Osteological and Radiological Study of Femoral Bicondylar Angle among Nepalese Population

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ABSTRACT

Introduction: The femoral bicondylar angle of femur is an angle between the axis of shaft of the femur and a line perpendicular to the infracondylar plane. The bicondylar angle was studied from earliest known bipedal human ancestors: australopithecines from about 4.2 million years ago. The bicondylar angle of the femur of australopithecines is often used as a marker of bipedality and is therefore an indicator of human lineage. Objectives: The main objective was to study the femoral bicondylar angle by osteological and radiological method as to show their relation between different measured parameters as well as the angle under respective method. Methods: A total sample of 200 (100 dried femurs—for osteological method and 100 radiological films—for radiological method) from Medical colleges of Nepal were included in this study. Femoral bicondylar angle was measured by using osteometric board, goniometer, vernier caliper and accessories. Collected data were analyzed statistically and presented in the form of tables and graph. The mean of femoral bicondylar angle was calculated and correlated with other parameters using the Pearson’s correlation. Result: The mean value of femoral bicondylar angle obtained were 9.31⁰±2.13 and 9.37⁰±2.25 for right and left femurs respectively by the osteological method. The mean value calculated from radiological method were 8.96⁰±2.24 for right and 9.40⁰±2.44 for left in males whereas in females 8.70⁰±2.48 for right and 9.31⁰±2.58 for left. Apart from the average value and standard deviation, the mean angle correlation with height and side, showed statistically insignificant (P>0.005). Conclusion: The finding of the study showed the femoral bicondylar angle was greater in left femur than right in osteological method whereas it was greater in both right and left femur of male when compared to female as per radiological method. Overall, the bicondylar angle was found to be greater in left femur than right. Thus, obtained observation of the bicondylar angle could be useful in forensic discipline to ascertain the age and sex of the dried femur in controversial situation.

Key Words: Anthropometry, osteometry, radiology, osteology, femoral bicondylar angle, sexual dimorphism and bipedalism.

INTRODUCTION

Anthropometry is the series of sympathized measuring techniques that express quantitatively the dimension of the human body and skeleton. It also includes any pathological or physiological trait. However, in practice anthropometry refers specially to the morphological traits which can be...
externally measured.\cite{1} Osteometry is the branch of anthropology that deals with the measurement of bones including femur. It is a technique of measurements through which a forensic scientist can study variation in bony skeleton of different population. It has been used in estimation of different stature, age, sex, and race in forensic and legal sciences.\cite{2} Radiology is the branch of anatomy in which the different part of human body are study by passing the X – ray through the body part for which diagnosis is desired. Radiographic film is used to take X – ray. Radiograph can be taken anteroposteriorly (AP view) and posteroanteriorly (PA view). Most of the used radiograph for the study of bone is AP view.\cite{3} Femur is the strongest and longest bone of the human body and only one bone of the thigh.\cite{4,5,6} Its length is associated with a striding gait, its strength with weight and muscular forces\cite{4} as well as most voluminous bone of the body as well.\cite{7} It is 45cm (18 inches) long in an average man which is approximately one fourth of the height of the individual. The body of the femur buried in muscle and obliquely place so that two femora are widely separated by pelvis but lies close at knees. The femur present upper end, lower end and intervening shaft.\cite{5,6}

**Bicondylar angle**

In the lower end of the femur angle can be measured between two condyles known as the bicondylar angle. It is the angle between an axis through the shaft of the femur and a line perpendicular to the infracondylar plane.\cite{8-16}

On the basis of fossil record from 3-1.8 million years ago the study argued that an increase in femoral obliquity angle added as the initial change involving selection for deepening of trochlear groove and prominence of its lateral lip under the influence of an increasing tendency for full extension of knee joint.\cite{16,17}

The presence of a femoral bicondylar angle in Australopithecus afarensis indicates that these 3.5-million-year-old hominids were bipedal,\cite{18,19} not only the bicondylar angle is reason for the hominid bipedalism but also associated with the some other reasons are due to presence of genu valgum and the associated skeletal features in the hominin lower limbs.\cite{20}

Ontogenetically, the bicondylar angle start appears as the femur start to grow in early childhood. When a child is born, angle is not developed i.e. bicondylar angle is 0° at birth. It appears when a child reach 1-year-old, it is because the medial side of the distal metaphysis grows faster than the lateral side, resulting in bicondylar angle. The angle reaches a stable value of 8°-11° by the age of 8 years.\cite{17,21-24}

**METHODS**

**Measurement of the height of femur**

Femur was fixed on the osteometric board as shown in figure and the height in cm (centimeter) was recorded on the scale placed in osteometric board and reading was noted.

**Procedure of measurement of bicondylar angle**

1. The femur was placed with anterior aspect of femoral condyles and greater trochanter touching the horizontal surface of an osteometric board, on which a paper sheet will be fixed.
2. The inferior margin of both the condyles was placed against the vertical surface of the osteometric board. Infracondylar plane (XY) was taken as the plane of the vertical plate and a horizontal line was drawn on the paper by joining X and Y.
3. The points (A and B) were marked on the paper showing maximum diameter of shaft just below the lesser trochanter.
Fig. 4: Marking the proximal point (AB) by using Vernier caliper.

4. At a level of about ¼ of the length of femur from its distal end, two points (C and D) were marked on the paper, using Vernier caliper.

Fig. 5: Marking the distal point (CD).

5. The axis of shaft was obtained by a line joining the mid points of AB and CD, i.e. $O_1$ and $O_2$ respectively with Z point at intracondylar plane (as shown in figure 4). Similar procedure (2, 3, 4 and 5) for radiology.

6. Therefore, the angle between the axis of shaft and the perpendicular axis (ZP) meeting the horizontal line denotes the Bicondylar angle.

Procedure for radiological method

As we used the X-ray plates of femur or knee joint, the procedure were as follow:

1. Infracondylar plane (XY) was taken by drawing a horizontal line touching the convexities of right and left femoral condyles on the X-ray plate.

2. The points (A and B) were marked on the left and right margin of upper end of femoral shaft visible on X-ray plate.

3. Two points (C and D) were marked on the left and right margin of distal end of femoral shaft on X-ray plate.

4. The axis of shaft was obtained by a line joining the mid points of AB and CD, i.e. $O_1$ and $O_2$ respectively with Z point at intracondylar plane (as shown in figure 13b).

5. Thus, the angle between the axis of shaft (OZ) and the perpendicular axis (ZP) meeting the horizontal line (XY) denotes the Bicondylar angle.

Fig 7: Showing the process of femoral bicondylar angle on X-ray plate: right femur.

RESULT

In osteological method, out of 100 dried bones, 48 were right and 52 were left femur and the bicondylar angle ranging from $4^\circ$ to $13^\circ$ was observed. The heights of femurs were observed ranging from 35cm to maximum of 48cm. When analyzing 100 X-ray plates which consisted of male (45) and female (55) the bicondylar angle was found to be ranging from $3^\circ$ to $14^\circ$.

In 45 X-ray plates of male 25 were of right sided and remaining 20 were the left sided. Similarly, among 55 X-ray plates of female, 23 plates were of right sided and remaining 32 plates belonged to left. The mean value of femoral bicondylar angle obtained were $9.31^\circ \pm 2.13$ and $9.37^\circ \pm 2.25$ for right and left femurs respectively studied by the osteological method whereas mean value calculated from radiological method were $8.96^\circ \pm 2.24$ for right and $9.40^\circ \pm 2.44$ for left in males but in females it was $8.70^\circ \pm 2.48$ and $9.31^\circ \pm 2.58$ for right and left respectively. Apart from the mean bicondylar angle correlations was also observed between sexes and sides in radiological method but osteologically it was only correlated between right and left femur.
Pearson’s correlation coefficient for mean bicondylar angle and height of femur was calculated as -0.05 but it was found negative correlation when compared between the mean bicondylar angle and mean femoral height being insignificant (P>0.005). Similarly, correlation is insignificant at P>0.005 for mean bicondylar angle and side of femur.

**DISCUSSION**

In the present study of the femoral bicondylar angle, the osteological method showed the mean bicondylar angle as 9.31° on right and 9.37° on left femur. It also showed that the mean bicondylar angle being greater in left femur compared to right femur. The present study showed that the mean bicondylar angle for male was 8.96° on right femur and 9.40° on left femur and further for female the angles were 8.70° on right and 9.31° on left femur by radiological method. In

Table 1: Frequency (f) of bicondylar angle with respect to side in osteological method

<table>
<thead>
<tr>
<th>Side</th>
<th>Bicondylar angle</th>
<th>Total (f)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angle</td>
<td>4° 5° 6° 7° 8° 9° 10° 11° 12° 13°</td>
<td>100</td>
</tr>
<tr>
<td>Right</td>
<td>f(N)</td>
<td>48</td>
</tr>
<tr>
<td>Left</td>
<td>f(N)</td>
<td>52</td>
</tr>
<tr>
<td>Total (f)</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: The average value of femoral bicondylar angle in osteological method

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Right</th>
<th>Left</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range of angle</td>
<td>4°-13°</td>
<td>4°-13°</td>
</tr>
<tr>
<td>Mean</td>
<td>9.31°</td>
<td>9.37°</td>
</tr>
<tr>
<td>SD</td>
<td>2.13</td>
<td>2.25</td>
</tr>
</tbody>
</table>

Table 3: Frequency (f) of bicondylar angle with respect to sex and side in radiological method

<table>
<thead>
<tr>
<th>Sex</th>
<th>Side</th>
<th>Angle and its frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>Right</td>
<td>3° 4° 5° 6° 7° 8° 9° 10° 11° 12° 13° 14°</td>
</tr>
<tr>
<td>Right</td>
<td>f</td>
<td>0 1 2 0 2 3 8 4 2 1 2 0</td>
</tr>
<tr>
<td>Left</td>
<td>f</td>
<td>1 0 0 0 3 3 3 3 2 2 0 1</td>
</tr>
<tr>
<td>Female</td>
<td>Right</td>
<td>3° 4° 5° 6° 7° 8° 9° 10° 11° 12° 13° 14°</td>
</tr>
<tr>
<td>Right</td>
<td>f</td>
<td>1 0 2 0 6 6 0 3 2 0 1</td>
</tr>
<tr>
<td>Left</td>
<td>f</td>
<td>1 1 0 2 6 6 0 2 6 2 3 1</td>
</tr>
</tbody>
</table>

Table 4: Bicondylar angle of femur

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Right</th>
<th>Left</th>
<th>Right</th>
<th>Left</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range</td>
<td>4°-13°</td>
<td>4°-13°</td>
<td>4°-13°</td>
<td>4°-13°</td>
</tr>
<tr>
<td>Mean</td>
<td>9.31°</td>
<td>9.37°</td>
<td>8.96°</td>
<td>8.70°</td>
</tr>
<tr>
<td>SD</td>
<td>2.13</td>
<td>2.25</td>
<td>2.24</td>
<td>2.48</td>
</tr>
<tr>
<td>SE</td>
<td>0.31</td>
<td>0.31</td>
<td>0.45</td>
<td>0.52</td>
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</tbody>
</table>
radiological method, greater bicondylar angle was noted in the left femur of both sexes whereas in left femur the bicondylar was found to be greater in male. A study conducted by Pearson K and Bell J\(^{[10]}\) reported that the mean bicondylar angle in English femora as greater in left femur in both sexes (male-11.59° and female-1.77°) than right femur. Report of the study showed bicondylar angle as 8.69° in male and 9.39° in female which was similar to the result obtained in the present study, however the angle obtained in the present study was slightly lower than the angle of English femora. Sharma RL et al also reported the similar findings in which the obliquity of femur was more in left femur (male-7.348° and female-8.729°) than the right femur (male-6.371° and female-8.206°). These findings were dissimilar to the present study finding. Chandrasekaran S et al\(^{[22]}\) also reported that the mean bicondylar angle greater in left femur (male-8.88° and female-10.62°) than in right femur (male-8.26° and female-9.74°) which was almost similar to the findings of the present study but it was found mild variation of the mean femoral bicondylar angle in both male and female in present study. In contrast to the present study the obliquity of left femur was more in both sexes, when compared to the study of Mahajan et al\(^{[24]}\) resulting the obliquity of right femur being more in both sexes (male-8.17° and female-8.82°) than in left femur (male-7.89° and female-8.59°). A study carried out by Singh SP and Singh SS\(^{[13]}\) also observed that the mean bicondylar angle was greater on right femur (male-8.16° and female-8.82°) as compared to that of left femur (male-7.79° and female-8.67°) which was quite similar to the present radiological study.
their study both right and left femurs of male had greater bicondylar angle than that of both right and left femurs of female as the present one. Comparatively both studies had showed nearly the similar value. According to Pandya et al \textsuperscript{21} the mean bicondylar angle in Gujarati population was found to be 8.88\(^\circ\) and 8.76\(^\circ\) in male right and left femur respectively and 10.50\(^\circ\) and 10.83\(^\circ\) in female right and left femur respectively which showed, the obliquity of femur was more in female than in male. Chandrasekaran S et al \textsuperscript{25} also observed that the obliquity of femur being more in female (right-9.74\(^\circ\) and left-10.62\(^\circ\)) than in male (right-8.26\(^\circ\) and left-8.85\(^\circ\)). In contrast, the present study showed that the obliquity of femur was greater in male (right-8.96\(^\circ\) and left-9.4\(^\circ\)) than in female (right-8.70\(^\circ\) and left-9.31\(^\circ\)). Ukooha U et al \textsuperscript{23} reported that the mean bicondylar angle in male was 8.35\(^\circ\)±0.24 on right femur and 8.66\(^\circ\)±0.23 on left femur and for female was 8.16\(^\circ\)±0.81 on right femur and 8.91\(^\circ\)±0.18 on left femur. Result of the study reported that the obliquity of femur was more on left femur than on right femur which was similar to the findings of the present study. With the comparison, it was also noted that the obliquity of femur was more in males than females on right femur and more in female than in male on left femur which was almost similar to the present study but the obliquity was more in male than in female in both sides. The present study showed that the mean bicondylar angle for male as 9.16\(^\circ\) and 9.0\(^\circ\) for female. Thus, the study showed that the obliquity of femur was more in male than female. In contrast to the present study, a study conducted by Lovejoy CO and Heiple KG \textsuperscript{12} reported that the mean bicondylar angle for male as 9.43\(^\circ\) and for female as 10.5\(^\circ\) which showed the greater value in female than in male. However, Chandrasekaran S et al \textsuperscript{25} also reported that the mean bicondylar angle was more in female (10.16\(^\circ\)) than in male (8.53\(^\circ\)).

**CONCLUSION**

Therefore, it is concluded that, osteologically the mean of femoral bicondylar angle was observed more in left femur being 9.37\(^\circ\) than that of right femur (9.31\(^\circ\)) with 0.06 differences. It is because of there was more obliquity in left dried femurs when compared to right.

Radiologically the mean femoral bicondylar angle was observed more in right and left femur of male were 8.96\(^\circ\) and 9.40\(^\circ\) respectively than that of female right femur (8.70\(^\circ\)) and left femur (9.31\(^\circ\)). It is because there was more obliquity in radiograph of male right and left femurs than female. Among the left and right femur, left had got more average femoral bicondylar angle due to its more obliquity. Therefore, higher the obliquity higher will be the femoral bicondylar angle and lesser the obliquity lesser will be the femoral bicondylar angle.

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