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Original Research Article

A study of femoral bicondylar angle in Udaipur, India zone

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ABSTRACT

Background: Human body consists of 206 bones; among which femur. The thigh bone is considered as the biggest and strongest bone of the body. The bone contains a femoral bicondylar angle which helps in maintaining the balance and certain movements of the body. Those movements are essential to stand upright and erect; therefore, helps in balancing the posture of the body. Bicondylar angle shows various gestures and characteristics essential for describing the necessary ailments of the human skeleton. Thus, the present study is designed with an aim to measure and compare the bicondylar angle of femur both in males and females in Udaipur, Rajasthan, India zone.
Methods: Totally, 96 bones were studied- 48 males and 48 females' bones in 2 years duration. The study was carried out in the Department of Anatomy of Geetanjali Medical College and Hospital and R.N.T. Medical College. The bicondylar angle was measured with a suitable apparatus comprising of compass, Digital Vernier Calliper, scale and protector (Figure 1) along with osteometric board. Bicondylar angle of male and female bone was calculated using SPSS software.
Results: The study shows that the bicondylar angle of left femur was greater than right femur in both the genders, but their side differences was statistically insignificant (p>0.05).
Conclusions: Hence, the bicondylar angle of female is larger than in comparison to males and these results can put emphasis/light on the orthopaedic clinicians and surgeons to know the etiology of osteometric diseases.

Keywords: Bicondylar angle, Bone, Femoral bicondylar angle, Femur, Genders

INTRODUCTION

Femur known to be the longest and strongest bone located alone in the thighs of the human body. It extends from the hip to the knee. Anatomically, its shaft is almost cylindrically structured in most of its length and is bowed forward having a proximal round.

The head of the femur is articular projecting medially on its short neck which is a medial curvature of the proximal shaft. There is a distal extremity which is more massive and is a double "knuckle" (condyles) that articulates with the tibia on one side. While in a standing position, the femoral shafts are oblique and their heads are separated by the pelvic width.[1,2]

The bicondylar angle of the femur is defined as an "angle ◦an axis through the femoral shaft and a line perpendicular to the infracondylar plane". The bicondylar angle or carrying angle is unique to humans playing an important role in maintaining locomotion and posture of the body. The normal bicondylar angle is 8° to 14° in humans but it slowly increases from 0° to 8°.

The bicondylar angle is of 0° at birth because the axis of the shaft is perpendicular to the metaphyseal growth of the bone.[3,4] The angle first develops when the child first starts to walks and it was found that the medial side of the distal metaphysic grows faster than the lateral side. This angle reaches adult value (8°-10°) when the child is about four to eight years of age depending on their walking activity.[5-7]

The femoral bicondylar angle is presented to show a characteristic feature of bipedal gait in an individual. Femoral bicondylar angle helps to keep the posture of humans erect by placing the knee and foot under the body's center of gravity during single support phase of gait. The bicondylar angle is found to be greater in the females due to their wider pelvis.[8]

This angle is not present in other primates existing around as they lack support phase of gait.[1,5]

In bedridden children, since birth, possessing some abnormality such as neuromuscular disorders and paraplegic unable to ambulate in childhood, the bicondylar angle does not develops. This abnormality shows that the formation of bicondylar angle is an epigenetic phenomenon.

In epigenetic phenomenon, growth of the distal femur is influenced by the mechanical loading environment. Because of the obliquity of the shaft of the femur bone, this angle plays an essential role for the reconstruction of the total length of the femur and stature reconstruction.[5,6]

Several studies have been undertaken in various parts of the world to know the relativity and status of the bicondylar angle of femur bone. To conduct more research on bicondylar angle of femur bone, authors aimed in conducting the study in Udaipur Rajasthan, India zone. So, the present study was done to measure and compare the femoral bicondylar angle in Udaipur zone, Rajasthan, India.

METHODS

The present study was designed as a comparative and descriptive study, which was started after obtaining ethical clearance from institutional ethical committee.

The Study population total 96 bones were included in the study for consideration. Known femur bones of male and female cadavers along with known bones from storage room were included in the study. In the study 48 males and 48 females' bones were taken; total of 96 femora were obtained in 2 years (i.e. September 2015 to September 2017) from the Department of Anatomy G.M.C.H. (Udaipur) and Department of Anatomy R.N.T. Medical College (Udaipur) after getting permission.

Inclusion criteria

A normal adult human femur without any apparent damage or congenital anomaly were included in the study.

Exclusion criteria

Abnormal human femur as seen in congenital anomalies, pediatric femur and damaged specimen were excluded from the study.

Methodology followed during study the bicondylar angle of the femur was measured using materials like Compass, Digital Vernier Caliper, Scale and Protector (Figure 1) and along with an instrument known as osteometric board (Figure 2). The methodology used for measurement of bicondylar angle of femur was that of Heiple and Lovejoy and S.P. and Singh S. S. method.[5]

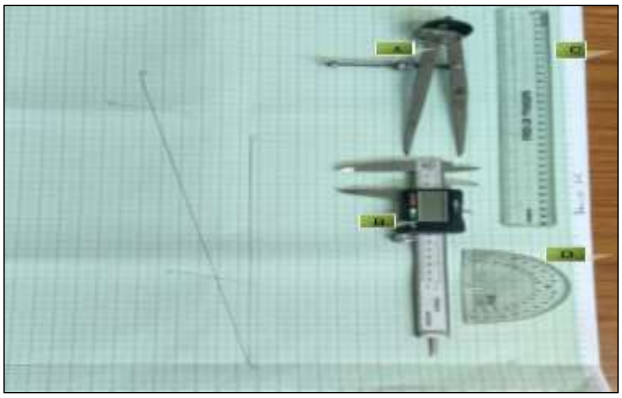

Figure 1: Materials used to measure Bicondylar angle of femur. A: Compass, B: Digital Vernier Caliper, C: Scale, D; Protector.

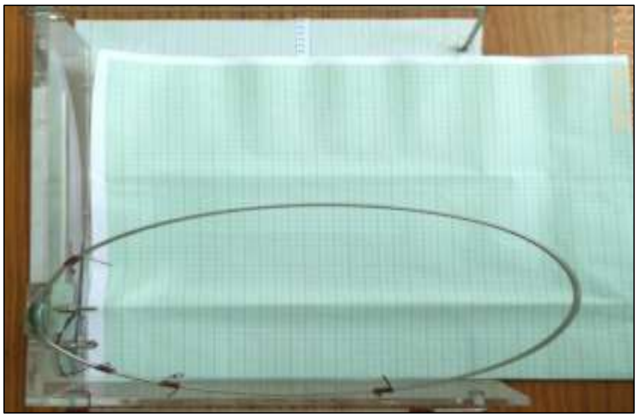

Figure 2: Osteometric board.

The selected femur bone was placed on the board with the posterior aspect of femoral condyles and greater trochanter touching the horizontal surface of an osteometric board; on which a paper sheet was fixed. The inferior margin of both the condyles was placed against the vertical surface of the osteometric board. Infracondylar plane was taken as plane of vertical plate and horizontal line was drawn on the paper (AB) (Figure 3).

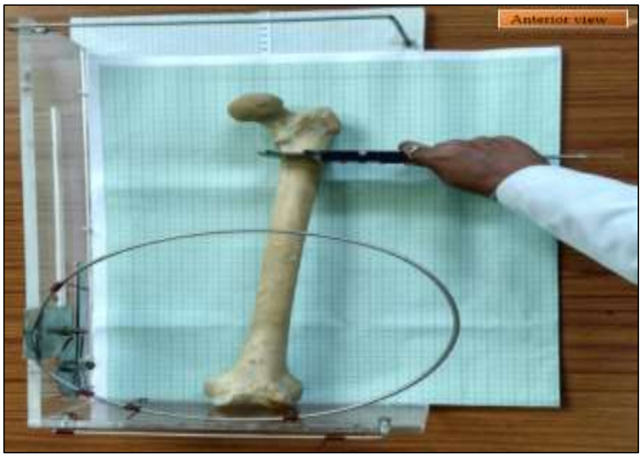

Figure 3: Marking of two points on the paper showing maximum diameter of the femoral shaft (male left side) just below the lesser trochanter with the help of a with the help of a digital vernier caliper.

Figure 4: Marking of two points on the paper showing maximum diameter of the femoral shaft (female left side) at distal ¼th with the help of a digital vernier caliper.

At a level of ¼th of the standard maximum length of the femur away from its distal end, two points were marked on the paper, with the assistance of vernier caliper. Similarly, two other points were marked on the paper showing maximum diameter of the shaft just below the lesser trochanter (Figure 4). The axis of the shaft was obtained by line joining the middle points of diameters at X and Y, and axis was prolonged to meet the infracondylar plane which was represented by horizontal line (Z). The angle drawn between the axis of the shaft and perpendicular to axis meeting the horizontal line was denoted as the bicondylar angle of the femur and was measured using protractor (Figure 5).

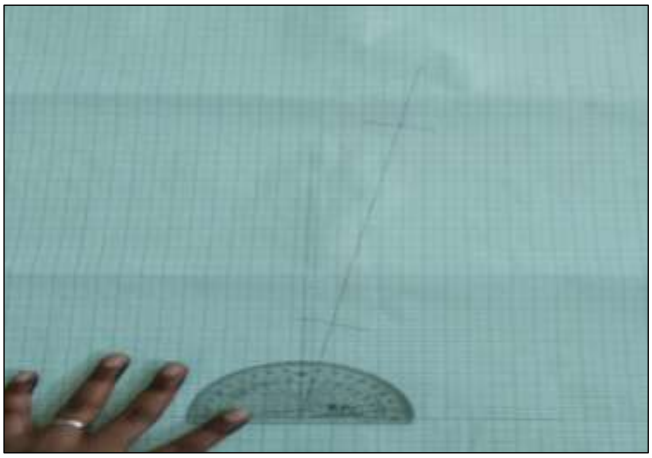

Figure 5: Measuring the bicondylar angle by using protector.

Statistical analysis

Mean and standard deviation of the bicondylar angle was calculated using SPSS software for comparison.

RESULTS

In the present study, the statistical analysis was evaluated as mean and standard deviation. The mean and standard deviation of bicondylar angle (left and right femora) of male and female bones were calculated. It was done using SPSS software and p value > 0.05 was considered insignificant while p value <0.05 was considered significant.

In this study, the mean and standard deviation of Bicondylar angle in Male (Right side) was found to be 7.7083°±1.781 (Table 1) while the Bicondylar angle in Male (Left side) was 8.0°±1.794 (Table 1). When compared to the female bicondylar angle the mean and standard deviation of Female (Right side) was 8.4166°±1.767 (Table 2) and Left side was 8.5833°±1.909 (Table 2).

Table 1: Comparison of Mean and SD of male (right and left side) bicondylar angle obtained.

Sex	Side	No.	Range		Bicondylar angle		p value	Remark
			Maximum	Minimum	Mean	Std. deviation		
Male	Right	24	5^0	11^0	7.7083	1.781	0.5746	Not significan
	Left	24	4^0	11^0	8.0	1.794		

Table 2: Comparison of Mean and SD of female (right and left side) bicondylar angle obtained.

Sex	Side	No.	Range		Bicondylar angle		p value	Remark
			Maximum	Minimum	Mean	Std. deviation		
Female	Right	24	5^0	12^0	8.4166	1.767	0.7551	Not significant
	Left	24	4^0	14^0	8.5833	1.909		

Table 3: Comparison of Mean and SD of bicondylar angle of female and male (right side) femora.

Sex	Side	No.	Range		Bicondylar angle		P value	Remark
			Maximum	Minimum	Mean	Std. deviation		
Female	Right	24	5^0	12^0	8.4166	1.767	0.1733	Not Significant
Male	Right	24	5^0	11^0	7.7083	1.781		

Table 4: Comparison of Mean and SD of bicondylar angle of female and male (left side) femora.

Sex	Side	No.	Range		Bicondylar angle		p value	Remark
			Maximum	Minimum	Mean	Std. deviation		
Female	Left	24	4^0	14^0	8.5833	1.909	0.2810	Not Significant
Male	Left	24	4^0	11^0	8.0	1.794		

It was seen that the bicondylar angle of left femur was greater than right in both the genders, but the side difference was statistically insignificant (P>0.05) (Table 3 and 4). Hence, it clearly shows the difference between the male and female bicondylar angle for both left and right femur bone.

Therefore, in the present study mean value of femoral bicondylar angle in Udaipur zone population was 7.7083°±1.781 on right side and 8.0°±1.794 on left side in males and in the females, the angle was 8.4166°±1.767 on the right side and 8.5833°±1.909 on left side respectively.

DISCUSSION

The bicondylar angle of the femur is defined as "Angle between an axis through the femoral shaft and a line perpendicular to the infracondylar plane."

The bicondylar angle or carrying angle is unique to humans and normally it lies in the range of 8° to 14°. It is a characteristic feature of bipedal gait in humans. Newborn femora does not exhibit femoral bicondylar angle but it is gradually formed during the initial years after birth as the child learns walking. The load axis that passes medial to the axis of shaft of the femur during the first three years of life, crosses the axis of shaft of femur later in life due to change in the angle of neck of femur. That increase in the bicondylar angle brings the knee closer to midline. Which also corresponds to the time the child is capable of walking independently.

Presence of genu valgum and associated femoral obliquity are the characteristic features of bipedal gait in humans. The bicondylar angle places the knee close to the body‟s centre of gravity during bipedal locomotion. Increase in bicondylar angle defines the shape of distal femoral epiphysis in adults. Protuberance of lateral trochlear lip and elliptical profile of lateral condyle of femur is attributed to the increase in bicondylar angle.

The present study is compared with other studies on Bicondylar angle (Table 5 and 6).

Tardieu, and Tardieu and Trinkaus have noticed bicondylar angle of 0° at birth and then a steady average increase in the angle through infancy and into the juvenile years indicating a high degree of potential for plasticity in the development of this angle.[9]

They have also reported ill development and non-development of a bicondylar angle in minimally ambulatory and non-ambulatory children respectively, showing the direct association of a bipedal locomotion with the developmental emergence of a human femoral bicondylar angle.

Shefelbine in the year reported that many studies have linked the obliquity with bipedality but the mechanism for the obliquity is poorly understood by researchers.[10] During bipedal walking, articular ends of femur are subjected to loads of three to four times of body weight and the stresses on the distal femur result from bipedal loading conditions which promote growth and ossification more on the medial side than on the lateral side of the femur, forming the bicondylar angle.

Igbigbi and Sharrif in the year studied the significant sexual dimorphism bilaterally in the adult Malawian population.[3] It shows that the higher obliquity in female was statistically highly significant on the left side (p<0.001) and significant on the right side (p<0.05) while Pandya and Singel estimated the mean femoral bicondylar angle in Gujarati population to be 8.88° and 10.50° in right male and female, and in left male and female it was 8.76° and 10.83° respectively.[11]

The higher obliquity in females was statistically highly significant on left side (p<0.001) and significant on right side (p<0.05).

In the year 2010 there was another study done by Shanta Chandrasekaran and Deepti and concluded that the bicondylar angle is higher in female population which can be linked with the broader pelvis and short stature of the female population as mentioned by the textbooks of anatomy.[5] In this study authors found that the bicondylar angle of left femur was greater than right in both the genders, but the side difference was statistically insignificant (p>0.05).

Table 5: Comparison of Mean and SD of bicondylar angle (right side) measured by various studies.

Year	Study	Parameters	Bicondylar angle	
			Male	Female
1919	Pearson and Bell	Range Mean±SD	- 8.69°±0.09	- 9.39°±0.11
1974	Singh and Singh	Range Mean±SD	2°-13° 8.16±2.21	5°-16° 8.82±2.17
2005	Igbigbi and Sharrif	Range Mean±SD	1.50°-12° 6.13±1.88	1.50°-12° 7.75±1.62
2008	Pandya and Singel	Range Mean±SD	3°-13° 8.88±2.05	5°-13° 10.50±2.42
2010	Shanta and Deepti	Range Mean±SD	4°-14° 8.26±2.47	6°-14° 9.74±2.21
2012	Mahajan and Seema	Range Mean±SD	2°-14° 8.17±2.31	5°-16° 8.82±2.17
2014	Sharma and Sharma	Range Mean±SD	3.6°-11° 6.371±1.82	4°-12° 8.206±2.11
2015	Jyoti Lakshmi and Afroze M.	Range Mean±SD	5°-12° 7.26±1.67	5°-12° 8.71±1.58
2017	Present Study	Range Mean±SD	5°-11° 7.70±1.78	5°-12° 8.41±1.76

Table 6: Comparison of Mean and SD of Bicondylar angle (Left side) measured by various studies.

Year	Study	Parameters	Bicondylar angle	
			Male	Female
1919	Pearson and Bell	Range Mean±SD	- 11.59°±0.08	- 11.77°±0.10
1974	Singh and Singh	Range Mean±SD	3°-16° 7.79±2.20	3°-13° 8.67±2.21
2005	Igbigbi and Sharrif	Range Mean±SD	1.5°-12° 6.13±1.88	1.5°-12° 7.75±1.62
2008	Pandya and Singel	Range Mean±SD	4°-13° 8.76±2.24	6°-13° 10.83±1.94
2010	Shanta and Deepti	Range Mean±SD	6°-14° 8.85^0±2.16	5°-18° 10.62°±3.17
2012	Mahajan and Seema	Range Mean±SD	3°-14° 7.89±2.23	4°-15° 8.57±2.19
2014	Sharma and Sharma	Range Mean±SD	3°-11° 7.348±2.36	5°-12.5° 8.729±2.30
2015	Jyoti Lakshmi and Afroze M.	Range Mean±SD	5°-10° 7.39±1.40	7°-13° 8.96±1.49
2017	Present Study	Range	4°-11°	4°-14°

Many studies were done in past in various regions of the world in order to find the difference in bicondylar angle in males and females of that region.

Jyoti Lakshmi and Afroze M. in the year reported that the difference in the bicondylar angle between males and females is found to be statistically significant on both sides in South Indian population whereas Sharma and Sharma reported that the femoral bicondylar angle was significantly ($p<0.05$) more on both right and left sides in females as compared to Males in the population of Madhya Pradesh region.[12,13]

Other approaches was also set by researchers in order to know the bicondylar angle. Ukoha tested a new radiographic approach.[14] He collected 250 radiographs of the Knee joints of Nigerians in Rivers State and from it estimated the mean bicondylar angle and the gender difference observed was statistically significant.

In the textbooks of anatomy, bicondylar angle is mentioned to have higher values in female linked with their broader pelvis and short stature by McMinn R.M.H, Standring S.[15]

Hence, in contrast to this study the bicondylar angle of left femur was greater than right in both the genders but the side difference was statistically insignificant ($p>0.05$). Thus, mechanical factor such as differential strain and stress experienced by the femur due to diverse physical activity coupled with the variation in the biological factor such as genetic constitution, hormonal environment, growth factor, nutrition etc. could be responsible for racial and regional variation of obliquity of shaft.

CONCLUSION

In conclusion, similar to this study Tardieu C. and Damsin J.P. have reported statistically insignificant sexual dimorphism of angle on both the sides. In contrary Pandya and Singel and Igbigbi and Sharrif reported that obliquity in female was statistically highly significant on the left side ($p>0.0001$) and significant on the right side ($p<0.05$). Authors reported that the mean value of femoral bicondylar angle in Udaipur zone population is 7.7083°±1.781 in right side and 8.0°±1.794 on left side in males and in the females, the angle is 8.4166°±1.767 on the right side and 8.5833°±1.909 on left side respectively. The bicondylar angle of left femur was greater than right in both the genders but authors found that the side difference was statistically insignificant ($p>0.05$).

In hypothesis, this result can be used for orthopedic clinicians and surgeons to understand the lesions/diseases/variations related to bicondylar angle and obliquity of shaft and can add advantage for reconstructive orthopedic surgeons. The study also emphasized on already known common significant as well as insignificant variations associated with femoral Bicondylar angle.

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