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A MORPHOMETRIC STUDY OF THE FEMORAL ANGLE OF ANTEVERSION AND NECK SHAFT ANGLE IN DRY BONE SPECIMEN

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ABSTRACT

Background: The femur is the longest and strongest bone in the human body. The femoral neck connects the head to the shaft at an average angle of 135° (range 120–140°). It is widest at birth and diminishes gradually until the age of 10 years. The neck is laterally rotated with respect to the shaft at approximate angle of 10–15° and is known as the angle of anteversion. The femoral angle of anteversion decreases from approximately 35- 40˚ at birth to 15˚ at skeletal maturity. The aim of this study was to try and establish any significant difference in the angle of anteversion and the neck shaft angle in the dry femur specimens. **Materials and Methods:** A cross-sectional study was conducted using 50 unpaired femurs over a period of six months from July, 2024 to December, 2024. The collected dry bone specimens were observed under daylight and measurement of the neck shaft angle and angle of anteversion was done using goniometer. The collected data was analysed using Microsoft Excel MSO 2021 Version 2508. **Result:** The mean value of the angle of Anteversion for right and left femur was found to be 15.40 ±4.12° and 14.56 ±2.67° respectively while the mean value of the Neck shaft angle was 129.22 ±5.22° and 129.17 ±5.71° for the right and left femurs respectively. **Conclusion:** The data obtained from this study may be valuable for clinicians in the diagnosis and treatment of conditions associated with gait difficulties and an increased risk of fractures, while also providing important reference points for comparative, evolutionary, and population-based studies that explore variations in the neck-shaft angle and angle of anteversion.

INTRODUCTION

The femur is the longest and strongest bone in the human body. It plays a critical role in weight-bearing and locomotion and has a shaft, proximal end and distal end.[1] Connecting the femoral head to the shaft, the femoral neck forms a neck-shaft angle averaging 135°,[1,2] with a physiological variation between 120° and 140°.[2] It measures approximately 5 cm in length, being narrowest at its midpoint and widest at the lateral end. Initially wider at birth, the neck-shaft angle decreases progressively until around age 10, with females typically showing a reduced angle compared to males.[1]

The femoral neck is laterally rotated in relation to the shaft at an angle of approximately 10–15°, known as the angle of anteversion.[1] As a child grows, the femoral angle of anteversion decreases from roughly 35–40° at birth,[3-6] to approximately 15° at skeletal maturity, influenced by the dynamic action of muscles during bipedal locomotion against gravity.[1,3,4] The values of this angle demonstrate variability across individuals and populations.[1,2,3]

From an evolutionary perspective, in quadrupeds with a horizontally oriented femur, the angle of anteversion optimally positions the femoral neck to align with the direction of forces encountered during heel strike.[7]

Over the course of evolution, as Homo erectus emerged from Australopithecus approximately 1.9 million years ago, the role of femoral anteversion was partially assumed by the neck-shaft angle, which more effectively aligned the proximal femoral epiphysis with the impact forces experienced during heel strike in bipedal gait. This adaptation contributed to more efficient long-distance walking in modern humans.[2,8,9]

In conditions such as developmental dysplasia of the hip (DDH) and cerebral palsy, inadequate development of hip abductor forces can lead to the persistence of an increased neck-shaft angle. This results in coxa valga (NSA > 140°), commonly associated with weak hip abductors. Coxa valga increases the risk of proximal femur fractures and contributes to impaired mobility, particularly in individuals with DDH and cerebral palsy. [2,7,10] Current researches indicate that variations in the neck-shaft angle across populations may be influenced by factors such as climate, clothing, and lifestyle. While some studies report statistically significant differences between sides, these findings remain subject to ongoing debate.[2] Coxa valga has been associated with an increased risk of proximal femoral fractures, genu varum, and medial compartment knee osteoarthritis. In contrast, coxa vara (neck-shaft angle <120°) is commonly linked to conditions such as greater trochanteric pain syndrome,[2,10] Paget's disease of bone, osteogenesis imperfecta, osteomyelitis, and osteoporosis.[2,12]

Excessive femoral anteversion with values over 20°, is a frequently observed abnormality, often associated with neurological conditions like cerebral palsy, as well as a range of orthopedic disorders, while values under 10° is termed femoral retroversion.[2,10,11]

In addition to bone mineral density, parameters such as neck-shaft angle, femoral anteversion, hip axis length, and femoral neck width collectively influence fracture risk, particularly in women.[12-14] Moreover, the values of neck shaft angle and Angle of anteversion are important in selection of patients for prosthesis and preoperative planning for total hip replacement surgery, evaluation of pathological conditions of the hip and planning corrective osteotomies of femur and anthropological studies.

A review of global and national literature reveals a wide range of normal values for femoral neck anteversion and neck-shaft angle, influenced by racial and geographic variations—likely attributable to genetic factors, sociocultural influences, and lifestyle differences. In this context, the present study aims to assess the neck-shaft angle and femoral neck anteversion in non-articulated dry femora, thereby providing deeper insights into the femoral geometry.

MATERIALS AND METHODS

The present descriptive cross-sectional study was conducted in the Department of Anatomy, Gauhati Medical College, Guwahati, with approval from the Institutional Ethics Committee. A total of 50 unpaired, non-articulated, and intact dry adult femora—comprising 27 right and 23 left—were obtained from the Department of Anatomy, GMCH. Femurs with any kind of gross pathology or surgical manipulation were excluded from the study. Dry bone specimens were analysed through observation and measurements. Materials used were goniometer, vernier calliper and a clean green cloth.

Method: The collected femurs were cleaned and placed on a green cloth. Assessments were done in daylight and a goniometer was used for measurement of the angles.

The angle of anteversion was measured using a goniometer by Kingsley Olmsted method after placing the specimen at the edge of a horizontal surface such that the condyles of the lower end rest on the surface.[15]

The centre of the femoral head was identified as the point of maximum anteroposterior thickness of the head. Similarly, the centre of the neck was defined as the point of maximum anteroposterior thickness at the base of the neck. These points were determined using a vernier calliper and marked on the surfaces of the head and neck, respectively. A line drawn through these two points was considered the central head–neck axis.

The horizontal limb of a goniometer was fixed at the edge of the experimental table. The vertical limb was held parallel along the axis of the head and neck of the femur. The horizontal surface has been considered as the plane of reference against which the angle of anteversion is measured. The angle thus subtended between the two limbs of the goniometer was recorded.

The neck-shaft angle was also measured using a goniometer. The long axis of the femoral neck was drawn by connecting the midpoints of the diameters of the head and neck. The long axis of the shaft was determined by joining the midpoints of two transverse diameters taken from the femoral shaft at levels below the lesser trochanter. The angle between the two axes was then recorded.

RESULTS

The measured values of the angle of anteversion and the neck–shaft angle were recorded. The obtained data were tabulated and statistically analyzed using Microsoft Excel (MSO 2021, Version 2508).

The mean values of the neck shaft angle and angle of anteversion were calculated and the data was further analyzed using t-test, with the level of significance set at $p < 0.05$. The mean neck shaft angle was found to be 129.17±5.71° on the left side and 129.22±5.22° on right-side. The observed range of neck shaft angle was 120-140° on left side and 118-139° on the right. The mean angle of anteversion was 14.56±2.67° on the left side and 15.40±4.12° on the right side. The observed range of angle of anteversion was 9-19° on left side and 7-23° on the right.

No statistically significant difference was found between sides for either parameter ($p > 0.05$).

Table 1: Mean values of the Neck shaft angle of femur.

Parameters	Number of samples	Mean (in degrees)	Minimum	Maximum	P value
Neck-shaft angle	Right (n=27)	129.22º(±5.22)	118º	139º	0.48
	Left (n=23)	129.17º(±5.71)	120º	140º	
	Total (n=50)	129.20º(±5.47)	118º	140º	

Table 2: Mean values of the Angle of anteversion of femur.

Parameters	Number of samples	Mean (in degrees)	Minimum	Maximum	P value
Angle of Anteversion	Right (n=27)	15.40º (±4.12)	7º	23º	0.19
	Left (n=23)	14.56º (±2.67)	9º	19º	
	Total (n=50)	14.98º (±3.47)	7º	23º	

Figure 1: Right femur being observed for any visible deformity

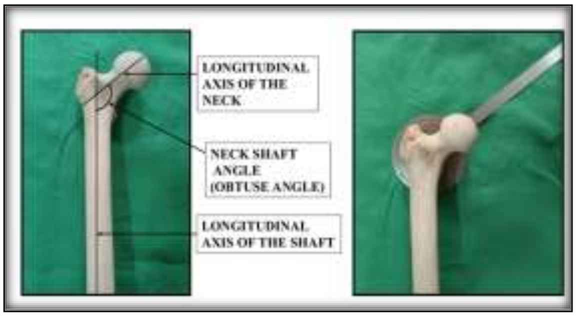

Figure 2: Measurement of the Femoral Neck shaft angle

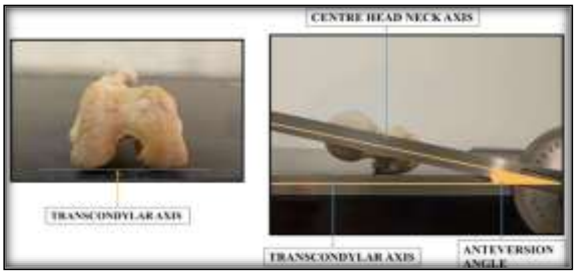

Figure 3: Measurement of the Angle of anteversion of femur.

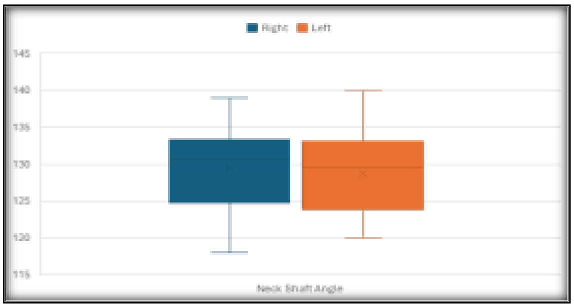

Figure 4: Box whisker plot showing distribution of neck shaft angle

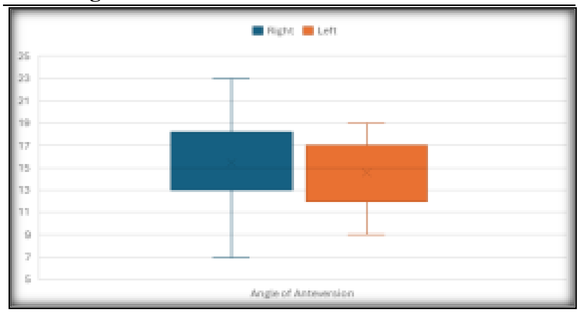

Figure 5: Box whisker plot showing distribution of angle of anteversion

DISCUSSION

Both the femoral neck-shaft angle and the angle of anteversion serve as key anatomical parameters in the assessment of biomechanics of the hip joint. Wolff's Law posits that the morphology of bone is dynamically regulated by its mechanical environment, such that alterations in load lead to structural adaptations in both the internal trabecular and external cortical architecture.[16] With the shift to upright walking, the femur became more vertical and aligned under the pelvis to better support body weight. This change affected the orientation of femoral neck, increasing the neck-shaft angle to reduce bending stress, while femoral neck anteversion adapted to torsional forces from muscle activity and joint movement, thereby reflecting Wolff's law.

Our study reported a mean femoral neck–shaft angle (NSA) of 129.20° ±5.47° across 50 dry bone specimens (27 right and 23 left), with no statistically significant side-to-side variation aligns well with previous research.

For instance, Anusuya et al. and Iakov et al. measured NSA on dry bones and found a mean value of

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127.72°and 127.63°, respectively, with no significant side-to-side difference.[17,18] Similarly, Gilligan et al.—also using dry bone samples—reported mean NSAs of 126.37°.[2] Notably, Gilligan's study reported significant right–left variation in NSA, contrasting with the bilateral symmetry observed in our study. Shivshankarappa et al. also conducted measurements on dry bones and found a relatively higher mean NSA of 138.15°, but did not report any significant side difference.[19]

In living subjects, Rogers et al. assessed 406 femora using standing anteroposterior pelvic radiographs and reported mean neck–shaft angles (NSA) of 131.56° in men and 133.61° in women, with no significant side-to-side differences.[20] Similarly, Tuck et al., in a study of UK men with fragility fractures, evaluated NSA using DXA scan printouts and reported a mean value of 130.7° ± 3.51°, with no observed inter-side discrepancies.[14] These findings are consistent with the results of our study, which demonstrated a mean NSA of 129.2° ± 5.47° measured on dry femoral specimens, with no statistically significant difference between the right and left sides. In parallel, Jiang et al. conducted a retrospective radiographic analysis using CT/PACS imaging of 466 healthy Chinese Han adults (353 men, 113 women) and reported a mean NSA of 133.02°. Their study also revealed age-related NSA changes, with individuals under 60 years showing significantly higher NSA values compared to those over 60 ($P < 0.001$), though no sex or side-to-side differences were observed for NSA, reinforcing bilateral symmetry in femoral morphology.[21] Angel-Mary et al. examined 109 live Igbos using goniometer measurements on hip radiographs. They found a mean NSA of 135.16° ± 3.86°, with males (135.94°) slightly higher than females (134.52°); no significant sex difference or lateral variation was observed.[22]

In our study of dry bone femurs, we found a mean femoral anteversion of 14.98±3.47°, with no significant side-to-side difference. These results closely align with those reported by Verlekar et al. and Srivatsa et al., who found mean angles of anteversion of 15.9° and 12.31°, respectively, with no significant bilaterality differences.[23,24] In contrast, Kingsley et al. reported a notably lower mean anteversion angle of 7.88° in dry bone specimens,[15] which is markedly less than the values observed in our study as well as those reported by Verlekar and Srivatsa. Similarly, Wali Ullah Khan et al. recorded a mean of 8.1°, again in dry bones, reporting no side-to-side variance.[25] Further in the literature, studies by Srimathi et al. and Kate B.R. et al. reported lower average anteversion angles of 9.8° and 8.8°, respectively—similar to the findings of Kingsley and Khan.[26,27] Notably, both studies documented statistically significant side-to-side differences, indicating a degree of anatomical asymmetry that was not observed in our findings.

Nan Jiang et al. evaluated 466 healthy Chinese Han adults using CT imaging and reported a mean femoral version of 10.62°. They found significant sex differences—females exhibiting higher values 14.76° vs 9.31° in males ($P < 0.001$)—but no laterality-based difference.[21] Their CT-based mean is lower than ours but still higher than values reported by Kingsley et al. (7.88°) and Wali Ullah Khan et al. (8.1°). Eckhoff et al conducted their analysis on adult African skeletal specimens (228 femurs). Their findings showed a statistically significant side-to-side difference—mean anteversion was higher on the right (21°) compared to the left (17°), $p < 0.001$. They found no significant gender differences in femoral anteversion.[28]

CONCLUSION

This study determined the mean femoral neck-shaft angle (NSA) and femoral neck anteversion angle (FNA) to be 129.2° and 14.98°, respectively, with no statistically significant differences between the right and left sides. These values align with previously reported anatomical ranges and reaffirm the utility of using the contralateral femur as a dependable anatomical template during surgical planning for proximal femur fractures and deformities.

While the angles measured remain within defined anatomical values, the study highlights subtle region-specific morphological distinctions, which emphasize the importance of establishing population-representative reference values. Such variation is clinically relevant in orthopedic surgery, prosthesis design, and gait rehabilitation, particularly in populations that are less studied or not well represented in standard anatomical datasets. The findings may necessitate continued interdisciplinary collaboration between anatomists, orthopedic surgeons, and biomedical engineers, ensuring that skeletal variability is appropriately accounted for in both diagnostic assessments and therapeutic strategies.

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