Anthropometric Analysis of Femur in South Indian Population

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Most of the femoral orthopaedic implants were designed and manufactured based on western anthropometry which is different from South Indian population and causes complications like aseptic loosening. This was an observational descriptive type of study which was performed on 95 fully ossified human femur bones (48 Right sided and 47 Left sided) collected from our institute. Vernier Caliper, Goniometer and Inch tape were used for taking measurements. The parameters studied were Neck Shaft Angle, Length of femur, Vertical Head diameter, Head circumference, Mid-shaft anteroposterior diameter and Mid-shaft Circumference. The results of the present study are the mean neck shaft angle was 146.25±4.18°, the mean length of femur was 3.38±3.14cm, the mean vertical head diameter was 39.9±3.42mm, mean head circumference was 14.13±1.04cm, mean midshaft anteroposterior diameter was 25.396±2.93mm and the mean midshaft circumference was 9.086±0.69cm. The mean values are also taken separately for the right and left femora. Comparing the results of this study with the previous study for right and left sided values, the results are found to be statistically significant. The mean values of the femoral parameters should be considered during surgical fixation of femoral fractures and also for designing orthopaedic implants and hip prosthesis for South Indian population.

Keywords: Anthropometry; Arthroplasty; Diaphyses; Femur; Femoral Fractures; Hip Prosthesis.

The anatomy of proximal end of femur is essential to understand the biomechanics of hip joint1,2. The neck shaft angle of femur3,4 also known as Cervicodiaphyseal angle5 (120°-140°)6 along with the proximal femoral geometry is of utmost importance in pre-operative planning of osteotomy, arthroplasty or fracture fixation7 and for implants of femoral neck8. Use of undersized or oversized femoral implants leads to altered soft tissue tensioning and altered patella femoral stresses9. In case of improper selection of femur implant, postoperative complications can arise.

MATERIALS AND METHODS

The objective of the study is to measure the various parameters of femur in South Indian Population and to correlate with the previous studies. This is an observational descriptive type of study which was performed on 95 fully ossified human femur bones (48 Right sided and 47 Left sided) collected from our institute, Chennai. Instruments used for taking measurement were Goniometer, Vernier Caliper and Inch tape.
Inclusion Criteria: Normal cadaveric bones of South Indian Population
Exclusion Criteria: Bones with any pathology and damaged bones

The following are the parameters of femur studied:
• Neck Shaft Angle
• Length of femur
• Vertical Head diameter
• Head circumference
• Mid-shaft anteroposterior diameter
• Mid-shaft Circumference

Appropriate statistical tests were done after the formulation of results.

RESULTS AND DISCUSSION

The average values of the above said parameters as found in the current study are as follows:

Neck Shaft Angle (NSA)

In this study, the neck shaft angle was measured and recorded among 95 dry femurs, out of which, 48 were right sided and 47 left sided. The minimum angle measured was $138^\circ$ on the right side and $137^\circ$ on the left side. The maximum angle measured was $154^\circ$ on the right side and $155^\circ$ on the left side. The mean NSA of all the femur was $146.25\pm4.18^\circ$. The mean NSA on the right side was $145.46\pm4.62^\circ$ and the mean NSA on the left side was $147.06\pm3.54^\circ$.

The variation in NSA between the right and left sides was found to be statistically insignificant. Comparing the results of this study with the study of Ravichandran et al\textsuperscript{10} (mean NSA is $126.55^\circ$), the values are found to be higher in this study. In a study done by RC Siwach et al\textsuperscript{11} in 2003 among people of Rohtak using 150 dry bones, the neck shaft angle was $123.5^\circ$, as against $146.25^\circ$, which is again higher. Comparing with the results of this study with the study of Minakshi verma et al\textsuperscript{12}, NSA was not significant on the right side whereas on left side, the two tailed p value is less than 0.0001. By conventional criteria, this difference is considered to be extremely statistically significant.

Tilman and Tondury suggested that NSA is around $150^\circ$ during fetal development and decrease to $125^\circ$ by the time of skeletal maturity\textsuperscript{14}. NSA varies with climate, clothing, age, side, lifestyle, occupation, gender and economic status of the individual\textsuperscript{15}. Orthopaedic manufacturers use data from various studies to develop femoral prosthesis to develop new hip stem designs for treating fractures of the proximal femur especially femoral neck fractures\textsuperscript{16}. It is an important parameter to predict the risk for a hip fracture, especially in osteoporosis and to start preventive treatment if there is an increased risk\textsuperscript{17}. Radiography of the angle aids in the diagnosis and further management of femoral neck fractures.

Length of Femur

The minimum length measured on the right side was 37.2cm and on the left side, 38.3cm. The maximum length measured on the right side was 51.7cm and on the left side was 52.3cm. The mean length of all femurs measured was $43.38\pm3.14$cm. The mean length of femur on the right side was $43\pm2.98$cm and the mean length on the left side was $43.77\pm3.29$cm. The variation in the length of femur between the right and left side was found to be statistically insignificant.

Comparing the results of this study with the study of Zuylan and Murshid\textsuperscript{18} (in their study left femur length was $42.84$ cm, right femur length was $41.68$ cm), femoral length was not significant on the right side whereas on left side, the two tailed p value is 0.0469. By conventional criteria, this difference is considered to be statistically significant.

The difference in mean femoral length in between populations is due to factors that affect bone morphology such as genetic constitution, diet, nutrition status, environment, and physical activity\textsuperscript{19}. Femur length is important in designing intramedullary femoral implants and surgical management of femoral shaft fractures. It is used in the estimation of body stature of the person in the field of forensic medicine\textsuperscript{20}.

Femoral Head Diameter

In this study, Vertical head diameter of the femur was measured using vernier caliper. It is taken at right angle to the long axis of neck of femur. The vertical diameter is the straight distance between the most superior to the most inferior point of the femoral head in a vertical plane. The least head diameter of the femur measured was 32.45mm on the right side and 33.19mm on the left side. The highest head diameter of the femur measured was 46.83mm on the right side and 46.27mm on the
left side. The mean head diameter of all femurs was 39.9±3.42mm. The mean head diameter on the right side was 39.95±3.15mm and the mean head diameter on the left side was 39.85±3.71mm. The variation in the vertical head diameter between the right and left side was found to be statistically insignificant.

Comparing the results of this study with the study of Khaleel N et al, on the right side, the two tailed p value is 0.0025 and on the left side, the two tailed p value is less than 0.0001. By conventional criteria, this difference is considered to be very statistically significant on both sides.

Rumapurkait found that head diameter alone could correctly determine sex to 92.5% of males and 95.5% females. In the same study they also found that vertical head diameter of right femur was significantly greater than left. Pons stated that the head diameter determined the sex better than any other part of bone. It is essential for selection of the implants of the head during Hemiarthroplasty of the hip. Vernier Caliper measurements of the vertical head diameter are more reliable than X ray and CT images for measuring the head diameter for the selection of prosthesis.

**Head Circumference**

The head circumference was measured around the head of the femur using an inch tape. The minimum head circumference measured was 12cm on the right side and 11.8cm on the left side. The maximum head circumference measured was 15.8 cm on the right side and 16.2cm on the left side. The mean head circumference of all femurs was 14.13±1.04cm. The mean head circumference on the right side was 14.15±0.99cm and the mean head circumference on the left side was 14.11±1.09cm. The variation in the head circumference between the right and left side was found to be insignificant. Ranjan Bajpai et al studied the head circumference of femur in Nashik district, Maharashtra and found to be significantly higher in males compared to females. Head circumference is important in deciding the range of movements after THA (Total Hip Arthroplasty).

**Table 1. Average Values of all Parameters**

| Parameter                  | Total Value | Right Femur | Left Femur |
|----------------------------|-------------|-------------|------------|
| Neck Shaft Angle           | 146.25±4.18°| 145.46±4.62°| 147.06±3.54°|
| Length of femur            | 43.38±3.14cm| 43±2.98cm   | 43.77±3.29cm|
| Head diameter              | 39.9±3.42mm | 39.95±3.15mm| 39.85±3.71mm|
| Head circumference          | 14.13±1.04cm| 14.15±0.99cm| 14.11±1.09cm|
| Midshaft anteroposterior diameter | 25.39±2.93mm | 25.51±2.89mm | 25.28±2.99mm |
| Midshaft Circumference     | 9.086±0.69cm | 9.002±0.64cm | 9.172±0.73cm |

The relevant statistical tests and their significance along with p value are discussed in the respective parameters.

**Table 2. Comparison of Neck Shaft Angle of Present Study with Previous Studies**

| Author                        | Year | Number of bones | Geographical Distribution | Materials | Neck Shaft Angle (in degrees) |
|-------------------------------|------|-----------------|----------------------------|-----------|--------------------------------|
| RC Siwach                     | 2003 | 150             | Rotak                      | Dry bones | 123.5±4.3                      |
| K C Saikia                    | 2008 | 92              | Guwahati                   | CT Scans  | 139.5±7.5                      |
| T R Deshmukh                  | 2010 | 77              | Vidarbha                   | X rays    | 131.5                          |
| Subhas Gujar                  | 2013 | 250             | Central Gujarat            | Dry bones | 136.2±6.0                      |
| Shaik hussain Saheb           | 2014 | 250             | South India                | Dry bones | 137.1                          |
| Vineeta Laxmi                 | 2018 | 62              | Bihar                      | Dry bones | 136.5±5.23                     |
| Minakshi verma et al          | 2017 | 91              | New Delhi                  | Dry bones | 130.3±3.875                    |
| Present Study                 | 2019 | 95              | South India                | Dry bones | 146.25±4.18                    |

p value with present study= 0.0001(significant)
i.e. hip movements increases with larger bearing sizes. Larger heads prevent dislocation after the surgery and the risk of revision surgery.

**Midshaft Anteroposterior Diameter**

Anteroposterior diameter of femur can be taken at three different levels:

- **Upper:** Just below the lesser trochanter
- **Middle:** Approximately at the middle of the shaft at the highest elevation of linea aspera
- **Lower:** Approximately 4 cm above the cartilaginous margin of condyles taken in mid sagittal plane.

In this study, midshaft anteroposterior diameter was measured and compared among 95 dry femurs, among which 48 were right and 47 left. The minimum midshaft anteroposterior diameter that measured was 21.32 mm on the right side.

### Table 3. Comparison of Femur Length in Different Population

| Authors          | Population      | Subdivision | Femur length    |
|------------------|-----------------|-------------|-----------------|
| Zuylan et al     | Anatolian       | Right       | 41.68±6.86 cm   |
|                  |                 | Left        | 42.84±2.49 cm   |
| Gujar et al      | Indian          | Right       | 43.99 cm        |
|                  |                 | Left        | 43.65 cm        |
| S Dhivya, V Nandhini | South Indian  | Right       | 41.29±3.39 cm   |
|                  |                 | Left        | 41.88±2.82 cm   |
| Khan and Saheb   | South Indian    | Right       | 44.66±2.66 cm   |
|                  |                 | Left        | 44.58±2.61 cm   |
| Present study    | South Indian    | Right       | 43±2.98 cm      |
|                  |                 | Left        | 43.77±3.29 cm   |

### Table 4. Comparison of Femoral Head Diameter with Previous Study

| Authors           | Population               | Subdivision | Vertical Head diameter of femur (mm)    |
|-------------------|--------------------------|-------------|----------------------------------------|
| Khaleel N et al   | SV medical College, Tirupathi, Andhra Pradesh. | Right       | 41.63 mm±3.09 mm                        |
|                   |                          | Left        | 42.96 mm±3.92 mm (significant)         |
| Present study     | South Indian Population  | Right       | 39.95 mm±3.15 mm                        |
|                   |                          | Left        | 39.85 mm±3.71 mm (significant)         |

### Table 5. Comparison of Midshaft Anteroposterior Diameter with the Previous Studies

| Authors           | Population               | Subdivision | Midshaft anteroposterior diameter    |
|-------------------|--------------------------|-------------|--------------------------------------|
| T.Jayachandra Pillai et al | Different medical institution and Anthropology department of S. V. University, Tirupati | Right | 26.20±2.02 mm                        |
|                   |                          | Left        | 26.61±2.40 mm (significant)          |
| Dr Ashish Kamdi et al | Telangana region              | Right       | 25.14 mm                             |
|                   |                          | Left        | 25.06 mm                             |
| Present study     | South Indian Population  | Right       | 25.51 mm                             |
|                   |                          | Left        | 25.28 mm                             |
Table 6. Comparison of Midshaft Circumference with Previous Study

| Author         | Population     | Subdivision | Midshaft Circumference       |
|----------------|----------------|-------------|-------------------------------|
| Zuylan et al   | Anatolian      | Right       | 8.62±0.65cm                  |
|                | Population     |             | p value with present study= 0.0001(significant) |
|                |                | Left        | 8.72±0.76cm                  |
|                |                |             | p value with present study= 0.0002(significant) |
| Present Study  | South Indian   | Right       | 9.002±0.64cm                 |
|                | Population     | Left        | 9.172±0.73cm                 |

side and 16.99 mm on the left side. The maximum midshaft anteroposterior diameter measured was 32.96mm on the right side and 32.19mm on the left side. The mean midshaft anteroposterior diameter of all femurs was 25.39±2.93mm, on the right side was 25.51±2.89mm and on the left side was 25.28±2.99mm. On statistical analysis, the difference in the midshaft anteroposterior diameter between the right and left side was found to be statistically insignificant.

Comparing the results of this study with the study of T.Jayachandra Pillai et al., midshaft anteroposterior diameter was not significant on the right side, whereas on the left side, the two tailed p value is 0.0074. By conventional criteria, this difference is found to be very statistically significant. This value is taken into consideration while making a best fit femoral prosthesis and also for the determination of sex by the forensic anthropologist. Ashish Kamdi observed that the values are slightly higher in males compared to females.

Midshaft Circumference

In this study, midshaft circumference was measured with an inch tape and compared among 95 dry femurs. The least value of midshaft circumference that was measured was 7.6cm on both the sides. The highest value recorded was 10.5cm on the right and 10.7cm on the left. The mean midshaft circumference of all femurs was 9.086±0.69cm. The mean midshaft circumference on the right side was 9.002±0.64cm and the mean midshaft circumference on the left side was 9.172±0.73cm. The difference in the midshaft circumference between the right and left side was found to be statistically insignificant.

Thomas K. Black et al. in their study observed that femoral circumference is a useful tool in the determination of sex especially when the skeletal remains are fragmentary or poorly preserved. They concluded that femur circumference greater than 81mm were classified as males and lesser than 81mm as females and those with a femoral circumference equal to 81mm were classified as indeterminate sex.

Comparing the results of this study with the study of Zuylan et al., the midshaft circumference, on the right side, the two tailed p value was 0.0001 and on the left side, the two tailed p value was 0.0002. By conventional criteria, this difference is found to be extremely statistically significant.

CONCLUSION

On studying and analysing the various parameters of femur, this study concludes that there is no statistically significant differences between the right and left femurs. There has been studies showing significant differences in femoral sizes and shapes across gender, age, race and region. These differences are challenge for the design of well-fitting prosthesis which suits the South Indian Population. Therefore, analyses of femur parameters with statistical methods are very essential.

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