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Original Article

MORPHOMETRY OF PROXIMAL FEMUR AND CORRELATIONS OF THE HEAD NECK SHAFT ASSEMBLAGE

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ABSTRACT

Introduction: Recent times have shown an increased incidence of proximal femur pathologies. The morphology and morphometry of the proximal femur is an important component of hip biomechanics. Altered diameters and angles affect the range of motion and have been found to be causative in hip pathologies. Understanding femoral shape and orientation can help to predict degenerative diseases, relate to hip instability, in designing hip replacement implants, in preoperative planning and for forensic identification of human remains. This study aimed at determining the morphometric parameters of proximal femur and to analyse the correlations between measured parameters.

Materials and Methods: Measurements were made on 120 dry adult human femora of unknown sex (Right-60, Left-60). Transverse and vertical diameters of the head and neck and anterior and posterior neck lengths were measured using digital vernier calliper and neck-shaft angle was measured using a goniometer. Measurements were statistically analysed. Correlation coefficient was used to analyse the relationship among variables.

Results: Mean vertical and transverse diameters of head were 43.23 mm and 43.16 mm and Mean Anterior and Posterior neck lengths were 28.37 mm and 35.81 mm respectively. Mean Neck shaft angle was 128.82□. On comparison between sides, statistically significant differences were observed in neck shaft angle and anterior neck length measurements. Correlation between neck shaft angle and neck length as well as between neck shaft angle and head diameters revealed variable patterns on left and right sides.

Conclusions: Our study has found a significant difference in anterior length of neck in left and right femur as well as a substantial and statistically significant positive correlation was observed between anterior neck length and neck shaft angle of the right femur.

Keywords : Femur, Morphometry, Vernier, Goniometer, Hip, Prosthesis

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INTRODUCTION

Femur and tibia form the greatest proportion of body stature and are of great importance for anthropologists and forensic experts. Various studies and methods have derived equations for femur morphometry, aiding in the estimation of stature across different races, age groups, genders, and populations, as well as assisting forensic experts. Orthopedic surgeons encounter various pathological conditions, congenital anomalies, and fractures related to the femur, and treatment can be planned using knowledge of morphometry [1].

The length of the femur is about one-fourth of the height of an individual. It consists of three parts: the upper end (proximal end), shaft, and lower end (distal end). The upper end comprises the head, neck, greater trochanter, and lesser trochanter. The head is often described as more than half a sphere, with a small rough fovea present postero-inferiorly, protruding medially from its short neck. The intracapsular head is encircled by the acetabular labrum distally to articulate with the acetabulum. The femoral neck has rounded contours with a slightly concave upper surface and an obliquely straight lower surface.

It is approximately 5 cm long, narrowest in its midpart, widest at the sides, and connects the head to the shaft at an average angle of 127°. The neck-shaft angle facilitates movement at the hip joint and provides leverage for the muscles acting around the hip joint, which are attached to the proximal femur. The neck-shaft angle is widest at birth and gradually decreases until age 10. The neck is laterally rotated to the shaft (angle of anteversion) by about 10–15°, although values of this angle vary between individuals and populations [2].

The incidence of femur fractures is higher in road traffic accidents, particularly among the geriatric population. Studies have also reported an increased rate of proximal femur fractures, intertrochanteric femur fractures, hip osteoarthritis, with most ailments being treated surgically using prostheses. The implants and prostheses available are designed based on European data [3]. The morphometry of the femur varies with age, race, gender, etc., so this should be considered when designing suitable implants [4].

We were unable to find enough literature on morphometric studies of the proximal femur among the population of Uttar Pradesh. Hence, this study was planned to address this gap. The primary objectives of the study were (i) to measure the indices of the proximal femur and (ii) to observe correlations between various measured bony parameters.

MATERIAL AND METHODS

The study was conducted in the Department of Anatomy, KGMU, UP. Observations were

made on the study sample which included 120 dry adult human femora of unknown sex (Right-60, Left-60), procured from the Bone Bank of the Department of Anatomy, King George's Medical University, Lucknow, UP. All measurements were taken using a Digital vernier caliper and Goniometer. The bones with visible deformities, fractures, and the bones that were broken were excluded from the study. Observations were made with respect to the following parameters:

1. Vertical and Transverse diameters of the head were measured using a digital vernier caliper as the distance between the most superior and inferior points on the articular margin of the head in the vertical plane (Fig. 1A) and the maximum distance of the femoral head on the articular margin of the head in the horizontal plane respectively (Fig. 1B).

2. Anterior and Posterior neck lengths were measured using a digital vernier caliper as the distance between the base of the head and the midpoint of the intertrochanteric line anteriorly (Fig. 2A) and the distance between the base of the head and the midpoint of the intertrochanteric crest posteriorly respectively (Fig. 2B).

3. Neck-shaft angle was measured using a goniometer as the angle between the long axis of the shaft of the femur and the axis of the neck of the femur (Fig. 3).

All measurements were performed twice by a single person, and then the arithmetic average was taken. The data were tabulated on a Microsoft Excel sheet.

Statistical analysis

All data were statistically analyzed as per standard statistical methods. Variables were compared using appropriate statistical tests to analyze significant effects. A P-value of less than 0.05 was considered statistically significant. The correlation coefficient was used to analyze the relationship among variables.

RESULTS

Mean Vertical diameter of the head was 43.23±3.26 mm. Mean Transverse diameter of the head was 43.16±3.26 mm. The mean anterior neck length was 28.37±3.32 mm. Mean Posterior neck length was 35.81±3.64 mm. Mean Neck shaft angle was 128.82±6.82 (Table 1).

On comparing the measurements of Vertical and Transverse diameters of the head between the right and left sides, there was no statistically significant difference (p-values > 0.05). The averages and standard deviations for these measurements were quite similar for both sides (Table 2). The mean anterior neck length for the left femur was 29.29 mm, and that of the right femur was 27.46 mm.

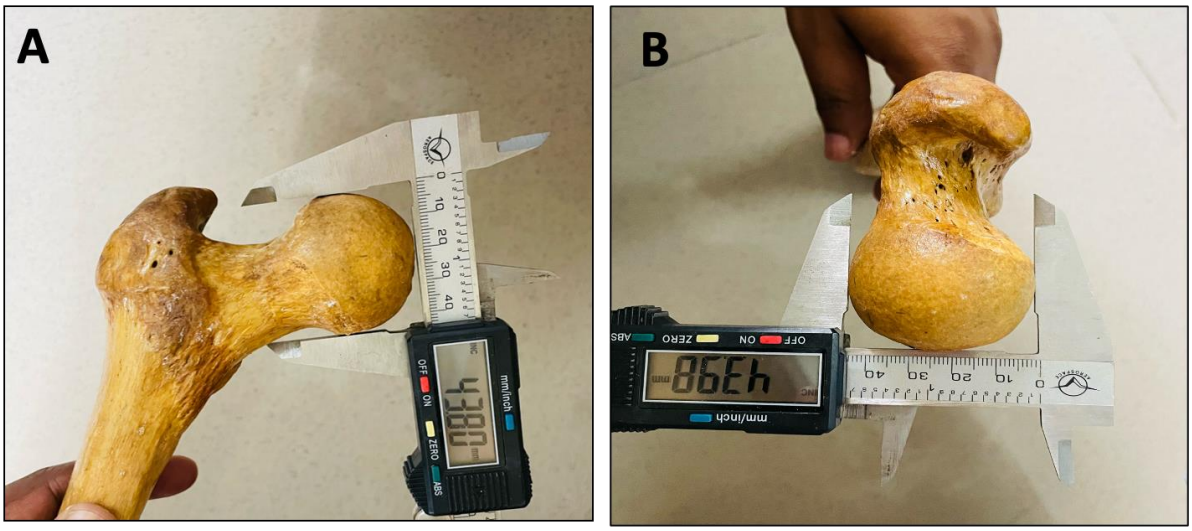

Fig. 1. Measurement of vertical diameter (A) and transverse diameter (B) of head of Femur using digital vernier caliper

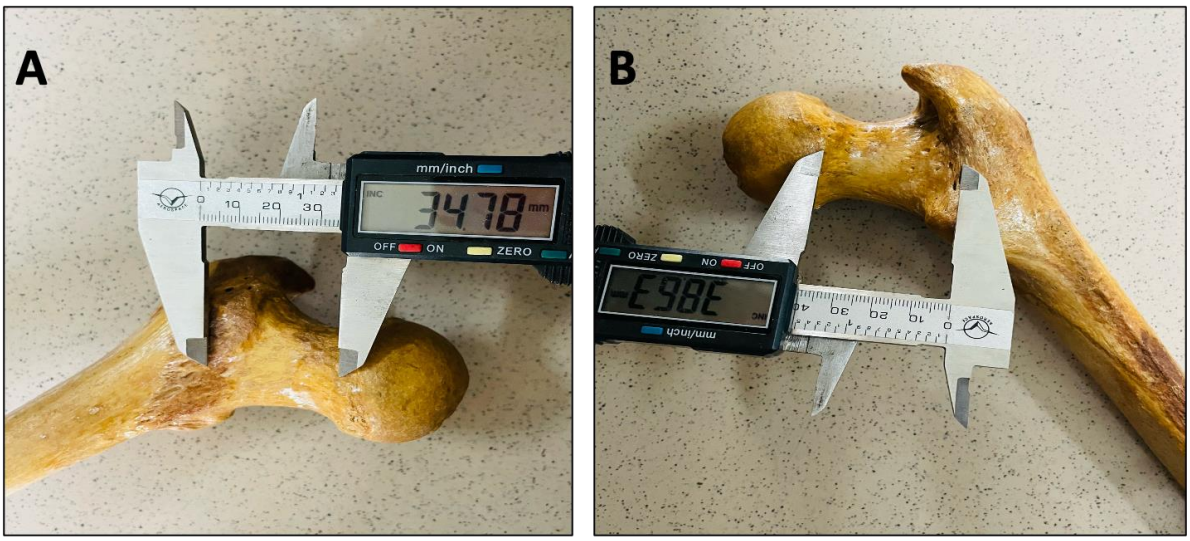

Fig. 2. Measurement of anterior neck length (A) and posterior neck length (B) of head of Femur using digital vernier caliper

On comparing the anterior neck length measurement for the femur of the right and left sides, the difference was statistically significant (p-value = 0.002) (Table 2). The mean posterior neck length measured 35.64 mm on the left side and 35.99 mm on the right side, and the difference was not found to be statistically significant (p-value = 0.596) (Table 2). The mean neck shaft angle was greater on the right side compared to the left side, and a highly significant difference was observed between the left and right femurs (p-value < 0.001) (Table 2).

On analysis of the correlation between neck shaft angle and other parameters of the left

Fig. 3. Measurement of neck-shaft angle of Femur using Goniometer

femur; a weak positive correlation was found between neck shaft angle and the vertical and transverse diameters of the head, and a weak negative correlation was found between neck shaft angle and the anterior and posterior neck lengths. No strong or statistically significant correlation was observed between neck shaft angle and the other measured variables on the left femur (Table 3).

On the analysis of the correlation between neck shaft angle and other parameters of the right femur, a variable and different pattern of correlation was observed compared to the left side. A slight positive correlation was observed between neck shaft angle and the vertical diameter of the head; a weak positive correlation was observed between neck shaft angle and the transverse diameter of the head, and the correlation of head diameters was not found to be statistically significant. A weak positive correlation was observed between neck shaft angle and posterior neck length, which was not significant (Table 4).

A substantial and statistically significant positive correlation was observed between neck shaft angle and anterior neck length ($p = 0.005$), suggesting that as the neck shaft angle increases, there tends to be an increase in anterior neck length of the right femur (Table 4).

DISCUSSION

The cases of total hip arthroplasties are on the increase worldwide, including in India. In this respect, the morphometric measurements of the proximal femur become important as they help in the design of better-fit implants and prostheses for better surgical outcomes. The design and accurate assessment of head prosthesis are major components of arthroplasty. Mismatch of the same may predispose to dislocation, imperfect biomechanics, and groin pain [5].

	Mean	SD	Median	Min	Max	Percentile 25	Percentile 75	Valid N
VERTICAL DIAMETER OF HEAD	43.23	3.26	43.59	28.84	50.75	41.42	45.27	120
TRANSVERSE DIAMETER OF HEAD	43.16	3.26	43.52	29.15	50.74	41.24	44.96	120
ANTERIOR NECK LENGTH	28.37	3.32	28.42	19.74	38.52	25.74	30.38	120
POSTERIOR NECK LENGTH	35.81	3.64	35.77	23.55	44.98	33.56	38.48	120
NECK SHAFT ANGLE	128.82	6.82	130.00	110.00	140.00	122.00	135.00	120

Table 1. Descriptive statistics of all measurements of the Femur (n=120)

In our study, the mean vertical diameter of the head was 43.23±3.26, which was concordant with the study done in the Chinese population where the vertical diameter of the head was 44.64±3.13 mm [6]. Another study on 50 femurs belonging to the Bihar population reported the mean vertical diameter of the head as 40.97±3.46 mm [7]. Dwivedi AK et al [8] conducted a study in the Maharashtrian population and reported the mean vertical diameter of the head as 40.53±3.51mm. Jaiswal et al [9] reported the values as 33.23±4.08 mm.

In our study, the mean transverse diameter of the head was 43.23±3.26 mm, which was higher than studies done by Sinha et al and Dwivedi et al [7,8]. Sinha SK et al studied 50 femurs of the population of Bihar and reported a mean transverse diameter of the head of 41.74±2.76 mm. Dwivedi AK et al [8] conducted a study in the Maharashtrian population and reported the mean transverse diameter of the head as 40.44±3.47 mm. Katch AU et al [6] conducted a study in the Chinese population and reported the values as 44.55±3.37 mm, which were higher than our values.

Optimum neck morphometrics allow the femur to adjust to the biomechanics of the implant. The mean anterior neck length in our study was 28.37±3.32 mm. Sinha SK et al [7] studied 50 femurs of the population of Bihar and reported that the mean anterior neck length was 29.75±5.30 mm. Dwivedi AK et al [8] conducted a study in the Maharashtrian population and reported the mean anterior neck length as 29.92±4.04 mm. Katchy AU et al [6] conducted a study in the Chinese population and reported the values as 31.86±4.22 mm.

The mean posterior neck length in our study was 35.81±3.64 mm, which was similar to Sinha et al and Dwivedi et al. Sinha SK et al [7,8] studied 50 femurs from Bihar and reported values as 35.03±4.87 mm. Dwivedi AK et al [8] conducted a study in the Maharashtra and reported the mean posterior neck length as 35.23±4.22 mm. Jaiswal et al [9] reported the values as 35.59±3.74 mm.

		Mean	SD	Median	Min	Max	Percentile 25	Percentile 75	Valid N
LEFT FEMUR	VERTICAL DIAMETER OF HEAD	42.90	3.83	43.62	28.84	50.75	40.57	45.41	60
	TRANSVERSE DIAMETER OF HEAD	42.75	3.78	43.50	29.15	50.74	40.59	44.91	60
	ANTERIOR NECK LENGTH	29.29	3.38	29.28	19.74	38.52	27.40	31.13	60
	POSTERIOR NECK LENGTH	35.64	4.05	35.77	23.55	43.93	33.40	38.58	60
	NECK SHAFT ANGLE	124.35	5.72	125.00	110.00	140.00	120.00	130.00	60
RIGHT FEMUR	VERTICAL DIAMETER OF HEAD	43.56	2.57	43.58	37.85	49.71	42.04	45.25	60
	TRANSVERSE DIAMETER OF HEAD	43.56	2.62	43.55	37.72	50.59	42.32	44.96	60
	ANTERIOR NECK LENGTH	27.46	3.01	27.63	20.22	36.33	25.23	29.58	60
	POSTERIOR NECK LENGTH	35.99	3.21	35.84	28.26	44.98	33.58	38.25	60
	NECK SHAFT ANGLE	133.28	4.54	133.50	120.00	140.00	130.00	135.00	60

Table 2. Comparison of measurements of various parameters of Femur between left and right

The neck shaft angle (NSA), which helps the acetabulum align with the femoral head, is of great structural and diagnostic value in hip joint mechanics. The angle is a beneficial structural adaptation that increases hip rotation and helps the lower limb to swing away from the pelvis, increasing freedom of movement [10]. In our study, the neck shaft angle was 128.82±6.82. The values are in the range of reported literature. Sinha SK et al [7] reported the mean neck shaft angle as 125.96±6.10. Katchy AU et al [6] reported the mean neck shaft angle as 132.15±7.30. These values were higher as the sample size was 716, and the population group was Chinese, which was different from our study.

Aparna et al [11] reported the mean neck shaft angle as 125 degrees. Ravi et al [1] in their study reported the neck shaft angle as 136.8±4.45. Kamath et al [12] reported in their study the mean neck shaft angle as 137.80±6.90. Kulkarni et al [4] performed a CT-based measurement of the head of the femur, and the values were 127.2±5.2.

K. Sreenivasa Reddy et al [13] conducted a study in the south Indian population and reported the neck shaft angle as 125.35±7.883. The neck shaft angle of the standard femoral prosthesis for arthroplasty is 131°. This is greater than the mean neck shaft angle observed in our study.

	NECK SHAFT ANGLE	ANTERIOR NECK LENGTH	POSTERIOR NECK LENGTH	VERTICAL DIAMETER OF HEAD	TRANSVERSE DIAMETER OF HEAD
Spearman's rho Correlation Coefficient	1.000	-.058	-.191	.050	.067
Sig. (2-tailed)	.	.661	.143	.703	.613
N	60	60	60	60	60

Table 3. Correlation analysis between neck-shaft angle and various other parameters of left Femur

An inappropriate neck shaft angle may increase difficulty in the surgical procedure during arthroplasty and can later impair the natural biomechanics of the hip joint during recovery [14]. In the case of angle mismatch in implants, there could be deformities such as valgus in high angle implants and varus deformities in cases of low angle implants leading to alterations in the biomechanics of the hip and knee joints [13]. This information may thus be useful in guiding prosthetists and orthopedic surgeons to construct suitable implants. The present study reports a significant difference between NSA of the right and left femurs (p-value < 0.001). This suggests a substantial anatomical distinction between the two sides, particularly in terms of the neck shaft angle. In our study, a notable and statistically significant positive correlation was found between the neck shaft angle and the anterior neck length of the right femur.

It can be observed that values for various bony parameters at the upper end of the femur display regional variations in India. Anthropometric measurements for the normal upper end of femora are also variable among western and Indian populations. The environment plays an important role in development; the regional variation of the femur bone is influenced by the geographical area, sex, stature, and heredity. As the proximal end of the femur varies in different ethnic groups with respect to their build, physique, habits, and genetic makeup, the anthropometric measurements of the proximal femur can serve as a valuable tool for designing better-fitting and well-adjusted femoral implants and prostheses to improve treatment outcomes.

	NECK SHAFT ANGLE	ANTERIOR NECK LENGTH	POSTERIOR NECK LENGTH	VERTICAL DIAMETER OF HEAD	TRANSVERSE DIAMETER OF HEAD
Spearman's rho Correlation Coefficient	1.000	.355**	.119	.153	.141
p-value	.	.005	.365	.244	.283
N	60	60	60	60	60

Table 3. Correlation analysis between neck-shaft angle and various other parameters of right Femur

Limitations of the study: The study was done on 120 femora and multiple parameters were analyzed. A variable pattern of correlations were obtained between parameters on left and right side and a strong and statistically significant correlation was observed between neck shaft angle and anterior length of neck on the right side.

The sample size can be expanded further and studied to confirm and further studies can be planned in future to assess the morphometry of distal end and correlation for providing further insight.

CONCLUSION

The knowledge of anatomy of proximal end of femur is very important for clinical and pathological states of the hip joint and for designing prostheses for hip replacement. Previous literatures have reported femoral morphometry to vary with age, gender, race, ethnicity etc. Regional differences among different groups of populations exist.

Though these differences have been explored much in other parts of the world, fewer studies have been conducted among the Indian population comprising of a heterogenous population of varying morphological subgroups. Our study attempted to bridge this gap and offers to give valuable insights for further exploration. A notable and statistically significant positive correlation was found between neck shaft angle and anterior neck length of right femur.

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