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The morphometric parameters of femur proximal part and its relationship with body mass index

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Abstract

Background: The femur is the longest bone in the body. Injury or fracture in this bone strongly affects the quality of life of people.
Objectives: The aim of this study was to investigate the morphometric parameters of femur proximal part and its relationship with body mass index (BMI).
Methods: This descriptive-analytical study was conducted on 200 patients over 50 years of age referred to Shahid Beheshti Hospital in Kashan and Ayatollah Kashani Hospital in Isfahan during 2018-2019. The participants had radiographs in the supine position of femur proximal part. BMI and bone mineral density of patients were determined by the DXA method. Using radiographic images of the femur, the morphological features were evaluated. Also, the relationship of these characteristics with age, gender, BMI and bone mineral density was investigated.
Results: The values of six morphological parameters of the femur in the patients under study were Q-angle=121.93±3.78, TW=86.06±7.65, HW=52.4±4.69, FW=37.74±4.29, HAL=118.43±10.47 and FAL=105.34±7.59 mm, which were higher in men. There was a direct and significant correlation of 23% between age and TW, which was significant according to the Pearson Correlation Test (P=0.039). Inverse correlation of 14% was observed between HAL width and BMI, which was statistically significant (P=0.042). FAL variable had a decreasing trend with decreasing BMD (P=0.031).
Conclusion: Proximal femur characteristics were significantly related to factors such as gender and BMI. The morphological specifications of femur proximal were higher in men than in women. Compared to evaluations in other regions, the included characteristics are distinct from other countries, which these differences can be caused by genetic characteristics, environment, nutritional status, and lifestyle.

Introduction

There are differences in various populations in terms of skeletal components, and these differences depend on genetics and environmental factors such as geography, nutrition, lifestyle, etc. Differences in the sizes of skeletal components show the racial characteristics of a population. Morphometric assessment is used to show differences between different populations or between individuals of the same population. In addition, morphometric evaluations can be used as a guide for doctors in the clinical department so that they can use it to obtain information such as fracture risk factors or useful information during surgery. Fractures have a very important place due to bearing a heavy burden on the shoulders of the health system and due to its complications, such as disability and death.[1-3]

In particular, hip fracture is a major problem, especially in the elderly. The shape of femoral head is considered as an important risk factor for hip and femoral neck fractures, regardless of bone strength and density.[3-5] A bone breaks when the total stress on it exceeds its endurance. Several factors play a role in the destructiveness of this pressure, including: the geometric shape of the bone, the strength of the material from which the bone is made, the amount of force applied and also the direction of the force applied to the bone.[6-8]

Many studies have been conducted in order to identify the risk factors of hip fracture and then prevent these fractures.[9,10] The risk of hip fracture can be predicted according to some factors. These factors include: Body Mass Index (BMI), Bone Mineral Density (BMD), muscle strength, physical habits, femur bone morphometry, family history, lifestyle, the direction and amount of [11] forces applied to the bone.[11-14] There are substantial differences in the incidence of hip fractures worldwide, which indicate the existence of important environmental factors and can reduce the incidence of hip fractures. These fundamental differences may be related to genetic factors and environmental conditions (climate, lifestyle factors, etc.) that affect BMI, BMD and proximal femur bone morphometry.[15, 16]

The femur has a proximal end, shaft, and distal end. The proximal end of this bone has been consisted of the head, neck, and greater and lesser trochanters.[17] Femur bone head supports all the weight of the body. For this reason, this hypothesis is proposed that the proximal part of the femur may play a role in the endurance of the femoral neck. The proximal part of the femur acts like a support band and its biomechanical properties (the amount of support for the femoral neck) depend on the length and width of the femoral neck.[18] The mechanical resistance of femoral head is related to the morphometric parameters of the thigh, including: the length of the hip axis, the length of the femoral neck axis, the width of the femoral neck, the width of the femoral head, the width between the trochanters, and the angle between the neck and the body of the femur.

Also, these criteria play a role in bone resistance against impact, which is the most important cause of hip fracture in different races.[19] Some factors are associated with a high risk of fracture, such as greater length of the hip axis,[20] greater angle between the neck and body of the femur, greater width of the femoral neck.[21]

Objectives

This study was done the aim of evaluation the morphometric parameters of the proximal part of the femur and BMI in the patients of Shahid Beheshti Hospital in Kashan and Ayatollah Kashani Hospital in Isfahan in the years 1998-1999.

Methods

Study setting

This descriptive-analytical study was conducted on 200 patients referred to the Shahid Beheshti Hospital in Kashan and the Ayatollah Kashani Hospital in Isfahan between 2018 and 2019. The target population was individuals seeking medical care at these facilities in 2018.

Inclusion and exclusion criteria

Inclusion criteria

- Referrals to Shahid Beheshti Hospital of Kashan and Ayatollah Kashani Hospital of Isfahan.
- Having at least one femur x-ray taken in the supine position.
- Willingness to participate in the study.
- Age above 50 years.

Exclusion criteria

- Serious injury in the examined organ.
- Conditions such as metabolic bone disease, malignancy, arthritis, or kidney failure.

Design procedure

Patients above the age of 50, encompassing both genders, who were referred to the aforementioned hospitals in 2018 were examined. Those with supine radiographs of the femur's proximal region were considered for inclusion in the study. However, patients displaying the listed exclusion criteria were omitted. Image J software measured the bone density in the femoral neck area. Participant data included age, gender, weight, height, and medical history. BMI was calculated by dividing the weight in kilograms by the square of height in meters. Radiographic images of the femur's proximal part were produced in line with the hospital's standard protocol. As per this protocol, patients were placed supine with their thigh and lower limb rotated 15-20 degrees inward, ensuring the femoral neck was parallel to the image receptor's surface. A knee holder was used to stabilize the pelvic rotation, with the heels positioned 20-24 cm apart. The radiation center targeted the soft tissue surface above the greater trochanter, situated between the ASIS and the symphysis pubis, from a distance of 100 cm. Measurements followed the details outlined in Figure 1. Data were collected by reviewing records and using a researcher-developed checklist.

Statistical analysis

Data were analyzed using SPSS (version 26.0, SPSS Inc, Chicago, IL, USA). The Chi-Square test was employed to compare nominal and qualitative data across two groups, while the Independent Samples T-Test was used to compare quantitative data between them. Pearson's correlation test was utilized to explore relationships among quantitative variables. A p-value of less than 0.05 was deemed statistically significant.

Ethical considerations

The study was conducted in accordance with the Declaration of Helsinki. This clinical trial was approved by the Medical Ethics Committee of Kashan University of Medical Sciences (number: IR.KAUMS.MEDNT.REC.1396.21). All participants signed an informed consent form.

Results

Sex distribution and BMI

This study was carried out on 200 patients referred to the Shahid Beheshti Hospital in Kashan and Ayatollah Kashani Hospital in Isfahan. The gender distribution showed that 40% (80 patients) were male, while 60% (120 patients) were female. Males had an average age of 62.34±9.67 years, whereas females had an average age of 59.45±8.78 years. The T-test indicated that males had a statistically significant higher average age (P=0.03). Moreover, when observing age group distribution, there was a significant discrepancy across various age brackets in terms of TW (P=0.014), as detailed in Table 1.

The average BMI for the evaluated patients was 26.57±3.7 kg/m^2. From the data, 2% (4 patients) were underweight, 30.5% (61 patients) had a normal weight, 51.5% (103 patients) were overweight, and 16% (32 patients) were obese.

BMD and morphological examination of femur bone angles

The average BMD for all patients was documented at 0.729±0.13, spanning from 0.25-1.07. BMD was higher in males, with an average of 0.768±0.15 compared to females at 0.703±0.11. The T-test revealed that men had a significantly higher bone density (P=0.001). In the evaluation of femur bone angles, the Q angle, representing the angle between the neck and body of the femur, had the smallest standard deviation. In contrast, the hip axis length showed the largest standard deviation within the studied population.

Examining the morphological characteristics of the proximal part of the femur according to the characteristics of the patients

The analysis revealed a notable 23% correlation between age and intertrochanteric width (TW), as confirmed by the Pearson correlation test (P=0.001). In contrast, no meaningful correlation was identified between this width and other angles of the femur bone (P>0.05) (refer to Table 2). When examining femur bone angles by gender, there were significant discrepancies between men and women. Specifically, all femur bone angles were consistently higher in men (P<0.05) (Table 2). Evaluating the link between BMI and femur bone angles showed a 14% inverse relationship with the HAL angle, which was statistically significant (P=0.042). However, no significant correlation was detected between BMI and other femur bone angles (Table 2). Lastly, bone density did not show a statistically meaningful relationship with any femur bone measurements (Table 2).

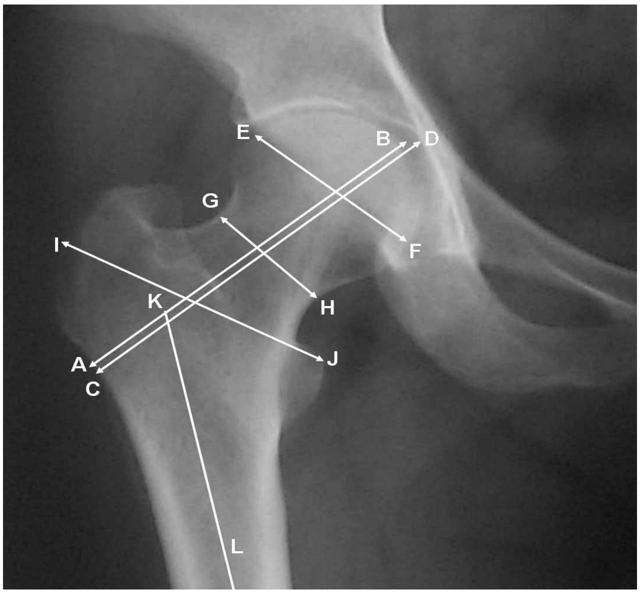

Figure 1. Definition of the parameters measured from the anteroposterior roentgenograms of the proximal femur. **A-B** (FAL): Length of the femoral neck axis from the base of the lateral part of the greater trochanter to the caput femoris; **C-D** (HAL): Length of the femoral neck axis from the base of the lateral part of the greater trochanter to the inner pelvic brim; **E-F** (HW): Broadest cross-section of the femoral head; **G-H** (FW): Narrowest cross-section of the femoral neck; **I-J** (TW): Cross-section from immediately above the lesser trochanter to the most lateral aspect of the greater trochanter; **B-K-L** (Q-angle): Angle between the femoral neck and shaft of the femur.

Table 1. Frequency distribution of the different age groups of men and women

Angles	Age			P-Value
	50-60	60-70	>70	
Q-angle	121.96±3.44	121.64±4.00	122.31±4.53	0.72
TW	84.02±10.20	88.18±6.20	87.37±10.18	0.014
HW	52.39±5.00	52.45±4.48	52.35±4.03	0.99
FW	37.44±4.15	38.23±3.75	38.00±5.55	0.51
HAL	117.35±9.41	120.81±11.84	118.15±11.18	0.13
FAL	102.70±14.69	107.12±7.63	102.28±20.67	0.14

(**Q-angle**): Angle between the femoral neck and shaft of femur; (**TW**): Cross-section from immediately above the lesser trochanter to the most lateral aspect of the greater trochanter; (**HW**): Broadest cross-section of the femoral head; (**FW**): femoral neck width; (**HAL**): The length of the hip axis; (**FAL**): Length of the femoral neck axis from the base of the lateral part of the greater trochanter to the caput femoris. All data were shown into Mean±Standard Deviation.

Table 2. Correlation between different parameters such as age, gender, Body Mass Index (BMI) and Bone Mineral Density (BMD) with morphological features of proximal femur in patients

Parameter Angles	Correlation rate with age	p-value	Male (mean±SD)	Female (mean±SD)	p-value	Correlation rate with BMI	p-value	Correlation rate with BMD	P-Value
Q (degree)	0.05	0.48	122.64±3.6	121.46±3.83	0.03	-0.067	0.35	-0.089	**0.21**
TW (mm)	0.23	0.001	91.06±7.03	82.13±9.15	<0.001	-0.046	0.52	-0.008	**0.92**
HW (mm)	0.039	0.58	54.79±4.81	50.8±3.87	<0.001	-0.103	0.15	0.043	**0.55**
FW (mm)	0.1	0.17	40.52±3.64	35.89±3.66	<0.001	0.009	0.9	0.064	**0.37**
HAL (mm)	0.103	0.15	124.03±8.78	114.7±9.84	<0.001	-0.14	0.042	-0.088	**0.21**
FAL (mm)	0.135	0.057	112.29±7.14	98.22±15.3	<0.001	-0.045	0.53	0.077	**0.031**

(**Q-angle**): Angle between the femoral neck and shaft of femur; (**TW**): Cross-section from immediately above the lesser trochanter to the most lateral aspect of the greater trochanter; (**HW**): Broadest cross-section of the femoral head; (**FW**): femoral neck width; (**HAL**): The length of the hip axis; (**FAL**): Length of the femoral neck axis from the base of the lateral part of the greater trochanter to the caput femoris. All data were shown into Mean±Standard Deviation.

Discussion

The femur bone is a pivotal component of the human skeletal system. It is essential for carrying out routine activities and maintaining human balance. Factors such as osteoporosis and individual variables are linked to fractures and injuries of the femoral head.[22] The morphology and structure of femur bone angles have emerged as significant determinants of hip and knee fractures and injuries.[23] This research sought to discern the morphometric parameters of the proximal segment of the femur and its association with various parameters in patients from Shahid Beheshti Hospital in Kashan and Ayatollah Kashani Hospital in Isfahan, utilizing radiographic images from 2018.

From our findings, six morphological parameters of the femur in the assessed patients were identified as follows: Q-angle=121.93±3.78, TW=86.06±7.65 mm, HW=52.4±4.69 mm, FW=37.74±4.29 mm, HAL=118.43±10.47 mm, and FAL=105.34±7.59 mm. In Dehghan et al.'s 2019 study at the Kurd University of Medical Sciences, the FAL measured 103.15±11.18 mm, and HAL was 118.48±14.21 mm. These values are in close agreement with our findings. Furthermore, the average FW in the Shahrekord population was 36.09±4.66 mm, aligning with our results.[24]

Conversely, when examining the morphological features of a Brazilian cohort, we found disparities in our data. Specifically, the average FHD on the right was 31.1±2.7 mm and on the left was 30.8±3.0 mm. The right and left FNL measured 30.1±3.4 mm and 30.5±4 mm, respectively. Other measurements include FNW at 2.94±30.96 mm, FAL at 5.9±98.2 mm, OS at 42.6±6.1 mm (right) and 42±5.6 mm (left), and CDA at 132±7.2 degrees (right) and 131.8±5.2 degrees (left).[25]

In Bhattacharya et al.'s study, the average values for six morphological features of the proximal femur- namely FAL, FW, HAL, HW, NSA, and TW- were reported as 10.04±1.03 cm, 2.6±0.49 cm, 9.8±0.75 cm, 4.89±0.28 cm, 125.04±2.06 cm, and 6.42±0.26 cm, respectively.[26] In contrast, Irdesel and Ari's 2006 research, which focused on the morphological attributes of the distal femur in a Turkish cohort, found the respective values to be 10.8, 10.14, 5.21, 3.54, 8.42 cm, and 131.52 degrees.[27] Our data and a comparison with other studies show that morphological features of the distal femur differ across populations. While genetic predispositions significantly influence these variations,[16] lifestyle, nutrition, physical activity, profession, mobility, and the individual's activity level can also impact these characteristics.[24, 26]

Our current research findings suggest that there is no significant difference in the morphological attributes of the proximal femur concerning age. However, distinctions are evident between genders, with males typically exhibiting more pronounced values than females. This observation aligns with the conclusions drawn by Faulkner et al.,[1] Dehghan et al.,[24] and Bhattacharya et al.[26] Generally, it is inferred that these values tend to be greater in males due to their larger skeletal framework. Nevertheless, other considerations, such as men's heightened physical activity and occupational factors, might also contribute to these differences between genders. Bhattacharya et al., further highlighted that in their research, a patient's age exhibited a significant correlation with only two metrics: FAL and HW.[26]

Analysis of the relationship between BMI and femur bone characteristics in our subjects revealed that only the length of the pelvic axis demonstrated a significant correlation with BMI. Other features showed no significant association with BMI. This observation mirrors the results from Soltani et al.'s study, where a direct and significant correlation was identified between individuals' height and weight and the length of the pelvic axis.[28]

In Bhattacharya et al.'s study, there was a pronounced direct correlation between the morphological indices of the proximal femur (except NSA) and weight. Furthermore, all values (except HAL) exhibited a direct and significant relationship with the height of patients. Every index showed a direct and significant association with BMI.[26] Similarly, in Irdesel and Ari's study, which assessed the morphological features of the proximal femur in a Turkish population, significant correlations were found between BMI and TW (r=0.23), FW (r=0.169), and HW (r=0.175).[27]

The influence of BMI on bone morphology can be approached from two viewpoints: direct and indirect effects. Directly, BMI impacts femur bone morphology due to the increased pressure from the upper body weight on the lower limb bones, such as the femur head and knee. In overweight or obese individuals, this added pressure on the knee and hip joints can lead to degenerative alterations, resulting in the wear of the femur head and knee.[29] The stress from excess weight might also induce anatomical changes in bones, especially the femoral head bone.[30]

Indirectly, BMI can affect the skeletal system through metabolic disorders that result in reduced bone density.[31]

Our research findings indicate that there is no significant association between the morphological attributes of the proximal femur and BMD (Bone Mineral Density). Contrastingly, in a study conducted by Malekzadeh et al., a notable negative correlation was observed between the mineral density of the femoral neck in the osteoporotic group and NSA. Their research further highlighted the influence of weight and BMI on bone strength and density in the femoral neck region, suggesting that within the osteoporotic group, the average BMI, weight, and NSA play predictive roles for the BMD at the proximal thigh's end.[32]

Gnudi et al.'s 2012 research found a significant inverse relationship between the femoral neck angle and its bone density.[33] Furthermore, Cummings and Melton's 2002 study revealed a significant association between the occurrence of femoral head fractures and the geometric properties of the femur, specifically the HAL dimension.[34]

The discrepancy between the outcomes of our research and the aforementioned studies can likely be attributed to differences in the populations under investigation. The previous studies primarily focused on the relationship between bone mineral density and proximal femur morphology in postmenopausal women. In contrast, our study centered on examining the morphological characteristics in a cohort of normal and healthy individuals.

It is recommended that future research on this topic employ a larger sample size. Additionally, the influences of individual, environmental, occupational, and nutritional factors on the morphology of the proximal femur should be explored. A study should also be conducted to determine how the characteristics of the proximal femur impact the likelihood of bone fractures.

One of this study's primary challenges and limitations was the insufficient number of eligible patients. Additionally, coordinating the transportation of patients to the radiology department for height and weight measurements and assessing the characteristics of the proximal femur posed further challenges. These issues were eventually addressed through persistent follow-up and collaboration with department officials and the patient's families.

Conclusions

In conclusion, there is a notable correlation between the characteristics of the proximal femur and factors like gender and BMI. Specifically, the morphological traits of the proximal femur in men surpass those in women. When juxtaposed with studies from other regions, it's evident that these characteristics vary across countries. Such variations can be attributed to genetic makeup, environmental influences, nutritional habits, and lifestyle choices. However, given the limitations of this study, particularly the limited sample size, further research in this area is highly recommended.

Acknowledgment

None.

Competing interests

The authors declare that they have no competing interests.

Abbreviations

Q-angle: The angle between the neck and the body of the femur,

TW: The width between the trochanters,

HW: The width of the femoral head,

FW: The width of the femoral neck,

HAL: the length of the hip axis,

FAL: Femoral neck axis length,

BMD: Bone Mineral Density.

Authors' contributions

All authors read and approved the final manuscript. All authors take responsibility for the integrity of the data and the accuracy of the data analysis.

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Availability of data and materials

The data used in this study are available from the corresponding author on request.

Ethics approval and consent to participate

This clinical trial was approved by the Medical Ethics Committee of Kashan University of Medical Sciences (number: IR.KAUMS.MEDNT.REC.1396.21).

Consent for publication

By submitting this document, the authors declare their consent for the final accepted version of the manuscript to be considered for publication.

References

1. Faulkner KG, Cummings SR, Black D, Palermo L, Glüer CC, Genant HK. Simple measurement of femoral geometry predicts hip fracture: the study of osteoporotic fractures. J Bone Miner Res. 1993;8:1211-17. doi:10.1002/jbmr.5650081008 PMid:8256658
2. Boonen S, Koutri R, Dequeker J, Aerssens J, Lowet G, Nijs J, et al. Measurement of femoral geometry in type I and type II osteoporosis: differences in hip axis length consistent with heterogeneity in the pathogenesis of osteoporotic fractures. J Bone Miner Res. 1995;10:1908-12. doi:10.1002/jbmr.5650101210 PMid:8619371
3. Gregory JS, Testi D, Stewart A, Undrill PE, Reid DM, Aspden RM. A method for assessment of the shape of the proximal femur and its relationship to osteoporotic hip fracture. Osteoporos Int. 2004;15:5-11. doi:10.1007/s00198-003-1451-y PMid:14605797
4. Głodek J, Milewska K, Tobolska A, Grabarczyk Ł, Maksymowicz W, Bada I, et al. Feline hip joint anatomy in magnetic resonance images. Anat Histol Embryol. 2019;48:449-54. doi:10.1111/ahe.12466 PMid:31348547
5. Carballido-Gamio J, Harnish R, Saeed I, Streeper T, Sigurdsson S, Amin S, et al. Structural patterns of the proximal femur in relation to age and hip fracture risk in women. Bone. 2013;57:290-99. doi:10.1016/j.bone.2013.08.017 PMid:23981658 PMCid:PMC3809121
6. Ravn P, Cizza G, Bjarnason N, Thompson D, Daley M, Wasnich R, et al. Low body mass index is an important risk factor for low bone mass and increased bone loss in early postmenopausal women. J Bone Miner Res. 1999;14:1622-27. doi:10.1359/jbmr.1999.14.9.1622 PMid:10469292
7. Karimzadeh A, Taheri M, Bayat M, Beale A, Ahmadi H. Localized gluteal skin pinch pressure hyperalgesia in patients with chronic low-back pain. Novel Clin Med. 2022; 1(1): 32-37. doi: 10.22034/ncm.2022.143713
8. Liu J-M, Zhao H-Y, Ning G, Zhao Y-J, Zhang L-Z, Sun L-H, et al. Relationship between body composition and bone mineral density in healthy young and premenopausal Chinese women. Osteoporos Int. 2004;15:238-42. doi:10.1007/s00198-003-1536-7 PMid:14727013
9. Hawker G, Hawker G, Jamal S, Jamal S, Ridout R, Ridout R, et al. A clinical prediction rule to identify premenopausal women with low bone mass. Osteoporos Int. 2002;13:400-06. doi:10.1007/s001980200046 PMid:12086351
10. Munasinghe RL, Botea V, Edelson GW. Association among age, height, weight, and body mass index with discordant regional bone mineral density. J Clin Densitom. 2002;5:369-73. doi:10.1385/JCD:5:4:369 PMid:12665637
11. Wang D, Shi L, Griffith JF, Qin L, Yew DT, Riggs CM. Comprehensive surface-based morphometry reveals the association of fracture risk and bone geometry. J Orthop Res. 2012;30:1277-84. doi:10.1002/jor.22062 PMid:22253193
12. Glüer CC, Cummings SR, Pressman A, Li J, Glüer K, Faulkner KG, et al. Prediction of hip fractures from pelvic radiographs: the study of osteoporotic fractures. J Bone Miner Res. 1994;9:671-77. doi:10.1002/jbmr.5650090512 PMid:8053396
13. Pande I, O" Neill T, Pritchard C, Scott D, Woolf A. Bone mineral density, hip axis length and risk of hip fracture in men: results from the Cornwall Hip Fracture Study. Osteoporos Int. 2000;11:866-70. doi:10.1007/s001980070046 PMid:11199191
14. Calis HT, Eryavuz M, Calis M. Comparison of femoral geometry among cases with and without hip fractures. Yonsei Med J.

2004;45:901-07. doi:10.3349/ymj.2004.45.5.901 PMid:15515202
15. Gnudi S, Ripamonti C, Lisi L, Fini M, Giardino R, Giavaresi G. Proximal femur geometry to detect and distinguish femoral neck fractures from trochanteric fractures in postmenopausal women. Osteoporos Int. 2002;13:69-73. doi:10.1007/s198-002-8340-2 PMid:11878458
16. Greendale GA, Young JT, Huang M-H, Bucur A, Wang Y, Seeman T. Hip axis length in mid-life Japanese and Caucasian US residents: no evidence for an ethnic difference. Osteoporos Int. 2003;14:320-25. doi:10.1007/s00198-002-1367-y PMid:12730747
17. Gupta M, Devadas D, Sahni C, Nayak A, Tiwari PK, Mishra A. Morphometric analysis of the proximal femur with its clinical correlation in Eastern Uttar Pradesh Region. Cureus. 2022;14. doi:10.7759/cureus.28780
18. Cheng X, Lowet G, Boonen S, Nicholson P, Brys P, Nijs J, et al. Assessment of the strength of proximal femur in vitro: relationship to femoral bone mineral density and femoral geometry. Bone. 1997;20:213-18. doi:10.1016/S8756-3282(96)00383-3 PMid:9071471
19. Nayak L, Baisakh P, Panda SK, Chinara PK. Co-relation between hip axis length and femoral neck-shaft angle with body mass index of indian population: a radiological study. Int J Cur Res Rev. 2021;13:115. doi:10.31782/IJCRR.2021.13826
20. Gnudi S, Ripamonti C, Gualtieri G, Malavolta N. Geometry of proximal femur in the prediction of hip fracture in osteoporotic women. Br J Radiol. 1999;72:729-33. doi:10.1259/bjr.72.860.10624337 PMid:10624337
21. Alonso CG, Curiel MD, Carranza FH, Cano RP, Pérez AD. Femoral bone mineral density, neck-shaft angle and mean femoral neck width as predictors of hip fracture in men and women. Osteoporos Int. 2000;11:714. doi:10.1007/s001980070071
22. Karlsson KM, Sernbo I, Obrant KJ, Redlund-Johnell I, Johnell O. Femoral neck geometry and radiographic signs of osteoporosis as predictors of hip fracture. Bone. 1996;18:327-30. doi:10.1016/8756-3282(96)00004-X PMid:8726389
23. Vasta S, Andrade R, Pereira R, Bastos R, Battaglia AG, Papalia R, et al. Bone morphology and morphometry of the lateral femoral condyle is a risk factor for ACL injury. Knee Surg Sports Traumatol Arthrosc. 2018;26:2817-25. doi:10.1007/s00167-017-4761-x PMid:29299611
24. Dehghan M, Abdoli-tafti A, Shafiei Alavijeh S, Rahmati Dehkordi F, Salehi Reyhani SM. Association between proximal femoral geometry and incidence of proximal femoral fractures. Koomesh. 2019;21:67-72.
25. De Sousa E, Fernandes RMP, Mathias MB, Rodrigues MR, Ambram AJ, Babinski MA. Morphometric study of the proximal femur extremity in Brazilians. Int J Morphol. 2010;28:835-40. doi:10.4067/S0717-95022010000300027
26. Bhattacharya S, Chakraborty PB, Mukherjee A. Study of proximal femoral morphometry by radiography and its correlation with body mass index. J Anat Soc India. 2012;61:183-88. doi:10.1016/S0003-2778(12)80029-3
27. Irdesel J, Ari I. The proximal femoral morphometry of Turkish women on radiographs. European J Anat. 2006;10:21-26.
28. Soltani A, Moayyeri A, Saadipoor A, Seyedahmadinejad S, Zandieh A, Ahmadi Abhari S. Determination of geometric indices of the femoral bone density and its association with bone density of proximal femur. Iran J Endoc Metab. 2009;10:557-62.
29. Agostini GM, Ross AH. The effect of weight on the femur: a cross-sectional analysis. J Forensic Sci. 2011;56:339-43. doi:10.1111/j.1556-4029.2010.01648.x PMid:21210806
30. Beck TJ, Petit MA, Wu G, LeBoff MS, Cauley JA, Chen Z. Does obesity really make the femur stronger? BMD, geometry, and fracture incidence in the women's health initiative-observational study. J Bone Miner Res. 2009;24:1369-79. doi:10.1359/jbmr.090307 PMid:19292617 PMCid:PMC2718796
31. Barrera G, Bunout D, Gattás V, de la Maza MP, Leiva L, Hirsch S. A high body mass index protects against femoral neck osteoporosis in healthy elderly subjects. Nutrition. 2004;20:769-71. doi:10.1016/j.nut.2004.05.014 PMid:15325685
32. Malekzadeh Shafaroudi M, Mohammadnegad B, Usefi G, Rezaei N. Study of relation between Neck Shaft Angle (NSA) and mineral density of the femoral head among old post menopausal women in east part of mazandaran province. Iran South Med J. 2016; 19: 586-97. doi:10.18869/acadpub.ismj.19.4.586
33. Gnudi S, Sitta E, Pignotti E. Prediction of incident hip fracture by femoral neck bone mineral density and neck-shaft angle: a 5-year longitudinal study in post-menopausal females. Br J Radiol. 2012;85:e467-e73. doi:10.1259/bjr/57130600 PMid:22096224 PMCid:PMC3587077
34. Cummings SR, Melton LJ. Epidemiology and outcomes of osteoporotic fractures. The Lancet. 2002;359:1761-67. doi:10.1016/S0140-6736(02)08657-9 PMid:12049882

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