Mohamed *et. al.*, Babcock Univ. Med. J.2026 9(1):83-90
https://doi.org/10.38029/babcockuniv.med.j..v9i1.1161
eISSN: 2756-4657

RESEARCH ARTICLE OPEN ACCESS

Role of DEXA-derived bone mineral density in orthopaedic surgical planning: A cross-sectional study

Mohammed DAA[1ID], Mohamed MM[2ID], Aziz ZSA[3,4ID]

[1]*Department of Physiology, College of Medicine, University of Baghdad, Baghdad, Iraq*
[2]*Department of Anatomy, College of Medicine, University of Baghdad, Baghdad, Iraq*
[3]*Department of Internal Medicine, Al-Yarmouk Teaching Hospital, Baghdad, Iraq*
[4]*Department of Dentistry, AL Hikma University College, Baghdad, Iraq*

Submitted: 8th September 2025
Accepted: 13th October 2025
Published: 31st March 2026
ID: Orcid ID

Abstract
Objective: This study aims to clarify the role of site-specific bone density measurement in surgical decision-making by comparing BMD in the spine and bilateral femurs of males and females.
Method: Cross-sectional comparative study of two hundred consenting individuals consisting of 100 osteoporotic patients and 100 healthy controls (in terms of the total spine and femur (left and right femurs)), matched for age and sex. The volunteers aged between 40 and 75, with heights between 158 and 180 cm, and weights between 63 and 87 kg.
Results: There were no significant differences in the mean values of the normal BMDs between the lumbar spine and right femur, or between the lumbar spine and left femur. There were statistically significant ($P < 0.001$) differences in the mean BMD for the normal lumbar spine and osteoporosis of the left and right femurs in both male and female cases, separately.
Conclusion: The significant reduction in femoral BMD among osteoporotic patients underscores the need to focus on bones other than the lumbar vertebrae and hip bones, which are traditionally assessed without taking into consideration the affected bone(s). Further, routine DEXA screening plus the bone(s) of interest (other than the lumbar spines and hip bones) should be integrated into orthopaedic practice to optimise patient outcomes, reduce the risk of fractures, and enhance surgical success rates in osteoporotic individuals. Osteoporotic patients requiring fracture fixation should undergo site-specific DEXA screening of the affected bone to guide fixation feasibility and procedure selection.

Keywords: DEXA, Osteoporosis, Fracture, Lumbar spine, Femur

Plain English Summary
This study looked at bone health using a special scan called a DEXA scan, which measures bone strength (bone mineral density). Weak bones can lead to osteoporosis, a condition that makes bones more likely to break. We tested 200 men and women between the ages of 40 and 75. The scan measured bone strength in the spine and in both legs (the left and right thigh bones, called femurs). We compared people with healthy bones to those with osteoporosis. The results showed that in healthy people, bone strength in the spine and legs was very similar. However, in people with osteoporosis, the leg bones (femurs) were much weaker than the spine. This means that looking only at the spine may not show the full picture of bone health. Our study suggests that doctors should check more than one area when scanning for osteoporosis, especially the thigh bones, because weak bones there can

Correspondence:
Mohamed Mahmoud M
Department of Anatomy, College of Medicine
University of Baghdad, Baghdad
Iraq
+9647702733478, mahmoud.m@comed.uobaghdad.edu.iq

increase the chance of fractures. By doing this, doctors can choose better treatments, reduce the risk of broken bones, and improve the success of surgery in osteoporotic patients with weak bones.

Background

Dual energy X-ray absorptiometry (DEXA) scans are employed to assess bone mineral density (BMD) in the spine, femur, and hip (1). These scans are essential in identifying individuals at risk of osteoporosis and instructing them on the proper utilisation of anti-fracture treatment (2).

Osteoporosis, characterised by the deterioration of bone microarchitecture resulting from reduced BMD, has emerged as a significant public health issue, nearing epidemic levels in both industrialised and developing nations (2). Various factors, including low vitamin D (3), diabetes (4, 5), radiotherapy and chemotherapy (6), and lipid disorders (7, 8), can lead to a decrease in BMD. All of these diseases cause a decrease in mineral absorption, leading to fragility and an increased risk of fracture (9). The greatest risk due to osteoporosis, however, is associated with orthopaedic surgery.

Orthopaedic surgery is regarded as a highly challenging surgical procedure due to the necessity to guarantee the bone's strength, particularly when joining a broken bone into two parts or between two bones (10). Therefore, the initial step is to guarantee that the bone component proportions are normal (11, 12). Consequently, the mineral density of the area in which the operation will be conducted is assessed by the DEXA instrument, where orthopaedic surgery is complicated by the increased bone fragility of a patient with osteoporosis, such as joint replacement (13). Unfortunately, elderly individuals who require joint replacement often have an increased risk of developing osteoporosis.

Therefore, our study aims to clarify the role of site-specific bone density measurement in surgical decision-making by comparing BMD in the spine and bilateral femurs of males and females. As DEXA is traditionally used to measure the BMD of the Lumbar spine and the hip bones, irrespective of the fractured or diseased bone, raises a question whether other bones have the same BMD as the hip and lumbar spine.

Materials and Methods

Study design and participants

A cross-sectional observational study was conducted at the Rheumatology Outpatient Clinic, Baghdad Teaching Hospital, Medical City, Baghdad, and Al-Yarmouk Teaching Hospital, Baghdad, in collaboration with the College of Medicine, University of Baghdad. It spanned the period from August 2023 until June 2024. Two hundred individuals provided consent for this research by signing a written consent form. The study comprised male and female volunteers aged between 40 and 75, whose heights were between 158 and 180 cm and who weighed between 63 and 87 kg. The study categorised individuals into two groups: osteoporotic patients and healthy subjects. The healthy subjects who reported a T-score between +1 and -1. The two groups were gained from a rheumatology outpatient clinic. Both groups reported generalised bone discomfort, particularly in the back and femur.

Eligibility criteria

The overall criteria for selecting participants, whether they were in a control group or osteoporotic patient group, were mainly related to back pain, regardless of chronic diseases and underlying causes of osteoporosis. Any participant who is treated or on treatment with chemotherapy and \or radiotherapy.

Patients with chronic diseases or secondary causes of osteoporosis (e.g., diabetes, anaemia, lipid disorders) were not excluded, as the objective was to capture a real-world spectrum of patients typically encountered in orthopaedic practice. This reflects clinical scenarios where multiple comorbidities coexist and influence bone health

Materials

The general instruments and equipment used in this survey were (DMS Stratos system DEXA), made in France, for the measurement of bone mineral density. This machine is linked to the Stratos computer for displaying the results and choosing the method of the test, and a Brother DCP-T510W printer to print the information in the report on A4 paper

The procedure of taking the BMD Scan

Standardised DEXA procedures were followed. Patients avoided calcium supplements 24 hours before scanning and were instructed to remove metallic items to avoid artefacts. Scans were conducted with the patients in a supine position, measuring lumbar spine and bilateral femoral BMD using the DMS Stratos system (France)

Measurement of BMD

All subjects involved in this research were subject to DEXA examination to determine their BMD, mainly in the total spine and femur (left and right femurs), using the T-score as a figure of comparison between normal and osteoporotic of

total lumbar spines and bilateral femurs. The normal limits for BMD were established by the T-score between +1 and -1 (14).

Statistical analysis

Statistical analyses were performed using Statistical Package for Social Sciences (SPSS for Windows (IBM Inc.) version 22). Independent samples t-tests were used to compare BMD between osteoporotic patients and healthy controls. Paired t-tests were applied to compare BMD across different skeletal sites (lumbar spine vs femur) within the same individuals. The differences between control (normal: no osteoporosis) and patient (osteoporosis) were analysed using paired and unpaired t-tests according to the number of samples. Mean and standard error means were reported, and the p-value of significance was equal to or less than 0.05.

Results

There were 100 subjects, 50 males and 50 normal females, and another 100 subjects, again 50 males and 50 females, who had osteoporosis. The participants' anthropometric measurements were recorded as follows: the mean age of the males was 67.75 ± 4.45, whilst that of the females was 65.5 ± 3.5; the mean height of the males was 170.55 ± 4.75 cm, whilst that of the females was 172.45 ± 4.65 cm; and the mean weight of the males was 78.75 ± 6.85 kg whilst that of the females was 72.5 ± 5.8 kg.

Bone mineral density of the spine for both sexes

From Table 1, the mean BMD readings for the lumbar spine were within normal ranges for both males and females. Simultaneously, mean BMD readings for the left and right femurs for both males and females were within normal ranges.

Table 1: Bone Mineral Density (BMD) in Healthy Controls

Organ	Female	P-value	Male	P-value
Lumbar Spine (normal)	1.062±0.035		1.102±0.055	
Right Femur (normal)	1.091±0.045	NS	1.071±0.055	NS
Left Femur (normal)	0.986±0.055	NS	0.956±0.045	NS

NS: non-significant correlation

From Table 1, there are no significant differences in the mean values of the normal BMD between the lumbar spine and right femur, or between the lumbar spine and left femur, for both males and females, as illustrated in Figure 1.

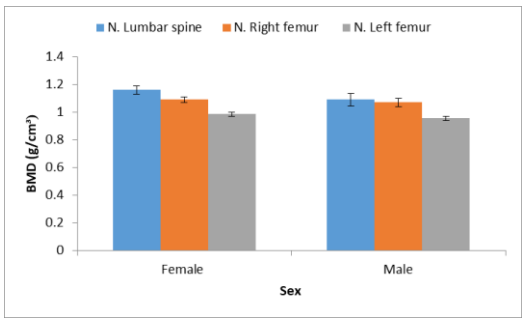

Figure 1: Bar chart comparing mean BMD (±SD) at the lumbar spine, right femur, and left femur of both sexes in the healthy control group.

Table 2 shows that mean BMD readings for the lumbar spine were within normal ranges for both males and females. Simultaneously, mean BMD readings for the left and right femurs for both males and females were within osteoporosis ranges.

Table 2: Bone Mineral Density (BMD) in Osteoporotic patients

Organ	Female	P-value	Male	P-value
Lumbar Spine (normal)	1.062±0.035		1.102±0.055	
Right Femur (osteoporosis)	0.616±0.041	P<0.001	0.586±0.038	P<0.001
Left Femur (osteoporosis)	0.606±0.045	P<0.001	0.528±0.045	P<0.001

In Table 2, there are statistically significant (P < 0.001) differences in the mean BMD for the normal lumbar spine and osteoporosis of the right femur in both males and females. There were also statistically significant (P < 0.001) differences in the mean BMD for the normal

lumbar spine and osteoporosis of the left femur in both males and females, as shown in Figure 2.

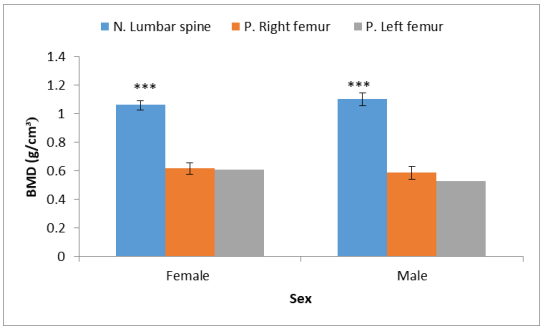

Figure 2: Bar chart comparing mean BMD (±SD) at the lumbar spine, right femur, and left femur of both sexes in the unhealthy group

Discussion

Two hundred subjects were divided equally into normal and osteoporotic patient groups regarding the BMD; each of them was divided equally according to their gender. The mean age of the males was 67.75, whilst that of the females was 65.5; the mean height of the males was 170.55 cm, whilst that of the females was 172.45 cm; and the mean weight of the males was 78.75 kg, whilst that of the females was 72.5 kg. One of the primary medical issues that results in the inability to make a correct diagnosis or administer appropriate treatment is a reliance on inaccurate patient data. Orthopaedic surgery is heavily dependent on BMD measurement, which is a critical indicator. The reliability of BMD in the spine as an indicator of osteoporosis is the subject of controversy in this case, despite numerous studies demonstrating the effectiveness of measuring BMD as an enabler of surgery in a specific part of the body (15). The surgical management of orthopaedic disorders, encompassing fracture repair and joint replacement, is increasing (16, 17). The prevalence of osteoporosis and related fractures is rising globally (18). Surgeons encounter particular difficulty in determining the best way to treat patients and choosing the right implant(s) for fixation due to the correlation between longer life, better mobility, and the severity of fractures caused by poor bone quality. Bone quality is evidently fundamental to this decision-making process (19).

Implications for Orthopaedic Surgical Decisions

1. Fracture Risk Assessment and Prevention Strategies

The significant reduction in femoral BMD among osteoporotic patients suggests a higher risk of hip fracture, which is among the most severe and debilitating complications associated with osteoporosis. This highlights the importance of routine preoperative DEXA screening to assess fracture risk and to guide preventive measures such as pharmacological interventions (e.g., bisphosphonates, denosumab), physical therapy, and lifestyle modifications to improve bone strength before elective orthopaedic procedures (20).

2. Surgical Planning and Implant Selection

Given the lower BMD in the femurs of osteoporotic individuals, orthopaedic surgeons must consider implant stability when planning hip replacement or fracture fixation surgeries. Additionally, for fracture fixation, the use of locking plates, intramedullary nails, or augmented fixation techniques may be necessary to ensure optimal outcomes for patients with poor bone quality (21).

3. Spinal Surgery Considerations

The relatively preserved BMD in the lumbar spine compared to the femur suggests that spinal surgical outcomes may not be as severely impacted by osteoporosis as hip surgeries. However, osteoporosis still poses a risk in terms of complications such as vertebral fractures, implant loosening, and poor fusion outcomes. Surgeons must consider the use of bone graft substitutes, vertebral augmentation techniques (e.g., kyphoplasty), and osteoporosis-targeted therapies to optimise the success of spinal fusion in osteoporotic patients (22).

4. DEXA as a Standard Preoperative Tool in Orthopaedic Surgery

The findings of this study reinforce the necessity to integrate routine DEXA screening into orthopaedic surgical planning, particularly for elderly patients or those undergoing major joint or spinal surgeries. By identifying the region of interest (bone(s)) that require orthopaedic intervention) With low BMD, surgeons can

proactively implement strategies to optimise bone quality and improve surgical outcomes (23). Our results revealed that in normal individuals, the mean BMD for the lumbar spine and femurs (left and right) showed no statistically significant differences between males and females, as illustrated in Table 1 and Figure 1. This finding is consistent with previous reports suggesting that sex-related variations in BMD are less pronounced in healthy adults, particularly when age and body size are controlled for. Several large population-based studies have demonstrated that while men generally have higher absolute bone mass due to larger skeletal size, the areal BMD values at the lumbar spine and femur do not always differ significantly between sexes in younger and middle-aged adults (24, 25). Looker et al. (26) reported that in the U.S. population, differences in lumbar spine and femoral BMD between men and women were minimal when adjusted for body composition and age. Similarly, Henry et al. (27), in the Geelong Osteoporosis Study, found that sex did not exert a statistically significant effect on BMD values in the spine and hip regions of healthy adults. One explanation is that BMD reflects not only bone size but also bone mineral content per unit area. Since men typically have larger bones, differences in volumetric BMD may be smaller than those suggested by areal BMD, leading to comparable mean values across sexes in certain skeletal sites (28, 29). Furthermore, lifestyle, nutrition, and physical activity, rather than sex alone, have been shown to exert stronger effects on BMD variations in healthy populations (30). This suggests that in the absence of osteoporosis, bone density is relatively stable across these skeletal regions, and surgical interventions in such patients may not require significant modifications based on BMD alone (14). Overall, the absence of significant differences in lumbar spine and femoral BMD between males and females in normal individuals highlights that sex alone may not be a major determinant of bone density in healthy populations. Instead, factors such as body composition, lifestyle, and hormonal changes with ageing play more decisive roles.

However, the question arises when the mineral density of the spinal column is normal, whilst the BMD of the femur is insufficient; that is, the latter is within the osteoporosis range. In our study, there were high statistically significant differences ($P < 0.001$) in BMDs between the lumbar spine and femurs for each of the sexes. Specifically, while lumbar spine BMDs remained within normal ranges, the BMDs for both the left and right femurs fell within osteoporosis ranges, as illustrated in Figure 2 and Table 2. This discordance between axial and appendicular skeletal sites has been well-documented in previous studies and reflects important clinical implications. Site-specific differences in BMD are not uncommon, as the lumbar spine and femoral regions differ in their composition and remodelling dynamics. The lumbar spine consists predominantly of trabecular bone, which is more metabolically active and responsive to hormonal and metabolic changes, whereas the femur is composed mainly of cortical bone, which undergoes slower turnover (31). These structural and physiological differences may explain why lumbar spine BMD remains preserved in some individuals, while femoral BMD shows more marked reductions. Spine–hip discordance (SHD) has been increasingly recognised as a clinical phenomenon. Akiyama et al. (31) highlighted that many individuals undergoing DEXA assessment may show significant differences between lumbar spine and femoral BMDs, which can complicate fracture risk prediction. Thus, the finding that femoral sites fell into the osteoporotic range despite normal lumbar values emphasises the need for site-specific evaluation rather than reliance on a single skeletal region.

Another explanation could be degenerative changes in the lumbar spine that artificially elevate BMD measurements in older individuals. Osteophytes, vascular calcifications, and facet joint sclerosis can falsely increase lumbar spine readings, leading to an underestimation of osteoporosis prevalence when relying solely on spinal BMD (32, 33). By contrast, femoral measurements are less affected by such artefacts, which makes them more reliable indicators of true bone fragility in older adults.

From a clinical standpoint, the discordance between lumbar spine and femoral BMDs suggests that diagnostic categorisation and fracture risk assessment must include multiple skeletal sites. The International Society for Clinical Densitometry (ISCD) guidelines recommend that both the lumbar spine and hip regions be assessed in all osteoporotic patients, given that osteoporosis diagnosis and therapeutic decisions may vary depending on the site examined (34). This indicates that the femur is more susceptible to osteoporosis-related bone loss than the spine, making it a critical site for assessing fracture risk and determining appropriate surgical approaches. Low femoral BMD may compromise screw fixation and implant stability, making surgery technically challenging or unfeasible. Consequently, the mineral density of the spine is not a dependable indicator for surgical operations on the femur, as well as other bones of interest. As a result, in osteoporotic

patients with normal spine BMD but low femur BMD, surgeons may need to either postpone the operation till BMD correction in elective orthopaedic surgery or do an alternative type of operation accordingly. Our findings support the recommendations of organisations such as the International Osteoporosis Foundation (IOF) and the American Academy of Orthopaedic Surgeons (AAOS), which both advocate routine osteoporosis screening in older adults undergoing orthopaedic procedures; moreover, they allocate the region of interest to assess its BMD directly.

Limitations and Future Research

Despite the valuable insights provided by this study, it does have certain limitations. First, the study did not assess the impact of factors such as physical activity levels, nutritional intake, or comorbid conditions (e.g., diabetes, rheumatoid arthritis) that may influence BMD. Second, this study focused on BMD measurements but did not evaluate how different orthopaedic surgical techniques or implants might influence outcomes in osteoporotic patients with varying BMDs. Moreover, we did not adjust for potential confounders (e.g., age, BMI, comorbidities, medications, physical activity, and diet). A hospital-based sample may not represent the general population. Cross-sectional design studies do not establish causality. Besides, the research was conducted in a single geographic and ethnic population (Iraqi), which may limit generalizability. Future research should explore longitudinal changes in BMD and their effects on postoperative recovery, implant survival, and fracture recurrence rates.

Conclusion

This study highlights the critical role of DEXA-derived BMD measurements in surgical decision-making. The significant reduction in femoral BMD among osteoporotic patients underscores the need for site-specific assessment beyond the lumbar spine. Routine preoperative femoral DEXA, especially in osteoporotic patients ≥60 years undergoing hip surgery, should be integrated into orthopaedic practice to improve surgical outcomes and reduce fracture risk.

List of Abbreviations

AAOS: American Academy of Orthopaedic Surgeons
BMD: Bone mineral density
DEXA: Dual energy X-ray absorptiometry
IOF: International Osteoporosis Foundation
NS: Non-significant correlation
SPSS: Statistical Package for the Social Sciences
WHO: World Health Organisation

Declarations

Ethical approval and consent to participate

Ethical approval for this study was granted by the Institutional Review Board of the College of Medicine, University of Baghdad (Reference Number). Before participation, all subjects were thoroughly informed about the study's purpose, procedures, potential risks, and benefits. Written informed consent was obtained from every participant. The study was conducted in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki Declaration and its later amendments.

To safeguard participant rights, the following measures were implemented:

Voluntary Participation: Participation was entirely voluntary, and individuals were free to withdraw at any point without providing a reason and without any penalty to their medical care.

Confidentiality: All participant data were anonymised and handled with strict confidentiality. Personal identifiers were removed, and data were stored securely, accessible only to the research team.

Safety: Standardised procedures for the DEXA scans were followed to minimise radiation exposure, and participants were instructed to remove metallic objects to prevent artefacts and ensure their safety during the procedure.

Consent for publication

Availability of data and materials

The data and materials associated with this review will be made available by the corresponding author upon reasonable request.

Competing interests

The author(s) declare that they have no competing interests.

Funding

None received

Author's contributions

MDAA: Conceptualisation, data curation, writing–original draft, formal analysis, investigation, supervision, methodology, writing–review and editing.

MMM: Conceptualisation, data curation, methodology, data collection, validation, investigation, formal analysis.

AZSA: writing–review and editing, validation, formal analysis, investigation.

Acknowledgment
Nil

References

1. Blake GM, Fogelman I. The role of DXA bone density scans in the diagnosis and treatment of osteoporosis. Postgraduate Medical Journal. 2007 Aug;83(982):509-17. https://doi.org/10.1136/pgmj.2007.057505
2. LeBoff MS, Greenspan SL, Insogna KL, Lewiecki EM, Saag KG, Singer AJ, Siris ES. The clinician's guide to prevention and treatment of osteoporosis. Osteoporosis international. 2022 Oct;33(10):2049-102. https://doi.org/10.1007/s00198-021-05900-y
3. Clynes MA, Harvey NC, Curtis EM, Fuggle NR, Dennison EM, Cooper C. The epidemiology of osteoporosis. British Medical Bulletin. 2020 Mar;133(1):105-17. https://doi.org/10.1093/bmb/ldaa005
4. Aziz ZA, Dawood NS, Al-Khalisy MH. Evaluation of the effect of type II diabetes mellitus on bone mineral density of upper and lower limbs by dual-energy X-ray absorptiometry. Journal of the Faculty of Medicine, Baghdad. 2023 Apr 27;65(1):27-33. https://doi.org/10.32007/jfacmedbagdad.6511980
5. Mussttaf RA, Al-Sahlanee MH, Dawood NS, Jenkins DF, Jha AN. Photobiomodulation Effect of 850 nm Near-infrared Diode Laser on the Release of M1-related Cytokines Inmonocytic THP-1 Cells. International Journal Bioautomation. 2023;27(1):5. https://doi.org/10.7546/ijba.2023.27.1.000857
6. Raheem HM, Dawood NS, Al-khalisy MH. The role of Modulation Complexity Score (MCS) of the VMAT and IMRT techniques in the treatment planning of left non-small lung cancer. Onkologia i Radioterapia. 2023 May 1;17(5).
7. Zhang J, Hu W, Zou Z, Li Y, Kang F, Li J, Dong S. The role of lipid metabolism in osteoporosis: Clinical implication and cellular mechanism. Genes & Diseases. 2024 Jul 1;11(4):101122. https://doi.org/10.1016/j.gendis.2023.101122
8. Ahmed RJ, Dawood NS, Al-Khalisy MH. The Relationship between Anemia and Bone Mineral Density Measured by Dual X-Ray Absorptiometry. Al-Rafidain Journal of Medical Sciences (ISSN 2789-3219). 2024 May 31;6(2):111-5. https://doi.org/10.54133/ajms.v6i2.800
9. Yuan VG. Rhythms in Remodeling: Posttranslational Regulation of Bone by the Circadian Clock. Biomedicines. 2025 Mar 13;13(3):705. https://doi.org/10.3390/biomedicines13030705
10. Magnusdottir R, Gohin S, Ter Heegde F, Hopkinson M, McNally IF, Fisher A, Upton N, Billinton A, Chenu C. Fracture-induced pain-like behaviours in a femoral fracture mouse model. Osteoporosis International. 2021 Nov;32(11):2347-59. https://doi.org/10.1007/s00198-021-05991-7
11. ElHawary H, Baradaran A, Abi-Rafeh J, Vorstenbosch J, Xu L, Efanov JI. Bone healing and inflammation: principles of fracture and repair. InSeminars in plastic surgery 2021 Aug (Vol. 35, No. 03, pp. 198-203). Thieme Medical Publishers, Inc.. https://doi.org/10.1055/s-0041-1732334
12. Dawood NS, Aziz ZS, Alkhaales HM. Evaluation of the relationship between osteoporosis and body fat mass of the upper and lower extremities by dual-energy X-ray absorptiometry. Al-Rafidain Journal of Medical Sciences (ISSN 2789-3219). 2024 Jan 4;6(1):34-8. https://doi.org/10.54133/ajms.v6i1.410
13. Shuhart C, Cheung A, Gill R, Gani L, Goel H, Szalat A. Executive Summary of the 2023 Adult Position Development Conference of the International Society for Clinical Densitometry: DXA reporting, follow-up BMD testing and trabecular bone score application and reporting. Journal of Clinical Densitometry. 2024 Jan 1;27(1):101435. https://doi.org/10.1016/j.jocd.2023.101435
14. Garg MK, Kharb S. Dual energy X-ray absorptiometry: Pitfalls in measurement and interpretation of bone mineral density. Indian Journal of Endocrinology and Metabolism. 2013 Mar 1;17(2):203-10. https://doi.org/10.4103/2230-8210.109659
15. Holanda N, Crispim N, Carlos I, Moura T, Nóbrega E, Bandeira F. Musculoskeletal effects of obesity and bariatric surgery–a narrative review. Archives of Endocrinology and metabolism. 2022 Dec 5;66(5):621-32. https://doi.org/10.20945/2359-3997000000551
16. Liang W, Zhou C, Bai J, Zhang H, Jiang B, Wang J, Fu L, Long H, Huang X, Zhao J, Zhu H. Current advancements in therapeutic approaches in orthopedic surgery: a review of recent trends. Frontiers in Bioengineering and Biotechnology. 2024 Feb 9;12:1328997. https://doi.org/10.3389/fbioe.2024.1328997
17. Dawood NS, Mussttaf RA, AL-Sahlanee MH. Model for Prediction of the Weight and Height

Measurements of Patients with Disabilities for Diagnosis and Therapy. International Journal Bioautomation. 2021 Oct 1;25(4). https://doi.org/10.7546/ijba.2021.25.4.000824
18. Özmen S, Kurt S, Timur HT, Yavuz O, Kula H, Demir AY, Balcı A. Prevalence and risk factors of osteoporosis: a cross-sectional study in a tertiary center. Medicina. 2024 Dec 23;60(12):2109. https://doi.org/10.3390/medicina60122109
19. Jia Q, Peng Z, Huang A, Jiang S, Zhao W, Xie Z, Ma C. Is fracture management merely a physical process? Exploring the psychological effects of internal and external fixation. Journal of Orthopaedic Surgery and Research. 2024 Apr 8;19(1):231. https://doi.org/10.1186/s13018-024-04655-6
20. Kim CH, Kim K, Kim JW. The effect of denosumab on minimum 3-years BMD changes in patients with osteoporotic hip fractures: a propensity score matching analysis. Osteoporosis International. 2025 Feb;36(2):265-74. https://doi.org/10.1007/s00198-024-07314-y
21. Lim C, Choi S, Choi TH, Kang H. Stable internal fixation with dual plate technique for osteoporotic distal femur fractures. Annals of Medicine and Surgery. 2022 Mar 1;75:103374. https://doi.org/10.1016/j.amsu.2022.103374
22. Feng F, Chen M, Wang X, Zhang H, Nie H, Tang H. Translation of a spinal bone cement product from bench to bedside. Bioactive Materials. 2022 Apr 1;10:345-54. https://doi.org/10.1016/j.bioactmat.2021.08.011
23. Hui SL, Slemenda CW, Johnston Jr CC. Baseline measurement of bone mass predicts fracture in white women. Annals of internal medicine. 1989 Sep 1;111(5):355-61. https://doi.org/10.7326/0003-4819-111-5-355
24. Mazess RB, Barden HS. Bone density in premenopausal women: effects of age, dietary intake, physical activity, smoking, and birth-control pills. The American Journal of Clinical Nutrition. 1991 Jan 1;53(1):132-42. https://doi.org/10.1093/ajcn/53.1.132
25. Seeman E. Growth in bone mass and size—are racial and gender differences in bone mineral density more apparent than real?. The Journal of Clinical Endocrinology & Metabolism. 1998 May 1;83(5):1414-9. https://doi.org/10.1210/jc.83.5.1414
26. Looker AC, Borrud LG, Dawson-Hughes B, Shepherd JA, Wright NC. Osteoporosis or low bone mass at the femur neck or lumbar spine in older adults, United States, 2005-2008.
27. Henry MJ, Pasco JA, Nicholson GC, Kotowicz MA. Prevalence of osteoporosis in Australian men and women: Geelong Osteoporosis Study. The Medical Journal of Australia. 2011 Sep 19;195(6):321-2. https://doi.org/10.5694/mja11.10571
28. Wang XF, Duan Y, Beck TJ, Seeman E. Varying contributions of growth and ageing to racial and sex differences in femoral neck structure and strength in old age. Bone. 2005 Jun 1;36(6):978-86. https://doi.org/10.1016/j.bone.2004.11.015
29. Lorentzon M, Mellström D, Ohlsson C. Association of amount of physical activity with cortical bone size and trabecular volumetric BMD in young adult men: the GOOD study. Journal of Bone and Mineral Research. 2005 Nov 1;20(11):1936-43. https://doi.org/10.1359/jbmr.050709
30. Porterfield F, Shapoval V, Langlet J, Samouda H, Stanford FC. Digital biometry as an obesity diagnosis tool: a review of current applications and future directions. Life. 2024 Jul 28;14(8):947. https://doi.org/10.3390/life14080947
31. Akiyama S, Tanaka T, Udaka J, Inagaki N, Kumagae Y, Chazono M, Matsuoka T, Saito M. Factors affecting spine–femur discordance in the percentage of young adult mean on dual-energy X-ray absorptiometry in the elderly population: a retrospective study. BMC Musculoskeletal Disorders. 2022 Jan 21;23(1):76. https://doi.org/10.1186/s12891-022-05015-3
32. Singh M, Arora S, Kaur A, Ghildiyal S, Kumar R. Patterns of age-and sex-related variations in bone mineral density of lumbar spine and total femur: a retrospective diagnostic laboratory-based study. Journal of Midlife Health. 2018 Jul 1;9(3):155-61. https://doi.org/10.4103/jmh.JMH_95_18
33. Choi KH, Lee JH, Lee DG. Sex-related differences in bone metabolism in osteoporosis observational study. Medicine. 2021 May 28;100(21):e26153. https://doi.org/10.1097/MD.0000000000026153
34. Mun C, Sho K, Kim O. Long-term changes in bone mineral density and associated risk factors in individuals with spinal cord injury: A retrospective study. Medicine. 2024 Sep 27;103(39):e39790. https://doi.org/10.1097/MD.0000000000039790