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Original Article

Association of body composition with bone mineral density and fracture in diabetic elderly: Results from AHAP study

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Abstract

Background: Diabetes is a common metabolic disorder and one of its comorbidities is osteoporosis. In previous studies, the effect of lean mass and fat mass on bone has been investigated separately. Therefore, the aim of this study was to investigate the association between body composition with bone mineral density (BMD) and fractures in diabetic elderly.

Methods: This population based cross-sectional study is part of the second phase of the Amirkola Health and Ageing Cohort Project (AHAP). Diabetes was diagnosed by fasting blood glucose level twice greater than or equal to 126 mg/dl. BMD and body composition were measured by Hologic Horizon-WI densitometer. History of fracture was obtained by asking the elderly individual. Then data were analyzed using statistical tests and ROC curve.

Results: Out of 469 elderly diabetics, 270 (57.57%) were women. The mean age was 68.70±6.18. Older people with osteopenia, osteoporosis and fracture had lower visceral fat mass (VFM), lean mass (LM) and waist circumference (WC) than normal people. The mean BMD in elderly with less than 10 years of diabetes history was greater and the percentage of fractures in elderly individuals with more than 10 years of diabetes was higher. In Roc analysis, the highest area under the curve was related to LM 78% (0.78±0.02), WC 67% (0.67±0.03) and VFM 62% (0.62±0.03) for estimation of osteoporosis.

Conclusion: In this study, LM, WC and VFM had the greatest effect on BMD and fracture in elderly diabetic.

Keywords: Body composition, Bone mineral density, Fracture in diabetic elderly.

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Diabetes is a very common metabolic disorder in society and one of its comorbidities is osteoporosis. The decrease in bone mineral density and the weakening of its microscopic structure in these patients causes a decrease in bone strength and an increase in the risk of fracture, especially in people over 50 years old (1). Despite the higher bone mineral density in diabetic compared to normal people, patients with type 2 diabetes are at a higher risk of fractures, and this issue indicates a complex relationship between type 2 diabetes and bone health. Overweight and obesity as a metabolic disorder are associated with type 2 diabetes in many cases (2, 3). In the past, it seemed that obesity and overweight have a protective effect on bone mineral density, but new studies have challenged this belief (4, 5). Body weight also has a positive effect on bone mineral density, but at the same time, obesity increases the risk of fractures. The way in which fat distribution and its metabolic effects influence bone mineral density is not completely understood (6).

Although some studies have indicated a negative effect of visceral fat on bone mineral density (7, 8), this effect has not been observed in other studies (9, 10). In previous studies, the effects of lean mass and fat mass on bone have been examined separately, and their results indicate a protective effect of lean mass on bone, while fat mass has led to bone damage and muscle atrophy due to the induction of inflammatory effects (11, 12). According to the assessments carried out by the researcher, few studies have been conducted on the association between body composition with bone mineral density and fractures in diabetic elderly people. The limitations of these studies include the small sample size (13, 14), hospitalized elderly diabetic patients (13) and the lack of strong and sufficient evidence regarding the association between visceral and subcutaneous fat mass with fracture risk (15) as well as body composition measurements using methods other than Hologic densitometry (15). Therefore, it is necessary to conduct a study with a larger, population-based sample size to simultaneously assess the impact of fat mass, visceral fat, body mass index, waist circumference, and lean mass on bone mineral density and fractures in elderly patients with diabetes.

Methods

This cross-sectional population-based study is a part of the second phase of the Amirkola Health and Ageing Cohort project, which is conducted on all diabetic elderly people of Amirkola city (16). The diagnosis of diabetes was based on measuring fasting blood glucose levels of 126 mg/dL or higher on two separate occasions and or patient self-report confirmed by reviewing the patient's previous medical records and medications (17). Exclusion criteria include having type 1 diabetes, drugs effective in the treatment of osteoporosis, drugs affecting bone metabolism for more than 6 months or during the last 12 months such as systemic corticosteroids, immunosuppressive drugs and hormone replacement therapy, Chronic renal failure, and malignancies. Demographic data including age, sex via questionnaire and anthropometric data such as height, weight, and waist circumference were measured using a standard method. Height (in centimeters) was measured by a standing scale with an accuracy of 0.1 cm and weight (in kilograms) was measured by a Seca digital scale with minimal clothing and no shoes and an accuracy of 0.1 kg. Waist circumference was measured at the midpoint between the highest point of the iliac crest and the lower edge of the ribs, parallel to the ground. The BMI was calculated by dividing weight in kilograms by height in meters squared, and individuals were categorized into four subgroups: underweight (BMI < 18.5), normal (18.5–24.9), overweight (25–29.9), and obese (BMI ≥ 30) (18). The amount of physical activity in the elderly was calculated using the standard questionnaire Physical Activity Scale for Elderly (PASE) (19). The validity and reliability of the Persian version of this questionnaire was determined in the study of Keikavoosi-Arani et al. (20).

Using the Hologic densitometer (model Horizon-WI), in addition to measuring the BMD of the spine and hip bone, bone density of the wrist, whole body scans, and soft tissue density measurements including visceral, regional, and total body fat were assessed, with results expressed based on the T-score. A T-score of -2.5 or lower was classified as osteoporosis, a T-score between -1 and -2.5 as osteopenia, and a T-score greater than -1 as normal (21). For the scan, the patient lay on their back on the table, with their arms at their sides, and before each scan, the device was calibrated according to the manufacturer's recommendations. The resulting data were then analyzed using Hologic Apex software version 5.6.0.2. DXA is a reliable method for body composition analysis that is based on resistance to x-ray transmission, allowing for the separation of body weight into fat mass, lean mass, bones, and minerals.

In this method, fat mass is measured in grams and includes visceral adipose tissue (VAT), local fat and total body fat. This software calculates visceral fat by subtracting subcutaneous adipose tissue (SAT) from total fat in the android region. The android and gynoid regions are automatically obtained using the software provided by the manufacturer. Additionally, all densitometry assessments were performed by a trained expert with years of experience in the radiology and densitometry center. To determine the serum level of 1,25-hydroxyvitamin D, which is the active form of this vitamin, a morning blood sample was taken from all the elderly and measured by ELISA in the Khazar Comprehensive Laboratory of Babol University of Medical Sciences using the Enzyme Immunoassay kit. After data entry and coding in the SPSS 22 software, the obtained information and data were analyzed using t test, ANOVA, Pearson's correlation coefficient and ROC curve. A p-value less than 0.05 was considered as a significant level.

Results

Out of 2135 elderly people examined in the second phase of the Amirkola cohort, 598 of them had diabetes, and by applying the exclusion criteria, 469 eligible people were included in the study. Among them, 199 (42.43%) were men and 270 (57.57%) were women. The mean age of the

participants was 68.70±6.18 (range 60-90 years). As shown in table 1, the body mass index (p<0.001) and the level of physical activity (P=0.08) were lower in patients with osteoporosis as compared to the patients with osteopenia and normal bone density. In addition, visceral fat mass, lean mass, and total fat mass were lower in patients with osteopenia and osteoporosis as compared to the patients with normal bone density (p<0.001). The waist circumference, height, and weight were also smaller in both groups compared with the normal group (p<0.001). Analyses by gender showed that the levels of lean mass, visceral fat mass, total fat mass, body mass index, waist circumference, height, and weight in osteoporotic and osteopenic patients were significantly lower compared to that of patients with normal bone density in both males and females ((p<0.01).

Table 2 gives the Pearson correlation coefficient of the bone mineral density and body composition and other quantitative variables. A positive and significant association in both genders is evident between the BMD of the femur or spine regions with visceral fat mass, total fat mass, lean mass, BMI, and waist circumference (p<0.001).

Table 1. Mean and standard deviation of the studied variables according to bone mineral density status in diabetic elderly people in Amirkola city

Variables	Normal Mean± SD	Osteopenia Mean± SD	Osteoporosis Mean± SD	P-value
Drug number	5.26±3.25	5.69±3.16	5.13±3.44	0.26
Number of chronic diseases	4.46±2.18	5.05±2.16	5.58±2.38	<0.001
Body Mass Index (kg/m^2)	30.15±4.15	29.45±4.86	27.74±4.96	<0.001
Physical activity (PASE score)	99.59±54.03	89.14±47.29	87.17±49.04	0.08
Vitamin D (ng/dl)	58.20±37.38	69.81±75.88	69.67±49.41	0.52
Calcium (mg/dl)	8.98±1.01	9.44±5.95	9.12±1.04	0.57
Phosphor (mg/dl)	3.80±0.62	4.05±1.73	3.94±0.51	0.19
Albumin (g/dl)	4.40±0.49	4.43±0.53	4.33±0.47	0.26
Lean mass (g)	44354.01±7174.63	39771.50±6695.95	34041.24±5672.53	<0.001
Fat mass (g)	30039.50±7751.07	29044.71±8786.34	26557.49±8533.73	0.005
Visceral fat mass (g)	1008.15±311.32	940.22±333.20	835.76±352.17	<0.001
BMD Femur (gr/cm^2)	0.88±0.09	0.72±0.07	0.62±0.09	<0.001
BMD Spine (gr/cm^2)	1.11±0.12	0.90±0.08	0.73±0.08	<0.001
Waist circumference (cm)	98.34±9.56	95.13±10.32	90.55±11.13	<0/001
Height (Cm)	160.59±8.11	156.24±8/59	150.31±7/79	<0/001
Weight (kg)	77.60±10.92	71.65±11.51	62.77±12.53	<0/001

Physical Activity Scale for Elderly (PASE), bone mineral density (BMD)

Table 2. Pearson correlation coefficient between bone mineral mass, body composition, and quantitative variables studied in diabetic elderly people in Amirkola city

Variable		Age	BMD Spine (gr/cm^2)	BMD Femur (gr/cm^2)	Visceral fat (g)	Fat mass (g)	Lean mass (g)	Drug number	Number of chronic diseases	Body Mass Index (kg/m^2)	Physical activity (PASE score)	Waist circumference (Cm)
BMD Spine (gr/cm^2)	r	-0.96	1									
	P value	0.03										
BMD Femur (gr/cm^2)	r	-0.22	0.69	1								
	P value	0.001	0.001									
Visceral fat mass (g)	r	-0.11	0.15	0.17	1							
	P value	0.01	0.001	0.001								
Fat mass (g)	r	-0.18	0.03	0.12	0.77	1						
	P value	0.001	0.40	0.005	0.001							
Lean mass (g)	r	-0.16	0.57	0.63	0.27	0.1	1					
	P value	0.001	0.001	0.001	0.001	0.001						
Drug number	r	-0.09	-0.01	0.003	0.11	0.19	-0.09	1				
	P value	0.04	0.72	0.95	0.01	0.001	0.03					
Number of chronic diseases	r	-0.16	-0.21	-0.21	0.11	0.18	-0.22	0.49	1			
	P value	0.001	0.001	0.001	0.01	0.001	0.001	0.001				
Body Mass Index (kg/m^2)	r	-0.18	0.08	0.21	0.74	0.88	0.24	0.18	0.18	1		
	P value	0.001	0.05	0.001	0.001	0.001	0.001	0.001	0.001			
Physical activity (PASE score)	r	-0.32	0.11	0.15	-0.06	-0.05	0.10	-0.14	-0.21	-0.04	1	
	P value	0.001	0.01	0.001	0.13	0.23	0.02	0.002	0.001	0.34		
Waist circumference (Cm)	r	-0.11	0.23	0.30	0.75	0.74	0.45	0.16	0.08	0.77	-0.01	1
	P value	0.01	0.001	0.001	0.001	0.001	0.001	0.001	0.06	0.001	0.71	
Calcium (mg/dl)	r	-0.62	-0.002	0.005	-0.01	-0.04	0.05	-0.04	-0.06	-0.01	0.02	0.008
	P value	0.17	0.96	0.91	0.72	0.35	0.27	0.36	0.18	0.70	0.55	0.85

Physical Activity Scale for Elderly (PASE), bone mineral density (BMD)

As shown in table 3, elderly individuals with a history of fractures had lower lean mass, visceral fat mass, waist circumference, height, and bone mineral density in both the femur and spine regions. However, only the association between fractures and lean mass (P=0.03), bone mineral density (P=0.001), and height were statistically significant. Analysis by gender shows that both men and women with a history of bone fractures had lower lean mass, visceral fat mass, waist circumference, height, and bone mineral density in both the femur and spine regions. However, only the association between fractures and bone mineral density in the spine region was significant in both genders (P<0.01).

The ROC curve analysis was used to determine the predictive role of each variable in estimating osteoporosis. As shown in figure 1, the highest area under the curve was related to lean mass 78% (0.78±0.02), followed by waist circumference 67% (0.67±0.03) and visceral fat mass 62% (0.62±0.03) (P<0.001). Analysis by gender shows the highest area under the curve in men, corresponds to lean mass 77% (0.77±0.04), body mass index 65% (0.65±0.07), and visceral fat mass 64% (0.64±0.07) and in women, corresponds to total fat mass 71.6% (0.71±0.03), lean mass 71.3% (0.71±0.03), and body mass index 69.7% (0.69±0.03) (table 4).

In this research, the mean bone mineral density in the both regions of spine (0.93±0.17 vs 0.89±0.14) (P=0.053) and femur (0.75±0.14 vs 0.73±0.13) (P=0.01) in elderly patients with less than 10 years of diabetes history was greater as compared to the patients with more than 10 years of diabetic history. The percentage of fractures in elderly individuals with more than 10 years of diabetes was lower than that in patients with a shorter history (29.14% vs 31.93%), although this did not reach statistical significance . In this study, the mean HbA1c (%) in elderly diabetic with osteoporosis was 7.93±1.73 as compared to 7.58±1.49 for elderly diabetic with normal bone mineral density, though this result was not significant (P = 0.608). HbA1c was measured for 154 elderly participants in the present study.

Table 3. Mean and standard deviation of the studied variables according to fracture history in diabetic elderly people in Amirkola city

Variables	Fracture (-) Mean± SD	Fracture (+) Mean± SD	P-value
Drug number	5.39±3.17	5.53±3.45	0.68
Number of chronic diseases	4.54±2.06	6.10±2.29	<0.001
Body Mass Index (kg/m^2)	29.22±4.66	29.35±5.00	0.79
Physical activity (PASE score)	92.52±50.74	89.70±47.79	0.57
Vitamin D (ng/dl)	57.90±49.37	84.67±77.03	0.10
Calcium (mg/dl)	9.24±4.95	9.21±1.00	0.94
Phosphor (mg/dl)	3.94±1.46	3.97±0.62	0.84
Albumin (g/dl)	4.39±0.54	4.40±0.42	0.87
Lean mass (g)	40235.30±7542.61	38615.81±7528.99	0.03
Fat mass (g)	28747.58±8266.44	28784.29±9138.37	0.96
Visceral fat mass(g)	939.23±325.51	927.20±363.22	0.72
BMD Femur (gr/cm^2)	0.75±0.12	0.71±0.12	0.001
BMD Spine (gr/cm^2)	0.94±0.16	0.86±0.14	<0.001
Waist circumference (Cm)	95.00±10.44	94.97±11.21	0.97
Height (Cm)	156.68±8.88	154.77±9.29	0.03
Weight (kg)	71.73±12.51	70.32±13.24	0.27

Physical Activity Scale for Elderly (PASE), bone mineral density (BMD)

Table 4. Area under the curve (AUC) of variables affecting bone mineral mass in the Roc curve in the elderly of Amirkola city in total and by gender

Variables	Area under the curve (total)	P-value	Area under the curve (Male)	P-value	Area under the curve (Female)	P-value
Fat mass (g)	0.61±0.03	<0.001	0.59±0.07	0.21	0.71±0.03	<0.001
Lean mass (g)	0.78±0.02	<0.001	0.77±0.04	<0.001	0.71±0.03	<0.001
Visceral fat mass (g)	0.62±0.03	<0.001	0.64±0.07	0.058	0.64±0.03	<0.001
Waist circumference (Cm)	0.67±0.03	<0.001	0.63±0.07	0.07	0.67±0.03	<0.001
Body Mass Index (kg/m^2)	0.63±0.03	<0.001	0.65±0.07	0.03	0.69±0.03	<0.001

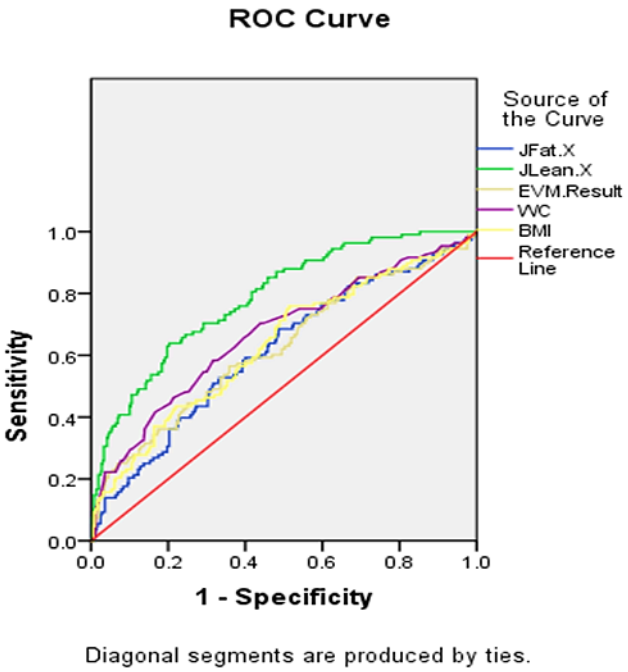

Figure1. Roc curve of quantitative variables in diabetic elderly people in Amirkola city

Discussion

The present study has been conducted to find out the relation between body composition with BMD and fractures among elderly diabetics using data from phase two of the Amirkola Health and Ageing Cohort Project (AHAP). While many studies have been carried out on the association between BMD and body composition in various groups, only a few relate to diabetic individuals.

This study found that muscle mass, fat mass, and visceral fat were significantly lower in diabetic elderly patients with osteoporosis and osteopenia than in diabetic patients with normal BMD. The analysis of the ROC curve showed that muscle mass, waist circumference, and visceral fat were the three most important predictive factors for osteoporosis in diabetic elderly patients, though the effect of fat mass was more significant in females.

In the research conducted by Meng et al. (2022), 233 diabetic elderly subjects were involved; a group that had normal bone mineral density both in the hip and spine were found to have higher muscle mass. It has also documented the positive impact of fat mass on BMD. This research gave the greatest mechanical effect to fat mass (13). In the study by Jia et al. (2020), which involved 187 participants, of whom 27 had diabetes and 28 had glucose tolerance

disorders, muscle mass was found to be a strong and positive predictor of bone mineral density (14). In most of these studies, the protective effect of muscle mass on bone mineral density is mainly attributed to the mechanical role of muscles, besides its beneficial effects at the microscopic structure of the bone.

In the present study, a positive and significant correlation was observed between visceral fat mass and bone mineral density in diabetic elderly individuals of both genders. It was also noted that women had a higher visceral fat mass compared to men, and the correlation coefficient with bone mineral density was greater in elderly diabetic women than in men. Previous studies have often pointed to the lack of effect or the negative impact of visceral fat mass on bone health. For instance, in the study by Liu et al. (2016) involving 710 participants from the Framingham study, visceral fat mass did not have a significant effect on bone mineral density (22). In the study by Spadaccini et al. (conducted on 795 elderly individuals aged 65 to 100), no association was found between visceral fat tissue and bone mineral density (23). The study by Zhu et al. also highlighted the negative role of visceral fat, stating that high levels of visceral fat are associated with low BMD (7). However, in the study by Hosseini et al. involving 1200 elderly individuals, a strong positive effect of visceral fat mass was reported (10). In the study by Gao et al. (2021), conducted on 137 diabetic menopausal women, it was observed that women over 65 years old had significantly higher visceral fat mass, body mass index, subcutaneous fat mass, and bone mineral density compared to the normal group. This study indicated that type 2 diabetes can affect abdominal fat distribution in menopausal women (24). Given the low weight of visceral fat, its positive effect on bone mineral density should be investigated not through mechanical means but rather through the role of this tissue as an endocrine gland. Numerous studies have explored the role of this tissue in secreting substances such as adiponectin, leptin, visfatin, resistin, and even interleukins. The study by Brener et al. (25) highlighted the positive effect of adiponectin. Additionally, the study by Xie et al. showed that visfatin plays a role in the mineralization of bone matrix (26).

In this study, the mean HbA1c in elderly diabetic patients with osteoporosis was higher compared to that in elderly diabetic patients with normal bone mineral density, though the result was not significant (P=0.608). Furthermore, in the present study, the mean HbA1c was not significantly different between elderly diabetic patients with and without previous history of bone fractures (P=0.628). The study by Oei et al. (2024), conducted on 420 diabetic patients, showed that the group with poor glycemic control, while having higher bone mineral density, was at a greater risk for fractures. It has been specified in the above study that the high risk for fracture in individuals with high bone mineral density while on improper glucose control might be due to the formation and accumulation of multiple microcracks, meaning poor healing and repair of the bone (27). Other possible reasons include changes in body composition such as muscle mass loss and the onset of sarcopenia (28), increased production of non-enzymatic cross-links in collagen fibers, which negatively affects the bone matrix (29), and alterations in bone remodeling regulation through effects on pathways for bone formation and resorption by impacting osteoblasts and osteoclasts (30, 31).

According to the results of the present study, the mean bone mineral density in both regions-femur, spine-was significantly lower in elderly individuals with a history of diabetes lasting 10 years or more compared to the other group. Additionally, diabetic elderly individuals with a history of bone fracture had a statistically significant lower mean bone mineral density in both two mentioned areas. In the study by Luo et al. (2024), conducted on 692 elderly diabetic individuals, it was found that people with diabetes had higher bone mineral density compared to the control group; however, the risk of fractures in diabetic patients was greater over the next ten years. Furthermore, as the duration of diabetes and its progression increased, bone mineral density sharply decreased, leading to a higher risk of fractures. The higher BMD in diabetic individuals has been attributed to weight gain and increased fat mass (32). Additionally, adipose tissue can play a role in regulating bone remodeling both directly and indirectly through the secretion of various adipokines (33, 34). Walsh et al. showed in their study that adipose tissue is the major source of estrogen among menopausal women through the mechanism of conversion of androgens to estradiol, and androstenedione to estrone. This can lead to an increase in bone mineral density due to the inhibition of osteoclast activity. Furthermore, adipose tissue, through the secretion of leptin and calpain, reduces the levels of sex hormone-binding globulin, consequently increasing the levels of free hormones (35).

During the prolongation of diabetes, the complications of microangiopathy and neuropathy occur more often. Microangiopathy appears to act as a risk factor for osteoporosis and for abnormal BMD (36). It has also been postulated that the peripheral nervous system in diabetic patients influences the regulation of bone metabolism through neurotransmitters and neuromodulation in blood vessels supplying bone cells. With the chronic course of

diabetes, accompanied by vascular and neural lesion, deficits of balance and coordination while walking appear which promotes sedentary lifestyle and further leads to bone mass loss and reduction in BMD (37). Moreover, nutritional deficiencies states, that might affect the bones, are rather common in elderly patients with a long-term disease (38). In the present study, waist circumference was also found to be positively associated with bone mineral density. The waist circumference of women was higher than that of men and the effect on bone mineral density was greater. The results are in agreement with the study conducted by Pan et al. (39) in 2024 on 11,165 participants. In contrast, in a study conducted by Hua et al. (40) in 2021 on 5,084 patients, it was remarked that waist circumference negatively and inversely correlates with bone mineral density in the lumbar region. Limitations of this cross-sectional study are that the assessment of the casual association becomes difficult. Although a significant relationship was established between VAT and BMD, but a prospective study along with a check on serum levels and effects of factors secreted from visceral adipose tissue could better elucidate the role of these factors. Also, the study did not measure any other variables related to the participants' socioeconomic status regarding alcohol consumption, nutrition, and smoking. Some strengths of this study include the large sample size, extensive body composition analysis which also involved muscle mass, fat mass and visceral fat mass; the measurement of the bone mineral density of all three regions: femur, spine, and whole body, using a Hologic densitometer.In this study, muscle mass had the greatest impact on bone mineral density and bone fractures. This highlights the significant importance of daily physical activity, especially in elderly diabetic individuals who are at a higher risk of developing osteoporosis. Fat mass also had a positive effect on bone mineral density; however, due to the greater impact of muscle mass and the associated complications and risks of higher fat mass on the health of other organs, it is more advisable to focus on increasing muscle mass rather than fat mass. Additionally, in this study, visceral fat mass also had a positive effect on bone mineral density, which cannot be attributed to mechanical effects given its lower weight. This positive effect is likely due to the endocrine properties of this organ, which requires further investigation and studies.

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Authors' contribution: SR H: Conceptualization, Data curation, Investigation, Methodology, Project administration, Supervision. Am H: Conceptualization, Investigation, Methodology, Writing–original draft. N M: Conceptualization, Investigation, Project administration. M B: Investigation, Validation. A B: Data curation, Formal analysis, Methodology, Software. R G: Investigation, Validation, Visualization. H N: Investigation, Methodology. All authors have reviewed and approved the final manuscript and agreed to the author order.

References

1. Vestergaard P. Discrepancies in bone mineral density and fracture risk in patients with type 1 and type 2 diabetes-a meta-analysis. Osteoporos Int 2007; 18: 427-44.
2. Fan Y, Wei F, Lang Y, Liu Y. Diabetes mellitus and risk of hip fractures: a meta-analysis. Osteoporos Int 2016; 27: 219-28.
3. Yamamoto M, Yamaguchi T, Yamauchi M, Kaji H, Sugimoto T. Diabetic patients have an increased risk of vertebral fractures independent of BMD or diabetic complications. J Bone Miner Res 2009; 24: 702-9.
4. De Laet C, Kanis JA, Odén A, et al. Body mass index as a predictor of fracture risk: a meta-analysis. Osteoporos Int 2005; 16: 1330-8.
5. Lloyd JT, Alley DE, Hawkes WG, et al. Body mass index is positively associated with bone mineral density in US older adults. Arch Osteoporos 2014; 9: 175.
6. Russell M, Mendes N, Miller KK, et al. Visceral fat is a negative predictor of bone density measures in obese adolescent girls. J Clin Endocrinol Metab 2010; 95: 1247-55.
7. Zhu K, Hunter M, James A, et al. Relationship between visceral adipose tissue and bone mineral density in Australian baby boomers. Osteoporos Int 2020; 31: 2439-48.
8. El-Masry SA, Hassan NE, El-Banna RA, El Hussieny MS. The relation between visceral and subcutaneous fat

to bone mass among Egyptian children and adolescents. Open Access Maced J Med Sci 2014; 2: 573-8.
9. Header EA, Al-Kushi AG, Ali HM, Hassan MB, Naser AE. Bone mineral density and body composition in Saudi adult females. MOJ Anat Physiol 2019; 6: 160-6.
10. Hosseini SA, Cumming RG, Bijani A, et al. Relationship between visceral adipose tissue and bone mineral density in older people: Results from AHAP study. J Clin Densitom 2023; 26: 1-9.
11. Bierhals IO, Dos Santos Vaz J, Bielemann RM, et al. Associations between body mass index, body composition and bone density in young adults: findings from a southern Brazilian cohort. BMC Musculoskelet Disord 2019; 20: 322.
12. Pellegrinelli V, Rouault C, Rodriguez-Cuenca S, et al. Human adipocytes induce inflammation and atrophy in muscle cells during obesity. Diabetes 2015; 64: 3121-34.
13. Meng C, Zhao D, Ye XH. Association of body composition with bone mineral density and fractures in Chinese male type 2 diabetes mellitus. Medicine (Baltimore) 2023; 102: e33400.
14. Jia X, Liu L, Wang R, et al. Relationship of two-hour plasma glucose and abdominal visceral fat with bone mineral density and bone mineral content in women with different glucose metabolism status. Diabetes Metab Syndr Obes 2020; 13: 851-8.
15. Wang H, Peng H, Zhang L, Gao W, Ye J. Novel insight into the relationship between muscle-fat and bone in type 2 diabetes ranging from normal weight to obesity. Diabetes Metab Syndr Obes 2022; 15: 1473-84.
16. Bijani A, Ghadimi R, Mikaniki E, et al. Cohort profile update: the Amirkola health and ageing project (AHAP). Caspian J Intern Med 2017; 8: 205-12.
17. Addendum. 2. Classification and diagnosis of diabetes: Standards of medical care in diabetes-2021. Diabetes Care 2021; 44: S15-S33.
18. NIH Publication. Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults--the evidence report. National Institutes of Health. Obes Res 1998; 6 Suppl 2: 51S-209S. Erratum in: Obes Res 1998; 6: 464.
19. Washburn RA, Smith KW, Jette AM, Janney CA. The physical activity scale for the elderly (PASE): development and evaluation. J Clin Epidemiol 1993; 46: 153-62.
20. Keikavoosi‐Arani L, Salehi L. Cultural adaptation and psychometric adequacy of the Persian version of the physical activity scale for the elderly (P-PASE). BMC Res Notes 2019; 12: 555.
21. Kanis JA, McCloskey EV, Johansson H, et al. A reference standard for the description of osteoporosis. Bone 2008; 42: 467-75.
22. Liu CT, Broe KE, Zhou Y, et al. Visceral adipose tissue is associated with bone microarchitecture in the framingham osteoporosis study. J Bone Miner Res 2017; 32: 143-50.
23. Spadaccini D, Perna S, Peroni G. DXA-derived visceral adipose tissue (VAT) in elderly: Percentiles of reference for gender and association with metabolic outcomes. Life (Basel) 2020; 10: 163.
24. Gao L, Zhang P, Wang Y, et al. Relationship between body composition and bone mineral density in postmenopausal women with type 2 diabetes mellitus. BMC Musculoskelet Disord 2022; 23: 893.
25. Berner HS, Lyngstadaas SP, Spahr A, et al. Adiponectin and its receptors are expressed in bone-forming cells. Bone 2004; 35(4):842-9.
26. Xie H, Tang SY, Luo XH, et al. Insulin-like effects of visfatin on human osteoblasts. Calcif Tissue Int 2007; 80: 201-10.
27. Oei L, Zillikens MC, Dehghan A, et al. High bone mineral density and fracture risk in type 2 diabetes as skeletal complications of inadequate glucose control: the Rotterdam Study. Diabetes Care 2013; 36: 1619-28.
28. Evans WJ, Campbell WW. Sarcopenia and age-related changes in body composition and functional capacity. J Nutr 1993; 123: 465–8.
29. Yamaguchi T, Sugimoto T. Bone metabolism and fracture risk in type 2 diabetes mellitus [Review]. Endocr J 2011; 58: 613–24.
30. Schurman L, McCarthy AD, Sedlinsky C, et al. Metformin reverts deleterious effects of advanced glycation end-products (AGEs) on osteoblastic cells. Exp Clin Endocrinol Diabetes 2008; 116: 333-40.
31. Zhou Z, Immel D, Xi CX, et al. Regulation of osteoclast function and bone mass by RAGE. J Exp Med 2006; 203: 1067-80.
32. Luo W, Li X, Zhou Y, Xu D, Qiao Y. Correlation between bone mineral density and type 2 diabetes mellitus in elderly men and postmenopausal women. Sci Rep 2024; 14: 15078.
33. Shanbhogue VV, Mitchell DM, Rosen CJ, Bouxsein ML. Type 2 diabetes and the skeleton: new insights into sweet bones. Lancet Diabetes Endocrinol 2016; 4: 159-73.
34. Zhao LJ, Jiang H, Papasian CJ, et al. Correlation of obesity and osteoporosis: effect of fat mass on the determination of osteoporosis. J Bone Miner Res 2008; 23: 17-29.

35. Walsh JS, Vilaca T. Obesity, type 2 diabetes and bone in adults. Calcif Tissue Int 2017; 100: 528-535.
36. Shanbhogue VV, Hansen S, Frost M, et al. Compromised cortical bone compartment in type 2 diabetes mellitus patients with microvascular disease. Eur J Endocrinol 2016; 174: 115-24.
37. Kluding PM, Bareiss SK, Hastings M, et al. Physical training and activity in people with diabetic peripheral neuropathy: Paradigm shift. Phys Ther 2017; 97: 31-43.
38. Fang XY, Xu HW, Chen H, et al. The efficacy of nutritional screening indexes in predicting the incidence of osteosarcopenia and major osteoporotic fracture in the elderly. J Bone Miner Metab 2024; 42: 372-81.
39. Pan R, Wang R, Zhang Y, et al. The association of waist circumference with bone mineral density and risk of osteoporosis in US adult: National health and nutrition examination survey. Bone 2024; 185: 117134.
40. Hua Y, Fang J, Yao X, Zhu Z. Can waist circumference be a predictor of bone mineral density independent of BMI in middle-aged adults? Endocr Connect 2021; 10: 1307-14.