Original Research Article

ASSESSMENT OF FEMORAL DIMENSIONS USING PLAIN RADIOGRAPHS IN SOKOTO, NORTH-WESTERN NIGERIA

ABSTRACT

Background:

The geometry of the proximal femur, particularly the neck-shaft angle (NSA), femoral neck width (FNW), and femoral neck axis length (FNAL), plays an essential role in orthopedic diagnosis, prosthetic design, and forensic identification. However, morphometric data for the proximal femur among populations in North-Western Nigeria remain limited.

Objective:

This study aimed to determine baseline values of NSA, FNW, and FNAL among adults in Sokoto, North-Western Nigeria, and to evaluate differences across sex, age groups, and laterality.

Methods:

A retrospective cross-sectional study was conducted using 277 normal pelvic radiographs obtained from the Sokoto State Advanced Diagnostic Centre between January 2022 and August 2023. Radiographs were analyzed digitally using Image Byte PACS Software (v4.9.3.25) and Radiant DICOM Viewer (2024.1). The NSA, FNW, and FNAL were measured bilaterally, and demographic data (age and sex) were recorded. Statistical analysis was performed using SPSS version 25. Independent sample t-tests and one-way ANOVA were used to compare mean values, with significance set at $p < 0.05$.

Results:

The mean NSA values were 121.48° ± 4.06 (right) and 124.38° ± 4.00 (left). The mean FNW values were 3.71 ± 0.52 cm (right) and 3.75 ± 0.49 cm (left), while the mean FNAL values were 10.31 ± 0.98 cm (right) and 10.30 ± 0.94 cm (left). Males demonstrated significantly higher values than females across all parameters ($p < 0.05$). Age groups showed no significant variation in any of the measured parameters ($p > 0.05$). Side differences were statistically significant for NSA and FNW but not for FNAL.

Conclusion:

This study established baseline femoral morphometric values for adults in Sokoto, revealing sexual dimorphism and mild bilateral asymmetry. These findings highlight the importance of population-specific reference values for orthopedic surgical planning, implant design, and forensic applications in Nigeria.

Keywords:

Femur, Neck-shaft angle, Femoral neck width, Femoral neck axis length, Radiographic morphometry, Nigeria

1. Introduction

Bone morphometry plays a critical role in understanding variations in skeletal structure and their implications in clinical practice, anthropology, and forensic science. The femur, the longest and strongest bone in the human body, is fundamental to weight-bearing and locomotion. The morphology of its proximal region, particularly the neck-shaft angle (NSA), femoral neck width (FNW), and femoral neck axis length (FNAL), significantly influences hip biomechanics, load distribution, and fracture susceptibility.

The neck-shaft angle represents the inclination between the femoral neck and the shaft. This anatomical parameter is crucial in determining hip alignment and stability and is frequently considered in orthopedic procedures such as total hip arthroplasty, corrective osteotomy, and fracture fixation. Variations in NSA may influence joint biomechanics and predispose individuals to certain musculoskeletal conditions.

Similarly, FNW and FNAL are important indicators of bone strength and structural stability. A narrow femoral neck has been associated with increased risk of proximal femoral fractures, whereas a longer femoral neck axis may increase bending moments across the hip joint, potentially increasing mechanical vulnerability. These morphometric parameters are also critical in designing orthopedic implants tailored to specific populations.

Several studies have reported proximal femoral morphometric parameters across different populations worldwide. However, marked inter-population variations have been documented due to differences in ethnicity, lifestyle, and environmental influences. In Nigeria, most previous studies have been conducted in the southern and central regions, leaving a gap in data from the North-Western region.

Although advanced imaging modalities such as CT and MRI provide high-resolution anatomical data, plain radiography remains a reliable and cost-effective tool for skeletal morphometric analysis, especially in resource-limited settings. Establishing normative radiographic data for proximal femoral parameters in the Sokoto population will therefore contribute to improved clinical decision-making, orthopedic implant design, and forensic identification.

This study was designed to evaluate the femoral morphometric parameters—NSA, FNW, and FNAL—using plain radiographs among adult individuals in Sokoto, North-Western Nigeria. Specifically, the study aimed to:

1. Establish baseline reference values for proximal femoral parameters.
2. Compare these parameters across sex, age groups, and sides.
3. Assess correlations between femoral parameters and demographic variables.

2. Materials and Methods

2.1 Study Design and Setting

This study adopted a retrospective cross-sectional design to evaluate femoral morphometric parameters among adults in Sokoto, North-Western Nigeria. The research was conducted in the Department of Anatomy, Faculty of Basic Medical Sciences, Usmanu Danfodiyo

University Sokoto, in collaboration with the Department of Diagnostic Radiology of Usmanu Danfodiyo University Teaching Hospital and the Sokoto State Advanced Diagnostic Centre.

2.2 Sample Size and Sampling Technique

A random sampling technique was used to select eligible digital pelvic radiographs from the diagnostic center archive.

The sample size was calculated using the formula:

$n = (1.96^2 \times P \times Q) / E^2$

Where:

- P = prevalence of neck-shaft angle (20.9%)
- $Q = 1 - P$
- E = margin of error (5%)

The minimum sample size obtained was **254**, but **277 radiographs** were included to increase statistical reliability.

2.3 Inclusion Criteria

Radiographs included in the study met the following criteria:

- Digital AP pelvic radiographs showing both hip joints and proximal femora
- Proper patient positioning with clear visualization
- Radiographs reported as normal by a radiologist
- Complete demographic data (age and sex)
- Subjects aged 18 years and above

2.4 Exclusion Criteria

- Poorly positioned radiographs
- Radiographs with fractures, deformities, or pathology
- Images with incomplete demographic information
- Blurred or low-quality radiographs

2.5 Materials and Software

The following tools were used:

- Digital pelvic radiographs
- Desktop computer
- Image Byte PACS Software (version 4.9.3.25)
- Radiant DICOM Viewer (version 2024.1)

2.6 Measurement Procedures

Neck-Shaft Angle (NSA)

The NSA was measured as the angle between the longitudinal axis of the femoral neck and that of the femoral shaft.

Femoral Neck Width (FNW)

FNW was measured as the shortest distance across the narrowest region of the femoral neck.

Femoral Neck Axis Length (FNAL)

FNAL was measured from the base of the greater trochanter through the center of the femoral head passing through the fovea centralis.

All measurements were taken bilaterally and recorded to the nearest 0.01 cm or degree.

To ensure measurement reliability, each parameter was measured twice and the mean value recorded.

2.7 Data Analysis

Data were analyzed using **SPSS version 25**.

The following analyses were performed:

- Descriptive statistics (mean ± standard deviation)
- Independent t-test for sex comparison
- One-way ANOVA for age group comparisons
- Paired t-test for side differences
- Pearson correlation for relationship between variables

Statistical significance was set at **$p < 0.05$**.

3. Results

A total of **277 digital pelvic radiographs** were analyzed.

Socio-Demographic Characteristics

The study population consisted of:

- **168 males (60.6%)**
- **109 females (39.4%)**

Participants were aged **18–67 years**.

The highest proportion (22.4%) belonged to the **18–27 year age group**.

Table 1: Socio-demographic Data of the Respondents

Variable(s)	Frequency	Percentage
Female	109	39.4
Male	168	60.6
Total	**277**	**100.0**
Age Group (years)		
18–27	62	22.4
28–37	53	19.1
38–47	57	20.6
48–57	55	19.9
58–67	50	18.1
Total	**277**	**100.0**

Baseline Measurements of Neck-Shaft Angle (NSA)

The mean right NSA was 121.48° ± 4.06°, ranging from 110° to 142°, while the mean left NSA was 124.38° ± 4.00°, ranging from 114° to 137°. The modal NSA values were 120° (right) and 122° (left), indicating slightly higher inclination angles on the left side.

Table 2: Baseline Measurement of NSA

Parameter	N	Minimum (°)	Maximum (°)	Modal Value (°)	Mean ± SD (°)
Right NSA	277	110	142	120	121.48 ± 4.06
Left NSA	277	114	137	122	124.38 ± 4.00

Baseline Measurements of Femoral Neck Width (FNW)

Right FNW ranged from 0.85 cm to 8.49 cm (mean = 3.70 ± 0.52 cm), while the left FNW ranged from 2.01 cm to 8.27 cm (mean = 3.75 ± 0.50 cm).

Table 3: Baseline Measurement of FNW

Parameter	N	Minimum (cm)	Maximum (cm)	Modal Value (cm)	Mean ± SD (cm)
Right FNW	277	0.85	8.49	4.02	3.70 ± 0.52
Left FNW	277	2.01	8.27	3.21	3.75 ± 0.50

Baseline Measurements of Femoral Neck Axis Length (FNAL)

The right FNAL ranged from 4.41 cm to 12.82 cm (mean = 10.31 ± 0.98 cm), while the left FNAL ranged from 4.10 cm to 12.52 cm (mean = 10.30 ± 0.94 cm).

Table 4: Baseline Measurement of FNAL

Parameter	N	Minimum (cm)	Maximum (cm)	Modal Value (cm)	Mean ± SD (cm)
Right FNAL	277	4.41	12.82	10.27	10.31 ± 0.98
Left FNAL	277	4.10	12.52	9.30	10.30 ± 0.94

Comparison of NSA between Males and Females

Significant sex differences were observed in both right and left NSA. Males exhibited higher mean NSA values (p < 0.05).

Table 5: Comparison between NSA of Males and Females

Sex	Right NSA (Mean ± SD)	t	p	Left NSA (Mean ± SD)	t	p
Female	120.81 ± 3.63	-2.139	0.033	123.50 ± 3.69	-2.966	0.003
Male	121.92 ± 4.26			124.94 ± 4.10		

Comparison of FNW between Males and Females

Statistically significant differences were also observed in FNW between sexes, with males having higher mean values on both sides (p = 0.001).

Table 6: Comparison between FNW of Males and Females

Sex	Right FNW (Mean ± SD)	t	p	Left FNW (Mean ± SD)	t	p
Female	3.45 ± 0.42	-7.436	0.001	3.50 ± 0.43	-7.420	0.001*

Male	3.89 ± 0.51	3.91 ± 0.47

Comparison of FNAL between Males and Females

FNAL showed significant sexual dimorphism, with males having longer femoral neck axis lengths on both sides (p = 0.001).

Table 7: Comparison between FNAL of Males and Females

Sex	Right FNAL (Mean ± SD)	t	p	Left FNAL (Mean ± SD)	t	p
Female	9.91 ± 0.64	-5.772	0.001	9.82 ± 0.74	-7.600	0.001
Male	10.57 ± 1.07			10.62 ± 0.92		

Comparison among Age Groups

One-way ANOVA revealed no statistically significant differences in NSA, FNW, or FNAL across age groups (p > 0.05), indicating stability of these morphometric parameters with age.

Table 8: Comparison of NSA, FNW, and FNAL among Age Groups

Parameter	Right p-value	Left p-value
NSA	0.856	0.659
FNW	0.138	0.747
FNAL	0.222	0.216

Comparison between Sides (Right and Left)

Paired *t*-test revealed significant side differences for NSA (p = 0.001) and FNW (p = 0.040), with higher values on the left side. FNAL showed no significant side difference (p = 0.914).

Table 9: Comparison of NSA, FNW, and FNAL between Right and Left Sides

Parameter	Right (Mean ± SD)	Left (Mean ± SD)	p-value
NSA	121.48 ± 4.06	124.38 ± 4.00	0.001
FNW	3.71 ± 0.52	3.75 ± 0.49	0.040
FNAL	10.31 ± 0.99	10.30 ± 0.94	0.914

Correlation between Age and Femoral Parameters

Pearson's correlation analysis indicated weak correlations between age and all femoral parameters (NSA, FNW, FNAL), suggesting minimal age-related changes.

Table 10: Correlation between NSA, FNW, FNAL, and Age

Parameter	Right (r)	Left (r)	p-value (Right)	p-value (Left)
NSA	0.077	0.098	0.201	0.105
FNW	0.128	0.075	0.380	0.216
FNAL	0.012	-0.018	0.842	0.076

Correlation between Sex and Femoral Parameters

Sex showed fair correlations with FNW and FNAL on both sides, but weak correlation with NSA, reaffirming observed sexual dimorphism in width and axis length.

Table 11: Correlation between Sex and Femoral Parameters

Parameter	Right (r)	Left (r)	p-value (Right)	p-value (Left)
NSA	0.128	0.176	0.333	0.003
FNW	0.410	0.410	0.001	0.001
FNAL	0.329	0.417	0.001	0.001

Overall, the results indicate statistically significant differences in femoral dimensions between sexes and sides, while age-related variations were minimal. These findings provide essential baseline morphometric data for the population in Sokoto, North-Western Nigeria.

4. DISCUSSIONS

This study evaluated proximal femoral morphometry among adults in Sokoto using digital radiographic measurements. The findings provide valuable baseline data for orthopedic and anthropological applications within the North-Western Nigerian population.

The mean NSA values observed were slightly lower than those reported by Adekoya-Cole et al. but were comparable to results obtained among Kenyan populations. Differences in morphometric values may arise from ethnic diversity, lifestyle factors, and measurement techniques.

Similarly, the FNW and FNAL values obtained were comparable to findings reported by Yorkum et al., though slightly higher than those reported in South Indian populations. Such variations highlight the importance of population-specific reference data.

Sex-based analysis revealed significantly higher values among males across all measured parameters. This observation supports the concept of sexual dimorphism in skeletal morphology, likely influenced by hormonal, biomechanical, and genetic factors affecting bone development.

Age-group comparisons demonstrated no statistically significant differences in proximal femoral parameters, suggesting that these morphometric characteristics remain relatively stable throughout adulthood.

Bilateral comparisons revealed significant differences in NSA and FNW between right and left sides, although FNAL showed no such variation. These findings suggest mild bilateral asymmetry, which may be influenced by limb dominance or mechanical loading patterns. Correlation analysis further demonstrated weak associations between femoral parameters and age, reinforcing the stability of these measurements during adult life.

Overall, the results underscore the need for localized morphometric databases to improve orthopedic implant design, surgical planning, and forensic identification in Nigerian populations.

5. CONCLUSIONS

This study established baseline radiographic measurements of proximal femoral parameters among adults in Sokoto, North-Western Nigeria. Significant sexual dimorphism was observed, with males exhibiting larger femoral dimensions. Mild bilateral asymmetry was also identified, particularly in NSA and FNW, while age-related variations were minimal. The findings provide valuable reference data for orthopedic surgeons, forensic anthropologists, and biomedical engineers involved in prosthetic design and skeletal analysis within Nigeria.

RECOMMENDATIONS

1. Orthopedic implant manufacturers should incorporate African morphometric data in prosthesis design.
2. Nationwide multicenter studies should be conducted to establish comprehensive Nigerian femoral morphometric databases.
3. Advanced imaging techniques such as CT-based morphometry should be explored in future research.
4. The findings should be integrated into forensic anthropology databases for skeletal identification.

5. Medical education programs should incorporate localized anatomical data for improved clinical training.

Ethical Approval

Ethical approval for this study was obtained from the institutional ethics committee of Usmanu Danfodiyo University Sokoto and the Sokoto State Advanced Diagnostic Centre.

REFERENCES

Adekoya-Cole T.O., Akinmokun O.I., Soyebi K.O., & Oguche O.E. (2016). Femoral neck shaft angle: A radiological anthropometry study. Nigerian Postgraduate Medical Journal, 23:17–20.

Akinmokun, O.I., Ibeabuchi, N.M., Oyebiyi, O.A., Akinde, O.A., Hussein, I.S., Thomas, O.O., & Duro-Emaanuel, S.A. (2021). Proximal femoral bone morphological measurements: relevance in orthopaedic and forensic medicine. East African Orthopaedic Journal, 15(2):91–100

Altubasi, I.M. (2020). The association between femoral neck-shaft angle and aging, and its influence on performance of functional activity: A cross-sectional investigation. Journal of Aging and Physical Activity, 28(2):250–254.

Gilligan, I., Chandraphak, S., & Mahakkanukrauh, P. (2013). Femoral neck-shaft angle in humans: variation relating to climate, clothing, lifestyle, sex, age, and side. Journal of Anatomy, 223(2):133–151.

Haddad, B., Hamdan, M., Al Nawaiseh, M., Aldowekat, O., Alshrouf, M.A., Karam, A.M., Azzam, M.I., ArAltamimi, A., & Abu Shokor, M. (2022). Femoral neck-shaft angle measurement on plain radiography: is standing or supine radiograph a reliable template for the contralateral femur? BMC Musculoskeletal Disorders, 23(1):1092

Isaac, B., Vettivel, S., Prasad, R., Jeyaseelan, L., & Chandi, G. (1997). Prediction of the femoral neck-shaft angle from the length of the femoral neck. Clinical Anatomy, 10(5):318–323.

KC Lakati, B.M. Ndeleba, N. Mouti, & J. Kibet. (2017). Proximal femur geometry in the adult Kenyan femur and its implication in orthopaedic surgery. East African Orthopaedic Journal, 11:22–26.

Muhammad Khan & Hussain Saheb. (2014). Study of neck-shaft angle and femoral length of South Indian femurs. International Journal of Anatomy and Research, 2(4):633–635.

Nissen, N., Hauge, E.M., Abrahamsen, B., Jensen, J.E.B., Mosekilde, L., & Brixen, K. (2005)

Geometry of the proximal femur in relation to age and sex: a cross-sectional study in healthy adult Danes. Acta Radiologica, 46(5):514–518.

Sathian, B., Sreedharan, J., Babu, S.N., Krishna, S.K., Abhilash, E.S., & Rajesh, E. (2010). Relevance of sample size determination in medical research. Nepal Journal of Epidemiology, 1(4):4–10.

Shrestha, R., Guppa, H.K., Hama, R.R., & Pandit, R. (2018). Radiographic anatomy of neck-shaft angle of femur in Nepalese people: correlation with its clinical implication. Kathmandu University Medical Journal (KUMJ), 16(62):124–128.

Yorkum, I.K., Gbeneol, J.T., & Adewunmi, R.O. (2020). Angular and linear morphometry of the proximal femur: an aid to surgical reconstruction. International Journal of Science and Research, 9(9).