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Original Article

Anatomy Section

Morphometric Study of Proximal Femur and its Applications in Prosthesis Designing: A Cross-sectional Study from Western India

SAJAN SKARIA[1], MANOJ KULKARNI[2], HETAL VAISHNANI[3]

ABSTRACT

Introduction: The hip joint is subjected to daily stresses as it bears the weight of the upper body. Osteoarthritis of the hip may cause irreversible damage. Proximal geometry of the femur, like neck-shaft angle and torsion is important in designing prostheses for a specific population. Most of the prostheses manufacturers follow the Western parameters as there is a scarcity of data in the Indian context.

Aim: To analyse the normal Neck-Shaft Angle (NSA) and torsion of the femur in the Indian population.

Materials and Methods: This cross-sectional analytical study was carried out in a total of 300 dried femur (150 right and 150 left) of unknown age and gender without any defect or damage during a period of 2.6 years (June 2019 to December 2021) in Sumandeep Vidyapeeth University, Gujarat, India. The NSA and the angle of femoral torsion was measured using a Goniometer. Mean and standard deviation were calculated. Student's t-tests was applied to ascertain the statistical difference between right and left femur.

Results: The average NSA was 128.55±6.99°. The mean values were 130.70±6.03° and 126.41±7.22° on right and left sides respectively with statistically significant difference (p-value <0.0001). The average femoral torsion was found to be 16.43±2.34°. On the left side, it was 16.43±2.31° and 16.43±2.36° on the right side with No statistically significant difference was found between right and left femorae (p-value=1.00).

Conclusion: The accuracy and success of the hip replacement surgery demands complete knowledge of the morphometry of the proximal femur which is highly specific among the races, region and gender. The present study provides the normal morphometry of the proximal femur of Indian population.

Keywords: Anatomy, Angle of anteversion, Arthroplasty, Morphometry, Neck-shaft angle

INTRODUCTION

The transition from quadrupedal to bipedal gait is a biomechanical landmark in the evolution of Homo Sapiens. The most important feature that makes humans different is the bipedal locomotion and prehensile use of hands. The legs and hands are quietly modified from that of other primates in their unique architecture and built. The femoral neck in humans is an important functional modification after man attained erect bipedal posture [1]. The neck of the femur is approximately 5 cm long which connects the head to the shaft usually at an angle of 125°. Neck-shaft angle facilitates movements at the hip joint and also acts as a lever for the muscles acting around the hip joint [2]. The angles at the proximal femur facilitates biomechanical advantageous erect (bipedal) postures during motion by reducing the horizontal bending forces experienced at the pelvic girdle and thereby reducing bony tensile stress [3].

Neck-Shaft Angle (NSA) or the Inclination angle and angle of torsion are important anatomic indicators in clinical orthopaedics. Neck-shaft angle or inclination angle is an angle between the femoral neck axis and diaphyseal axis. The neck-shaft angle varies with the age, stature and width of the pelvis. When this angle is>135°, the condition is known as coxa valga. When angle is <120°, it is known as coxa vara [4]. The angle of femoral neck is reduced with age. In early infancy the neck-shaft angle is about 150°, in childhood 140°, in adult about 125°and in elderly about 120.5º [5].

Angle of Femoral Torsion (AFT) is an important factor for hip stability and normal walking. A sound knowledge of the normal range of femoral torsion is important for corrective osteotomies, arthroplasty and manufacturers of hip prosthesis [6]. Any alterations in this angle is associated with many pathological conditions. An increased angle is associated with cerebral palsy, postural defects, flat foot, intoing and external tibial rotation and decreased angle is seen in conditions like chondrodystrophy, toing out, rickets [7].

The hip joint is subjected to daily stresses as it bears the weight of the upper body. With advancing age, these stresses can encounter smooth functioning. Osteoarthritis is one of the most common alterations of the hip, which causes intense pain and inflammation leading to irreversible damage to the entire joint complex. These conditions may affect the normal neck-shaft angle and thereby alter the biomechanics and the gait. This may necessitate the replacement of the compromised joint complex with an artificial one [8].

A hip prosthesis is an artificial device that replaces a damaged hip joint. It has a femoral head articulated to acetabulum of the pelvis and is supported by a synovial joint capsule [9]. The surgical operation is referred to as Total Hip Arthroplasty (THA). There are three components in a hip prosthesis- a femoral component (consisting of a stem/pin and head), an acetabular cup, and an acetabular interface [10]. The function of the femoral component is to transmit the force generated at the centre of rotation to the proximal femur. The major process in Total Hip Arthroplasty (THA) is to restore or increase the femoral offset [11]. A femoral offset is defined as the perpendicular distance between the long femoral axis and the centre of rotation of the head. Normally, the total hip prostheses have a higher neck-shaft angle than the host bone and there is a tendency to reduce the femoral offset [12]. Restoration of the femoral offset is a crucial step in hip replacement surgery as it enhances hip stability and improves the range and strength of abduction. So, femoral component design is important in restoring the femoral offset [13].

Geometric parameters of the femoral neck like torsion and NSA are therefore two important parameters of femur anatomy in the selection and designing of proper hip prostheses [14]. The architecture of hip joints in Indians are different from the western population, so the authors studied the normal neck-shaft angle and torsion of the femur in the Indian population.

MATERIALS AND METHODS

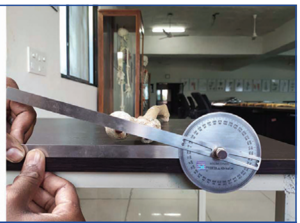
This cross-sectional analytical study was carried out on 300 dry (150 right and 150 left) femur of unknown age and gender from June 2019 to December 2021. The bones were collected from various Medical Colleges of Rajasthan and Gujarat after obtaining Institutional Ethical Committee approval. Neck-shaft angle and the angle of femoral torsion were measured using Goniometer.

Inclusion criteria: Intact, dried and non pathological adult bones were included in the study.

Exclusion criteria: Femur with any gross defect, arthritic deformity or damage were excluded from the study.

Angle of Femoral Torsion

The Angle of Femoral Torsion (AFT) was measured by Kingsley Olmsted method [15] by placing the specimen at the edge of a horizontal surface. A midpoint is marked at the proximal and distal of the neck with a vernier calliper. A thin needle fixed through these points represent the axis of the neck. The horizontal surface represents the transcondylar plane. The horizontal limb of the goniometer was fixed on the edge of the table. The vertical limb was held parallel to the needle fixed i.e. along the central axis of the neck and the angle subtended was recorded [Table/Fig-1-3] [16].

[Table/Fig-1]: Measurement of angle of torsion of femur. **[Table/Fig-2]:** Photograph of right femur showing the torsion of 15º. (Images from left to right)

Neck-shaft Angle of the Femur (NSA)

It is the angle formed between the axis of the shaft of the femur and the head-neck axis. The axis of the femoral shaft was identified by joining a line from the trochanteric fossa (piriform fossa) to the middle of the femoral shaft measured 2 cm below the vastus ridge with the help of vernier calliper. The axis of the head and neck were identified by a line joining the midpoint of the head of the femur in its centre and the midpoint of the neck at its base. The midpoint was identified using a vernier calliper. The angle formed was recorded [17] [Table/Fig-4-6].


[Table/Fig-3]: Photograph of left femur showing the torsion of 10º.
[Table/Fig-4]: Measurement of NSA of femur. (Images from left to right)


[Table/Fig-5]: Photograph of right femur showing the NSA of 120º.
[Table/Fig-6]: Photograph of left femur showing the NSA of 114º. (Images from left to right)

STATISTICAL ANALYSIS

The results were tabulated and analysed by Statistical Package for the Social Sciences (SPSS) Software for windows version 18.0 (SPSS Inc., Chicago, IL,USA).The mean and standard deviation was calculated. Unpaired student's t-test was used to compare the means and p-value <0.05 was considered as statistically significant.

RESULTS

Neck-shaft angle of the femur: The mean values of NSA of total (300) femur was found to be 128.55±6.99°. The values were 130.70±6.03° and 126.41±7.22° on right and left sides respectively [Table/Fig-7]. The right side bones showed higher NSA than the left and the difference between the two was found to be statistically significant.

Side	N	NSA Mean±SD	t-value	p-value*
Left side	150	126.41±7.22°	5.59	<0.0001
Right side	150	130.70±6.03°		

[Table/Fig-7]: Neck-Shaft Angle of femur right and left side.
*Students' 't' test for the difference of means; p-value <0.05 was considered as statistically significant

Torsion of femur: The mean value of femoral torsion of 300 femora was 16.43±2.34°.On the left side, it was 16.43±2.31° and 16.43±2.36° on the right side [Table/Fig-8]. No statistical difference was found between the right and left sides.

Sides	N	Mean torsion	t-value	p-value*
Left side	150	16.43±2.31°	0.00	1.000
Right side	150	16.43±2.36°		

[Table/Fig-8]: Statistical results of femoral torsion right and left side.
*Student's t-test test for the difference of means; p-value <0.05 was considered as statistically significant

DISCUSSION

The angle of the neck and shaft of the femur has a direct relationship with the lifestyle. The NSA is found to be increasing in population with a sedentary lifestyle [18]. This infers the developmental plasticity of NSA with respect to changing habitual load levels during development. The neck-shaft angle is affected by physical activity and levels of mobility. Multiple factors like epiphyseal perfusion, cartilage activity at the epiphysis, action of muscles, static factors, hormones, and body weight have been identified to influence neck-shaft angle in postnatal life. Age has the most spectacular influence on the neck-shaft angle.

Preoperative evaluation of the neck-shaft angle of an individual subject is an important concern in many basic and advanced surgical procedures. To perform total hip arthroplasty, it is an essential prerequisite to know the normal acetabular and proximal femoral morphology like femoral neck-shaft angle and femoral torsion, which is specific. Hence specific NSA measurements in relation to population, gender and races is a must for preoperative planning [19].

In the present study, the mean values of NSA of total (300) femur were found to be 128.55±6.99°. [Table/Fig-9] shows the side difference reported in various other studies [3,4,20-39].

In the present study, the right side bones showed higher NSA than the left and the difference between the two was found to be statistically significant. Mukherjee B et al., found statistically significant bilateral difference in femoral NSA in their study [20]. Gilligan I et al., observed a statistically significant side differences (p-value=≤0.001) in the NSA of femur on assessing the globally available data [21]. Ahmed Z et al., also reported a statistically significant bilateral difference in the neck-shaft angle of femur [22]. The authors opinionated that this difference can be due to the characteristics of the regional population. Most of the other Indian studies reported no significant side difference [35-39].

Authors and year of publication	Sample size	Population	NSA (Mean±SD)
Present study (2022)	300	India	Total=128.55°±6.99° Right=130.70°±6.03° Left=126.41°±7.22°
Mukherjee B et al., [20] (2020)	281	West Bengal	Total=124.12°±6.231° Right=124.91°±5.885° Left =123.33°±6.47°
Choudhary KK and Dhan MR, [29] (2020)	82	Bihar	Total=134.34°±4.55° Right=133.63°±4.38° Left=134.34°±4.55°
Rajendran HS et al., [27] (2020)	95	South India	Total=146.25°±4.18° Right =145.46°±4.62° Left=147.06°±3.57°
Zaghloul A et al., [22] (2020)	200	Egypt	Right=133.04°±5.36° Left=133.42°±5.27°
Sharma A and Lal RK, [3] (2019)	200	Bihar	124.50°±5.94°
Fischer CS et al., [23] (2019)	3226	Pomerania	127°±7°
Suresh NM et al., [35] (2019)	100	Kolar	Right=129.04°±4.47° Left=127.98°±4.01°
Agrawal J et al, [37] (2019)	153	Central India	Right=132.81°±15.81° Left=133.88°±15.05°
Sengupta I et al, [38] (2019)	50	Kolkata India	Right=124.53°±6.35° Left=126.9°±7.67°
Sharma V et al., [30] (2018)	93	Himachal Pradesh	126.90°±2.50°
Siwach R, [25] (2018)	150	Rohtak, Haryana	123.5°±4.34°
Bharathi R et al., [39] (2018)	50	Chennai	Right=127.98°±4.41° Left=124.00°±7.43°
Chaudhary PN et al., [4] (2017)	100	Karnataka	Right=126.78°±4.52° Left=127.64°±4.17° Total: 127.21°
Verma M et al., [31] (2017)	91	New Delhi	130.3°±3.875°
Roy T et al., [32] (2017)	220	Andhra Pradesh	126.65°±5.92°
Ravi GO et al., [33] (2016)	592	Karnataka	Total=136.80°±4.45° Right=136.90°±4.40° Left=136.70°±4.40°
Neelima P et al., [34] (2016)	60	Andhra Pradesh	126.28°±6.55°
Thipse JD et al., [28] (2016)	2000	Ahmednagar, India	Total=136.8° Right=137.1° Left=136.7°
Ravichandran D et al., [24] (2011)	578	Chennai	126.55°
Khan SM et al., [36] (2014)	250	South India	Right=137.7° Left=136.90°
Gilligan I et al., [21] (2013)	8000	Global data	Right=126±5.693° Left=127±5.356°
Saikia KC et al., [26] (2008)	92	North East India	139.5°

[Table/Fig-9]: Comparison of mean NSA of the present study with the other studies [3,4,20-39].

The torsion angle of the femur is an important factor for hip stability and normal walking A sound knowledge of the normal range of femoral torsion is important for corrective osteotomies, arthroplasty and manufacturers of hip prosthesis [38]. The average femoral torsion of 300 femora was 16.43°±2.34° in the present study. No statistical difference was found between the right and left sides. The right side femora showed a little greater torsion than the left. The study found similar with the findings of Dhurandhar D et al,. They reported the average femoral neck anteversion of the right side as 19.03º±12.11º and the left side as 18.63º±10.8º.They also found no significant statistical between the values of the Right and Left sides [40]. [Table/Fig-10] shows the mean torsion reported by other workers [5,16, 40-46].

Authors and year of publication	Sample size	Population	Mean torsion femur
Present study (2022)	300	India	Total=16.43°±2.34° Right=16.43°±2.36° Left=16.43°±2.31°
Yadav SK et al., [46] (2020)	60	Nepal	Right=16.73°±3.095° Left=16.67°±2.963°
Dhurandhar D et al., [40] (2018)	152	Raipur	Right=19.03°±12.11º Left=18.63°±10.8º
Sharma V et al., [41] (2018)	93	Sub Himalayan	14.57°±2.67º
Amith R et al., [44] (2017)	171	Karnataka	Total=11.4°±8.8° Right=10.6°±8.0° Left=12.3°±9.7°
Debnath M et al., [45] (2016)	100	Bengal	Total=20.05° Right=18.68° Left=21.42°
Verma L et al., [5] (2016)	100	Kota, Rajasthan	Total=13.45±8.58° Right=12.9±8.22° Left=14±8.98°
Ravichandran D et al., [43] (2014)	187	Andhra Pradesh	Right=18.54±9.05º Left=19.42±10.89º
Varlekar P et al., [42] (2011)	200	Gujrat	Right=16.1º Left=15.65º (Male) Right=18.17º Left=17.95º (Female)
Maheshwari AV et al., [16] (2004)	62	Delhi	11.7°±4.6º

[Table/Fig-10]: Comparison of the mean torsion of the present study with the other studies [5,16, 40-46].

Limitation(s)

The major limitation of this study was that the bones selected was of unknown gender as they were not documented in the records. Relying on the gender morphological features of the bone alone could not have shown high degree of accuracy. The gender-wise observations can be more effective in prosthesis development. There may be a change in dimension of bones during the drying process of bones. The exact origin of the bones were unknown; the knowledge of the place of origin of bones, the exact age group etc can give more specific data.

CONCLUSION(S)

The current study made an effort to build a population-specific data on the dimensions of proximal end femur (neck-shaft angle and angle of torsion) of Indians. The mean neck-shaft angle was 128.55±6.99°. There was statistically significant difference between the NSA of right and left femur. The mean value of femoral torsion was 16.43±2.34° without any significant side differences. The normative data will give an insight to anthropologists to determine the racial variations of the proximal femur. Findings of the study will also be helpful to surgeons, therapists, implant manufactures and researchers as a ready reference of Indian population. However further progressive study in the same direction is requires with gender specific data to give more accurate results.

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PARTICULARS OF CONTRIBUTORS:
1. PhD Scholar, Department of Anatomy, Sumandeep Vidyapeeth, Deemed to be University, Vadodara, Gujarat, India.
2. Professor, Department of Anatomy, Sumandeep Vidyapeeth, Deemed to be University, Vadodara, Gujarat, India.
3. Professor, Department of Anatomy, Sumandeep Vidyapeeth, Deemed to be University, Vadodara, Gujarat, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Sajan Skaria,
PhD Scholar, Department of Anatomy, American International Institute of Medical Sciences, Near Transport Nagar, Bedwas, Air Port Road,
Udaipur-313001, Rajasthan, India.
E-mail: sajan.scaria@gmail.com

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