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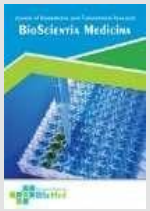

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Accuracy of Fat Mass and Muscle Mass Measured by Bioelectrical Impedance Analysis in Predicting Osteoporosis in Older Adults

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A B S T R A C T

Background: Osteoporosis is a prevalent bone disease characterized by reduced bone mineral density (BMD) and increased fracture risk. This study aimed to evaluate the accuracy of fat mass (FM) and muscle mass measured by bioelectrical impedance analysis (BIA) in predicting osteoporosis in older adults. **Methods:** A cross-sectional study was conducted on 109 outpatients aged 60 years and older. FM parameters (total fat mass, visceral fat level, and fat mass index [FMI]) and muscle mass parameters (total muscle mass, appendicular skeletal muscle mass [ASM], and appendicular skeletal muscle mass index [ASMI]) were measured using BIA. Osteoporosis was diagnosed based on BMD measurements using dual-energy X-ray absorptiometry (DXA). Receiver operating characteristic (ROC) curves were used to determine cut-off points and assess the accuracy of BIA parameters in predicting osteoporosis. **Results:** The prevalence of osteoporosis was 52.3% (n=57). The optimal cut-off points for predicting osteoporosis were: total fat mass >36.25%, visceral fat level >12.05, FMI >7.82 kg/m^2, total muscle mass <37.82 kg, ASM <16.795 kg, and ASMI <6.895 kg/m^2. Among the FM parameters, visceral fat level had the highest accuracy (AUC = 60.9%, sensitivity = 64.9%, specificity = 78.8%) while FMI had the lowest (AUC = 53.5%, sensitivity = 56.1%, specificity = 57.7%). For muscle mass parameters, ASM showed the highest accuracy (AUC = 74.0%, sensitivity = 70.2%, specificity = 76.9%). **Conclusion:** BIA-derived FM and muscle mass parameters, particularly visceral fat level and ASM can be used to predict osteoporosis in older adults with good accuracy. This non-invasive and accessible method may be useful as a screening tool for osteoporosis, especially in settings where DXA is unavailable.

1. Introduction

Osteoporosis, a prevalent bone disease, is characterized by a decline in bone mineral density (BMD) and deterioration of bone microarchitecture, leading to heightened bone fragility and increased risk of fractures. This condition poses a significant public health challenge due to its substantial impact on morbidity, mortality, and healthcare costs, particularly among aging populations. The prevalence of osteoporosis escalates with age, and it is more common in women, especially following menopause. The diagnosis of osteoporosis is typically confirmed through the measurement of BMD using dual-energy X-ray absorptiometry (DXA). However, DXA has limitations, including cost, accessibility, and radiation exposure. Consequently, there is a need for

alternative, non-invasive, and accessible methods for osteoporosis screening and risk assessment.[1-3]

Bioelectrical impedance analysis (BIA) is a non-invasive, accessible, and relatively inexpensive method for assessing body composition. It measures the resistance and reactance of body tissues to a low-level electrical current. BIA can provide estimates of various body composition parameters, including fat mass (FM) and muscle mass. Several studies have investigated the relationship between body composition parameters and BMD. Some studies have suggested that FM may have a negative impact on BMD, while others have found a positive correlation. The relationship between muscle mass and BMD is generally considered to be positive, as muscle mass contributes to bone loading and mechanical stimulation. The pathogenesis of osteoporosis involves an imbalance between bone formation and resorption, resulting in a net loss of bone mass. Various factors contribute to this imbalance, including hormonal changes, nutritional deficiencies, and lifestyle factors. In women, the decline in estrogen levels after menopause is a major contributor to osteoporosis. Estrogen plays a crucial role in maintaining bone density by inhibiting bone resorption and promoting bone formation. Adequate intake of calcium and vitamin D is essential for bone health. Calcium is a key component of bone tissue, and vitamin D promotes calcium absorption and bone mineralization. Smoking, excessive alcohol consumption, and lack of physical activity can also contribute to osteoporosis. Smoking and alcohol can interfere with bone metabolism, and physical inactivity can lead to reduced bone loading and mechanical stimulation.[4-7]

Body composition, particularly the distribution of FM and muscle mass, may also play a role in the development of osteoporosis. FM is the total amount of fat in the body, while muscle mass refers to the amount of skeletal muscle tissue. The relationship between FM and BMD is complex and not fully understood. Some studies have suggested that FM may have a protective effect on bone health, while others have found a negative association. The relationship between muscle mass and BMD is generally considered to be positive, as muscle mass contributes to bone loading and mechanical stimulation.[8-10] This study aimed to evaluate the accuracy of FM and muscle mass measured by BIA in predicting osteoporosis in older adults.

2. Methods

This cross-sectional study was conducted at the internal medicine outpatient clinic of a tertiary care hospital. The study population comprised outpatients aged 60 years and older who visited the clinic during the study period. The study protocol was approved by the hospital's ethics committee, and all participants provided written informed consent before enrollment. Individuals were considered eligible for the study if they met the following inclusion criteria; Age 60 years or older; Ability to understand and provide informed consent; Ability to stand upright and maintain balance for the duration of the BIA measurement. Participants were excluded from the study if they met any of the following exclusion criteria; Unwillingness to participate in the study; Cognitive impairment or inability to follow study procedures; Immobility or inability to lie supine for DXA scan; Presence of artificial implants, internal electronic devices, or metallic objects that may interfere with BIA or DXA measurements; Body weight exceeding the maximum limit of the BIA or DXA equipment; Medical conditions causing tremors or involuntary movements that may affect BIA measurements (e.g., Parkinson's disease); History of amputation that may affect body composition assessment; Chronic kidney disease with glomerular filtration rate <60 ml/min; Steroid use for more than 3 months; Autoimmune diseases (e.g., systemic lupus erythematosus, rheumatoid arthritis); Liver cirrhosis; Acute heart failure or chronic heart failure with NYHA functional class III-IV. These exclusion criteria were established to ensure the safety of participants, the accuracy of measurements, and the reliability of study results.

The sample size was calculated based on the estimated prevalence of osteoporosis in the study population. A previous study reported a prevalence of 50% among older adults in a similar setting. Using this estimate, a sample size of 100 participants was determined to provide sufficient power to detect a significant difference in body composition parameters between participants with and without osteoporosis. Potential participants were identified from the outpatient clinic registry and approached by trained research staff. The study objectives and procedures were explained to potential participants, and those who expressed interest and met the eligibility criteria were invited to participate. Written informed consent was obtained from all participants before enrollment.

Data collection involved a combination of anthropometric measurements, body composition assessment using BIA, and bone mineral density measurement using DXA. Anthropometric measurements included height, weight, and body mass index (BMI). Height was measured using a stadiometer, and weight was measured using a digital scale. BMI was calculated as weight in kilograms divided by height in meters squared. Body composition was assessed using a commercially available BIA device (Tanita BC-545N, Tokyo, Japan). The device operates on the principle of bioelectrical impedance, which involves measuring the resistance and reactance of body tissues to a low-level electrical current. The BIA device provides estimates of various body composition parameters, including; Total fat mass (kg); Visceral fat level (a unitless score indicating the amount of fat surrounding internal organs); Fat mass index (FMI, kg/m^2); Total muscle mass (kg); Appendicular skeletal muscle mass (ASM, kg); Appendicular skeletal muscle mass index (ASMI, kg/m^2). Before the BIA measurement, participants were instructed to adhere to the following guidelines; Avoid eating or drinking for at least 4 hours prior to the measurement; Avoid strenuous exercise for at least 12 hours prior to the measurement; Void their bladder within 30 minutes prior to the measurement; Remove any metallic objects, such as jewelry or watches; Wear light clothing and no shoes. Participants were then positioned on the BIA device according to the manufacturer's instructions, with their feet placed on the designated electrodes and their hands holding the handgrips. The BIA measurement was performed in a standing position, and the results were displayed on the device's screen.

Bone mineral density (BMD) was measured using dual-energy X-ray absorptiometry (DXA) (GE Medical Systems, Monterrey, Mexico). DXA is the gold standard for BMD measurement and is widely used for the diagnosis of osteoporosis. The DXA scan involves exposing the participant to a low dose of radiation, which is used to differentiate between bone and soft tissue. The BMD is then calculated based on the attenuation of the X-ray beams through the bone. BMD was measured at two skeletal sites: the proximal femur (femoral neck) and the lumbar spine (L2-L4). These sites are commonly used for osteoporosis assessment because they are prone to osteoporotic fractures. The DXA scan was performed by a trained technician, and the results were analyzed using the manufacturer's software.

Osteoporosis was diagnosed based on the World Health Organization (WHO) criteria, which defines osteoporosis as a T-score of -2.5 or lower at either the femoral neck or lumbar spine. The T-score is a standardized measure of BMD that compares an individual's BMD to the average BMD of young, healthy adults of the same gender. Data analysis was performed using SPSS statistical software. Descriptive statistics were used to summarize the characteristics of the study participants, including mean, standard deviation, median, and interquartile range for continuous variables, and frequency and percentage for categorical variables. Receiver operating characteristic (ROC) curve analysis was used to determine the optimal cut-off points for BIA parameters in predicting osteoporosis. The ROC curve is a graphical plot that illustrates the diagnostic ability of a test by plotting the true positive rate (sensitivity) against the false positive rate (1-specificity) at various threshold settings. The area under the ROC curve

(AUC) was used to quantify the overall accuracy of the BIA parameters in predicting osteoporosis. An AUC of 1.0 indicates perfect accuracy, while an AUC of 0.5 indicates no better than chance. Sensitivity, specificity, positive predictive value, negative predictive value, and likelihood ratios were also calculated for each BIA parameter at the optimal cut-off point. These measures provide additional information about the diagnostic performance of the BIA parameters. The relationship between BIA parameters and BMD was further explored using correlation analysis. Pearson's correlation coefficient was used to assess the linear association between continuous variables. The study findings were presented in tables and figures, and the results were interpreted in the context of the study objectives and existing literature. The limitations of the study were also discussed, and recommendations for future research were provided.

3. Results

This table presents the characteristics of the participants in the study, divided into two groups: those with osteoporosis (n=57) and those without osteoporosis (n=52). The average age of participants with osteoporosis was slightly higher (69 years) than those without (65 years), though this difference wasn't statistically significant (p=0.099). This suggests that age alone may not be the sole determinant of osteoporosis in this sample. There was a significant difference in gender distribution between the two groups (p<0.001). A larger proportion of females had osteoporosis (63.5%) compared to males (13.5%). This aligns with the known higher prevalence of osteoporosis in women, especially after menopause. The prevalence of diabetes, hypertension, and smoking was similar between the two groups (p>0.05). This indicates that these comorbidities may not be strong independent risk factors for osteoporosis in this study population. A notable difference was observed in BMI categories (p=0.007). A higher percentage of participants with osteoporosis were underweight (28.1%) compared to those without osteoporosis (3.8%). This suggests that lower BMI could be associated with an increased risk of osteoporosis. Participants with osteoporosis had significantly lower vitamin D levels (25.79 ng/mL) compared to those without osteoporosis (28.97 ng/mL) (p<0.001). This highlights the crucial role of vitamin D in maintaining bone health. While there were some minor differences in calcium and estimated glomerular filtration rate (eGFR) between the two groups, these differences were not statistically significant.

Table 2 provides valuable insights into the ability of various BIA measurements to predict osteoporosis in older adults. The table presents the optimal cut-off points for each BIA parameter to differentiate between individuals with and without osteoporosis. For example; Total fat mass: A value greater than 36.25% indicates a higher likelihood of osteoporosis; Visceral fat level: A score above 12.05 suggests an increased risk; ASM: A value below 16.795 kg indicates a higher risk. These cut-off points can be used in clinical practice to identify individuals who may benefit from further assessment for osteoporosis. The table also shows the accuracy of each BIA parameter in predicting osteoporosis, as measured by the area under the ROC curve (AUC), sensitivity, and specificity. Visceral fat level demonstrated the highest accuracy among the fat mass parameters (AUC = 60.9%, sensitivity = 64.9%, specificity = 78.8%). This suggests that visceral fat may be a particularly important factor in osteoporosis development. ASM showed the highest accuracy among the muscle mass parameters (AUC = 74.0%, sensitivity = 70.2%, specificity = 76.9%). This highlights the crucial role of muscle mass in maintaining bone health. FMI had the lowest accuracy among all parameters (AUC = 53.5%, sensitivity = 56.1%, specificity = 57.7%). This may be because FMI doesn't differentiate between subcutaneous and visceral fat, which may have different effects on bone health. The table also includes positive predictive value (PPV), negative predictive value (NPV), and likelihood ratios (LR). These measures provide additional information about the diagnostic performance of each BIA parameter.

PPV indicates the probability that an individual with a positive test result actually has osteoporosis. NPV indicates the probability that an individual with a negative test result truly does not have osteoporosis. LR indicates how much a test result changes the likelihood of having osteoporosis.

Table 1. Participant characteristics.

Characteristic	Osteoporosis (n=57)	No osteoporosis (n=52)	Total (n=109)	p-value
Age (years)	69 ± 6.6	65 (60-81)	66 (60-83)	0.099*
Gender				<0.001**
Male	10 (13.5%)	25 (33.8%)	35 (32.1%)	
Female	47 (63.5%)	27 (36.5%)	74 (67.9%)	
Diabetes mellitus				0.436**
Yes	7 (9.5%)	9 (12.2%)	16 (14.7%)	
No	50 (67.6%)	43 (58.1%)	93 (85.3%)	
Hypertension				0.666**
Yes	19 (25.7%)	26 (31.5%)	45 (41.3%)	
No	38 (51.4%)	26 (31.5%)	64 (58.7%)	
Smoking				0.193**
Yes	11 (19.3%)	16 (30.8%)	27 (24.8%)	
No	46 (80.7%)	36 (69.2%)	82 (75.2%)	
BMI (kg/m²)				0.007**
Underweight	16 (28.1%)	2 (3.8%)	18 (16.5%)	
Normal	19 (33.3%)	25 (43.9%)	44 (40.3%)	
Overweight	19 (33.3%)	20 (35.1%)	39 (35.7%)	
Obese	3 (5.3%)	5 (8.8%)	8 (7.3%)	
Vitamin D 25 OH (ng/mL)	25.79 ± 3.39	28.97 ± 3.19	27 (17-35)	<0.001***
Calcium (mg/dl)	8.6 (7.9-10.5)	8.8 (8.5-9.7)	8.70 (7.9-10.5)	0.004*
eGFR (ml/min/1.73 m^2)	79.75 (60.1-130.8)	72 (60.5-128.3)	78.07 (60.1-130.8)	0.097*

Data are presented as mean ± standard deviation, number (percentage), or median (range) as appropriate. *Mann-Whitney test; **Chi-square test; ***Independent T-test. eGFR = estimated glomerular filtration rate.

Table 2. The optimal cut-off points for predicting osteoporosis based on BIA measurements.

Measurement	Cut-off point	AUC (%)	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Positive LR	Negative LR	Accuracy (%)
Total fat mass	>36.25%	65.3	64.9	71.2	71	65	2.24	0.49	67.89
Visceral fat level	>12.05	60.9	64.9	78.8	77	67.2	03.06	0.44	71.5
FMI	>7.82 kg/m²	53.5	56.1	57.7	59.2	54.5	1.32	0.76	56.8
Total muscle mass	<37.82 kg	69.3	71.9	63.5	68.3	67.3	1.97	0.44	67.8
ASM	<16.795 kg	74.0	70.2	76.9	74	70	03.03	0.39	73
ASMI	<6.895 kg/m²	73.6	70.2	61.5	66.6	65.3	1.8	0.48	66

PPV = Positive Predictive Value; NPV = Negative Predictive Value; LR = Likelihood Ratio.

Figure 1 displays the receiver operating characteristic (ROC) curves, which illustrate the diagnostic ability of different BIA measurements to predict osteoporosis. These curves plot sensitivity (true positive rate) against 1-specificity (false positive rate) at various thresholds; A. ROC Curve for Fat Mass: This graph shows the ROC curves for three fat mass parameters: total fat mass, visceral fat level, and FMI. The closer the curve is to the upper left corner, the better its discriminatory power. The visceral fat level has the curve closest to the upper left corner, indicating it's the best predictor of osteoporosis among the fat mass parameters. This aligns with Table 2, which showed visceral fat levels having the highest AUC (60.9%). Total fat mass also shows a decent predictive ability, though not as strong as visceral fat level. FMI has the curve closest to the diagonal line, indicating its lower accuracy in predicting osteoporosis compared to the other two measures. This is consistent with its lower AUC (53.5%) in Table 2; B. ROC Curve for Muscle Mass: This graph displays the ROC curves for three muscle mass parameters: total muscle mass, ASM, and ASMI. ASM has the curve closest to the upper left corner, suggesting it's the most accurate predictor of osteoporosis among the muscle mass parameters. This supports the findings in Table 2, where ASM had the highest AUC (74.0%). ASMI and total muscle mass also show good predictive abilities, but ASM appears to be slightly superior.

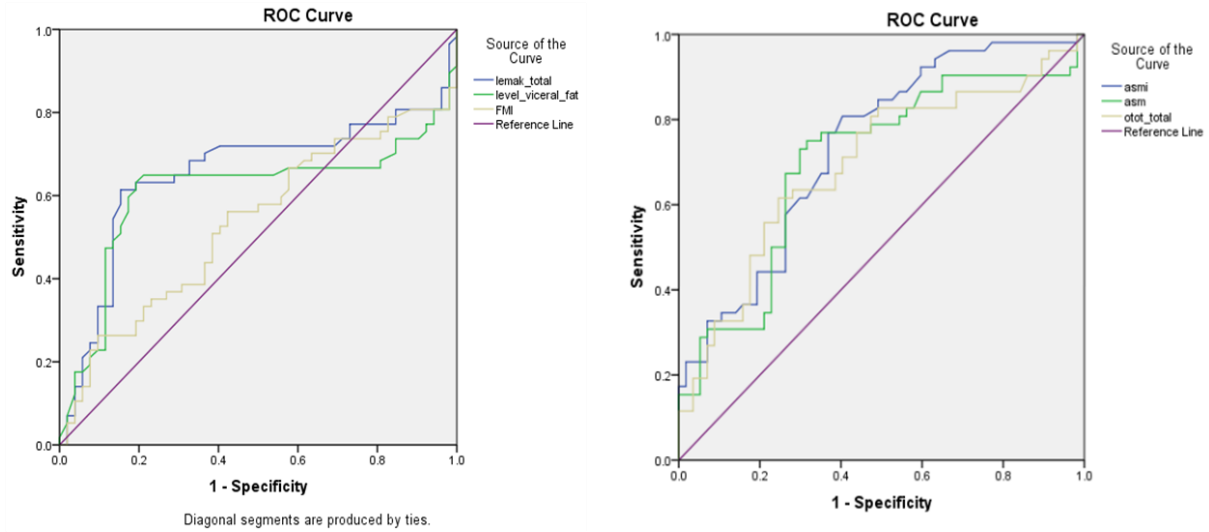

Figure 1. A. ROC curve for fat mass. B. ROC Curve for muscle mass.

4. Discussion

This study singles out visceral fat as a significant predictor of osteoporosis among the various fat mass parameters measured. This finding corroborates a growing body of research that underscores the detrimental impact of visceral fat on bone health. Visceral fat, often termed 'active fat,' exhibits distinct metabolic characteristics compared to subcutaneous fat. It releases a complex array of adipokines (hormones produced by fat cells) and inflammatory cytokines (signaling molecules involved in inflammation). These substances can disrupt the delicate balance between bone formation and resorption, tilting the scales towards bone loss. Visceral fat is associated with a chronic, low-grade inflammatory state. This persistent inflammation can negatively impact bone remodeling, the ongoing process of bone renewal. Inflammation can stimulate osteoclasts, the cells responsible for breaking down bone tissue, leading to increased bone resorption and

decreased bone density. Visceral fat can also interfere with hormonal regulation, further contributing to bone loss. For instance, it can elevate cortisol levels, a stress hormone known to inhibit bone formation and promote bone resorption. The adipokines secreted by visceral fat can also directly affect bone health. Leptin, an adipokine involved in appetite regulation, has been shown to have complex effects on bone metabolism. While some studies propose that leptin may have a protective role, others indicate that high levels of leptin, often associated with increased visceral fat, can contribute to bone loss. Visceral fat's location plays a crucial role in its detrimental effects on bone health. Situated deep within the abdominal cavity, surrounding vital organs, it can release inflammatory mediators directly into the portal circulation, which carries blood to the liver. This can lead to systemic inflammation, affecting various tissues, including bone. The accumulation of visceral fat is often associated with other metabolic disturbances, such as insulin resistance and dyslipidemia (abnormal blood lipid levels). These disturbances can further exacerbate bone loss and increase the risk of osteoporosis. The negative impact of visceral fat on bone health may be particularly pronounced in postmenopausal women. With declining estrogen levels, the protective effects of estrogen on bone diminish. This makes postmenopausal women more susceptible to the detrimental effects of visceral fat. The strong association between visceral fat and osteoporosis underscores the importance of assessing visceral fat levels in older adults, especially those at risk for osteoporosis. Lifestyle modifications, including regular exercise, a balanced diet, and weight management, are crucial for reducing visceral fat and promoting bone health. This study revealed that FMI, a measure of total body fat relative to height, had the lowest accuracy in predicting osteoporosis compared to other assessed parameters. This might be due to FMI's inability to differentiate between different types of FM, which is crucial in understanding their impact on bone health. Subcutaneous fat, stored beneath the skin, has been associated with a protective effect on bone health. It may act as a buffer, releasing estrogen, a hormone vital for maintaining bone density. Visceral fat, on the other hand, has a detrimental effect on bone health. Located deep within the abdominal cavity, surrounding vital organs, it releases inflammatory mediators that can disrupt bone metabolism. FMI provides an overall picture of body fat but fails to capture the nuances of fat distribution. This limitation may explain its lower accuracy in predicting osteoporosis compared to visceral fat level, which specifically targets the type of fat most harmful to bone health. Subcutaneous and visceral fat exhibit distinct metabolic properties. Visceral fat is more metabolically active and releases a greater amount of adipokines and inflammatory cytokines, which can negatively impact bone health. The different types of fat also interact differently with hormones. Subcutaneous fat can aromatize androgens to estrogens, contributing to the protective effect of estrogen on bone. Visceral fat, however, is associated with increased cortisol production, which can have a detrimental effect on bone. Visceral fat is associated with a greater risk of metabolic disorders, such as insulin resistance, type 2 diabetes, and cardiovascular disease. These conditions can also indirectly contribute to bone loss and increase osteoporosis risk. Healthcare providers should be aware of the limitations of FMI in assessing osteoporosis risk. It is crucial to consider other measures, such as waist circumference or imaging techniques, to specifically assess visceral fat levels. Lifestyle interventions, including exercise and diet modifications, should focus on reducing visceral fat to promote bone health. The findings of this study have important implications for osteoporosis screening and management. Healthcare providers should consider incorporating measures of visceral fat, such as waist circumference or imaging techniques, into their osteoporosis risk assessment. This targeted approach can help identify individuals who may benefit from early intervention. It is important to differentiate between subcutaneous and visceral fat, as they have distinct effects on bone health. Visceral fat is a stronger predictor of

osteoporosis than subcutaneous fat. Measuring visceral fat can help identify individuals at higher risk of osteoporosis who may not be identified by traditional risk factors such as age and gender. Lifestyle modifications play a crucial role in reducing visceral fat and promoting bone health. These modifications include regular physical activity, a balanced diet rich in calcium and vitamin D, and maintaining a healthy weight. Regular exercise, especially weight-bearing and resistance training, can help increase bone density and reduce bone loss. A balanced diet rich in calcium and vitamin D is essential for maintaining bone health. Maintaining a healthy weight can help reduce the risk of osteoporosis, as obesity, especially abdominal obesity, is associated with increased bone loss. Understanding the interplay between FM and bone health allows for more personalized interventions. For instance, individuals with high visceral fat may benefit from targeted strategies to reduce this specific type of fat, in addition to traditional osteoporosis management. Personalized interventions may include targeted exercise programs, dietary counseling, and weight management strategies. Individuals with high visceral fat may benefit from additional interventions such as stress management techniques and adequate sleep, as these factors can also influence visceral fat accumulation and bone health. The findings of this study may also have implications for the prevention of osteoporosis. By identifying individuals at higher risk of osteoporosis, healthcare providers can implement preventive measures such as lifestyle modifications and pharmacological interventions. The use of BIA as a screening tool for osteoporosis may be particularly beneficial in settings where DXA is unavailable or inaccessible. BIA is a non-invasive, accessible, and relatively inexpensive method that can be easily performed in various healthcare settings.[11-13]

This study found that appendicular skeletal muscle mass (ASM) had the highest accuracy among the muscle mass parameters in predicting osteoporosis. This finding is consistent with previous studies that have shown a positive association between muscle mass and bone mineral density (BMD). Muscle mass contributes to bone loading and mechanical stimulation, which are essential for maintaining bone health. The study found that total muscle mass and ASMI also had good accuracy in predicting osteoporosis, although not as high as ASM. This suggests that all three muscle mass parameters may be useful indicators of osteoporosis risk. Muscle mass plays a vital role in maintaining bone health through a complex interplay of mechanisms. This study's findings, which highlight the accuracy of muscle mass parameters in predicting osteoporosis risk, underscore the importance of preserving muscle mass, particularly in older adults. The contraction and relaxation of muscles exert mechanical forces on bones, stimulating bone formation and strengthening bone tissue. These forces create microscopic deformations in the bone matrix, triggering a cascade of cellular events that lead to increased bone formation and mineralization. The magnitude and frequency of these forces influence the extent of bone adaptation. Activities that generate high-impact forces or require significant muscle exertion, such as weightlifting, plyometrics, and stair climbing, are particularly effective in stimulating bone formation. This mechanical loading is essential for maintaining bone density and preventing bone loss. Bone is a dynamic tissue that constantly adapts to the mechanical demands placed upon it. In the absence of adequate mechanical loading, bone resorption exceeds bone formation, leading to a net loss of bone mass and increased risk of osteoporosis. Weight-bearing exercises, such as walking, running, and jumping, are particularly effective in stimulating bone formation. These activities generate ground reaction forces that are transmitted through the skeleton, stimulating bone adaptation. The impact forces generated during these activities are greater than those experienced during non-weight-bearing activities, such as swimming or cycling. Resistance training, which involves working against a force, can also help increase bone density. Resistance training involves the use of weights, resistance bands, or bodyweight

exercises to challenge muscles and stimulate bone adaptation. Resistance training can be particularly beneficial for older adults who may have reduced muscle mass and strength. Muscle tissue produces hormones, such as insulin-like growth factor 1 (IGF-1), that promote bone growth and mineralization. IGF-1 is a growth factor that stimulates osteoblast proliferation and differentiation, leading to increased bone formation. IGF-1 also enhances calcium absorption in the gut, increasing the availability of calcium for bone mineralization. Maintaining muscle mass helps ensure adequate production of IGF-1 and other hormones that support bone health. Muscle mass and strength decline with age, which can lead to reduced production of IGF-1 and other bone-protective hormones. Regular exercise and adequate protein intake can help preserve muscle mass and hormone production, supporting bone health. Muscle tissue is a major site of protein synthesis, and adequate protein intake is essential for maintaining both muscle and bone mass. Protein provides the amino acids necessary for building and repairing muscle tissue. Adequate protein intake also supports bone formation and mineralization. Protein provides the building blocks for muscle protein synthesis, which is essential for muscle growth and repair. Muscle protein synthesis is a continuous process that is influenced by various factors, including exercise, nutrition, and hormonal status. Adequate protein intake ensures that the body has the necessary amino acids to support muscle protein synthesis. Adequate protein intake also supports bone formation and mineralization. Protein is a key component of bone matrix, providing the structural framework for bone mineralization. Adequate protein intake ensures that the body has the necessary resources to support bone formation and mineralization. Older adults may require higher protein intake than younger adults to maintain muscle and bone mass. Age-related decline in muscle mass and strength, known as sarcopenia, can be exacerbated by inadequate protein intake. Higher protein intake can help mitigate sarcopenia and preserve bone health in older adults. Strong muscles improve balance and coordination, reducing the risk of falls and fractures, especially in older adults. Muscle strength and balance are essential for maintaining postural stability and preventing falls. Falls are a major cause of fractures in older adults, and osteoporosis increases the risk of fractures from falls. Falls are a major cause of fractures in older adults, and osteoporosis increases the risk of fractures from falls. Osteoporosis weakens bones, making them more susceptible to fractures. Falls can result in fractures even in individuals with relatively healthy bones, but the risk is significantly higher in those with osteoporosis. Maintaining muscle strength and balance can help prevent falls and reduce the risk of fractures. Regular exercise, particularly strength training and balance exercises, can help improve muscle strength and balance, reducing the risk of falls. Other measures, such as home safety modifications and medication review, can also help prevent falls in older adults. Appendicular skeletal muscle mass (ASM), which represents the muscle mass of the limbs, emerged as a significant predictor of osteoporosis in this study. This finding aligns with the understanding that the muscles in our limbs play a crucial role in weight-bearing and locomotion, activities that exert substantial mechanical forces on bones. Maintaining ASM is thus vital for preserving bone health and preventing osteoporosis. The human skeleton is a dynamic structure that constantly adapts to the mechanical demands placed upon it. When muscles contract and relax during movement and weight-bearing activities, they exert forces on the bones. These forces stimulate bone formation and enhance bone strength. The muscles in our limbs, responsible for supporting our body weight and facilitating movement, play a central role in this process. ASM, encompassing the muscle mass of both arms and legs, is a key contributor to the mechanical loading that promotes bone health. Stronger muscles in the limbs generate greater forces during weight-bearing and locomotion, leading to increased stimulation of bone formation. This is crucial for maintaining bone density and structural integrity,

reducing the risk of osteoporosis and fractures. Preserving ASM is particularly important with advancing age. Age-related decline in muscle mass, known as sarcopenia, is a common phenomenon that can contribute to decreased bone density and increased risk of osteoporosis. Maintaining ASM through regular exercise and adequate nutrition can help mitigate these age-related changes and promote bone health. The strong association between ASM and bone health underscores the importance of assessing and monitoring ASM in individuals, especially older adults. Healthcare providers can use various methods, including BIA, to estimate ASM and identify individuals at risk of osteoporosis. Promoting interventions that help maintain ASM, such as strength training and resistance exercises, is crucial for preserving bone health and preventing osteoporosis-related fractures. While appendicular skeletal muscle mass (ASM) emerged as the most accurate predictor of osteoporosis in this study, total muscle mass and ASMI also demonstrated good predictive ability. This suggests that overall muscle mass, and not just the muscle mass in the limbs, plays a significant role in maintaining bone health. Total muscle mass represents the cumulative muscle content throughout the body, including skeletal muscles in the limbs, trunk, and head. Maintaining adequate total muscle mass is essential for overall health and functional capacity. Muscle tissue plays a crucial role in regulating metabolism, glucose homeostasis, and energy expenditure. Maintaining adequate total muscle mass can help prevent metabolic disorders that can indirectly affect bone health. Total muscle mass contributes to overall strength and power, which are essential for performing daily activities and maintaining independence. Muscle tissue produces hormones, such as IGF-1, that support bone growth and mineralization. Preserving total muscle mass helps ensure adequate production of these bone-protective hormones. ASMI is a measure of muscle mass relative to body size, calculated by dividing ASM by height squared. It provides a standardized assessment of muscle mass that accounts for individual differences in height. It helps determine whether an individual has adequate muscle mass for their height, which is crucial for maintaining bone health and functional capacity. Low ASMI can indicate sarcopenia, a condition characterized by age-related loss of muscle mass and strength, which increases the risk of osteoporosis and fractures. Healthcare providers should consider both total muscle mass and ASMI when assessing osteoporosis risk and developing intervention strategies. Encouraging regular exercise, including both resistance training and weight-bearing activities, is crucial for maintaining total muscle mass and ASMI. Adequate protein intake is essential for preserving muscle mass. Older adults may benefit from dietary counseling or protein supplementation to ensure they meet their protein needs. Maintaining muscle strength, balance, and coordination can help reduce the risk of falls and fractures, particularly in older adults with osteoporosis.[14-17]

Bioelectrical impedance analysis (BIA) has emerged as a promising tool for osteoporosis screening, offering several advantages over traditional methods like dual-energy X-ray absorptiometry (DXA). This study's findings, which demonstrate the accuracy of BIA in predicting osteoporosis risk, support its potential use in a variety of healthcare settings. BIA does not involve any radiation exposure or injections, making it a safe and comfortable option for patients. BIA devices are portable and relatively inexpensive, increasing their accessibility in various healthcare settings, including primary care clinics, community health centers, and even pharmacies. BIA measurements can be performed quickly, typically within minutes, allowing for efficient screening of large populations. BIA devices are easy to operate, requiring minimal training for healthcare providers. Compared to DXA, BIA is a more cost-effective screening tool, making it a viable option for resource-constrained settings. BIA can provide valuable information for osteoporosis screening by assessing body composition parameters associated with bone health. Particularly visceral fat, which has been linked to increased osteoporosis risk. BIA can

help identify individuals with high levels of visceral fat who may benefit from further assessment and intervention. Muscle mass plays a crucial role in maintaining bone health through mechanical stimulation and hormonal influence. BIA can assess muscle mass and identify individuals with low muscle mass who may be at higher risk of osteoporosis. BIA can be integrated into routine primary care checkups for older adults, providing a quick and accessible assessment of osteoporosis risk. BIA can be used in community health centers to screen individuals who may not have regular access to healthcare services. BIA can be used to target osteoporosis screening for individuals with specific risk factors, such as family history, low BMI, or history of fractures. BIA can be used to monitor the effectiveness of lifestyle interventions, such as exercise and diet modifications, in improving body composition and reducing osteoporosis risk. BIA may be particularly useful in settings where DXA is unavailable or inaccessible, such as in rural areas or developing countries. Its portability and affordability make it a feasible option for expanding osteoporosis screening to underserved populations. BIA can provide information on various body composition parameters beyond FM and muscle mass, such as total body water, bone mineral content, and basal metabolic rate. These parameters can provide a more comprehensive assessment of an individual's health status and risk factors for osteoporosis. BIA can be used in conjunction with other screening tools, such as questionnaires and clinical risk factors, to improve the accuracy of osteoporosis risk assessment. BIA can be used to monitor changes in body composition over time, which can help assess the effectiveness of interventions and track disease progression. BIA is a safe and effective tool for osteoporosis screening in various populations, including older adults, postmenopausal women, and individuals with chronic diseases.[18-20]

5. Conclusion

This study indicates that BIA-derived fat mass and muscle mass parameters, specifically visceral fat level and ASM, can effectively predict osteoporosis in older adults. This non-invasive, accessible method holds potential as a valuable screening tool for osteoporosis, particularly in settings where DXA is unavailable. Utilizing BIA for osteoporosis screening could lead to earlier identification of at-risk individuals, enabling timely intervention and better bone health outcomes.

6. References

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