Original article

doi:10.5633/amm.2026.0302

Correlation Between Bone Mineral Density and Muscle Mass in Postmenopausal Women

Vuk Pejčić[1], Vukota Radovanović[1,2], Božidar Janković[1], Marija Luković[1], Maja Radojlović[1], Anita Stanković[1,2], Dragan Zlatanović[1,2]

[1]University Clinical Center Niš, Clinic for Physical Medicine and Rehabilitation, Niš, Serbia
[2]University of Niš, Faculty of Medicine, Department of Physical Medicine and Rehabilitation, Niš, Serbia

Contact: Vuk Pejčić
48 Dr. Zorana Djindjića Blvd., 18000 Niš, Serbia
E-mail: vukpejcic96@gmail.com

Osteoporosis is a medical condition characterized by reduced bone strength and an increased risk of fractures. The diagnosis of osteoporosis is established using DXA (Dual-Energy X-ray Absorptiometry) scanning.

The aim of this study was to determine BMD categories in postmenopausal women and to examine the relationship between BMD and muscle mass.

A prospective clinical study was conducted at the Clinic for Physical Medicine and Rehabilitation, University Clinical Center Niš, from September to December 2025. The study included 41 women in stable menopause. In addition to BMD, appendicular skeletal muscle mass (ASM) and the appendicular skeletal muscle mass index (ASMI) were measured using osteodensitometry.

Based on BMD values, participants were divided into three groups. The first group consisted of women with normal BMD, the second with osteopenia, and the third with osteoporosis. The mean ASM value was statistically significantly higher in women with normal BMD compared to those with osteoporosis ($p < 0.01$). ASM in women with osteopenia was significantly higher than in those with osteoporosis

($p < 0.05$). ASMI was also significantly higher in women with normal BMD compared to those with osteoporosis ($p < 0.01$).

A statistically significant difference in appendicular skeletal muscle mass and its corresponding index was demonstrated in postmenopausal women with normal BMD compared to those with osteopenia and osteoporosis. The coexistence of reduced bone density and muscle mass loss is common, highlighting the important role of physical and rehabilitation medicine in the prevention and treatment of these conditions.

Key words: bone mineral density, appendicular skeletal muscle mass, osteopenia, osteoporosis

Originalni rad

doi:10.5633/amm.2026.0302

Korelacija mineralne koštane gustine i mišićne mase kod žena u menopauzi

Vuk Pejčić[1], Vukota Radovanović[1,2], Božidar Janković[1], Marija Luković[1], Maja Radojlović[1], Anita Stanković[1,2], Dragan Zlatanović[1,2]

[1]Univerzitetski klinički centar Niš, Klinika za fizikalnu medicinu i rehabilitaciju, Niš, Srbija
[2]Univerzitet u Nišu, Medicinski fakultet, Katedra za fizikalnu medicinu i rehabilitaciju, Niš, Srbija

Kontakt: Vuk Pejčić
Bul. dr Zoran Đinđić 48, 18000 Niš, Srbija
E-mail: vukpejcic96@gmail.com

Osteoporoza je zdravstveno stanje koje karakteriše slabost kostiju i sklonost lomljenju. Dijagnoza osteoporoze se postavlja pomoću DXA (Dual-Energy X-ray Absorptiometry) skeniranja. Vrednosti mineralne koštane gustine (BMD) iznad -1 SD (standardne devijacije) su normalno stanje, između -1 i -2,5 SD je osteopenija, a vrednost ≤ -2,5 SD je osteoporoza.
Cilj rada je bio da se odredi BMD grupe žena u postmenopauzi kao i odnos između BMD i količine mišićne mase.
Prospektivna klinička studija je rađena na Klinici za Fizikalnu medicinu i rehabilitaciju UKC Niš od septembra do decembra 2025. Istraživanje je obuhvatilo 41 ženu u stabilnoj menopauzi, kod kojih je pored BMD, izmerena masa apendikularnih skeletnih mišića (ASM) i indeks apendikularne skeletne mase (ASMI) osteodenzitometrijom.
Prema vrednostima BMD, ispitanici su podeljeni u 3 grupe. U prvoj grupi bile su pacijentkinje sa normalnom vrednosti BMD, u drugoj grupi sa osteopenijom, a u trećoj sa osteoporozom. Prosečna vrednost ASM je bila statistički značajno veća u pacijentkinja sa normalnom BMD u odnosu na one sa osteoporozom ($p<0.01$). ASM kod pacijentkinja sa osteopenijom je bila značajno veća u poređenju sa grupom sa osteoporozom ($p<0.05$). ASMI bio je statistički značajno veći kod pacijentkinja sa normalnom BMD u odnosu na grupu sa osteoporozom ($p<0.01$)
Pokazana je statistički značajna razlika količine apendikularne skeletno-mišićne mase i istoimenog indeksa kod žena u menopauzi sa normalnom BMD u odnosu na one sa osteopenijom i osteoporozom. Učestalost koegzistiranja smanjenja gustine kostiju i gubitka mišićne mase je značajna te je potrebno istaći ulogu fizikalne i rehabilitacione medicine u prevenciji i lečenju ovih stanja.

Kljuučne reči: mineralna koštana gustina, apendikularna skeletna masa mišića, osteopenija, osteoporoza.

Introduction

Osteoporosis is a bone disease characterized by reduced bone mineral density and bone mass, resulting in altered bone structure and strength. The consequence is bone weakness, fragility, and an increased risk of fractures (1). It develops slowly over many years and is often diagnosed only after a fall or if a minor trauma causes a fracture. There are no symptoms that directly indicate osteoporosis; the first symptom is often a fracture. The most common fractures associated with osteoporosis are wrist fractures, femoral neck fractures, and vertebral fractures. The diagnosis of osteoporosis is established using osteodensitometry (Dual-Energy X-ray Absorptiometry – DXA), a short, non-invasive method that compares the patient's bone mineral density with an appropriate reference group of young, healthy women or men. Reference sites include the lumbar spine (L1–L4), femoral neck, and radius. The difference between the patient's BMD and reference values is expressed in standard deviations (SD). BMD values above −1 SD are considered normal, values between −1 and −2.5 SD indicate bone loss defined as osteopenia, and values below −2.5 SD define osteoporosis (2,3).

Before the widespread use of DXA analysis, osteoporosis was rarely diagnosed and primarily identified in women with symptomatic vertebral fractures or osteopenia noted incidentally on radiographs. Hip fractures were long considered a consequence of aging or were neglected in terms of treatment. Measurement of bone mineral density (BMD) using DXA at any skeletal site is a strong predictor of future vertebral and hip fractures (2).

Risk factors for osteoporosis in both men and women include smoking, family history of fractures, age over 65 years, and both low and high body mass index (BMI), particularly in men. Secondary causes of osteoporosis include chronic glucocorticoid therapy, gastrointestinal disorders, diabetes mellitus (type 1 and type 2), rheumatoid arthritis, liver disease, celiac disease, multiple myeloma, and other hematological disorders. However, primary osteoporosis is most commonly associated with estrogen loss in postmenopausal women or age-related deterioration of skeletal microarchitecture. Increased bone resorption characterizes most forms of osteoporosis, although the etiology is multifactorial.

Advances in DXA technology now allow whole-body scanning, enabling assessment not only of bone density but also total bone mass and the amount of muscle and fat tissue.

Muscle mass is expressed as appendicular skeletal muscle mass (ASM) and the appendicular skeletal muscle mass index (ASMI). ASM represents the muscle mass of the upper and lower extremities, while ASMI is calculated as ASM divided by the square of the patient's height.

Several studies have demonstrated a positive correlation between muscle mass and bone mineral density (4–6).

There is a close relationship between muscle mass, bone density, and physical exercise. Exercise not only increases muscle mass but also improves bone density (7,8).

Aim of the Study

The aim of this study was to determine bone mineral density using DXA scanning in postmenopausal women and to assess the correlation between bone density and muscle mass.

Methodology

This prospective clinical study was conducted at the Clinic for Physical Medicine and Rehabilitation, University Clinical Center Niš, from September to December 2025. Inclusion criteria were female sex, age over 50 years, and stable menopause. The study included 41 women in stable menopause, with a mean age of 61.49 ± 12.95 years.

Body height and body weight were measured for all participants, and BMI was calculated. Measurements were performed using a calibrated scale (Kern and Son GmbH).

After medical history assessment and physical examination, appendicular skeletal muscle mass (ASM) was measured in all participants, and the appendicular skeletal muscle mass index (ASMI) was calculated as ASM divided by the square of body height. Based on current diagnostic guidelines by European Working Group for Sarcopenia in older people (EWGSOP2), ASMI < 5,5kg/m^2 is one of the diagnostic criteria for sarcopenia in older woman. Bone mineral density and ASM measurements were performed using a DXA device (GE Healthcare X-ray Bone Densitometer with enCore v18 software).

BMD was measured at the lumbar spine (L1–L4) and bilaterally at the femoral neck. T-scores were determined, indicating deviation from the average BMD of young, healthy women, expressed in standard deviations (SD). Normal T-score values are above −1 SD. Based on T-score values, participants were divided into three groups: normal BMD (T-score ≥ −1 SD), osteopenia (T-score between −1 and −2.5 SD), and osteoporosis (T-score ≤ −2.5 SD). ASM was measured using the total body scanning mode. Exclusion criteria included: treatment with bisphosphonates, monoclonal antibodies, corticosteroids, anabolic drugs, or any medication affecting bone density. Patients with diagnosed malignancies, autoimmune diseases, severe chronic illnesses or osteosynthetic material in the lumbar spine or hips were also excluded.

Statistical analysis was performed using IBM SPSS v27.0. Measures of central tendency and variability were calculated. The Shapiro–Wilk test was used to assess data normality. One-way ANOVA was used to determine statistical significance, with $p < 0.05$ considered significant.

Results

The study included 41 women. Based on T-score values, participants were divided into three groups: 13 women (31.7%) with normal bone density, 16 women (39%) with osteopenia, and 12 women (29.3%) with osteoporosis (Table 1, Figure 1).

Table 1. Distribution of subjects by group according to bone mineral density (BMD)

		Number of subjects	%
Group	Normal BMD	13	31.7
	Osteopenia (-1 do -2.5SD)	16	39.0
	Osteoporosis (≤-2.5)	12	29.3
Total		41	100.0

BMD- Bone Mineral density

Figure 1. Distribution of respondents by group (in %)

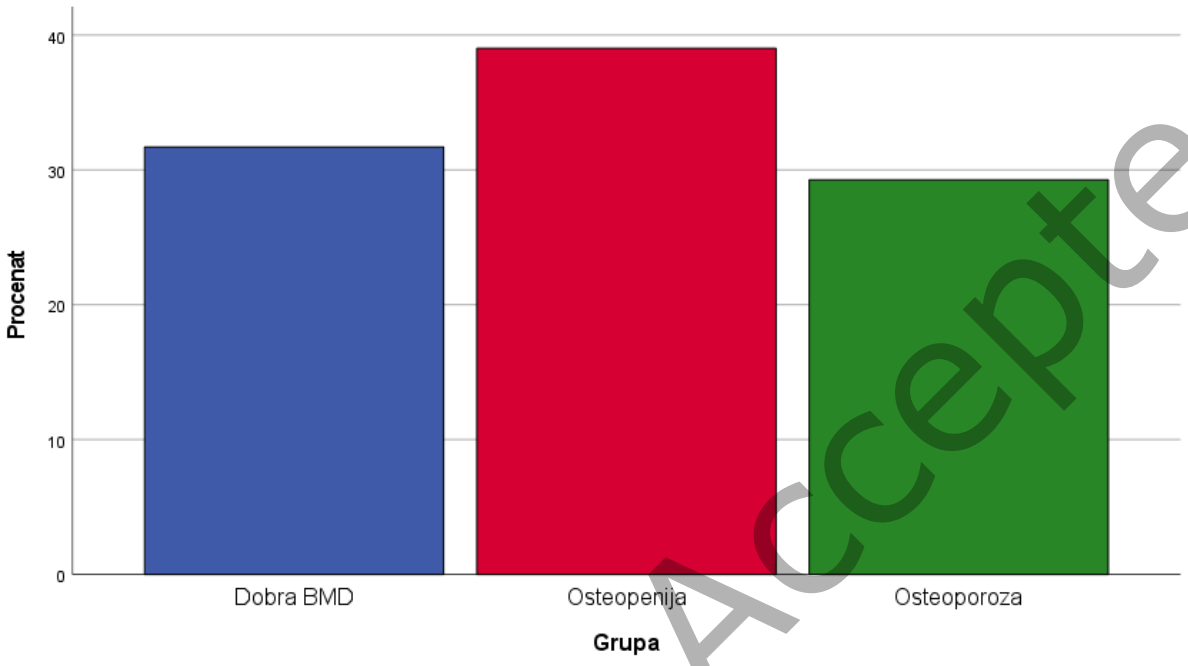


Table 2 presents the mean age, height, body weight, BMI, mean ASM, and ASMI values of all participants. The mean age was 61.49 ± 12.95 years, and mean height was 162.24 ± 6.02 cm. Mean body weight was 70.80 ± 11.46 kg, and mean BMI was 26.89 ± 4.09 kg/m². The mean ASM was 17,045.98 ± 3,006.47 g, and mean ASMI was 6.46 ± 1.02 kg/m².

According to the Shapiro–Wilk test ($p > 0.05$), ASM and ASMI data showed a normal distribution.

Table 2. Mean and standard deviation (SD) for demographic and body-skeletal parameters

	AS ± SD
Age (years)	61.49 ± 12.95
Height (cm)	162.24 ± 6.02
Weight (kg)	70.80 ± 11.46
BMI (kg/m^2)	26.89 ± 4.09
ASM (g)	17045.98 ± 3006.47
ASM Index (kg/m^2)	6.46 ± 1.02

BMI-Body mass Index, ASM- appendicular skeletal muscle mass, ASMI appendicular skeletal muscle mass Index

Table 3 presents mean age, BMI, age at menopause onset, ASM, and ASMI across the three groups. No statistically significant differences were found in age, BMI, or age at menopause onset between the groups.

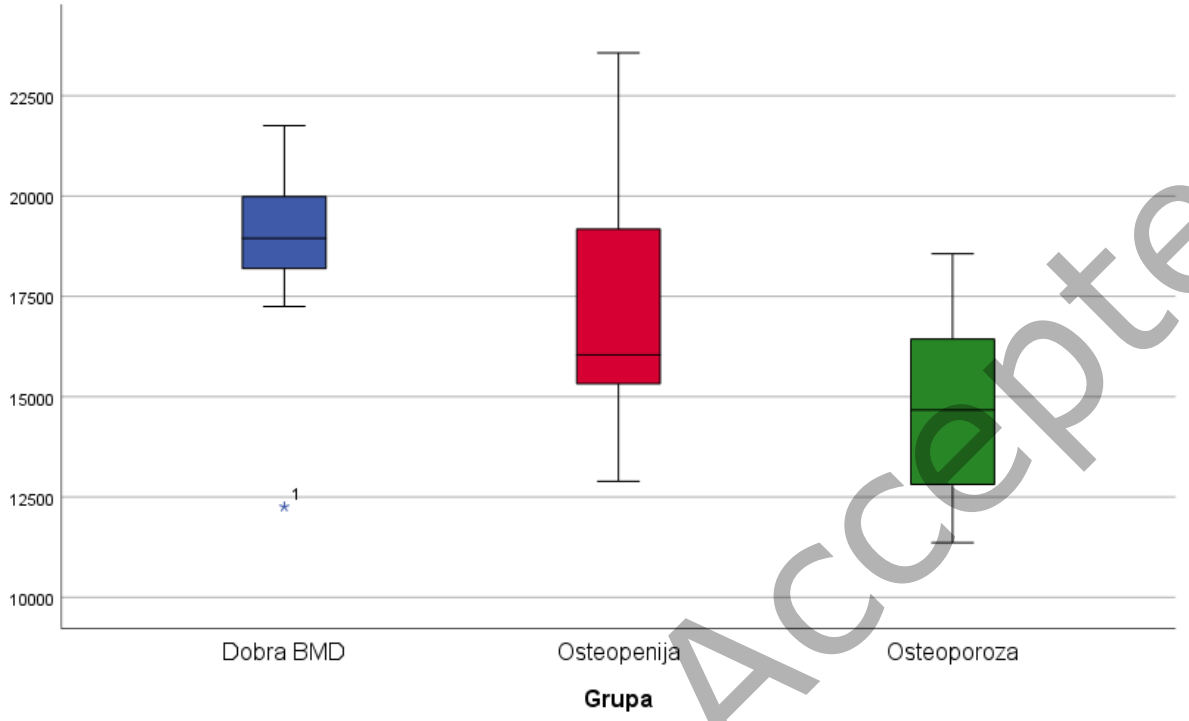
Mean ASM in the normal BMD group was 18,755.00 ± 2,400.29 g, with an ASMI of 6.97 ± 0.84 kg/m². In the osteopenia group, mean ASM was 17,417.06 ± 2,996.15 g, and ASMI was 6.59 ± 1.02 kg/m². In the osteoporosis group, mean ASM was 14,699.75 ± 2,164.47 g, and ASMI was 5.75 ± 0.85 kg/m² (Table 3, Figure 2).

Mean ASM was significantly higher in women with normal BMD compared to those with osteoporosis ($p < 0.01$). ASM was also significantly higher in women with osteopenia compared to those with osteoporosis ($p < 0.05$). Mean ASMI was significantly higher in women with normal BMD compared to those with osteoporosis ($p < 0.01$) (Table 3, Figure 3).

Table 3. Mean values (± SD) for subjects' age, BMI, age at menopause onset, ASM and ASM Index by group

	Group			Statistical results
	Normal BMD	**Osteopenia**	**Osteoporosis**	
Age (years)	56.92± 5.96	62.86+6.90	66.73+ 7.79	p> 0.05
BMI (kg/m^2)	27.53 + 4.63	27.59 + 4.04	25.57 + 3.31	p> 0.05
Age at menopause (age)	49.69 + 3.47.	51.31 + 5.65	49.58 + 5.02	p>0.05
ASM (g)	18755.00±2400.29	17417.06±2996.15	14699.75±2164.47	F=7.905, p=0.001
ASM Index (kg/m^2)	6.97±0.84	6.59±1.02	5.75±0.85	F=5.795, p=0.006

Figure 2. Average value of appendicular muscle mass (ASM) in the studied groups



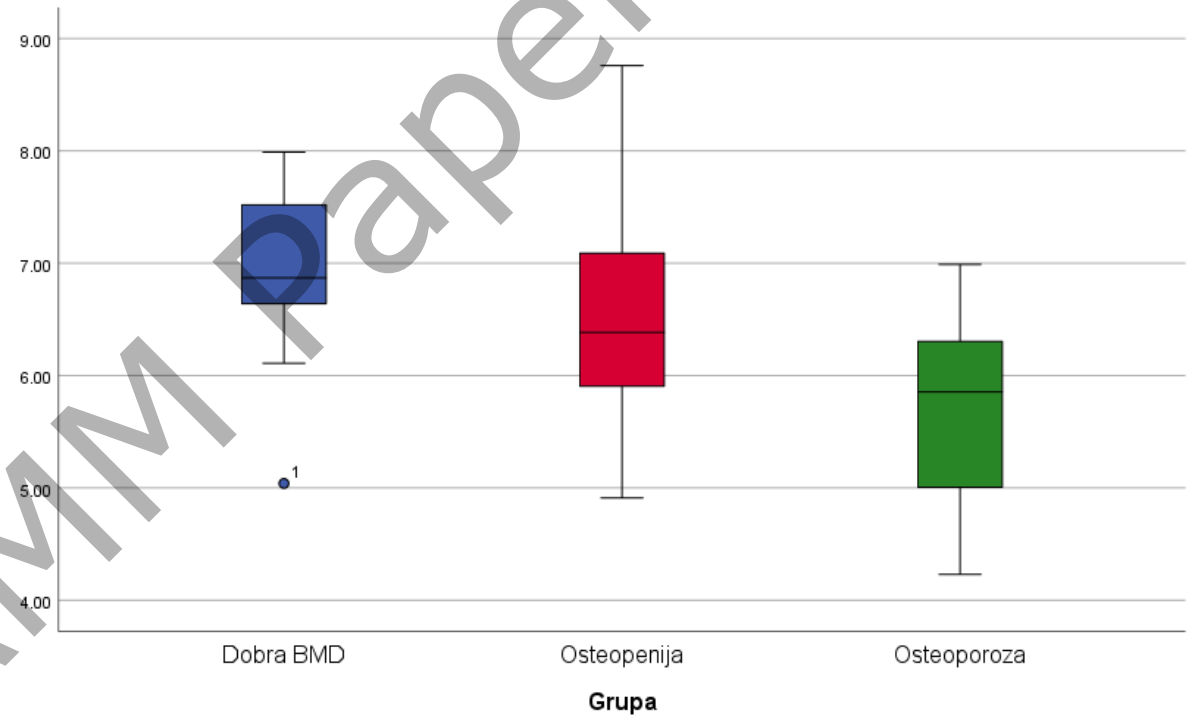


Figure 3. Display of the value of the ASM index in the examined groups

Discussion

Our study demonstrated homogeneity of the examined groups with respect to BMI and age at menopause onset. The results showed statistically significant differences in appendicular skeletal muscle mass and ASMI relative to bone density status, with lower muscle mass and ASMI observed in women with osteopenia and osteoporosis. These findings are consistent with those reported by other authors.

Qin et al. examined 948 patients of both sexes and demonstrated a positive correlation between bone mineral density and ASMI. Patients with normal BMD had significantly higher ASM and ASMI compared to those with osteopenia and osteoporosis, and women with osteopenia had higher ASM and ASMI than those with osteoporosis (4).

A similar study by Han et al., involving 2,165 patients, showed a positive correlation between ASMI and BMD measured at the lumbar spine and femoral neck. Muscle strength of the quadratus lumborum also showed a positive correlation with ASMI and BMD (9).

These findings suggest directions for future research focusing on muscle strength and endurance in patients with osteoporosis. Exercise programs aimed at increasing muscle strength may contribute to osteoporosis prevention.

Studies in early postmenopausal women with osteopenia have shown that long-term exercise programs positively influence multiple risk factors associated with menopausal transition and aging (7). Other studies have demonstrated that higher exercise intensity correlates positively with bone mineral density (8).

Muscles and bones are anatomically and functionally connected tissues. Sarcopenia refers to the loss of muscle mass and was internationally classified as a disease in 2016. There is limited literature on its impact on bone density. Both sarcopenia and osteoporosis are associated with increased fracture risk, impaired mobility, and mortality. Rather than focusing solely on bone or muscle weakness, it is necessary to understand their interrelationship and develop integrated therapeutic approaches (10).

Sarcopenia and osteoporosis share common pathophysiological mechanisms, including hormonal, inflammatory, mechanical, and metabolic factors. Both osteoblasts and myocytes originate from mesenchymal progenitor cells. Muscle contraction exerts mechanical load on bones, stimulating bone maintenance. Loss of muscle mass and strength reduces skeletal loading, accelerating bone loss. Hormonal deficiencies (reduced estrogen in menopause, decreased testosterone, growth hormone decline, and increased cortisol) reduce bone density and muscle protein synthesis. Chronic inflammation in older adults increases cytokine levels (IL-6, TNF-α, CRP), inhibiting muscle regeneration and stimulating osteoclast activity. Endocrine signaling between muscle and bone also plays a role, with myostatin inhibiting muscle and bone growth and osteocalcin influencing muscle function. Nutritional factors, such as vitamin D deficiency, and physical inactivity further contribute to both conditions.

Early diagnosis and integrated treatment strategies are essential. Nutrition, exercise, and pharmacological therapy may slow the development of osteosarcopenia, with combined approaches proving more effective than treating each condition separately (11,12).

The main limitation of this study is the small sample size. Larger future studies are needed to confirm the relationship between muscle mass loss and osteoporosis and to draw definitive conclusions.

Conclusion

This study demonstrated a significant difference in appendicular skeletal muscle mass and ASMI in postmenopausal women with normal bone density compared to those with osteopenia and osteoporosis. These findings highlight the importance of investigating shared risk factors, pathogenesis, and treatment strategies for osteoporosis and sarcopenia. The frequent coexistence of these conditions, particularly in postmenopausal women, underscores the important role of physical and rehabilitation medicine in their prevention and treatment.

Abbreviations

- **BMI** – Body Mass Index
- **BMD** – Bone Mineral Density
- **T-score** – Value indicating deviation from average bone density of a healthy young adult
- **ASM** – Appendicular Skeletal Muscle Mass
- **ASMI** – Appendicular Skeletal Muscle Mass Index

Literature

1. Meeta M, Harinarayan CV, Marwah R, Sahay R, Kalra S, Babhulkar S. Clinical practice guidelines on postmenopausal osteoporosis: *An executive summary and recommendations – Update 2019–2020. J Mid-life Health 2020;11:96-112.

2. Cummings SR, Nevitt MC, Browner WS, Stone K, Fox KM, Ensrud KE, Cauley J, Black D, Vogt TH. Risk factors for hip fracture in white women. N Engl J Med. 1995;332:767–773.

3. Kanis JA, Melton LJ, Christiansen C, Johnston CC, Khaltaev N. The diagnosis of osteoporosis. J Bone Min Res. 1994;9:1137–1141.

4. Qin H, Jiao W. Correlation of muscle mass and bone mineral density in the NHANES US general population, 2017-2018. Medicine (Baltimore). 2022 Sep 30;101(39):e30735.

5. Edwards MH, Gregson CL, Patel HP, et al. Muscle size, strength, and physical performance and their associations with bone structure in the hertfordshire cohort study. J Bone Miner Res. 2013;28:2295–304.

6. Gandham A, Vandenput L, Turbic A, MacRae M, Nassar H, Kolterman OG, et.al. Associations between muscle mass and strength and bone microarchitecture in Caucasian postmenopausal women. Osteoporos Int. 2025 Oct;36(10):2031-2039.

7. Hettchen M, von Stengel S, Kohl M, et al. Changes in menopausal risk factors in early postmenopausal osteopenic women after 13 months of high-intensity exercise: the randomized controlled ACTLIFE-RCT. Clin Interv Aging. 2021;16:83–96

8. Kistler-Fischbacher M, Weeks BK, Beck BR. The effect of exercise intensity on bone in postmenopausal women (part 1): a systematic review. Bone. 2021;143:115696.

9. Han, H., Chen, S., Wang, X. et al. Association between muscle strength and mass and bone mineral density in the US general population: data from NHANES 1999–2002

10. Gielen E, Dupont J, Dejaeger M, Laurent MR. Sarcopenia, osteoporosis and frailty. Metabolism. 2023 Aug;145:155638.

11. Edoardo Mocini, Claudia Piciocchi, Giuseppe Defeudis, Silvia Migliaccio; Sarcopenia and Osteoporosis. Gerontology 18 August 2025; 71 (8): 649–655

12. Das C, Das PP, Kambhampati SBS. Sarcopenia and Osteoporosis. Indian J Orthop. 2023 Nov 19;57(Suppl 1):33-41.