Medical Science

25(113), July, 2021

Correlations among body mass index, body balance and bone mineral density in elderly women

Azza Mohammed Abdelmohsen[1✉], Bassam Ahmed Nabil[2], Asmaa Foad Abdelmonem[3]

To Cite:
Abdelmohsen AM, Nabil BA, Abdelmonem AF. Correlations among body mass index, body balance and bone mineral density in elderly women. *Medical Science*, 2021, 25(113), 1598-1605

Author Affiliation:
[1]Lecturer, Biomechanics Department, Faculty of Physical Therapy, Cairo University, Giza, Egypt; Email: dr_azzamohammed@yahoo.com
[2]Lecturer, Biomechanics Department, Faculty of Physical Therapy, October 6 University, 6th of October city, Egypt; Email: Bassam.nabilpt@gmail.com
[3]Lecturer, Biomechanics Department, Faculty of Physical Therapy, Cairo University, Giza, Egypt; Email: asmaa.foad@pt.cu.edu.eg

✉**Corresponding author**
Lecturer, Biomechanics Department, Faculty of Physical Therapy, Cairo University, Giza,
Egypt;
Email: dr_azzamohammed@yahoo.com

Peer-Review History
Received: 05 June 2021
Reviewed & Revised: 06/June/2021 to 26/June/2021
Accepted: 28 June 2021
Published: July 2021

Peer-review Method
External peer-review was done through double-blind method.

DISCOVERY SCIENTIFIC SOCIETY

© 2021 Discovery Scientific Society. This work is licensed under a Creative Commons Attribution 4.0 International License.

ABSTRACT

Objective: The target of this study was to assess the correlation between each two of the following variables; body mass index (BMI), body balance, and bone mineral density (BMD) in postmenopausal women in order to detect the threatening factors that predispose them to fractures. *Methods*: Forty-eight elderly postmenopausal women contributed to this study. Their ages ranged from 50 to 55 years. The valid and objective Berg Balance Scale (BBS) was used to assess their body balance. The BMD of lumbar vertebrae was measured by the golden standard scanning method known as dual energy X-ray absorptiometry (DEXA). *Results:* The obtained findings of Pearson correlation analysis revealed a substantial negative correlation between BMI and body balance with p value = 0.000 and r = -0.49 and also a significant negative correlation between BMI and BMD with p value = 0.008 and r = -0.38. In addition, there was a statistical positive correlation between body balance and BMD with P value = 0.005 and r = 0.6. *Conclusions*: Increasing BMI is a risk factor to a disturbed balance and a decreased BMD and this in turn increases the susceptibility of falls developing fractures in elderly females. Furthermore, increased BMD augments body balance. Trial registration; Clinical Trials.gov Identifier: NCT03280693.

Keywords: Body mass index; Balance; Bone density; Postmenopause

1. INTRODUCTION

Bone mineral density (BMD) is defined as the quantity of hydroxyapatite per area of bone (g/cm^2) and it is considered the best indicator of fracture occurrence (Abd El Mohsen et al., 2016; Chen et al., 2018). Post-menopausal women show an average 20 to 25 % drop in BMD over a 16-year period after menopause (Hansen et al., 1995). It was demonstrated that one in two postmenopausal women has an osteoporotic fracture in their continuing lifetime (Harvey et al., 2006). Studies found that white woman after stop of menstrual cycle are in a danger of hip fracture occurrence, which increases the mortality rate one year after sustaining fracture (Roche et al., 2005). The foremost type of fractures to be considered post menopause is vertebral fractures as they are concomitant with extensive disability and morbidity, including reduced function, back pain, loss of height, deformity, and decreased quality of life (Cummings & Melton, 2002). Lumbar spine and femoral DEXA scanning are the most accurate and reported ways for BMD measuring (Abd El Mohsen et al., 2016). The deficiency of balance or postural control, lower extremity muscle weakness, and walking difficulty have been found to be very important intrinsic threatening factors for falls and fractures in patients with osteoporosis. By comparing women with osteoporosis with other healthy women, we can conclude that women with osteoporosis are more vulnerable to fracture. Fractures result not only from low BMD but also from the increased risk of falls due to poor balance and muscle weakness (Runge et al., 2001). Improving balance is necessary to be able to avoid any risk of perturbations in static and dynamic postures and conditions (Liu-Ambrose et al., 2003). Therefore, it is very important to take care of muscles˒ flexibility, power, body balance, during assessment and treatment in clinical practice (Shumway-Cook et al., 2000). One of the most objective, valid, and functional methods to evaluate body balance and estimate risk of disturbed movements and perturbations for the elderly people is the BBS (Iwamoto et al., 2009). Many researchers used the BBS as an objective, valid and reliable method for balance evaluation in their studies (Bogle Thorbahn & Newton, 1996; Viveiro et al., 2019).

The rate of bone turnover is influenced by subject's weight (Cifuentes et al., 2003; Kujath et al., 2015), but the actual cause concerning mass type (lean or fat) can't be predicted. However, a challenging study established an explanation. It concluded that lean mass is the chief element related to bone density. Studies reported that the two of the most serious diseases firmly associated with a higher prevalence in both mortality and morbidity worldwide are obesity and osteoporosis (Greco et al., 2015). A number of searchers supported the defensive role of obesity against osteoporotic fractures. However, others revealed that obesity may demonstrate to remain a threatening element for diminished bone mineral content and increased the incidence of fractures (Cifuentes et al., 2003). Another research which was conducted on the South African women confirmed the theory that consider lean mass as a greater predictor for BMD and fracture risk than fat mass (Sotunde et al., 2015). Although, there is a gap in research investigating the relationship between total body fat and BMD (Kang et al., 2015), possible positive associations between total body fat and BMD were argued, proposing the idea of considering the fat as a co-element helps in transformation of androgens to estrogens. These hormones are directly related to BMD (Gremion et al., 2001, Maïmoun et al., 2003). Valuable searches connecting between fat mass and density of bone are still missing, especially in cases of people of varying levels of dietary habits.

Taffee et al., (2003) stated that it is still unclear to detect the certain measure of BMD to which the elderly people depend on in their daily physical activities. Not only the measure of BMD but also body size and other factors affect bone and physical activity for instance medications, smoking status, sex,and race. They concluded in their cohort study that both bone density and physical activity are vital elements to decrease fracture risk as much as possible. A gap is still present in finding the associations among BMD, postural control and body size. Consequently, the principal objective of our study was to examine the correlation between each two of the following variables; body mass index (BMI), body balance, and bone mineral density (BMD) in postmenopausal women in order to detect the threatening factors that predispose to fractures.

2. METHODS

Participants

Forty-eight postmenopausal elderly women ageing from 50 to 60 years contributed to this study. Their ages, body masses, heights, and body mass indices were respectively as follows: 53.5 ± 2.75 y, 89.08 ± 12.3 kg, 159.67.8 ± 2.54 cm, and 34.89 ± 4.89 Kg/m². They didn't take part in any sports or athletic activities. All of them signed informed consents that they agree to contribute to the study. The total experimental duration of the study lasted for about a year from December 2019 to November 2020.

Lumbar vertebrae DEXA scan was used to assess women BMD. It is a scan of the spine starting at the last lumbar vertebra (L5) and ending at the last thoracic vertebra (T12). During scanning, the women relaxed their backs on the scanning table, with bending knees and elevating legs on a positioning cube to decrease lumbar lordosis. The BMD measure was classically detected for the whole lumbar spine in the posterior-anterior projection, while the x-ray tube was placed behind the patient and the detectors over her abdomen (Franck et al., 1995).

Assessment of body balance

The authors of this study used BBS to assess body balance for all participants. As known, it involves 14 items. Each item has five points ranging in its score from zero to four, so that the total score equals 56. The 14 items are as follows; 1) sitting to standing, 2) standing unsupported, 3) sitting unsupported, 4) standing to sitting, 5) transfers, 6) standing with eyes closed, 7) standing with feet together, 8) reaching forward with outstretched arm, 9) retrieving object from floor, 10) turning to look behind, 11) turning 360°, 12) placing alternate foot on stool, 13) standing with one foot in front, and 14) standing on one foot. For all items, "0" represents the

© 2021 Discovery Scientific Society. All Rights Reserved. ISSN 2321–7359 EISSN 2321–7367 I OPEN ACCESS

lower most functional status and "4" represents the upper most functional status. Overall marks of 41-56 indicates the minimum level of fall and disturbances, 21-40 indicates medium fall threatening status, and 0-20 indicates high fall threatening status (Viveiro et al., 2019). It was designed to assess balance in elderly population who suffer balance deficits by evaluating their levels of performing functional tasks. A lot of studies investigating the efficacy of treatment protocols confirmed BBS validity and reliability in balance assessment (Bogle Thorbahn & Newton, 1996; Viveiro et al., 2019).

Statistical analysis

Since the data were normally distributed, Pearson correlation analysis was done to calculate if there was any significant association among BMI, body balance, and BMD. Data analysis was executed via the statistical package for social sciences (SPSS) and the alpha level of significance of difference has been adjusted at $p < 0.05$.

3. RESULTS

Pearson correlation analysis investigated the relationships among BMI, BMD measured by DEXA scan, and body balance measured by BBS in postmenopausal women. Results revealed a moderate significant positive correlation (p = 0.000, r = 0.6) between BMD and body balance (Table 1, Figure 1).

Table 1 Pearson correlation analysis

Correlation among BMD (g/cm2), balance scores and BMI (kg/m2)		
	Pearson correlation (r)	P value
BMD & balance	0.6	0.000**
BMI & balance	-0.49	0.000**
BMD & BMI	-0.38	0.008

** Correlation is significant at the 0.01 level (2-tailed)

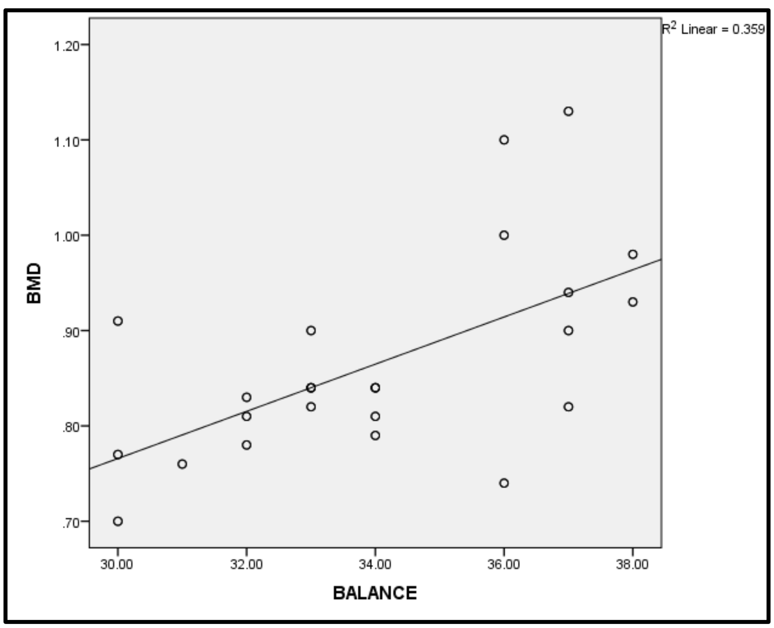

Figure 1 Positive correlation between BMD and balance

This indicates that when BMD was increasing, body balance was also increasing. Furthermore, a moderate significant negative correlation (p = 0.000, r = - 0.49) was detected between BMI and body balance (Table 1, Figure 2). This means that when BMI was increasing, body balance was also decreasing.

© 2021 Discovery Scientific Society. All Rights Reserved. ISSN 2321–7359 EISSN 2321–7367 I OPEN ACCESS

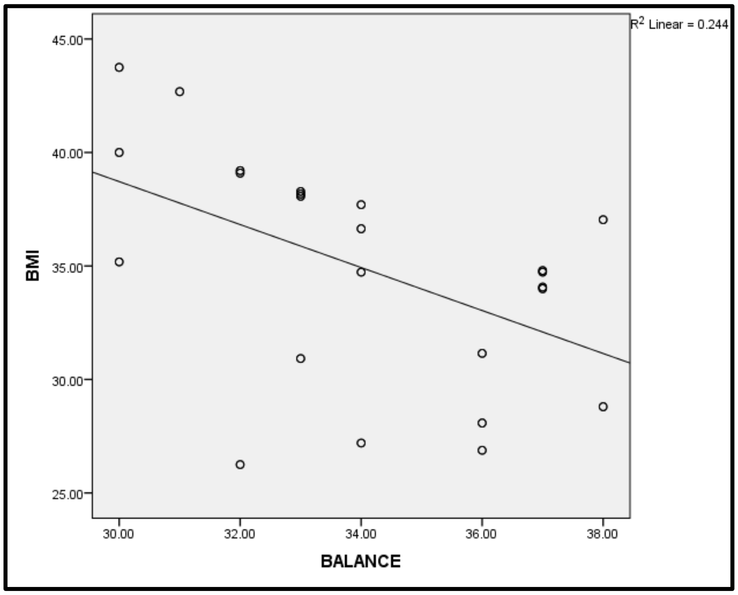

Figure 2 negative correlations between BMI and balance

Moreover, a weak significant negative correlation (p = 0.008, r = - 0.38) between BMI and BMD was also detected (Table 1, Figure 3) indicating that when BMI was increasing, BMD was decreasing.

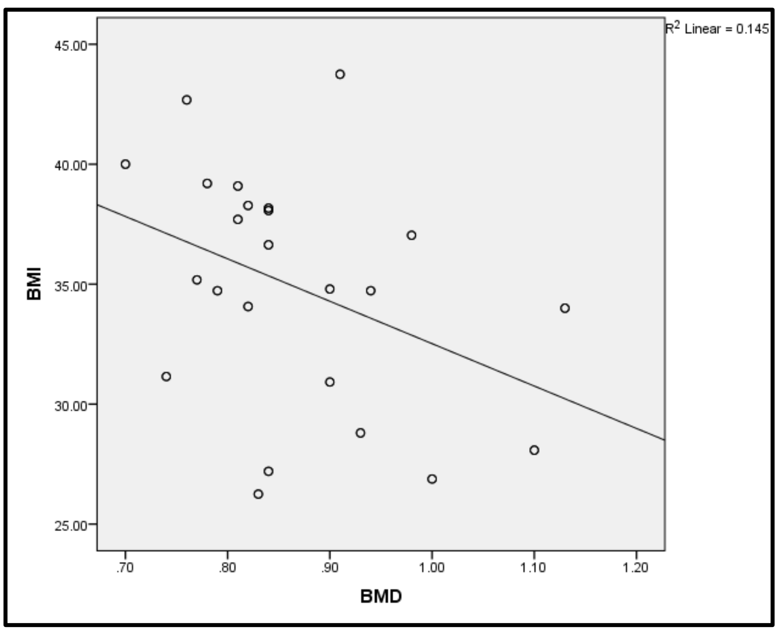

Figure 3 negative correlations between BMI and BMD

4. DISCUSSION

The statistically significant positive correlation between body balance and BMD in this manuscript may be clarified that balance is managed by three organized steps starting with a sensory input followed by proper central processing to reach the purposeful and efficient neuromuscular responses. An efficient performance of the motor system needs a healthy neuromuscular system and strong muscles for maintaining the center of body mass inside the supporting base area if balance is affected (Saravi & Sayegh, 2013). Control of body posture in patients suffering from osteoporosis is considerably affected compared with healthy subjects. It was revealed that the results of balance in patients with osteoporosis were 11% lower than those of healthy subjects (Liu-Ambrose et al., 2003). In addition to the disfiguring consequence of osteoporosis by increasing the thoracic kyphotic curve, major problems including locomotion problems, disturbed balance, and increased risk of falls can arise (Sinaki et al., 2005).

The previous mentioned osteoporosis consequences lead to back pain. Patients with back pain are forced to minimize their physical activity through the day and this in turn leads to muscle weakness, poor balance and impaired function. Beside these

© 2021 Discovery Scientific Society. All Rights Reserved. ISSN 2321–7359 EISSN 2321–7367 I OPEN ACCESS

musculoskeletal problems, any deficiency of the neuromuscular system can destructively disturb body balance and locomotion (Liu-Ambrose et al., 2002). Liu-Ambrose et al., (2003) also agreed with the current study results and concluded that women with osteoporosis have balance problems and this in turn increases the risk of falls and fractures. Therefore, sustaining fractures is a viscous circle including both balance and BMD.

In the same context, Lynn et al., (1997) observed marked sway and posture imbalance among women with osteopenia as result of increased thoracic during assessment of gait on the force platform representing increased foot center of pressure (COP) shift during testing. It was also reported that postmenopausal women suffering from osteopenia and exaggerated kyphosis of the thoracic spine rely on the hip strategy to sustain balance during motion. The destructive effect of this type of compensation may increases the foot COP shift increasing the postural sway in all directions compared with depending on the ankle strategy. Sinaki et al., (2005) opposed the results of Lynn et al., (1997) reporting that osteopenia/osteoporosis and hyper kyphotic curve of the thorax showed lower foot COP shift compared with the healthy controls.

In addition, the presented current study findings demonstrated a statistically negative correlation between BMI and BMD and also between BMI and body balance in the tested women. These outcomes may be attributed that overweight elderly women are habitually scared of falls and developing fractures, so they select immobility and reduce their mobility to the lowermost level. Since bone is developed if used and damaged if not used as stated in Wolff's law (Kerr et al., 2001), BMD diminishes and osteopenia/osteoporosis results. Decreased BMD impacts bone health as it leads to brittle weak bone and this in turn affects postural control and body balance. Besides, obese women can't control their center of gravity (COG) within base of support (BOS) distressing their postural mechanism and body balance, maximizing risk of falls and making them more predisposed to fractures.

Some authors have agreed with the current study results and illustrated that there is an adverse effect of adipose tissue on bone mineral content. Taes et al., (2009) showed that greater mass of fat is associated with smaller bone size where as lean mass is a dependable positive determining factor of bone size. Janicka et al., (2007) confirmed these findings in a group of mature adolescents and young adults. Kim et al., (2010) supported the current study results as they assessed the relationships between obesity and BMD and vertebral fracture in postmenopausal women. The results revealed that elevated body fat percentage and increased waist circumference were positively associated with low BMD and vertebral fracture. Zhao et al., (2007) also concluded that body lean mass was positively associated with bone mass. On the other hand, body fat mass was negatively related to bone mineral content.

Additionally, Chang et al., (2013) proposed that abdominal obesity was negatively correlated with BMD in elderly women. Interestingly, Bansal and Bansal (2017) detected no statistically strong relationship between BMI and BMD. Accordingly, they revealed that there is no defensive role of obesity against the development of Osteoporosis. They also recommended that there must be more searches in the histological structures of fat cells to clarify the role and influence of obesity on BMD in old women. Greco et al., (2010) demonstrated that obese patients have a marked decreased lumbar BMD than estimated for age. Robbins et al., (2006) reported that BMI is not meaningful to be correlated with bone mineral content in selected individuals. According to Oommen et al., (2014), there was no statistically major relationship between BMI and BMD. A study conducted by Saravi et al., (2013) also revealed no substantial effect of BMI on BMD. Body weight, BMI and aging are not the only factors that influence bone loss. The correlation between BMI and BMD is slightly lower compared to the correlation between body composition parameters and BMD (Sheng et al., 2011).

Several studies disagreed with the current study results and have proposed a strong direct relationship between muscle mass and BMD (Wong et al., 2020). According to the concept that muscle mass is related to BMD, it could be concluded that individuals with sarcopenia have an increased incidence of osteopenia/osteoporosis. Sarcopenia is a condition of decreased lean mass (muscle mass) relative to height (below 5.45 kg/m2) (Ormsbee et al., 2014). The mechanical influence of adipose tissue on bone and estrogen synthesis by adipocytes were long assumed to be the main causal reasons for the lower incidence of osteoporotic fractures detected in obese or overweight women (Ribot et al., 1994). In contrast, underweight women were observed to be particularly vulnerable to the effects of health and lifestyle factors on bone (Boutari et al., 2020).

It was documented in some studies that body mass is one of the primary factors affecting BMD measures with a typical correlation (r) ranging from 0.3 to 0.6 (Reid, 2010). Females after menopause have 1.5 and 3 times higher spinal BMD because of their body weight rise as compared to premenopausal women and men, respectively (Mendez et al., 2012; Puntus et al., 2011). However, up to now this assumption is debated (Forsmo et al., 2006). Sowers et al., (1992) concluded that the average values of bone density around femoral neck are significantly elevated by increasing the entire body muscle mass in premenopausal women.

The current study results are also opposed by Gentil et al., (2007), who studied the correlation between low lower limb muscle mass and low femoral neck and low trochanter BMD. They reported that decreased lower limb muscle mass was associated with low BMD. The authors illustrated that the reason for this relationship is uncertain, but it may be because bone density and muscle mass are affected by related stimuli, as proposed by the findings of other searches (Kerr et al., 2001). It was hypothesized that the

© 2021 Discovery Scientific Society. All Rights Reserved. ISSN 2321–7359 EISSN 2321–7367 I OPEN ACCESS

relationship between diminished bone density and diminished muscle mass is very critical since diminished muscle mass indirectly increases the liability of fracture occurrence because of disturbed balance. Furthermore, the bulk of muscles around a bone provide a way of protection by acting as a cushion that absorbs forces during falling. Therefore, when low BMD is combined with low muscle mass, a greater danger of fractures is present. Therefore, they recommended that DEXA scan has to be used to recognize both BMD and muscle mass in women after menopause to evaluate the predisposing factors of fractures and disability more precisely (Rosenberg et al., 1995).

Dishman et al., (2004) also indicated that people with a higher BMI also have a higher BMD. Ambroszkiewicz et al., (2015) carried out a study on elderly people with ranging in their BMD from diminished to a standard level. They noticed a great danger of fractures occurrences in those with a significant reduction in BMD (osteoporosis).

The limitation of this study was that the body mass was evaluated as a whole including both lean mass and fat mass. The association between each mass of them to BMD and balance wasn't assessed separately.

5. CONCLUSION

It can be concluded from the current study that body balance and BMD are positively correlated to each other. Furthermore, body balance and BMD are negatively correlated to BMI. This in turn means that bone health (bone density) and postural control are strongly dependent on each other. Even low BMD is not the reason for balance deficits and balance deficits are not the reason for low BMD, both these problems are present in postmenopausal women and each of them affects the other. Therefore, postmenopausal women, who suffer balance deficits and weak bones, have to seek rehabilitation programs that challenge both balance and bone strength. Additionally, increasing body mass is a risk factor to decreased balance and bone density increasing the danger of falls and fracture in old females. Therefore, women have to control their body mass relative to their heights to manage balance deficits, encourage physical activity without fear of fall, minimize bone resorption due to disuse, and reduce fracture risk.

Acknowledgements

The authors would like to thank the women who contributed to the study for their active participation in the study.

Funding

This study has not received any external funding.

Conflict of interest

The authors declare that there are no conflicts of interests.

Ethical Approval

Ethical approval was cleared by The Research ethical committee of Faculty of Physical Therapy, Cairo University (P.T.REC/012/00731).

Data and materials availability

All data associated with this study are present in the paper.

REFERENCES AND NOTES

1. Abd El Mohsen AM, Abd el Ghaffar HEF, Nassif NS, Elhafez GM, The weight-bearing exercise for better balanceprogram improves strength and balance in osteopenia: a randomized controlled trial. *J Phys Ther Sci* 2016; 28(9):2576-2580
2. Abdelmohsen AM. Bone Mineral Density in Postmenopausal Women: Comparison of Central and Peripheral Bone Mineral Density Measurements in Postmenopausal Women. J Chiropr Med 2017;16 (3):199-203
3. Ambrszkiewicz J, Klemarczyk W, Rowicka G, Chełchowska M, Ołtarzewski M, Gajewska J. Adipokines, body composition and bone mineral density in underweight children. Pol Merkur Lekarski 2015; 39(229):18-22
4. Bansal S, Bansal A. Relation between obesity and osteoporosis in women. IJMDS 2017; 6 (1):125559
5. Bogle Thorbahn LD, Newton RA. Use of the Berg Balance Test to predict falls in elderly persons. Phys Ther 1996; 76(6):576-583
6. Boutari C,Panagiotis D, Pappas,Mintziori G,Meletios P, Nigdelis,Athanasiadis L,Dimitrios G, Goulis,Christos S, Mantzoros. The effect of underweight on female and male reproduction. Metabolism 2020;107:154229

© 2021 Discovery Scientific Society. All Rights Reserved. ISSN 2321–7359 EISSN 2321–7367 I OPEN ACCESS

7. Chang CS, Chang YF, Wang MW, Chen CY, Chao YJ, Chang HJ, , Kuo PH, Yang YC, Wu CH. Inverse relationship between central obesity and osteoporosis in osteoporotic drug naive elderly females: the Tianliao Old People (TOP) Study. J Clin Densitom 2013; 16(2):204-211
8. Chen W, Simpson JM, March LM, Blyth FM, Bliuc D, Tran T, Nguyen TN, Eisman JA, Center JR. Comorbidities Only Account for a Small Proportion of Excess Mortality After Fracture: A Record Linkage Study of Individual Fracture Types. J Bone Miner Res 2018; 33(5):795-802
9. Cifuentes M, Johnson MA, Lewis RD, Heymsfield SB, Chowdhury HA, Modlesky CM, Shapses SA. Bone turnover and body weight relationships differ in normal weight compared to heavier postmenopausal women. Osteoporos Int 2003; 14(2):116-122
10. Compston JE, Flahive J, Hosmer DW, Watts NB, Siris ES, Silverman S, Saaq KG, Roux C, Rossini M, Pfeilschifter J. Relationship of weight, height, and body mass index with fracture risk at different sites in postmenopausal women: The Global Longitudinal Study of Osteoporosis in Women (GLOW). J Bone Miner Res 2014; 29(2):487-493
11. Cummings SR, Melton LJ. Epidemiology and outcomes of osteoporotic fractures. Lancet 2002; 359 (9319):1761-1767
12. Dishman RK, Heath G, Washburn RA. Physical activity epidemiology. Champaign: Human Kinetics 2004
13. Forsmo S, Aaen J, Schei B, Langhammer A. "What is the influence of weight change on forearm bone mineral density in peri- and postmenopausal women? The health study of Nord-Trondelag, Norway", Am J Epidemiol 2006; 1; 164 (9): 890-897
14. Franck H, Munz M, Scherrer M. Evaluation of dual-energy X ray absorptiometry bone mineral measurement-comparison of a single-beam and fan-beam design: The effect of osteophytic calcification on spine bone mineral density. Calcif. Tissue Int 1995; 56(3):192-195
15. Frost HD. Wolff's law and bone's structural adaptations to mechanical usage: an overview for clinicians. The angle Orthod 1994; 64(3):175-180
16. Gentil P, Lima RM, de Oliveira RJ, Pereira RW, Reis VM. Association between Femoral Neck Bone Mineral Density and Lower Limb Fat-Free Mass in Postmenopausal Women. J Clin Densitom 2007; 10(2):174-178
17. Greco EA, Fornari R, Rossi F, Santiemma, IV, Prossomariti IG, Annoscia C, Aversa A, Brama M, Marini M, Donini LM, Spera G, Lenzi A, Lubrano C, Migliaccio1 S. Is obesity protective for osteoporosis? Evaluation of bone mineral density in individuals with high body mass index. Int J Clin Pract 2010; 64(6):817-820
18. Greco EA, Lenzi A, Migliaccio S. The obesity of bone. Ther Adv Endocrinol Metab 2015; 6 (6):273-286
19. Gremion G, Rizzoli R, Slosman D, Theintz G, Bonjour JP. Oligo-amenorrheic long-distance runners may lose more bone in spine than in femur. Med Sci Sports Exerc 2001; 33(1):15-21
20. Hansen MA, Overgaard K,Christiansen C. Spontaneous postmenopausal bone loss in different skeletal areas followed up for 15 years.J Bone Miner Res 1995; 10(2):205-210
21. Harvey N, Earl S, Cooper C. Epidemiology of osteoporotic fractures. In: Favus MJ, editor. Primer on the metabolicbone diseases and disorders of mineral metabolism. 6th ed.Washington (DC) 2006
22. Iwamoto J, Suzuki H, Tanaka K, Kumakubo T, Hirabayashi H, Miyazaki Y, Sato Y, Takeda T, Matsumoto H. Preventative effect of exercise against falls in the elderly: a randomized controlled trial. Osteoporos Int 2009; 20(7):1233-1240
23. Janicka A, Wren TA, Sanchez MM, Dorey F, Kim PS, Mittelman SD. Fat mass is not beneficial to bone in adolescents and young adults. J Clin Endocrinol Metab 2007; 92:143-147
24. Kang DH, Guo LF, Guo T, Wang Y, Liu T, Feng XY, Che XQ. Association of body composition with bone mineral density in northern Chinese men by different criteria for obesity. J Endocrinol Invest 2015; 38(3): 323-331
25. Kerr D, Ackland T, Maslen B, Morton A, Prince R. Resistance training over 2 years increases bone mass in calcium replete postmenopausal women. J Bone Miner Res 2001;16(1):175-181
26. Kim KC, Shin DH, Lee SY, Im JA, Lee DC. Relation between Obesity and Bone Mineral Density and Vertebral Fractures in Korean Postmenopausal Women. Yonsei Med J 2010; 51(6):857-863
27. Korkmaz N, Tutoglu A, Korkmaz I, Boyacı A. The Relationships among Vitamin D Level, Balance, Muscle Strength, and Quality of Life in Postmenopausal Patients with Osteoporosis. J Phys Ther Sci 2014; 26(10):1521-1526
28. Kujath AS, Quinn L, Elliot ME, LeCaire TJ, Binkley N, Molino AR. Danielson KK. Different health behaviours and clinical factors associated with bone mineral density and bone turnover in premenopausal women with and without type 1 diabetes. Diabetes Metab Res Rev 2015; 31(4):421-432
29. Liu-Ambrose T, Eng J, Khan K., Carter ND, McKay HA. Older women with osteoporosis have increased postural sway and weaker quadriceps strength than counterparts with normal bone mass: overlooked determinants of fracture risk? J Gerontol A Biol Sci Med Sci 2003; 58 (9):862-866
30. Liu-Ambrose T, Eng JJ, Khan KM, Mallinson A, Carter ND, McKay HA. The influence of back pain on balance and functional mobility in 65 to 75 year old women with osteoporosis. Osteoporosis Int 2002; 13(11):868-873

© 2021 Discovery Scientific Society. All Rights Reserved. ISSN 2321–7359 EISSN 2321–7367 I OPEN ACCESS

31. Lynn SG, Sinaki M, Westerlind KC. Balance characteristics of person with osteoporosis. Arch Phys Med Rehabil 1997; 78(3):273-276
32. Maïmoun L, Lumbroso S, Manetta J, Paris F, Leroux JL, Sultan C. Testosterone is significantly reduced in endurance athletes without impact on bone mineral density. Horm Res 2003; 59(6):285-292
33. Mendez JP, Rojano-Mejia D, Pedraza J, Coral-Vazquez RM, Soriano R, Garcia E, Aguirre-Garcia MD, Coronel A, Canto P. Bone mineral density in postmenopausal Mexican-Mestizo women with normal body mass index, overweight, or obesity. Menopause (New York, N.Y.) 2012; 20(5):568-572
34. Oommen A, AlZahrani IH, Shoro AS, Alruwaili J, Aboalseel B. Relationship between body mass index and Bone mineral density in Saudi women above 40 years with Vitamin D deficiency. Science Journal of Public Health 2014; 2(6):601-604
35. Ormsbee MJ, Prado CM, Ilich JZ, Purcell S, Siervo M, Folsom A, Panton L. Osteosarcopenic obesity: the role of bone, muscle, and fat on healthJ Cachexia Sarcopenia Muscle 2014; 5(3):183-192
36. Puntus T, Schneider B, Meran J, Peterlik M, Kudlacek S. Influence of age and gender on associations of body mass index with bone mineral density, bone turnover markers and circulating calcium-regulating and bone-active sex hormones. Bone 2011; 49(4):824-829
37. Reid IR. Fat and bone. Arch Biochem Biophy 2010; 503(1):20-27
38. Ribot C, Tremollieres F, Pouilles JM. The effect of obesity on postmenopausal bone loss and the risk of osteoporosis. Adv Nutr Res 1994; 9:257-271
39. Robbins J, Schott AM, Azari R, Kronmal R. Body mass index is not a good predictor of bone density: results from WHI, CHS, and EPIDOS. J Clin Densitom 2006; 9(3):329-334
40. Roche J, Wenn R, Sahota O, Moran CG. Effect of comorbidities and postoperative complications on mortality after hip fracture in elderly people: prospective observational cohort study. BMJ 2005;10; 331(7529): 1374
41. Rosenberg IR, Roubenoff R. Stalking sarcopenia. Ann Intern Med 1995; 1; 123 (9):727-728
42. Runge M, Rehfeld G, Resnicek E. Balance training and exercise in geriatric patients. J Musculoskel Neuronal Interact 2001; 1(1):61-65
43. Saravi FD, Sayegh F. Bone mineral density and body composition of adult premenopausal women with three levels of physical activity. J Osteoporos 2013; 953271
44. Sheng Z, Xu K. Ou Y, Dai R, Luo X, Liu S, Su X, Wu X, Xie H, Yuan L, Liao E. Relationship of body composition with prevalence of osteoporosis in central south Chinese postmenopausal women. Clinic EndocrinoL 2011; 74(3):319-324
45. Shumway-Cook A, Brauer S, Woollacott M. Predicting the probability for falls in community-dwelling older adults using the timed up and go test. Phys Ther 2000; 80(9):896-903
46. Sinaki M, Brey RH, Hughes CA, Larson DR, Kaufman KR. Balance disorder and increased risk of falls in osteoporosis and kyphosis: significance of kyphotic posture and muscle strength. Osteoporos Int 2005; 16(8):1004-1010
47. Sotunde OF, Kruger HS, Wright HH, Havemann-Nel L, Kruger IM., Wentzel-Viljoen E, Kruger A, Tieland M. Lean mass appears to be more strongly associated with bone health than fat mass in urban black South African women. J Nutr Health Aging 2015; 19(6):628-636
48. Sowers MF, Kshirsagar A, Crutchfield MM, Updike S. Joint influence of fat and lean body composition compartments on femoral bone mineral density in premenopausal women. Am J Epidemiol 1992; 136(3):257-265
49. Taaffe DR, Simonsick EM, Visser M, Volpato S, Nevitt MC, Cauley JA, Tylavsky FA, Harris TB. Lower Extremity Physical Performance and Hip Bone Mineral Density in Elderly Black and White Men and Women : Cross-Sectional Associations in the Health ABC Study 2003; 58(10):934-942
50. Taes YE, Lapauw B, Vanbillemont G, Bogaert V, De Bacquer D, Zmierczak H, et al. Fat mass is negatively associated with cortical bone size in young healthy male siblings. J Clin Endocrinol Metab 2009; 94(7):2325-2331
51. Viveiro LA, GomesGC, Bacha JM, Junior NC, Kallas ME, ReisM, Filho WC, Pompeu JE. Reliability, Validity, and Ability to Identity Fall Status of the Berg Balance Scale, Balance Evaluation Systems Test (BESTest), Mini-BESTest, and Brief-BESTest in Older Adults Who Live in Nursing Homes. J Geriatr Phys Ther 2019; 42(4):45-54
52. Wong AK, Pokhoy A, Chandrakumar A, Cvejkus RK, Zmuda JM. Short- and Long-Term Reciprocal Bone-Muscle Relationships in the Upper and Lower Extremity of Afro-Caribbean Men by DXA: A Longitudinal Analysis of the Tobago Bone Health Study. JBMR Plus 2020; 4(10):e10406
53. Zhao LJ, Liu YJ, Liu PY, Hamilton J, Recker RR, Deng HW. Relationship of obesity with osteoporosis. J Clin Endocrinol Metab 2007; 92(5):1640-1706

© 2021 Discovery Scientific Society. All Rights Reserved. ISSN 2321–7359 EISSN 2321–7367 I OPEN ACCESS