ORIGINAL RESEARCH

Evaluation of Neck-shaft Angle and Anteversion in Dry Femora of Adult Indian Population: A Descriptive Analysis

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Received on: 30 December 2023; *Accepted on:* 17 February 2024; *Published on:* xxxx

Abstract

Aims and background: Proximal femoral angles, specifically the neck-shaft angle (NSA) and anteversion (AV), are pivotal factors in understanding hip joint biomechanics, the changes in different hip pathologies and guiding various orthopedic interventions. Our study aims to evaluate these angles in the subcontinent of India.

Materials and methods: A total of 50 dry samples of femora were selected at the Anatomy Department, Madras Medical College. Inclusion and exclusion criteria were established based on the study design. The AV and NSA were measured using three methods—direct measurement, biplanar radiography, and axial computed tomography (CT). Comparative analyzes were performed to assess the precision of these measurement techniques.

Results: Our study revealed that the X-ray method was the most accurate in measuring the NSA among the three techniques. The measurements of AV were more accurate using the X-ray method than the CT method. Additionally, a prevalence of 20% for retroversion was identified in the Indian population, signifying a higher occurrence compared to prior studies.

Conclusion: These findings underscore the critical importance of precise angle measurements in orthopedic hip procedures. The study's data supports informed preoperative planning and the enhancement of orthopedic interventions, particularly in the Indian population.

Clinical significance: The study's findings on AV and NSA in the adult Indian population provide significant insights for orthopedic interventions, emphasizing the need for accurate measurements to enhance preoperative planning and optimize surgical outcomes.

Keywords: Anteversion, Axial computed tomography, Biplanar radiography, Neck-shaft angle, Proximal femoral angles.

Journal of Orthopedics and Joint Surgery (2024): 10.5005/jojs-10079-1152

Introduction

Since the mid-19th century, the proximal femoral angles have been of interest in debate in the orthopedic community. To understand the hip joint biomechanics completely, a knowledge of femoral anatomy is essential.[1] It serves as a foundation for addressing diverse femoral and hip joint conditions. India possesses a diverse array of cultural, genetic, and morphological characteristics.[2] The role of anteversion (AV) in the normal gait and hip joint stability is crucial. Any deviation in femoral AV can lead to diverse clinical situations. The AV angle is defined as the intersection between the axis of the femoral neck and the retrocondylar axis. Various skeletal studies indicate that the average adult femoral AV typically falls within the range of 7–16°, though Le Damany[3] noted a broader range. AV is affected by evolutionary outcomes, hereditary factors, intrauterine positioning, and biomechanical forces. An elevation in AV is linked to conditions such as apparent genu valgum, medial femoral torsion, cerebral palsy, Perthes disease, slipped capital femoral epiphysis, and unsuccessful treatment of congenital hip dislocation.

As a result, a reduction in femoral AV is often associated with conditions like rickets, chondrodystrophy, and a labral tear of the acetabulum. The neck-shaft angle (NSA) represents the angle created by the intersection of the long axis of the femur and the head–neck axis. The neck of the femur establishes a connection between the head and the shaft of the femur at an angle of approximately 125°, enabling hip movements and preserving its natural biomechanics. This angle undergoes variations associated with factors such as age, stature, and pelvic width, typically being less in adults, individuals with shorter limbs, and women.[4] Femoral AV exhibits substantial variation among the population, with mean values from 120° to 134° and in apparently normal individuals ranging from approximately 112° to nearly 152°.[5,6] Interestingly, race, geology, and climate have minimal influence on the patterns observed in AV and NSA.[7]

In India, squatting, household hygiene, and other floor-level activities require extreme movement at the hip joint. In terms of evolution and morphology, this distinction results in differences between Indian hips and those in the West. Precise measurements of NSA and AV are essential in the preoperative planning of various

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How to cite this article: Hosthota A, Thandapani M, M Ismail ND, *et al.* Evaluation of Neck-shaft Angle and Anteversion in Dry Femora of Adult Indian Population: A Descriptive Analysis. J Orth Joint Surg 2024;https://doi.org/10.5005/jojs-10079-1152.

Source of support: Nil

Conflict of interest: None

orthopedic procedures at the proximal femur to maintain normal biomechanics of the hip.

Numerous approaches have been developed to gauge proximal femoral angles, each with its own set of merits and drawbacks. Direct visual measurements and imaging techniques, such as ultrasonography (USG), axial roentgenography, axial computed tomography (CT), and magnetic resonance imaging (MRI), have been employed to calculate the AV and NSA of the femur. The observed values vary significantly due to the diverse methods employed and interpopulation differences. Achieving anticipated results in clinical practice is not always feasible due to various confounding factors.

Taking these principles into consideration, our study assesses the NSA and AV in the dry femora of the population of India through direct visual measurements, biplanar radiography, and axial CT. This analysis aims to scrutinize and interpret the obtained values.

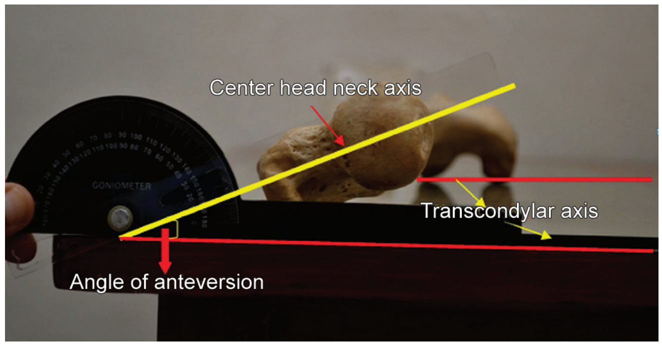

Fig. 1: Direct measurement of NSA


Fig. 2: Direct measurement of anteversion

Materials and Methods

Our study was carried out at Madras Medical College over a 2-year period spanning from 2012 to 2014, with prior approval from the ethics committee and under the supervision of the Barnard Institute of Radiology and Anatomy.

Inclusion Criteria

The study utilized 50 dry femora sourced from the Department of Anatomy at Madras Medical College.

Exclusion Criteria

Immature bones and those displaying anatomical or pathological variations were excluded from the study.

The NSA and AV of the dry femora were measured using three methods:

- Direct visual measurement: The Kingsley and Olmsted method was employed to calculate the AV.[8]
- Simple biplanar method: A radiographic approach by Ogata and Goldsand was used for both NSA and AV measurement.[9]
- Multislice axial CT: Murphy et al. method applied for NSA and AV measurement using multislice axial CT.[10]

Direct measurements served as reference values, and the data collected was compared with the other methods used. The study adhered to ethical guidelines and received approval from the relevant committees.

Direct Measurement

Neck-shaft angle: As illustrated in Figure 1, the orientation of the shaft axis is determined by drawing a straight line starting at the pyriform fossa to the midpoint of the femur shaft, 2 cm inferior to the vastus ridge, using a vernier caliper. The axis of the femoral head–neck is represented by a straight line which connects the central point of the head of the femur to the center point of the neck of the femur at its base, with the midpoint localized using a vernier caliper. The angle subtended by the two axes is designated as NSA.

Anteversion: The Kingsley and Olmsted[8] method was employed for measuring AV in the dry femur. As illustrated in Figure 2, the specimen was positioned at the edge of a table, allowing the distal femur to be horizontal. A goniometer was utilized, with its horizontal limb fixed at the table's edge and the vertical kept along the femoral neck axis. The horizontal surface represented the retrocondylar axis, serving as the reference plane against which AV is measured.

Biplanar Radiography

Ogata and Goldsand utilized the measurement technique for this study.[9] The femur was positioned in the anatomical orientation on a radiolucent table, approximately 10 cm above the X-ray detector, mimicking the natural position during X-ray imaging in a clinical scenario. The source was situated 125 cm above the X-ray machine, directed at the lesser trochanter, and an AP view was captured. The source height was maximized to reduce errors arising from magnification. For the lateral view, the X-ray source and receiver were tilted by 90° without changing the femur position. The angle between the long axis of the femoral shaft and the neck was assessed in both the AP view (α) and lateral view (β), as depicted in Figure 3. Subsequently, the NSA and the AV angle were calculated.

Axial Computed Tomography

Anteversion angle: For CT measurements, the femur was positioned over a surface parallel to the ground. Perpendicular CT cuts of 5 mm were taken at the proximal third of the femur up to the lesser trochanter, and similarly, 5 mm thick distal femoral cuts were taken perpendicular to the femoral shaft and femoral condyles. The femoral cut most accurately determined the alignment of the femoral head, and the neck was selected to measure the neck-horizontal angle (NHA).[10–12] Likewise, the distal femoral cuts that provided the clearest view of the condyles were selected for measuring the condyle-horizontal angle (CHA).[10–14] The AV was then

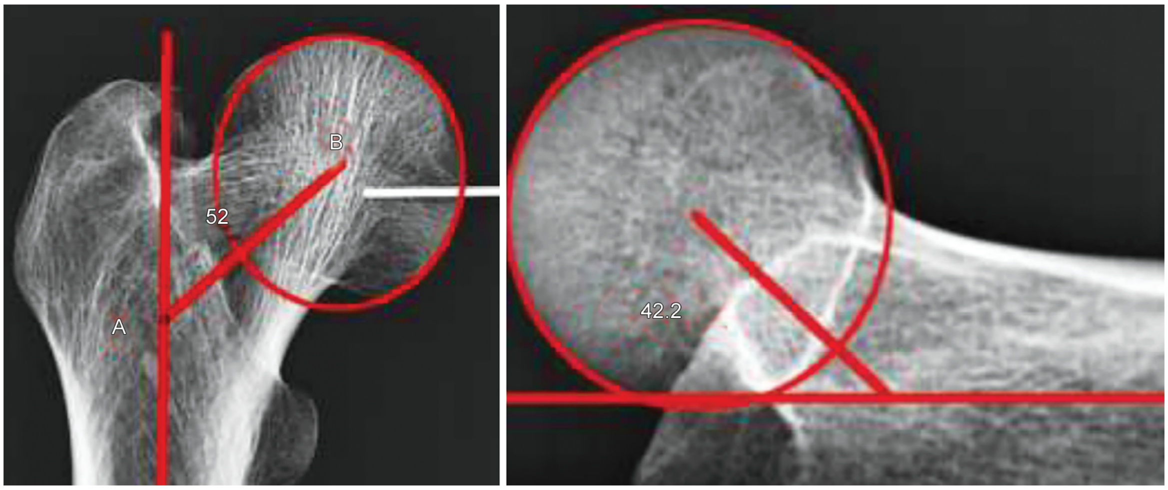

Fig. 3: Radiographic measurement of NSA

Table 1: Descriptive statistics describe the measurements of NSA by direct, X-ray, and CT methods

	N	*Mean*	*Standard deviation*	*Minimum*	*Maximum*
Direct-NSA	50	131.94	5.332	123	148
X-ray-NSA	50	130.30	4.082	124	147
CT-NSA	50	133.928	5.0109	125.1	148.7

Table 2: Friedman test ranks for descriptive statistics

	Mean rank
Direct-NSA	1.89
X-ray-NSA	1.45
CT-NSA	2.66

calculated using the following formula, with measurements taken around the distal condylar axis:

$AV = NHA - CHA$

Neck-shaft angle: The process involved marking the midpoint of the head and the center of the femoral neck. The straight line connecting these two was identified as the femoral head-neck axis. Additionally, the midpoint of the shaft is selected, and a line is drawn along. This extended line was considered the axis of the shaft of the femur. The angle between these two axes was then measured and recorded as the NSA.

Descriptive statistics, such as mean values and standard errors, were utilized to present a summary of the measurements obtained through direct, X-ray, and CT methods. Additionally, inferential statistics, including the Friedman test and paired *t*-tests, were employed to evaluate the precision of these methods and assess the significance of differences between them. The Friedman test was utilized to compare the three methods, determining the most accurate one for both NSA and AV measurements. Paired *t*-tests were applied to assess statistical significance within specific pairs of measurements. The study consistently reported *p*-values, with a threshold of significance set at 1%, providing a quantitative basis for determining the reliability of the results.

Results

Results of Neck-shaft Angle Measurement

According to the results presented in Table 1, the Friedman test indicates that the biplanar radiography method appears more precise in measuring the NSA. Furthermore, there is no noteworthy distinction between the sides of the femora, as confirmed by the paired *t*-test. In all three pairs of measurements, the *p*-value is < 0.001, signifying statistical significance at the 1% level.

Results of Anteversion in the Dry Femora

According to the information presented in Table 2, the CT method demonstrates greater precision in measuring the AV angle. No notable distinction is observed based on the side of the femur. Paired *t*-tests were performed for each of the three sets of readings, and the results were not significant statistically, with a *p*-value of <0.001 (Table 3).

Retroversion

In our study, 10 of the dry femora exhibited retroversion. The prevalence of the same was 20%, ranging from –5 to –8°. Kingsley and Olmsted reported 14.7% retroversion in a study. In India, Jain reported it to be 9.2% (Tables 4 and 5). In 1963, Kate noted a 7.8% prevalence of retroversion in the Indian population (Tables 6 and 7).[15,16] In our study, there is a notably higher prevalence of retroversion when comparing it to Western studies and previous research conducted in India (Table 8).

Discussion

Evaluation of Anteversion

Comparison of Femoral Anteversion with Previous International Studies

The comparison reveals that the femoral AV in our study femora closely aligns with findings from studies on dry bones by Kingsley and Olmsted,[8] Yoshioka,[17] Toogood et al.,[18] and research by Teo et al., in Malaysia.[19] However, the mean AV angle in this study was 8–10° lower compared to other studies. This analysis underscores a significant disparity in AV measurements among different

Table 3: Describes the group statistics of the study. No significant difference was observed between the left and right femur in all three methods

	Side	*N*	*Mean*	*Standard deviation*	*Standard error mean*
Direct-NSA	Left	22	130.73	5.284	1.127
	Right	28	132.89	5.266	0.995
X-ray-NSA	Left	22	129.77	2.861	0.610
	Right	28	130.71	4.845	0.916
CT-NSA	Left	22	132.622	4.6017	0.9811
	Right	28	134.954	5.1591	0.9750

Table 4: Paired samples statistics—no statistical significance was noted between the measurements of NSA by all three methods

		Mean	*N*	*Standard deviation*	*Standard error mean*	*p-value*
Pair 1	Direct-NSA	131.94	50	5.332	0.754	0.001**
	X-ray-NSA	130.30	50	4.082	0.577	
Pair 2	Direct-NSA	131.94	50	5.332	0.754	<0.001**
	CT-NSA	133.928	50	5.0109	0.7086	
Pair 3	X ray-NSA	130.30	50	4.082	0.577	<0.001**
	CT-NSA	133.928	50	5.0109	0.7086	

** Denotes significant at 1% level

Table 5: Descriptive statistics—describes the measurements of AV by direct, X-ray and CT methods

	N	*Mean*	*Standard deviation*	*Minimum*	*Maximum*
Direct-AV	50	10.30	9.569	−5	32
X-ray-AV	50	10.4142	11.65693	−1.01	37.86
CT-AV	50	9.939	10.0455	−8.7	30.0

Table 6: Friedman test ranks—the CT method of AV measurement was observed to be the most accurate one among the three methods

	Mean rank
Direct-AV	2.16
X ray-AV	1.95
CT-AV	1.89

populations and using various methods. When comparing the AV data obtained from dry femurs utilizing the above methods, it was found that CT measurements are more precise, with the direct method serving as a reference.[8,17–22]

Despite the superior accuracy of CT measurements, practical challenges such as application difficulty on a large scale, high radiation risks (especially in the pediatric group), and investigation costs arise. Statistical analysis in our study indicates that the biplanar radiography method is as effective as the CT method in measuring AV, with no significant difference noted statistically (*p*-value < 0.001). Consequently, the findings from our study suggest that the biplanar method would be a good option in substituting the CT method in basic trauma. The use of the CT method may be considered for complex trauma pediatric conditions such as congenital dysplasia and other deformities related to the hip joint.

Comparison of Anteversion with Indian Studies

The findings of our study align with previous studies by Kate, Jain, Maheshwari et al., Zalawadia, and Srimathi.[16,23–26] The AV angle in the Indian population ranges between 9° and 12°, contrasting with the foreign population, where the AV predominantly falls within the range of 15–20°. This supports the necessity for specially designed implants tailored to the Indian population. The precise measurement of AV is crucial for the success of advanced surgical techniques, as demonstrated in Dorr et al. 2012 study on AV technique for robotic total hip arthroplasty.[2,16,23–27]

Accurate preoperative determination of proximal femoral angles is equally important for basic trauma surgeries like a dynamic hip screw, proximal femoral nailing, hemiarthroplasty, proximal femoral deformity corrections, as well as advanced surgeries.

Evaluation of the Femoral Neck-shaft Angle

Comparison of the NSA with Foreign Studies

There is a 6–8° higher variation in NSA observed in the Indian population compared to findings from foreign studies. Notably, the NSA measurements in our study correspond closely with those reported in a 2011 study by Inam et al. in Pakistan.[17,20,22,28–31]

Comparison of NSA with Indian studies

The mean NSA in our study was consistently 5–8° higher compared to the mean NSA reported in India. Isaac et al. in 1997 reported a mean NSA value of 125.7, while subsequent studies by Siwach and Dahiya in 2003 in Rohtak (India) and Ravichandran et al. in 2011 in Tamil Nadu (India) suggested mean NSA values of 123.3 and 126.3°, respectively.[2,27,32–34]

Our study suggests that X-ray measurements of NSA are more precise among the three methods, as determined by the Friedman test ranking.

Table 7: Describes the group statistics of the study. No significant difference observed between the left and right femur in all three methods

	Side	*N*	*Mean*	*Standard deviation*	*Standard error mean*
Direct-AV	Left	22	9.05	8.737	1.863
	Right	28	11.29	10.223	1.932
X-ray-AV	Left	22	9.4941	12.31184	2.62489
	Right	28	11.1371	11.29052	2.13371
CT-AV	Left	22	8.919	8.8686	1.8908
	Right	28	10.740	10.9749	2.0741

Table 8: Paired samples statistics—no statistical significance was noted between the measurements of NSA by all three methods

		Mean	*N*	*Standard deviation*	*Standard error mean*	*p-value*
Pair 1	Direct-AV	10.30	50	9.569	1.353	<0.001**
	X-ray-AV	10.4142	50	11.65693	1.64854	
Pair 2	Direct-AV	10.30	50	9.569	1.353	<0.001**
	CT-AV	9.939	50	10.0455	1.4206	
Pair 3	X-ray-AV	10.4142	50	11.65693	1.64854	<0.001**
	CT-AV	9.939	50	10.0455	1.4206	

** Denotes significant at 1% level

Conclusion

In our research, the Friedman test ranking revealed that X-ray measurements of the NSA were more accurate compared to the other two methods analyzed. This study suggests that the straightforward biplanar method can serve as a viable substitute for CT measurements of the AV in clinical applications, especially when utilizing a cross-leg lateral view. For specific cases, such as those involving congenital or neuromuscular disorders, CT can be employed for the calculation of these angles preoperatively. Notably, our study found a 20% prevalence of retroversion, a significantly higher rate compared to previous research. The gathered data holds potential for designing future implants and techniques, aiding in preoperative assessment, and mitigating intraoperative complications.

Clinical Significance

This study significantly contributes to orthopedic practice, particularly within the realm of hip joint biomechanics and prevalent pathologies in the adult Indian population. Through the evaluation of AV and NSA using diverse measurement techniques, the research yields valuable insights for well-informed preoperative planning and orthopedic interventions. In essence, the study's outcomes bolster the refinement of clinical decision-making and surgical strategies in orthopedics, specifically tailored to the characteristics of the Indian population.

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