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A Study of Anthropometric and Morphological Variation in Adult Human Femora and Its Clinical Relevance

Bharat[1], Ashish Khokhariya[2], Nilay Kumar A. Kapadia[3]

[1]Assistant Professor, Department of Anatomy, Banas Medical College & Research Institute, Palanpur, Gujarat
[2]Associate Professor, Department of Anatomy, Banas Medical College & Research Institute, Palanpur, Gujarat
[3]Associate Professor, Department of Physiology, Banas Medical College & Research Institute, Palanpur, Gujarat

Corresponding Author: Bharat

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ABSTRACT

Introduction: The femur is the longest bone in the body and it is also known as thigh bone. Femur have proximal and distal end. The proximal end is articulated with the acetabulum cavity of hip bone and foes the hip joint. The proximal end has head, neck and two trochanters (greater and lesser) on the upper part of the shaft.

Aims and Objectives: To determine the morphological and morphometric measurements of the femur and to find the correlation between the length and head dimensions of femur

Material and Methods: Sixty human femur bones were employed in the study. The measurement of head and neck of femur dimensions was conducted to determine the average femur length, vertical, and transverse diameter of head, position of nutrient foramina and neck shaft angle of femur. All the measurements were made with assistance of osteometric board, digital vernier caliper and goniometer.

Result: A total of 60 human femora were analyzed for side, length, head dimensions, shape of the fovea capitis, number of nutrient foramina, and neck shaft angle. The length of the femora ranged between 35.5 cm and 46.0 cm. Most bones measured between 40–45 cm, with the majority clustering around 42–44 cm, suggesting a relatively consistent length across the sample. The vertical head dimension varied between 34.3 mm and 46.3 mm, while the horizontal head dimension ranged from 35.2 mm to 46.2 mm.

Conclusion: The current study offers comprehensive morphometric information on the neck shaft angle, head measurements, and femoral length in dry femora. The neck shaft angle showed the most fluctuation, although all other metrics showed a normal distribution.

Keywords: Femur, Neck shaft angle, Nutrient foramen, Fovea

INTRODUCTION

The femur is longest bone in the body and it is also known as thigh bone. Femur have proximal and distal end. The proximal end is articulated with the acetabulum cavity of hip bone and foes the hip joint. The proximal end has head, neck and two trochanters (greater and lesser) on the upper part of the shaft. The head is spherical in shape and have non articular pit (fovea) on its medial surface for the attachment of the ligamentum teres femoris. The neck of the femur is cylindrical type and it connects

head to the shaft of femur. Neck of the femur projects superomedially from the shaft at an angle of approximately 125 degree and it is slightly projects forward. Distal end of femur is articulate with the upper end of tibia and patella and forms the knee joint. [1]

Femur is a principal supporting structure of the lower limbs. It is the point of origin of many of the major locomotor and supportive muscles of the hip, thigh, and leg. They are significant in running, walking, and standing functions. In young individuals, the head epiphysis is supplied with blood by a small branch of the obturator artery, which travels to the head through the ligament of the head of the femur. The cranial part of the femoral neck is a generous recipient of blood supply from the medial femoral circumflex artery. These perforating branches pass through the capsule and travel up the neck deep to the synovial membrane. [2]

The neck shaft angle of the femur is about 160° in the child and about 125° in the adult. An increase in the angle is termed as coxa valga, and it occurs, e.g., in congenital dislocation of the hip. Adduction of the hip joint is limited in this condition. Reduction in this angle is referred to as coxa vara, and occurs in femoral neck fractures and in slipping of the epiphysis of the femur. Abduction of the hip joint is limited in this condition. Shenton' line is a useful technique for measuring the angle of the femoral neck on a hip region radiograph. [2]

Fractures of the distal third of the shaft of the femur, the same displacement of the distal fragment occurs as seen in fractures of the middle third of the shaft. However, the distal fragment is smaller and is rotated backward by the gastrocnemius muscle to a greater degree and may exert pressure on the popliteal artery and interfere with the blood flow through the leg and foot. From these accounts, it is clear that knowledge of the different actions of the muscles of the leg is necessary to understand the displacement of the fragments of a fractured femur. Considerable traction on the distal fragment is usually required to overcome the powerful muscles and restore the limb to its correct length before manipulation and operative therapy to bring the proximal and distal fragments into correct alignment. [2]

MATERIALS & METHODS

The present study was conducted in the Department of Anatomy, Banas medical college and research institute, Palanpur, Gujarat. It is cross sectional study conducted on 60 adult human femurs of unknown age and sex. Ethical clearance approved by internal ethical committee. The following measurements were measured i.e. side, length, vertical head dimension, horizontal head dimension, number of nutrient foramen and neck shaft angle.

Length of femur- The straight line connecting the head's highest point and the femur's medial condyle's lowest point was used to measure it. (Fig. 1)

Vertical diameter of head - It was calculated as the vertical distance between the head's most superior and inferior points on the articular border. (Fig. 2)

Horizontal diameter of head- The femoral head's maximal distance on the articular edge in a horizontal plane was used to measure it. (Fig. 3)

Neck shaft angle - It is angle between the long axis of shaft of femur and axis of neck of femur (Fig. 4)

Inclusion criteria: Femur bones of both right and left side for present study.

Exclusion criteria: Femur bones have any disease, surgical procedure or any fracture.

Tools: Osteometric board (Bone length measurement device), Digital vernier calliper Goniometer, and marker pencil.

Study procedure and techniques: The selected 60 dry femurs placed on the table and start labelling of femurs. Then one by one bone is placed on osteometric board and start measuring the length of femur. After the length we measures the head dimensions by digital vernier caliper and neck shaft angle of femur by goniometer and identify the nutrient foramen.

Fig. 1

Fig. 2

Fig. 3

Fig. 4

STATISTICAL ANALYSIS

The data were summarised using descriptive statistics like mean, median, standard deviation, coefficients of variation, range, inter quartile range (IQR), and Shapiro Wilk test. The correlation between the length and the head dimensions was checked using Mann-Whitney U test. All the measurements were tabulated and calculated by Microsoft excel.

RESULT

A total of 60 human femora were analyzed for side, length, head dimensions, shape of the fovea capitis, number of nutrient foramina, and neck shaft angle. The length of the femora ranged between 35.5 cm and 46.0 cm. Most bones measured between 40–45 cm, with the majority clustering around 42–44 cm, suggesting a relatively consistent length across the sample. The vertical head dimension varied between 34.3 mm and 46.3 mm, while the horizontal head dimension ranged from 35.2 mm to 46.2 mm. Both vertical and horizontal diameters were found to be fairly similar in most cases, with average values lying around 39–41 mm. This indicates proportionality in head shape across the sample. The shape of the fovea capitis femoris showed variation. The most common type observed was circular, followed by horizontal oval and irregular forms. A few specimens also showed a horizontal circular pattern. This demonstrates that although circular fovea was predominant, other shapes were not uncommon. With respect to the nutrient foramina, most femora had either one or two

foramina. Single foramina were slightly more common, but the presence of two foramina was also frequently observed.

Table No. 1 showing various descriptive parameters.

	Length (cm)	Vertical head dimension (mm)	Horizontal head dimension (mm)	Numbers of nutrient foramen	Neck shaft angle
Median	42.550	39.800	40.500	2.000	125.500
Mean	42.237	39.957	40.657	1.533	124.767
Std. Deviation	2.495	3.109	2.992	0.503	4.339
IQR	3.000	3.300	4.200	1.000	7.000
Shapiro-Wilk	0.952	0.964	0.961	0.635	0.954
P-value of Shapiro-Wilk	0.019	0.072	0.052	< .001	0.025
Minimum	35.500	34.300	35.200	1.000	117.000
Maximum	46.000	46.300	46.200	2.000	133.000

The neck shaft angle (NSA) demonstrated considerable variability, ranging from 117° to 133°. The mean angle was close to 124–125°, which aligns with the typical adult anatomical range. Most femora had angles between 120° and 130°, while a few outliers showed lower or higher values. Femoral length was relatively consistent, mostly in the 42–44 cm range.

Table no. 2 showing the correlation between the length and head dimensions

	Vertical head dimension	Horizontal head dimension
Length	4.1438	2.842
P value	0.00001	0.00452

Correlations of the length with vertical and horizontal dimension were statistically significant. Femoral head dimensions (vertical and horizontal) were nearly equal, averaging \~40 mm, showing proportional head morphology. The circular fovea was the most common type, though oval and irregular shapes were also seen. One nutrient foramen was slightly more frequent than two. The neck shaft angle showed the widest variation among all parameters (117–133°), but the majority lay within the normal anatomical range.

DISCUSSION

The present study evaluated the morphometric parameters of the femur including length, head dimensions, and neck shaft angle in dry femora. All parameters followed a normal distribution, and notable variability was observed particularly in the neck shaft angle. The mean femoral length in the current study was 42.24 mm, which aligns with previously reported values in Indian populations. Chaudhary et al. (2017) reported comparable measurements in their cross-sectional analysis of femoral length and neck dimensions in dry bones. [11] The vertical and horizontal head dimensions observed in this study (39.96 mm and 40.66 mm, respectively) are consistent with the findings of Sinha et al. (2022), who highlighted the clinical significance of femoral head and neck measurements in relation to prosthesis design and hip joint biomechanics [7]. Roy et al. (2019) also demonstrated significant morphometric variations in the femoral head, particularly regarding the fovea capitis femoris, which may contribute to differences in head dimension measurements across populations [5]. The neck shaft angle (NSA) is a critical parameter due to its direct relevance to hip stability and load transmission. In the present study, the mean NSA was 124.77°, which falls within the range reported in previous Indian studies. Vaishnani et al. (2019) reported a mean NSA of 125.3° in South Gujarat, supporting the regional consistency of this measurement across

western and northern India [10]. Changil et al. (2020) also documented similar NSA values in Central India, further reinforcing the population-specific stability of this parameter [9].

On the other hand, Ceynowa et al. (2019) noted that the position and morphometry of the fovea capitis femoris could influence NSA and head dimensions, particularly in radiological assessments [4]. These anatomical nuances may account for minor variations across studies. Moreover, Khaleel and Shaik (2014) emphasized that femoral morphometry exhibits population-based differences, which should be considered in orthopedic planning and forensic identification [8]. Clinically, variations in NSA and head dimensions play a vital role in prosthesis design, fracture management, and reconstructive surgeries. A reduced NSA predisposes to coxa vara and altered biomechanics, while an increased NSA may lead to coxa valga and instability [3, 7]. The wide range of NSA observed in the current study (16°) highlights the necessity of considering individual variability during surgical interventions. Overall, our results confirm earlier findings while providing region-specific baseline data. The close agreement with studies from different parts of India [9,10] suggests a relatively consistent femoral morphometry across populations, although minor differences are attributable to ethnic and geographical factors.

Table no. 3 showing the various previous studies.

Ref. No.	Author(s), Year	Population/Region	Parameter(s) Studied	Key Findings	Comparison with Present Study
3	Singh & Dhindsa, 2021	North India	Neck-shaft angle	Mean NSA = 124.7°	Almost identical to present study (124.77°)
4	Ceynowa et al., 2019	Radiological (CT)	Fovea capitis femoris, NSA	Position of fovea influences NSA and head dimensions	Supports variability in NSA and head dimensions
5	Roy et al., 2024	Kolkata, West Bengal	Fovea capitis femoris	Morphological & morphometric variations	Explains possible variability in head dimensions
6	Akhter et al., 2024	North India	Nutrient foramina	Number & position of foramina in femur	Not directly comparable, but highlights regional femoral variability
7	Sinha et al., 2022	India	Head & neck dimensions	Mean head diameter ~40 mm; clinical significance	Matches present head dimension values (39.96 mm, 40.66 mm)
8	Khaleel & Shaik, 2014	South India	Osteometry of femur	Highlighted population-based variations	Supports that femoral morphometry differs regionally
9	Changil et al., 2025	Central India	Neck diameter, length, thickness, NSA	NSA values within 124–126°	Comparable to present study (124.77°)
10	Vaishnani et al., 2019	South Gujarat	Femur length & NSA	Mean NSA = 125.3°	Very close to present study; confirms regional consistency
11	Chaudhary et al., 2017	Karnataka, India	Femoral length, neck length, NSA	Provided baseline morphometry data	Femoral length matches present study values
12	Das et al., 2022	India	Femoral length, neck length, NSA	Mean femoral length consistent with Indian norms	Confirms present study findings on length and NSA

The current study offers comprehensive morphometric information on the neck shaft angle, head measurements, and femoral length in dry femora. The neck shaft angle showed the most fluctuation, although all other metrics showed a normal distribution. Regional consistency was suggested by the mean neck shaft angle, which closely matched values previously recorded in several Indian populations.

CONCLUSION

The femoral head measurements also show good agreement with previous findings, confirming their clinical significance for orthopaedic procedures and prosthesis design.

These results emphasize how crucial population-specific morphometric information is in anthropological and therapeutic settings. Understanding the biomechanical variability of the hip joint, creating orthopedic implants, and planning surgeries all depend on knowing the size of the femur.

Declaration by Authors

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