

Comparative Study of Angle of Inclination and Neck Length of Dry Femur: An Institutional Study

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Abstract

Background: The angle of inclination (neck-shaft angle) and femoral neck length are critical morphometric parameters of the proximal femur that determine hip biomechanics, fracture risk, and implant design requirements

Objective: To determine the angle of inclination and neck length of dry femur and to analyze side differences, correlations, and its clinical relevance.

Methods: A cross-sectional observational study was conducted on 50 dry adult human femur (25 right, 25 left) obtained from the Department of Anatomy, Sher-i-Kashmir Institute of Medical Sciences (SKIMS), Bemina, Srinagar. The angle of inclination was measured using a standard osteometric board and goniometer, while neck length was measured with a sliding caliper. Data were analyzed using SPSS version 23.0 for descriptive statistics, independent t-tests, and Pearson correlation.

Results: The overall mean angle of inclination was $128.42^\circ \pm 4.18^\circ$ (range 119° – 139°). The mean neck length was 29.6 ± 2.8 mm (range 24–36 mm). Right-sided femur showed a mean angle of $129.18^\circ \pm 4.42^\circ$ and neck length of 30.2 ± 2.6 mm, while left-sided femur showed a mean angle of $127.66^\circ \pm 3.82^\circ$ and neck length of 29.0 ± 2.9 mm. No statistically significant side differences were observed for either parameter ($p > 0.05$). A statistically significant positive correlation was found between the angle of inclination and neck length ($r = 0.412$, $p = 0.003$).

Conclusion: The mean angle of inclination and neck length in the present sample are consistent with South Asian reference ranges but lower than Western and East Asian standards. The significant positive correlation between these parameters supports integrated proximal femoral architecture. Population-specific implant designs are recommended for optimal orthopedic outcomes in this geographic region.

Keywords: Femur, angle of inclination, neck-shaft angle, collodiaphyseal angle, femoral neck length, osteometry

1. INTRODUCTION

The proximal femur constitutes one of the most biomechanically significant regions of the human skeleton, bearing substantial weight-bearing responsibility while facilitating bipedal locomotion. Two morphometric parameters—the angle of inclination (also termed neck-shaft angle or collodiaphyseal angle) and the femoral neck length—serve as critical determinants of hip joint biomechanics, fracture risk patterns, and prosthetic design requirements [1].

The angle of inclination is defined as the angle formed between the long axis of the femoral shaft and the axis of the femoral neck, projected onto the coronal plane. In the adult human, this angle typically ranges between 120° and 140° , though considerable variation exists across populations and demographic groups [2]. A pathologic increase beyond this range is termed coxa valga, while a pathologic decrease constitutes coxa vara—both conditions associated with altered biomechanics and increased fracture susceptibility [3].

Femoral neck length, measured from the base of the greater trochanter to the articular surface of the femoral head, directly influences hip joint leverage, abductor muscle efficiency, and the mechanical loads transmitted across the femoral neck [4]. Together, these parameters determine the offset of the hip joint and the mechanical advantage of the abductor musculature.

Despite their clinical importance, substantial gaps remain in understanding population-specific norms for these measurements. Most commercially available hip

prostheses are designed based on Caucasian anthropometric data, potentially leading to suboptimal outcomes in Asian and other non-Caucasian populations [5]. Previous studies from Nepal, various regions of India, Brazil, China, and multi-ethnic cohorts have documented significant inter-population variation [6–9].

The present study was undertaken to determine the angle of inclination and neck length of dry femur obtained from the Department of Anatomy, SKIMS Bemina, and to compare our findings with existing regional and international literature.

2. MATERIALS AND METHODS

Study Design and Sample

This descriptive cross-sectional observational study was conducted in the Department of Anatomy, Sher-i-Kashmir Institute of Medical Sciences (SKIMS), Bemina, Srinagar over a period of 6 months. A total of 50 dry adult human femur were obtained from the osteological collection of the department. The sample comprised 25 right femur and 25 left femur. All specimens were fully ossified adult bones with intact proximal segments. Bones showing evidence of pathological changes, gross deformities, previous fractures, or significant osteophytic lipping were excluded from the study. The sex and exact age of the specimens were unknown.

Ethical Consideration

The study utilized cadaveric dry bone specimens from the institutional osteological collection. No living human subjects were involved; therefore, informed consent was

not applicable. The study protocol was approved by the Institutional Ethics Committee.

Measurement Techniques

All measurements were performed by a single observer to minimize inter-observer error. Each measurement was repeated three times, and the mean value was recorded.

Angle of Inclination

The angle of inclination (neck-shaft angle) was measured using a standard osteometric board and a 360° goniometer. Each femur was placed in a standardized position with the posterior surface of the femoral condyles resting firmly on a flat horizontal surface, ensuring that the long axis of the shaft lay parallel to the board. The axis of the femoral neck was determined by placing the fulcrum of the goniometer at the center of the femoral head and aligning one arm along the neck axis (passing through the center of the head and the midpoint of the neck base) and the other arm along the shaft axis. The angle was read to the nearest degree[1,3].



Figure 1: Showing angle of inclination by goniometer

Neck Length

Femoral neck length was measured using a Vernier sliding caliper accurate to 0.01 mm. The measurement was taken from the most superolateral point at the base of the greater trochanter to the center of the femoral head articular surface (fovea capitis region), representing the maximum linear dimension of the femoral neck [4,6].



Figure 2: Showing femur neck length

Statistical Analysis

Data were entered into Microsoft Excel and analyzed using IBM SPSS Statistics for Windows, Version 23.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics including mean, standard deviation, range, and standard error of mean were calculated for all parameters. An independent samples t-test was used to compare right and left side values. The Pearson correlation coefficient (r) was calculated to assess the relationship between the angle of inclination and neck length. A p -value of < 0.05 was considered statistically significant.

Table 1: Descriptive Statistics of Angle of Inclination and Neck Length

Parameter	N	Mean	SD	SEM	Minimum	Maximum
Angle of Inclination (°)						
Overall	50	128.42	4.18	0.59	119	139
Right side	25	129.18	4.42	0.88	121	139
Left side	25	127.66	3.82	0.76	119	136
Neck Length (mm)						
Overall	50	29.6	2.8	0.40	24	36
Right side	25	30.2	2.6	0.52	25	36
Left side	25	29.0	2.9	0.58	24	35

Table 2: Side-to-Side Comparison

Parameter	Right (Mean $\pm$ SD)	Left (Mean $\pm$ SD)	t-value	p-value
Angle of Inclination (°)	129.18 $\pm$ 4.42	127.66 $\pm$ 3.82	1.324	0.192
Neck Length (mm)	30.2 $\pm$ 2.6	29.0 $\pm$ 2.9	1.552	0.128

3. RESULTS

The morphometric analysis of 50 dry femur (25 right, 25 left) revealed the following findings:

Side Comparison

Comparison between right and left sides using independent samples t-test revealed no statistically significant differences for either parameter.

The mean angle of inclination was marginally higher on the right side (129.18°) compared to the left side (127.66°), with a mean difference of 1.52° . Similarly, neck length was marginally greater on the right side (30.2 mm) compared to the left side (29.0 mm), with a mean difference of 1.2 mm. However, neither difference reached statistical significance ($p > 0.05$).

Correlation Analysis

Pearson correlation analysis revealed a statistically significant positive correlation between the angle of inclination and femoral neck length ($r = 0.412$, $p = 0.003$). This indicates that specimens with greater neck-shaft angles tended to exhibit proportionally longer femoral necks. The coefficient of determination ($r^2 = 0.170$) suggests that approximately 17.0% of the variance in neck length can be explained by the angle of inclination.

Distribution Characteristics

The frequency distribution of the angle of inclination showed that the majority of specimens (62%, $n = 31$) fell within the 126° – 132° range. Only 4 specimens (8%) exhibited values below 124° , and 6 specimens (12%) exhibited values above 134° . For neck length, 58% of specimens ($n = 29$) fell within the 28–32 mm range. No specimens demonstrated neck length below 24 mm or above 36 mm.

4. DISCUSSION

Principal Findings

The present study on 50 dry adult femur documented a mean angle of inclination of $128.42^\circ \pm 4.18^\circ$ and a mean neck length of 29.6 ± 2.8 mm. These values fall within the reported South Asian reference range and are consistent with the morphometric profile characteristic of this geographic region. Our findings demonstrate close concordance with several South Asian studies. Adhikari et al. (2017) [6], in a study of 50 dry femur from Nepal, reported a mean angle of inclination of $128.98^\circ \pm 4.55^\circ$ and mean neck length of 29.3 ± 2.4 mm—values remarkably similar to our own. Isaac et al. (1997) [10] reported mean neck-shaft angles of 126.9° (right) and 126.5° (left) with corresponding neck lengths of 28.6 mm and 28.1 mm in a South Indian population. Chaudhary et al. (2017) [7], studying 100 dry femur from Karnataka, documented a mean neck-shaft angle of 127.21° and anterior neck length of 28.8 mm. Sharma et al. (2024) [11] reported an overall mean of $129.75^\circ \pm 3.70^\circ$ in North India. The consistency of our results with these regional studies supports the existence of a relatively homogeneous South Asian morphometric profile for proximal femoral geometry, characterized by neck-shaft angles approximately 6° – 10° lower than Western Caucasian standards [5,12].

Our mean neck-shaft angle of 128.42° is notably lower than values reported for East Asian populations. Edwards et al. (2020) [8], in a multi-racial analysis, documented that Chinese hips demonstrated a lesser angle of alignment between femoral neck and shaft compared to European and American Caucasians. However, a Singapore study [9] reported mean neck-shaft angles of 137.48° in Chinese women and 127.00° in Indian women, highlighting the substantial inter-ethnic variation even within geographically proximate populations.

Da Silva et al. (2003) [13] reported mean neck-shaft angles of 131.8° (right) and 132.1° (left) in a Brazilian population, representing an intermediate position between South Asian and East Asian values. Gujar et al. (2013) [14] from Gujarat, India, reported higher values (136.6° right, 136° left), which deviate from the broader South Asian pattern and may reflect regional genetic diversity or methodological differences.

Our finding of no significant side difference in either angle of inclination ($p = 0.192$) or neck length ($p = 0.128$) aligns with the majority of published literature. Adhikari et al. (2017) [6], Chaudhary et al. (2017) [7], and Da Silva et al. (2003) [13] all reported bilateral symmetry in these parameters. However, Ranzeetha et al. (2025) [15] documented significant side differences in an Andhra Pradesh sample, suggesting that population-specific or methodological factors may occasionally disrupt symmetry. The marginal right-side predominance observed in our sample (1.52° for angle; 1.2 mm for length) is consistent with the slight directional asymmetry reported by several authors, though this pattern lacks statistical confirmation in our data.

The significant positive correlation between angle of inclination and neck length ($r = 0.412$, $p = 0.003$) is one of the most important findings of this study. This relationship was previously documented by Adhikari et al. (2017) [6], who reported a statistically significant positive correlation in their Nepalese sample. A study from Vadodara [16] derived a linear regression equation quantifying this relationship: Neck-Shaft Angle = $95.28^\circ + 1.20 \times \text{Neck Length}$. The biomechanical interpretation is that specimens with more vertically oriented femoral necks tend to exhibit proportionally longer necks, potentially maintaining consistent hip offset and abductor lever arm despite angular variation. This correlation suggests that proximal femoral morphology represents an integrated structural system rather than independent variables.

The documented population variation carries substantial clinical significance. Current orthopedic practice in India and neighboring regions frequently employs prostheses designed based on Caucasian anthropometric data, which typically assume a neck-shaft angle of approximately 135° [5]. The 6° – 7° difference between this standard and our documented mean of 128.42° may result in suboptimal biomechanical restoration, altered hip offset, leg length discrepancy, and compromised abductor function when unmodified standard implants are used. This is particularly relevant for total hip arthroplasty,

hemiarthroplasty for femoral neck fractures, and corrective osteotomies.

Forensic Applications

In forensic anthropology, the correlation between neck-shaft angle and neck length, combined with population-specific reference ranges, may assist in establishing biological affinity from fragmentary skeletal remains. The relatively narrow standard deviation observed in our sample (4.18°) suggests these measurements offer reasonable discriminatory power when combined with other cranial and postcranial metrics.

Limitations

This study has several limitations. The sample size of 50 femur, while adequate for preliminary characterization, limits the generalizability of findings. The unknown sex and age of specimens precluded analysis of sexual dimorphism and age-related morphometric changes, both of which are well-documented in the literature [8,9]. Additionally, the study was confined to osteological measurements; radiological validation was not performed. Future studies should incorporate larger, sex-documented samples and correlate osteological findings with radiological and computed tomographic measurements.

5. CONCLUSION

The present study on 50 dry femur from SKIMS Bemina establishes baseline morphometric values : a mean angle of inclination of $128.42^\circ \pm 4.18^\circ$ and mean neck length of 29.6 ± 2.8 mm. These values are consistent with South Asian reference ranges but lower than Western and East Asian standards. The significant positive correlation between neck-shaft angle and neck length supports the concept of integrated proximal femoral architecture. No significant side differences were observed. These findings underscore the necessity of population-specific orthopedic implant designs and contribute to the growing database of South Asian osteometric standards.

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