosa MA, Moreira-Pfrimer LD, Matsudo SM, Lazaretti-Castro M (2010) Association between lean mass and handgrip strength with bone mineral density in physically active postmenopausal women. J Clin Densitom 13: 96-101.

5. Sipilä S, Narici M, Kjaer M, Pöllänen E, Atkinson RA, et al. (2013) Sex hormones and skeletal muscle weakness. Biogerontology 14: 231-245.

6. Ho-Pham LT, Nguyen ND, Lai TQ, Nguyen TV (2010) Contributions of lean mass and fat mass to bone mineral density: A study in postmenopausal women. BMC Musculoskelet Disord 11: 59.

7. Lauretani F, Russo CR, Bandinelli S, Bartali B, Cavazzini C, et al. (2003) Age-associated changes in skeletal muscles and their effect on mobility: an operational diagnosis of sarcopenia. J Appl Physiol (1985) 95: 1851-1860.

8. Walsh MC, Hunter GR, Livingstone MB (2006) Sarcopenia in premenopausal and postmenopausal women with osteopenia, osteoporosis and normal bone mineral density. Osteoporos Int 17: 61-67.

9. Janssen I, Heymsfield SB, Wang ZM, Ross R (2000) Skeletal muscle mass and distribution in 468 men and women aged 18-88 yr. J Appl Physiol (1985) 89: 81-88.

10. McClung MR (2012) Revisiting the prevention of bone loss at menopause. Menopause 19: 1173-1175.

11. Bohannon RW, Peolsson A, Massy-Westropp N, Desroriers J, Bear-Lehman J (2006) Reference values for adult grip strength measured with a Jamar dynamometer: A descriptive meta-analysis. Physiotherapy 92: 11-15.

12. Akbari M, Mousavikhatir R (2012) Changes in the muscle strength and functional performance of healthy women with aging. Med J Islam Repub Iran 26: 125-131.

13. Bohannon RW (2006) Reference values for the timed up and go test: A descriptive meta-analysis. J Geriatr Phys Ther 29: 64-68.

14. Wallmann HW, Evans NS, Day C, Neelly KR (2012) Interrater Reliability of the Five-Times-Sit-to-Stand Test. Home Health Care Management and Practice 1: 14-17.

15. Buatois S, Perret-Guillaume C, Gueguen R, Miget P, Vançon G, et al. (2010) A simple clinical scale to stratify risk of recurrent falls in community-dwelling adults aged 65 years and older. Phys Ther 90: 550-560.

16. Namwongprom S, Rojanasthien S, Mangklabruks A, Soontrapa S, Wongboontan C, et al. (2013) Effect of fat mass and lean mass on bone mineral density in postmenopausal and perimenopausal Thai women. Int J Womens Health 5: 87-92.

17. Finkelstein JS, Brockwell SE, Mehta V, Greendale GA, Sowers MR, et al. (2008) Bone Mineral Density Changes during the Menopause Transition in a Multiethnic Cohort of Women. The Journal of clinical Endocrinology and Metabolism 3: 861-868.

18. Schlüssel MM, dos Anjos LA, de Vasconcellos MT, Kac G (2008) Reference values of handgrip dynamometry of healthy adults: a population-based study. Clin Nutr 27: 601-607.

19. Compston JE, Watts NB, Chapulat R, Cooper C, Boonen S, et al. (2011) Obesity Is Not Protective against Fracture in Postmenopausal Women: GLOW. The American Journal of Medicine 11: 1043-1050.

20. Orsatti FL, Nahas EA, Nahas-Neto J, Orsatti CL, Marocolo M, et al. (2011) Low appendicular muscle mass is correlated with femoral neck bone mineral density loss in postmenopausal women. BMC Musculoskelet Disord 12: 225.

21. Bijlsma AY, Meskers MC, Molendijk M, Westendorp RG, Sipilä S, et al. (2013) Diagnostic measures for sarcopenia and bone mineral density. Osteoporos Int 24: 2681-2691.

22. Buttros Dde A, Nahas-Neto J, Nahas EA, Cangussu LM, Barral AB, et al. (2011) Risk factors for osteoporosis in postmenopausal women from southeast Brazilian. Rev Bras Ginecol Obstet 33: 295-302.

23. Compston JE, Watts NB, Chapulat R, Cooper C, Boonen S, et al. (2011) Obesity Is Not Protective against Fracture in Postmenopausal Women: GLOW. The American Journal of Medicine 11: 1043-1050.

24. Tang X, Liu G, Kang J, Hou Y, Jiang F, et al. (2013) Obesity and risk of hip fracture in adults: A meta-analysis of prospective cohort studies. PLoS One 8: e55077.

25. Patil R, Uusi-Rasi K, Pasanen M, Kannus P, Karinkanta S, et al. (2013) Sarcopenia and osteopenia among 70-80-year-old home-dwelling Finnish women: Prevalence and association with functional performance. Osteoporos Int 24: 787-796.

26. Janssen I, Heymsfield SB, Ross R (2002) Low relative skeletal muscle mass (sarcopenia) in older persons is associated with functional impairment and physical disability. J Am Geriatr Soc 50: 889-896.

27. Rouzi AA, Al-Sibiani AA, Al-Senani NS, Radaddi RM, Ardawi MM (2012) Independent predictors of all osteoporosis-related fractures among healthy Saudi postmenopausal women: The CEOR Study. Bone 3: 713-722.

28. Lima RM, Bezerra LM, Rabelo HT, Silva MA, Silva AJ, et al. (2009) Fat-free mass, strength, and sarcopenia are related to bone mineral density in older women. J Clin Densitom 12: 35-41.

29. Janssen I, Heymsfield SB, Ross R (2002) Low relative skeletal muscle mass (sarcopenia) in older persons is associated with functional impairment and physical disability. J Am Geriatr Soc 50: 889-896.

30. Patil R, Uusi-Rasi K, Pasanen M, Kannus P, Karinkanta S, et al. (2013)

Sarcopenia and osteopenia among 70-80-year-old home-dwelling Finnish women: Prevalence and association with functional performance. Osteoporos Int 24: 787-796.

31. Cruz-Jentoft AJ, Baeyens JP, Bauer JM, Boirie Y, Cederholm T, et al. (2010) Sarcopenia: European consensus on definition and diagnosis: Report of the European Working Group on Sarcopenia in Older People. Age Ageing 39: 412-423.

32. Park JH, Song YM, Sung J, Lee K, Kim YS, et al. (2012) The association between fat and lean mass and bone mineral density: The Healthy Twin Study. Bone 50: 1006-1011.

33. De Laet C, Kannis JA, Odén A, Johanson H, Johnell O (2005) Body mass index as a predictor of fracture risk: A meta-analysis. Osteoporosis International 16: 1330-1338.

34. Siris ES, Brenneman SK, Barrett-Connor E, Miller PD, Sajjan S, et al. (2006) The effect of age and bone mineral density on the absolute, excess, and relative risk of fracture in postmenopausal women aged 50–99: results from the National Osteoporosis Risk Assessment (NORA). Osteoporos Int. 17: 565-574.

35. Prieto-Alhambra D, Premaor MO, Fina Avilés F, Hermosilla E, Martinez-Laguna D, et al. (2012) The association between fracture and obesity is site-dependent: A population-based study in postmenopausal women. J Bone Miner Res 27: 294-300.

36. Nur H, Toraman NF, Arica Z, Sarier N, Samur A (2013) The relationship between body composition and bone mineral density in postmenopausal Turkish women. Rheumatol Int 33: 607-612.

37. Reid IR (2010) Fat and bone. Arch Biochem Biophys 503: 20-27.

38. Lee K (2012) Soft Tissue Composition and the Risk of Low Bone Mineral Density: The Fourth Korea National Health and Nutrition Examination Survey (KNHANES IV-3) 2009. Calcified Tissue International 3: 186-192.