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# Original Research

## Morphometric assessment of upper end of femur and its clinical significance

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***ABSTRACT:***
**Aims**: To derive the regression equation for the estimation of total length of femur from parameters of its upper end. **Methods and Materials**: 200 adult, dry, fully ossified femora of unknown sex were obtained for this study from the anatomy department of Govt. Medical College, Patiala. Numerous factors relating to its proximal end were examined, including the head's vertical and transverse diameter, anterior and posterior neck lengths, maximum femoral breadth, intertrochanteric distance, and intertrochanteric crest length. The information gathered was then statistically analyzed. **Results**: All the parameters of the proximal end of femur showed significant correlation with the total length of femur. Generally, a low to moderate degree of correlation was observed. Maximum width of femur, Vertical and transverse diameters of head displayed the highest correlation. Anterior neck length and maximum width of femur are the best predictors for estimation of total length of femur on the right side while width of greater trochanter at upper border is the best predictor for estimation of total length of femur on the left side. **Conclusions**: This study provides a detailed analysis of the morphometry of the proximal end of the femur. Clinically, it plays an important role for orthopedicians and prosthetists to build suitable prostheses for adult Indian population.

**Key words**: Femoral Length, Proximal End, Morphometry, Long Bones, Regression Equation, Hip Prostheses.

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## INTRODUCTION

For a variety of reasons, the identity of the deceased is a crucial component of the postmortem examination. These include the moral and humanitarian imperatives to identify the deceased, particularly so that surviving families can be informed. Identification is necessary to satisfy legal claims and duties relating to property, estate debts, pensions, and financial matters, as well as to establish the fact of death for official, legal, and statistical purposes [1].

The ability to gauge stature from bones, particularly long bones, is crucial for both anthropology and forensic science. Because of crush injuries, earthquakes, natural disasters, and other factors, intact bones are rarely found in forensic investigations. Therefore, to generate a biological profile, the whole length of the femur must be reconstructed from its bony landmarks [2]. Studies have indicated that using long bones to rebuild stature is most suitable. As these bones support weight, there is a direct relationship between their length and an individual's height. Femur would be the preferable option of the two [3].

The femur is the longest and sturdiest bone in the human body. It gives the thighs skeletal stability. It has a shaft, a proximal end, and a distal end. The head, neck, and two sizable projections known as the greater trochanter and lesser trochanter all make up the proximal end of the femur. Understanding a variety of clinical sickness issues, such as the most common site of fracture, changes in osteoporosis, associated congenital anomalies, and medicolegal situations, can be helped by the morphometric examination of the femur [4].

The anthropometric studies were first conducted by Pearson [5], Trotter and Glesser [6]. Later, their findings sparked a number of significant studies, including those by Pelin [7] on the Turkish population and Chibba [8] on South Africans of European heritage. A study by Pan [9] on Hindus in Bengal, Bihar, and Orissa not only sparked interest in studies in India but also gained attention from outside the Indian subcontinent. Shrof et al. [10] did research in India in 1999 to determine the entire length of the femur from its segments. They determined the percentile length of different segments and contrasted the results to the femur's overall length. In each case, the regression coefficient was found to be highly significant.

Hip osteoarthritis, femur neck fractures, and other hip joint conditions are becoming more frequent every day. The only effective treatment for these patients is arthroplasty [11]. Race, sex, environmental variables, and way of life all have a significant impact on the morphology of bones. According to a population-based study by Nurzenski et al. [12], factors related to lifestyle also affect geometric measures of bone strength in the proximal femur. The ability to select implant and other structure designs that take into account a patient's unique hip morphology is crucial for the success of hip replacements and augmentation of hip stability. Planning for surgery must take hip morphological variances into account. When Indians receive Western implants, they are much more likely to experience implant failure, which can result in avascular necrosis, malunion, or non-union. Geography, sex, stature, and inheritance all have an impact on the regional variance of the femur bone, since the environment has a significant impact on how it grows. Understanding the changes in dry femoral characteristics will help orthopedists and prosthetists to create an appropriate prosthesis. Studies on the morphology of the proximal femur in a number of people and cultures have discovered social and regional variances in femoral morphometry [13]. The purpose of this study was to develop the regression equation for estimating the entire length of the femur from upper end parameters. The findings of this research will persuade implant manufacturers to alter their designs in order to better meet the needs of Indian patients.

## MATERIALS AND METHODS

It is a cross-sectional study that was conducted on 200 (adult, dry, fully ossified) femora bones of unknown sex that were taken from the Department of Anatomy, Government Medical College, Patiala.

## INCLUSION CRITERIA

Fully ossified, dried, and processed femora irrespective of age, sex, and race were included in the study.

## EXCLUSION CRITERIA

Unossified bones and bones with disease, injury or fragmentation were excluded.

## INSTRUMENTS USED

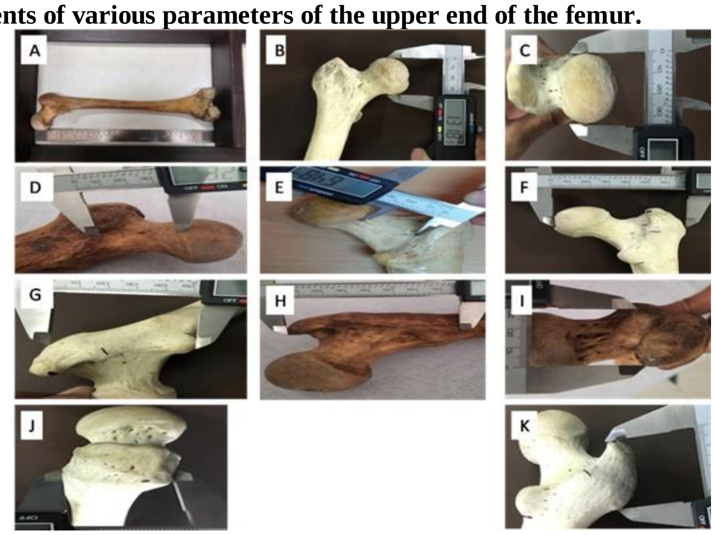
An osteometric board and a digital vernier caliper were used for taking the various measurements of the femur bone.

**The following parameters were measured:**

1. Total length of femur
2. Vertical head diameter
3. Transverse head diameter
4. Anterior neck length
5. Posterior neck length
6. Maximum width of femur
7. Intertrochanteric distance
8. Intertrochanteric crest length
9. Greater trochanter width at the upper border
10. Greater trochanter width at the lower border
11. Greater trochanter maximum vertical length

The maximum length of the femur was measured with the use of an osteometric board, and the remaining measurements were done with the digital vernier caliper as shown in figure 1. The data so obtained was subordinated to statistical analysis. Descriptive statistics and Pearson correlation were done. To create a regression equation for estimating the total length of the femur, a linear regression analysis was carried out.

**Figure 1: Measurements of various parameters of the upper end of the femur.**




**(A)Total length of femur; (B) Vertical head diameter; (C) Transverse head diameter; (D) Anterior neck length; (E) Posterior neck length; (F) Maximum width of femur; (G) Intertrochanteric distance; (H)**

**Intertrochanteric crest length; (I) Greater trochanter width at the upper border; (J) Greater trochanter width at the lower border; (K) Greater trochanter maximum vertical length**

## RESULTS

Using the independent samples t-test, Pearson's correlation coefficient, and linear regression analysis, the length of the femur and other parameters of its proximal section of 200 femora (100 right and 100 left) were measured and statistically analysed in the current study. A p-value of <0.05 was considered significant and <0.01 highly significant. The statistical descriptive summaries of all the measurements taken from the femur are presented in Table 1. The mean maximum length of the femur was 429.74±27.61mm and 442.19±26.66 mm on the right and left sides respectively. Table 2 shows the correlations between measurements of fragments of the femur and the maximum femoral length. All the parameters of the proximal end of the femur showed a significant correlation with the total length of the femur. Generally, a low to moderate degree of correlation was observed. The maximum width of the femur, the vertical and transverse diameters of the head displayed the highest correlation. Anterior neck length and maximum width of the femur are the best predictors for estimation of the total length of the femur on the right side as predicted in Table 3. Greater trochanter width at the upper border is the best predictor for estimation of the total length of the femur on the left side as shown in Table 4.

**Table 1: Morphometric variables of all the parameters of femur on both sides**

| Parameters | Side | Mean | SD | N |
|---|---|---|---|---|
| Total length | Right | 429.74 | 27.61 | 100 |
| | Left | 442.19 | 26.66 | 100 |
| Vertical head diameter | Right | 41.70 | 3.95 | 100 |
| | Left | 42.80 | 3.53 | 100 |
| Transverse head diameter | Right | 42.16 | 3.71 | 100 |
| | Left | 43.26 | 3.39 | 100 |
| Anterior neck length | Right | 34.65 | 5.59 | 100 |
| | Left | 35.82 | 5.92 | 100 |
| Posterior neck length | Right | 27.96 | 5.55 | 100 |
| | Left | 28.73 | 5.00 | 100 |
| Maximum width of femur | Right | 87.84 | 9.03 | 100 |
| | Left | 90.11 | 8.15 | 100 |
| Intertrochanteric distance | Right | 57.10 | 5.47 | 100 |
| | Left | 58.04 | 7.21 | 100 |
| Intertrochanteric crest length | Right | 59.14 | 7.34 | 100 |
| | Left | 62.46 | 8.24 | 100 |
| Greater trochanter width at the upper border | Right | 29.78 | 3.92 | 100 |
| | Left | 30.21 | 5.91 | 100 |
| Greater trochanter width at the lower border | Right | 36.49 | 3.86 | 100 |
| | Left | 36.98 | 4.51 | 100 |
| Greater trochanter maximum vertical length | Right | 41.22 | 4.94 | 100 |
| | Left | 42.49 | 4.22 | 100 |

**Table 2: Showing correlation of individual parameters with total length**

| Parameters | | Right | Left |
|---|---|---|---|
| Vertical head diameter | Pearson Correlation | .850** | .719** |
| | P Value | .000 | .000 |
| | N | 100 | 100 |
| Transverse head diameter | Pearson Correlation | .846** | .750** |
| | P Value | .000 | .000 |
| | N | 100 | 100 |
| Anterior neck length | Pearson Correlation | .631** | .397** |
| | P Value | .000 | .000 |
| | N | 100 | 100 |
| Posterior neck length | Pearson Correlation | .529** | .270** |
| | P Value | .000 | .007 |
| | N | 100 | 100 |
| Maximum width of femur | Pearson Correlation | .855** | .674** |

| | | | |
|---|---|---|---|
| | P Value<br>N | .000<br>100 | .000<br>100 |
| Intertrochanteric distance | Pearson Correlation<br>P Value<br>N | .670**<br>.000<br>100 | .495**<br>.000<br>100 |
| Intertrochanteric crest length | Pearson Correlation<br>P Value<br>N | .383**<br>.000<br>100 | .496**<br>.000<br>100 |
| Greater trochanter width at the upper border | Pearson Correlation<br>P Value<br>N | .628**<br>.000<br>100 | .242*<br>.015<br>100 |
| Greater trochanter width at the lower border | Pearson Correlation<br>P Value<br>N | .697**<br>.000<br>100 | .531**<br>.000<br>100 |
| Greater trochanter maximum vertical length | Pearson Correlation<br>P Value<br>N | .648**<br>.000<br>100 | .517**<br>.000<br>100 |

** Correlation is significant at 0.01 level (2 tailed)
* Correlation is significant at 0.05 level (2 tailed)

**Table 3: Regression analysis of right sided femur bones. Anterior neck length and Maximum width of femur are the best predictors for estimation of total length of femur on right side**.

| Model | Unstandardized Coefficients Beta | Std. Error | Standardized Coefficients Beta | T test | P value |
|---|---|---|---|---|---|
| (Constant) | 166.293 | 15.835 | | 10.502 | <0.001 |
| Vertical head diameter | 1.718 | 1.517 | .246 | 1.132 | .261 |
| Transverse head diameter | 1.370 | 1.644 | .184 | .834 | .407 |
| Anterior neck length | .750 | .338 | .152 | 2.216 | .029 |
| Posterior neck length | .253 | .297 | .051 | .853 | .396 |
| Maximum width of femur | .796 | .359 | .260 | 2.220 | .029 |
| Intertrochanteric distance | -.256 | .444 | -.051 | -.577 | .565 |
| Intertrochanteric crest length | -.077 | .207 | -.020 | -.372 | .711 |
| Greater trochanter width at the upper border | .623 | .467 | .088 | 1.335 | .185 |
| Greater trochanter width at the lower border | .271 | .607 | .038 | .447 | .656 |
| Greater trochanter maximum vertical length | .528 | .376 | .095 | 1.404 | .164 |

**Table 4**: **Regression analysis of left sided femur bones. Width of greater trochanter at upper border is the best predictor for estimation of total length of femur on left side.**

| Model | Unstandardized Coefficients Beta | Std. Error | Standardized Coefficients Beta | T test | P value |
|---|---|---|---|---|---|
| (Constant) | 170.732 | 23.752 | | 7.188 | <0.001 |
| Vertical head diameter | .421 | 1.636 | .056 | .257 | .798 |
| Transverse head diameter | 3.433 | 1.869 | .437 | 1.837 | .070 |
| Anterior neck length | .336 | .357 | .075 | .939 | .350 |
| Posterior neck length | .333 | .384 | .062 | .866 | .389 |
| Maximum width of femur | .424 | .388 | .130 | 1.092 | .278 |
| Intertrochanteric distance | .762 | .520 | .206 | 1.464 | .147 |
| Intertrochanteric crest length | -.034 | .333 | -.011 | -.103 | .918 |
| Greater trochanter width at the upper border | -1.085 | .517 | -.241 | -2.099 | .039 |
| Greater trochanter width at the lower border | .210 | .607 | .035 | .345 | .731 |
| Greater trochanter maximum vertical length | .662 | .680 | .105 | .973 | .333 |

**DISCUSSION**

Regression equations have been derived for the assessment of stature in several population groups using intact long bones of the upper and lower extremities. Sometimes, these bones are delivered to forensic anthropologists at various levels of fragmentation, rendering the equations that were generated useless. This has made it necessary to evaluate the value of measurements of lengthy bone fragments [14].

In order to create orthopaedic implants used in the treatment of femur fractures, this study was conducted to assess the morphometry of the femur and determine the differences between the right and left sides. There is an increase in the frequency of injuries such as femur neck fractures. Implants that are based on the upper femur's measurements are used to treat such fractures [15].

Shweta Solan et al. [16], in a study on the South Indian population, divided the femur into 5 segments and the proportion of segments to the total length was calculated, which helps in stature estimation. Ajay M. Parmar et al. [17] have observed the strongest correlation of femoral length with the distance between the apex of the greater trochanter to the lower margin of the lesser trochanter. In our study, the femoral length correlates best with the vertical head diameter, transverse head diameter and maximum width of the femur on both sides.

Dwivedi AK et al. [18] derived the regression equation by measuring femur length, circumference, vertical and transverse diameter of head, vertical and transverse diameter of neck, anterior and posterior neck length. Various studies of proximal femur parameters were conducted in Asian countries, such as in the Malay population [19], Chinese population [20], and the Pakistani population [21]. In India, various studies were carried out regionally. Table 9 shows the comparison of femoral length and various parameters of the proximal femur in the present study with those of others.

**Table 5: Comparison of femoral length and various parameters of proximal end of femur, of the present study with that of others**

| Parameters | | Sarasammal SR et al[3], South Indian population | Dwivedi AK et al[18], Maharashtrian population | Abledu JW et al [22], Gana population | Chandran M[23], Chennai region | Sinha SK et al[24], Bihar population | Present study, adult population |
|---|---|---|---|---|---|---|---|
| Maximum femoral length | Rt | 419.0±34.0 | 414.96±30.57 | 449.7±23.4 | 395.0±14.0 | 434.6±24.8 | 429.74±27.61 |
| | Lt | | 410.29±30.05 | | | 435.7±27.6 | 442.19±26.66 |
| Vertical head diameter | Rt | - | 40.57±3.54 | 43.0±3.0 | 380.0±2.0 | 41.25±3.71 | 41.70±3.95 |
| | Lt | - | 40.49±3.49 | | | 40.68±3.23 | 42.80±3.53 |
| Transverse head diameter | Rt | - | 40.59±3.47 | 44.8±3.1 | - | 41.82 ± 3.01 | 42.16±3.71 |
| | Lt | - | 40.30±3.48 | | | 41.66 ± 2.55 | 43.26±3.39 |
| Anterior neck length | Rt | - | 29.96±4.23 | - | - | 41.66 ± 2.55 | 34.65±5.59 |
| | Lt | - | 29.87±3.87 | - | - | 29.98±5.32 | 35.82±5.92 |
| Posterior neck length | Rt | - | 35.41±4.25 | - | - | 34.93±4.87 | 27.96±5.55 |
| | Lt | - | 35.02±4.20 | - | - | 35.12±4.97 | 28.73±5.00 |
| Maximum width of femur | Rt | 80.2±11.1 | 82.23±6.20 | - | 79.0±5.0 | - | 87.84±9.03 |
| | Lt | | 82.60±6.20 | - | | - | 90.11±8.15 |
| Intertrochanteric distance | Rt | 58.1±7.8 | - | - | - | - | 57.10±5.47 |
| | Lt | | - | - | - | - | 58.04±7.21 |
| Intertrochanteric crest length | Rt | - | - | - | - | - | 59.14±7.34 |
| | Lt | - | - | - | - | - | 62.46±8.24 |
| Width of greater trochanter at upper border | Rt | 34.4±5.9 | - | - | - | - | 29.78±3.92 |
| | Lt | | - | - | - | - | 30.21±5.91 |
| Width of greater trochanter at lower border | Rt | 32.4±5.9 | - | - | - | - | 36.49±3.86 |
| | Lt | | - | - | - | - | 36.98±4.51 |
| Maximum vertical length of greater trochanter | Rt | 39.5±5.6 | - | - | - | - | 41.22±4.94 |
| | Lt | | - | - | - | - | 42.49±4.22 |

## LIMITATIONS

The gender of the bone is unknown, and the right and left femurs did not come from the same person.

## CONCLUSION

This study comes to the conclusion that any of the femur's parameters that exhibit high correlation can be used to estimate its length. The equations proposed in this study can provide a reliable estimation of the maximal femoral length in the absence of intact long bones. This study offers information to help surgeons choose the right implant size for adult patients undergoing complete hip replacement surgery. Additionally, it gives information to implant producers so they can make good implants. By using proximal fragments, forensic experts can use this information to determine a person's height and femur length.

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