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# Computerized Tomography Based Evaluation of Morphometric and Angular Parameters of the Adult Femur among Kenyans

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## Abstract

# Background

The femur and the pelvis are large weight bearing bones in the human body. The femur, the bone of the thigh region, is the longest and strongest bone. Anatomically, the femur is divided into proximal, mid and distal segments. The evaluation of the structural morphology of body structures using Computer Tomography (CT) scan enables 3-dimensional evaluation; study of both the external and internal anatomy of bones without necessitating their destruction and the evaluation of the relationship of bone structures with vital structures such as nerves and vessels. This radiological evaluation of the Femur would inform placement of intramedullary devices and safe surgical approaches for both open and minimally invasive surgeries.

# Objective

To describe the radiological topography of the adult femur in Kenya.

# Methods

A descriptive cross-sectional study was conducted at Moi Teaching and Referral Hospital and St. Luke's Orthopaedic and Trauma Hospital. Lower limb CT scan images from 120 participants of either sex aged at least 18 years were analysed. Three-dimensional reconstruction was performed using MATLAB 9.7, and measurements were analysed using STATA/MP 13.0. Morphometric and angular parameters were summarized using mean and corresponding standard deviation.

# Results

Morphometric parameters of the femur revealed a mean anteroposterior (AP) width at the isthmus of 13.987 ± 2.265 mm and mediolateral (ML) width at the isthmus of 10.943 ± 2.598 mm. Angular parameters included a mean proximal diaphysis angle (PDA) of 8.871 ± 2.282° and distal diaphyseal angle of 9.358° (± 2.331).

# Conclusion

The study provides key anatomical parameters of the femur and pelvis, which can inform the design of implants tailored for the local population. These findings also support improved surgical planning and fracture stabilization techniques.

## Introduction

The femur, the longest and strongest bone in the human body, plays a vital role in supporting body weight and facilitating movement. It is anatomically divided into proximal, mid, and distal segments, each demonstrating racial and ethnic variations that impact orthopaedic implant design and surgical approaches (1, 3). Femoral anatomical variations have important implications in both trauma and reconstructive surgery, including antegrade and retrograde femoral nailing, primary and revision hip and knee arthroplasty (3–11). The sagittal curvature of the femur has been widely studied in many populations, including Kenyans (8, 12, 13). Although most of the studies have focused on the curve of the whole bone, some studies have shown that each segment of the femur has its own unique radius of curvature and angulation, both in the sagittal and coronal planes (8). Differences between the curve of the femur and the curve of intramedullary nails have been described and can potentially lead to difficulties in locking, angular malreduction, or anterior cortical perforation (12, 14).

The dimensions of the medullary canal at the isthmus have important implications in both trauma and reconstruction surgery. Intramedullary nailing of femoral fractures is now one of the most successful procedures done by the orthopaedic surgeon. During IM nailing, the canal is reamed to an appropriate size depending on the size of the nail. In nailing of unstable trochanteric fractures, it is advisable that the implant at least reaches or goes beyond the isthmus for optimal stability (15). During cementless hip arthroplasty, the dimensions of the canal and the implant need to match closely, to afford stability to the implant (13). Narrow canals have resulted in intramedullary devices and nails being jammed during introduction, especially in the Asian populations (13, 16).

The mechanical and anatomical axes of the femur have been well described, the mechanical axis being drawn from the center of the femoral head to the intercondylar notch of the distal femur, and the anatomical axis bisecting the femur through the medullary canal (17, 18). The angle between the two axes is reported as being between $5^0$-$7^0$ (18). These axes play an important role in determining accurate alignment in operations around the knee, like corrective osteotomies, total knee arthroplasty, and distal femoral fracture fixation (19). Proper insertion of the femoral component in TKA with respect to both the anatomic and mechanical axes ensures optimal functional recovery and favorable long-term outcomes (19–21).

Radioanatomy, the evaluation of structural morphology using imaging modalities such as CT and MRI, enables detailed examination of bone anatomy without necessitating bone destruction. These imaging techniques allow for the assessment of both external and internal structures, aiding in the design of intramedullary devices and guiding surgical interventions. Despite the widespread use of orthopaedic implants in Kenya, local data on femoral and pelvic anatomy is scarce. Previous studies have largely relied on dry bone specimens, which lack the precision and comprehensiveness of imaging-based

evaluations. This study aimed to bridge this gap by using three-dimensional CT imaging to describe the radiological topography of the adult femur and pelvis in Kenya.

## Materials and Methods

**Study Design and Setting**

This was a descriptive cross-sectional study conducted at Moi Teaching and Referral Hospital and St. Luke's Orthopaedic and Trauma Hospital, both serving ethnically diverse populations in western Kenya.

**Study Population**

CT scan images from 120 adult patients (≥ 18 years) were analysed. Images were included if they depicted the pelvis and the whole lower limbs. Excluded were images from patients who had previously undergone a surgical procedure distorting the bony anatomy of the pelvis or femur. Also excluded were patients who had deformity of the pelvis or femur from other congenital or acquired conditions.

**Data Collection**

Eligible CT scan images were retrieved in DICOM® format and imported into MATLAB® 9.7 for three-dimensional reconstruction. Morphometric measurement (AP and ML widths of the medullary canal) and angular (PDA, AMAC) parameters were recorded. Patient identifiers were removed to ensure confidentiality. These measurements were made according to the method described by Cho et al (3). The isthmus was identified and the width of the medullary canal measured in both anteroposterior (AP) and mediolateral (ML) planes. The width of the medullary canal was measured at the femoral shaft's midpoint (Fig. 1).

The angular measurements of the femoral diaphysis were also taken according to the method described by Cho et al(3). Using sagittal images of the femur, the angles made by the proximal, middle and distal thirds of the femur with the anatomical axis were measured. These were designated as proximal diaphyseal (PDA), central (CDA) and distal diaphyseal angles (DDA) respectively. This is shown in Fig. 2 and Fig. 3. These angles were measured as an indicator of anterior femoral curvature. Previous studies have studied anterior femoral curvature using radiological or anatomic specimens of the whole bone, with the drawback that this only gives the overall curvature of the femur and not whether curvature differs in different parts of the femur, which has indeed been shown to be the case (13, 22, 23).

In the coronal plane of the femur, the angle between the anatomical and mechanical axes (AMAC), was also measured (Fig. 4).

**Statistical Analysis**

Data were analyzed using STATA/MP 13.0. Continuous variables were tested for normality using the Shapiro-Wilk test, and results were summarized as means and standard deviations. T-tests were employed to compare parameters between male and female participants. Results were presented in tables and graphs.

**Ethical Considerations**

Ethical approval was obtained from the Institutional Research and Ethics Committee of Moi University. Data confidentiality was maintained throughout the study.

## Results

**Participant Characteristics**

The study enrolled a total of 120 patients who attended both public (Moi Teaching and Referral Hospital) and private (St. Luke's Orthopaedic and Trauma Hospital) tertiary healthcare facilities in Eldoret Kenya. The mean age of the patients was 62.8 ± 17.0 years), with equal representation of males and females.

## Morphometric parameters of Femur and Pelvis

The morphometric parameters of interest were anteroposterior (AP) and mediolateral (ML) width of the femoral medullary canal at the isthmus and the mid-center. These were measured according to the method described by Cho et al., (3). The mean AP width of the canal at isthmus was 13.987 (± 2.265) mm while the mean ML width at isthmus was 10.943 (± 2.598) mm. Furthermore, the AP width of the medullary canal at mid-center was estimated at 20.358 (± 3.904) mm while ML width at mid-center was estimated at 19.629 (± 3.921) mm, as shown on Table 1. The angular parameters are shown on Table 2.

Table 1
Morphometric parameters of Femur

| Parameter | Mean | Median |
|---|---|---|
| AP width of medulla at isthmus (APWI)(mm) | 13.987 (± 2.265) | 13.750 (IQR:12.575, 15.500) |
| ML width of medulla at isthmus (MLWI) (mm) | 10.943 (± 2.598) | 10.400 (IQR: 9.298, 12.675) |
| AP width of medulla at mid-center (APWC) (mm) | 20.358 (± 3.904) | 19.650 (IQR: 18.125, 22.950) |
| ML width of medulla at mid-center (MLWC) (mm) | 19.629 (± 3.921) | 19.400 (IQR: 16.700, 22.200) |

Table 2
Angular parameters of Femur

| Parameter | Mean | Median |
|---|---|---|
| Femoral proximal diaphysis angle (PDA) in sagittal plane (degrees) | 8.871 (± 2.282) | 8.550 (IQR: 6.925, 10.875) |
| Femoral central diaphysis angle (CDA) in sagittal plane (degrees) | 6.430 (± 3.330) | 5.800 (IQR: 4.000, 8.200) |
| Femoral distal diaphysis angle (DDA) in sagittal plane (degrees) | 9.358 (± 2.331) | 9.200 (IQR: 7.850, 11.400) |
| Angle between anatomical and mechanical axes (AMAC) in coronal plane (degrees) | 4.0 (± 1.114) | 3.750 (IQR: 3.325, 4.850) |

Table 3 below shows comparison with dimensions from other populations.

Table 3
Comparison with other populations

| Parameter | Current study | Koreans (3) | Turkish(6) | American(24) | Italian(25) | Taiwanese(26) | Belgian(22) |
|---|---|---|---|---|---|---|---|
| AP width of medulla at isthmus (APWI)(mm) | 13.987 (± 2.265) | 11.24 | 13.7 | 16.9 | 11.7 | | |
| ML width of medulla at isthmus (MLWI) (mm) | 10.943 (± 2.598) | 9.60 | 10.7 | 12.3 | 9.9 | 9.93 | |
| AP width of medulla at mid-center (APWC) (mm) | 20.358 (± 3.904) | 12.97 | | | | | |
| ML width of medulla at mid-center (MLWC) (mm) | 19.629 (± 3.921) | 10.77 | | | | | |
| Femoral proximal diaphysis angle (PDA) in sagittal plane (degrees) | 8.871 (± 2.282) | 7.56 | | | | | 4.4 |
| Femoral central diaphysis angle (CDA) in sagittal plane (degrees) | 6.430 (± 3.330) | -0.23 | | | | | |
| Femoral distal diaphysis angle (DDA) in sagittal plane (degrees) | 9.358 (± 2.331) | -7.08 | | | | | 4.5 |
| Angle between anatomical and mechanical axes (AMAC) in coronal plane (degrees) | 4.0 (± 1.114) | 5.46 | | | | | |

## Discussion

This study provides essential data on the radiological topography of the femur and pelvis in a Kenyan population. The morphometric and angular parameters observed highlight significant anatomical features relevant to orthopedic implant design and surgical approaches.

As far as the medullary dimensions go, the AP diameter at both the isthmus and the midpoint of the femoral shaft were longer than corresponding mediolateral dimensions. This has also been in previous studies in other populations like Koreans, Turkish, American and Italian populations (3, 6, 25, 27). However, these dimensions were less than those seen in the study in the American population, and more than those in Italian and Korean femurs. They closely matched those seen in the study in the Turkish population. A study from Tanzania found a mean ML isthmic canal diameter of 11.3mm, which is close to that obtained in the current study (28). The canal diameter at the midpoint of the femur was also greater than that seen in the study on Korean femora (3). Siddiqi et al also found the width in American specimens to be consistently greater than in other populations, with the narrowest diameter being seen in Taiwanese femora (26). A study from India found that the AP canal width at the isthmus 11.4mm, while the mediolateral width was 9.02mm (29). These dimensions are less than those found in the current study. The implications of these differences among various populations are that implants that depend on a press-fit for stability may not be suitable across populations. In total hip arthroplasty, especially cementless hip arthroplasty close adaptation of the prosthesis to the bone geometry is required to achieve optimal primary stability and secondary biologic fixation (7, 30, 31). A stem whose dimensions closely match those of the femur would be ideal. The width of the femoral stem must be narrow enough to pass the narrowest part of the isthmus (26). A poor fit between the stem and the canal may result in micromotion and ultimately loosening of the stem(32). Use of implants designed for a larger skeletons necessitates removal of more bone by broaching or reaming, thus reducing bone stock and increasing the risk of intra-operative fractures (33). Consequently,

prosthetic implants need to be tailored to fit the anatomical characteristics of different populations (27, 34). A possible limitation of the current study was the generally higher mean age of the patients (62.8 years). It has been shown that canal diameter increased with age, especially in females(35, 36).

The sagittal curvature of the femur has been well described in many populations(12, 22, 37, 38). The segmental curvature has important implications in intramedullary nailing of the femur, primary and revision total hip and knee arthroplasties and deformity correction planning (9, 37, 39, 40). The proximal and distal diaphyseal angles obtained in the currently were slightly larger than those obtained in a Korean study by Cho et al(3). A study from Russia calculated the angles between the mid-diaphyseal lines of the proximal, middle and distal thirds of femur in 30 femora, and found the angles between the mid-diaphyseal lines at the level of the proximal third as 10°, at the level of the middle third 16°, and at the level of the distal third 7°(40). These angles are slightly larger than those obtained in the current study. What is similar between the current study and the Russian study by Solomin et al is the large distal angulation compared to the proximal angulation. This larger distal angulation has been found in other studies (9). Tang et al found average radii of curvature of the proximal, middle and distal one-third of the femora to be 1081.6 mm, 926.2 mm and 715.1mm respectively, with the angle between the longitudinal axis and the distal anterior cortex of the femur was $9.4^{o}$, which is close to the value obtained in the current study (9). The larger distal femoral angulation compared to proximal femoral angulation described by Tang et al in the Chinese population has been described as the “J” shaped contour (9). It would appear that the same obtains in the Kenyan femora too, going by the findings of this study. A study done on American patients undergoing TKA however found that angles of curvature of the proximal, middle, and distal thirds of the femur were 5.2°, 0.3°, and 3.1°, respectively, showing that the proximal femur is more curved than the distal part(41). One of the most widely used intramedullary nails in Kenya is the Surgical Implant Generation Network (SIGN) nail (42). It is used for both antegrade and retrograde nailing of femoral shaft fractures, and has a $9^{o}$ proximal bend, which closely corresponds to the proximal and distal femoral angulation obtained in the current study (43).

Proximal diaphyseal angulation has important implications in orthopaedic and trauma surgery. In total hip arthroplasty, failure to take this into account may result in the femoral component tip approaching or abutting the posterior endosteal surface of the femur. In a cemented hip arthroplasty, this results in an incomplete cement mantle around the prosthesis(44). Hip prostheses that closely matched the anatomical shape of the femur have been shown to have very high survival rates (45–47). The anatomical Lubinus SP II® stem has been shown to have better centralization of the stem, with a resultant even cement mantle thickness and fewer cement cracks (48, 49). Studies have shown that this particular stem has had excellent long-term results (46, 47, 50).

Positioning of a total knee implant has been shown to be an important determining factor in its long-term survival (9, 51, 52). The implant must therefore be well aligned both in the coronal and sagittal planes (9, 52, 53). In use of an intramedullary alignment guide in TKA, a short guide can easily follow the angulation of the distal femoral medulla. However, a long guide will abut the anterior cortex, be tilted, and be pushed anteriorly. Consequently, this results in a femoral component being in an excessively extended position, or notching of the femur if the cuts are referenced on this guide (9).

In the coronal plane, during TKA, neutral alignment of the limb can be achieved by perpendicular cuts made to the tibia and femoral mechanical axes (54). The goal is to restore the mechanical axis of the limb to within $3^{o}$ of the normal (55, 56). The degree of the femoral valgus resection is determined by the angle between the anatomical and mechanical axes. In routine uncomplicated TKA, this resection is usually set at between $5^{o}$ to $7^{o}$ of valgus (54, 57–59). In the present study, the angle between the femoral mechanical and anatomical axes was an average of $4.0^{o}$, which was slightly less than that found in some studies. Sivaram et al found an average of $6.45^{o}$ degrees in an Indian population (60). A study by Vaishya et al, also in an Indian population, found an average of $5.83^{o}$ (54). A study from the United Kingdom found a mean $5.4^{o}$, which was close to $5.6^{o}$ reported in a study from United States of America (57, 58).

Limitations of the current study include the retrospective nature of the study and the reliance on hospital-based samples, which may not fully represent the general population. Future research should aim for larger, population-based samples and explore the biomechanical implications of these anatomical variations.

## Conclusion

This study provides the first comprehensive radiological description of femoral morphology in a Kenyan adult population using three-dimensional CT analysis. The findings demonstrate measurable differences in morphometric and angular parameters compared to other populations, underscoring the importance of region-specific anatomical data in orthopaedic implant design and surgical planning. In particular, variations in femoral canal dimensions and diaphyseal angulation have direct implications for intramedullary nailing, arthroplasty, and fracture fixation techniques. Adoption of implants tailored to the anatomical characteristics of the Kenyan population may improve operative fit, reduce intraoperative complications, and enhance long-term functional outcomes. Future multicentre, population-based studies with broader age representation are recommended to validate these results and guide the development of optimized, locally appropriate orthopaedic solutions.

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## Figures

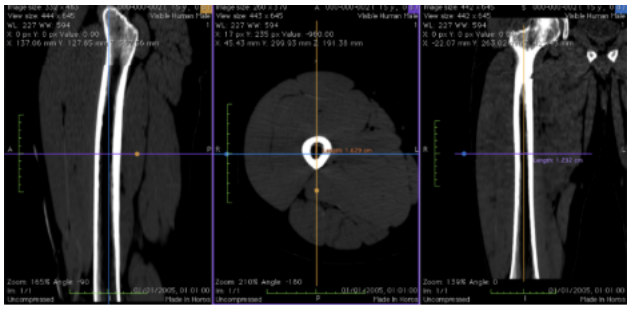


Figure 1

**Canal width measurement**




Figure 2

**Proximal diaphyseal angle**




Figure 3

**Distal diaphyseal angle**

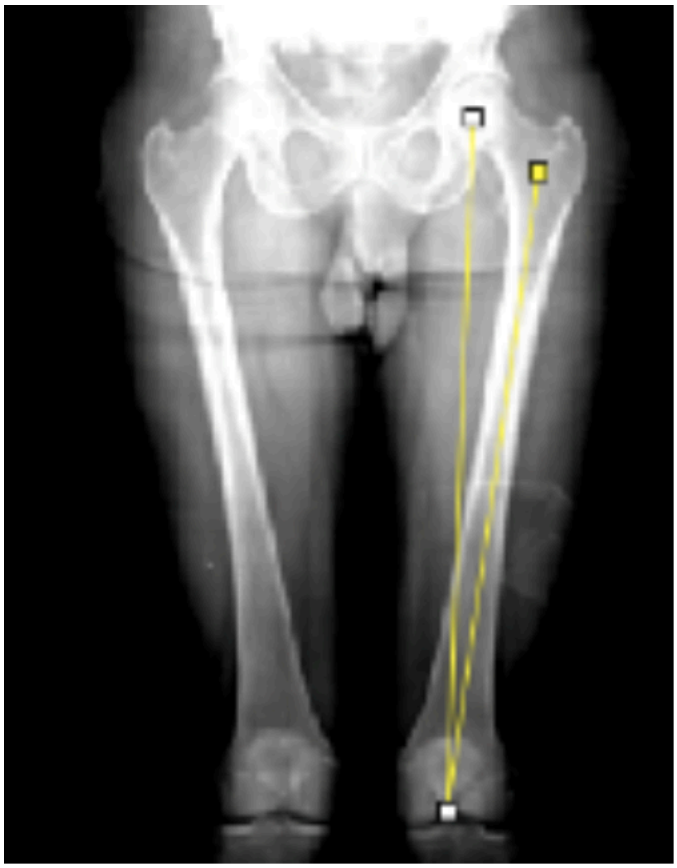


**Figure 4**

**Measurement of angle between the anatomical and mechanical axes (AMAC)**