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Radiological Morphometry of the Proximal Femur in Kenyan Adult Patients at Moi Teaching and Referral Hospital, Eldoret, Kenya

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Abstract: Background: The prevalence of proximal femur and hip ailments is increasing, requiring appropriate treatments such as osteosynthesis and arthroplasty. Preoperative planning relies on morphometric dimensions of the proximal femur, yet anatomical variations across populations mean many commercial implants may not fit optimally. Selecting the correct implant is crucial to avoid postoperative complications, hence the need for this study. Objectives: To determine the radiomorphometric measurements of the neck-shaft angle (NSA) and femoral head diameter (FHD) in Kenyan adults at Moi Teaching and Referral Hospital (MTRH) to guide implant design and assess variations by gender, laterality, and influencing factors. Methods: A cross-sectional survey was done on 118 normal radiograph patients comprising of 57 (48.3%) males and 61 (51.7%) females. Student-*t*-test was used to compare the measurements of the proximal femur in relation to gender and laterality. Statistical significance was determined by a *p*-value less than 0.05. Continuous data was presented as mean, standard deviation, median, interquartile range, while categorical data as frequency and proportions. Results: Results reveal that, for factors affecting NSA and FHD, Age (*p*-value 0.911), Gender (*p*-value 0.643), Region (*p*-value 0.449) and Level of activity (*p*-value 0.498) did not have statistical significance on the findings while Diet (*p*-value 0.029) was statistically significant. Majority of patents were of middle age. The mean Femoral NSA and FHD diameter in Kenyan adult patients varied from those of other populations. The mean NSA and FHD varied in relation to gender (males greater) and laterality (right greater, but difference not statistically significant) in terms of measurements. Diet factor finding was statistically significant. Conclusion and Recommendations: Implants should be designed according to the new measurements in this study. Orthopaedic Surgeons should always consider morphometric dimensions before osteosynthesis in the proximal femur and arthroplasty of the hip.

Keywords: Anatomical variation, Femoral head diameter, Implant design, Neck-shaft angle, Proximal femur, Radiomorphometry.

INTRODUCTION

The morphology of the proximal femur, specifically the relationships between the head, neck, and proximal shaft, has been a subject of interest and debate in orthopaedic literature dating back to at least the middle of the 19th century (Toogood et al., 2009). Orthopaedics research involves morphometric analysis of proximal femur for joint studies in order to design fixators and define the axes for orthopaedic surgery (Cho et al., 2015). Among the various dimensions studied are the neck-shaft angle (NSA) and the femoral head diameter (FHD). Variations in the anthropometric values of these dimensions have been associated with various disorders including pain syndromes about the hip (Jiang et al., 2015) and hip fractures (Filipov, 2014). Surgery involving the proximal femur is one of the most prevalent orthopaedic procedures and involves the use of implants such as screws, plates, intramedullary nails, and prostheses. It is prudent that the design, dimensions and the placement of these implants be as accurate as possible in order to restore the functional biomechanics of the proximal femur and the functional capacity of the patient as a whole. Several population based studies have demonstrated a significant diversity among different populations (Gilligan et al., 2013; Igbigbi & Msamati, 2002). Clinical experience has shown that addressing variations in bone morphology are important in the development of successful implant designs (Joshi et al., 2000; Rubin et al., 1992). In clinical practice, if the implant happens to be ill-fitting, complications such as dislocations and implant breakage are common (Gnudi et al., 2002; Siwach, 2018). Availability of the right implants for the right population is paramount for patient management. In Kenya, all orthopaedic implants are imported. Since the resources for procurement and stocking of these necessary implants are limited, it is very important that the dimensions of the proximal femur are known for our population because it will be helpful for surgical planning and effective use of resources for procuring and stocking of the right sizes of implants for Kenyans.

Data from numerous population-based studies show that the morphometric measurements of the proximal femur vary significantly among regions, sex, genetics, food, location, and degree of activity are a few of the variables that have been linked to these variations (Gilligan et al., 2013; Igbigbi & Msamati, 2002). This has led to the development and purchase of implants that pay close attention to the needs of a particular community.

Currently, the majority of commercially accessible implants for usage in Kenya are created using data from the United States, Europe, and Asia. In Kenya, there are few resources available for purchasing these implants in a range of sizes, and the right sizes frequently run out of stock. Although preoperative templating and intraoperative image intensification are two techniques used to help with size selection, the effectiveness of these techniques requires that a variety of implants with the proper sizes and dimensions for the Kenyan population be made available in order to guarantee adequate surgical and functional outcomes.

The complications of mismatched sizing and or placement of an implant in the proximal femur are well documented and may include: loosening, unbalanced weight distribution, breakage and impingement (McGrory et al., 1995). These add to the cost of hospitalization, surgery undertaken for revision of the implant, loss of man-hours out of the place of work and burden to the relatives, community and the nation at large. As the demand for proximal femur implants is increasing with the increasing population and proximal femur disorders, there is need to have baseline data as a guide to maximize the limited resources by stocking the appropriate range of implants with the dimensions fitting the local population and to also probably influence the designing of Kenyan specific implants in the future. This study is justified by the need to establish baseline proximal femur dimensions for Kenyan adults to guide implant design.

This study sought to determine the morphometric radiological dimensions of the proximal femur by specifically, determining the morphometric radiological measurements, dimensions in relation to gender and the determinants of NSA and FHD in Kenyan adult patients at MTRH for implant designing.

MATERIALS AND METHODS

A cross-sectional descriptive study was conducted at Directorate of Radiology and Imaging, X-ray unit(s) at Moi Teaching and Referral Hospital (MTRH) in Eldoret, between October 2023 and January 2023.

The study targeted all Kenyan adult patients who took pelvic x-rays at the Radiology and Imaging Department of MTRH during the period of study. The inclusion criteria was participants with normal proximal femur anatomy as read from an anteroposterior and lateral pelvic radiograph.

A sample of 118 participants was determined using the formula for estimating a mean in one group, based on Branco de Sousa et al., (2010), who reported a mean femoral head diameter of 46.56 mm ± 3.6 mm; applying $N = 4Z_{\alpha/2}^2 S^2 / W^2$ at a 95% confidence level and a desired confidence interval width of 1.3 mm (as adapted from Eduardo et al.), yielded the required sample size. Patients who participated in the research with an anteroposterior proximal femur X-ray images with normal anatomy were purposively recruited into the study until the sample size was attained. Data was analyzed with the help of a Biostatistician, using a software operating system FeiTian III- Linux OS. Descriptive statistics and continuous data expressed as mean, standard deviation, median, interquartile range, while categorical data was expressed as frequency and proportions. For further analysis, data was exported from a Microsoft Excel spreadsheet and imported into STATA version 15.0, and was analyzed for NSA and FHD. Student-*t*-test was used to compare the measurements of the proximal femur in males and females. Statistical significance was determined by a *p*-value less than 0.05.

The Institutional Research and Ethics Committee (IREC) (Ref: IREC/616/2023, Approval Number: 0004580, Dated 4th October, 2023) and the Chief Executive Officer (CEO) of MTRH (Ref: ELD/MTRH/R&P/10/2/V.2/2010, Dated 5th October, 2023) both provided their approval before this study could be carried out. This study is strongly relevant and significant since it is among the first studies by the PI to document the radiological morphometry of the proximal femur in Kenyan adults.

RESULTS

A total of 118 participants comprising of 61 (51.7%) females and 57 (48.3%) males were purposively recruited in the study. The mean age of the participants was 42.01 (SD: 12.11) years. The mode was 46- 50 years old age group. The range was 20- 70 years.

Table 1: Socio-demographic characteristics

Characteristic	Frequency	Percentage
Sex		
Male	57	48.3
Female	61	51.7
Region		
Western	78	66.1
Central	16	13.6
Northern	11	9.3

Eastern	13	11.0
Level of activity		
Mildly active	19	16.1
Moderately active	64	54.2
Very active	35	29.7
Diet (Balanced)		
Almost always (3 or more times a week)	14	11.9
Sometimes (less than 3 times a week)	81	68.6
Almost never	23	19.5

The majority 78 (66.1%) of the participants came from the Western Region, 16 (13.6%) from Central, and 13 (11%) from Eastern and the least number of participants came from the Northern 11(9.3%). The majority of participants 64 (54.2%) were moderately active in most of their life time. The majority of participants 81 (68.6%) ate the balanced diet sometimes (less than 3 times a week).

Analysis of Mean NSA

The combined left and right side mean for the NSA was 129.77^{o} (SD: 3.31^{o}). The maximum NSA was 141.7^{o} from the left side of a male participant from the Western region. The minimum NSA was 120.1^{o} from the right side of also a male participant from the central region. The mode was 126.9^{o} for the right side and 128.5^{o} for the left side.

Analysis of Mean FHD

The combined left and right side mean for FHD was 50.84 (SD: 3.59) mm. The maximum FHD was 57.5mm from the right side coming from a male participant. The minimum FHD was 39.8mm for both the left and right side coming from a female participant. The mode was 52.5mm for the right side and 54.1mm for the left side.

Analysis of Neck Shaft Angle

These comparisons were based on an overall mean value. The null hypothesis being tested was: The mean neck shaft angle is not different between males and females. The test statistics of choice was the Student- *t*- test because the data was approximately normally distributed and the number of observations was more than 30.

Table 2: Student- *t*- test analysis for comparison of NSA between males and females

Sex	Mean	Standard deviation	*p*-value
Male (n=57)	129.98^{o}	3.39^{o}	0.450
Female (n=61)	129.52^{o}	3.23^{o}	

The mean NSA in males appeared slightly greater than for the females though this difference was not statistically significant.

Analysis of Femoral Head Diameter

Table 3: Dimensions of femoral head diameter

Sex	Mean (mm)	Standard deviation	p-value
Male (n=57)	53.11	2.56	<0.001
Female (n=61)	48.42	2.90	

The mean FHD in males appeared slightly greater than for the females and this difference was statistically significant.

Table 4: Dimensions of neck- shaft angle

Side	Mean	Standard deviation	Minimum	Maximum	Mode
Right side(n=118)	129.86°	3.59°	120.1°	138.9°	126.9°
Left side(n=118)	129.60°	3.58°	121.8°	141.7°	128.5°

The mean NSA in the right side was 129.86° (SD: 3.59°) while in the left was 129.60° (SD: 3.58°).

Table 5: Dimensions of femoral head diameter

Side	Mean	Standard deviation	Minimum	Maximum	Mode
Right(n=118)	50.85mm	3.63mm	39.8mm	57.5mm	52.5mm
Left (n=118)	50.77mm	3.71mm	39.8mm	57.3mm	54.1mm

The mean FHD in the right side was 50.85 (SD: 3.63) mm while in the left side was 50.77 (SD: 3.71) mm.

Factors that Affected the Morphometry of the Proximal Femur in Kenyan Adult Patients at MTRH

The linear regression method was used to determine the factors associated with morphometry of the proximal femur. The neck shaft angle was considered as the outcome. The measure of association was the coefficients. The nature of diet was statistically significant with a *p*- value 0.029. The level of activity and the region of origin did not show statistical significance.

Table 6: Linear regression analysis of factors that affect the morphometry of the proximal femur

Characteristic	Coefficients, β	95% confidence Intervals	*p*- value
Level of activity	0.404	-0.773 – 1.581	0.498
Diet	1.253	0.131-2.376	0.029
Region	0.139	-0.223-0.509	0.449
Sex	0.286	-0.932-1.505	0.643
Age	-0.002	-0.047-0.423	0.911

DISCUSSION

From a total of 220 femoral NSAs and FHDs, 118 radiographs of purposively recruited participants meeting eligibility criteria were used in this study. The small sample size used in this study was due to the low turnover of patients that did pelvic X-rays that at least had one side with normal anatomy of the proximal femur during the period of study. The clinicians' focus on the pathological region and only using the non- pathological region for comparison or ruling out its involvement, applying "the rule of two" as it is recommended in the clinical practice could be another reason for small sample size.

Socio-demographic Characteristics of Participating Adult Patients at Moi Teaching and Referral Hospital, Eldoret, Kenya

The mean age obtained in this study was 40.01 (SD: 12.11) years. The majority of the patients 64 (54.24%) were above 40 years. This mean age could have been influenced by the nature of patients handled at the study site by the clinicians who mostly do pelvic X-rays as part of a skeletal survey to rule out metastatic cancer, and other disorders.

The finding could also be explained by the deliberate selection of adult participants of 20 years of age and above. The mean age in this study is close to the mean age and range documented in other studies (Nissen et al., 2005; Zaki, et al., 2017). In this study, advancing age did not show any statistical significance on the NSA or FHD and this is in agreement with other studies (Gilligan et al., 2013; Zaki, et al., 2017). Majority (78; 66.1%) of the participants in this study originated from the western region of Kenya representing the biggest contribution. This finding could be explained by the fact that the study site was located at MTRH within easy access by patients from the western region in Kenya.

The majority of the participants also reported to be moderately active (64; 54.2%). This probably resulted from the fact that most of the participants originating from the urban areas within the western region where most economic activities do not require much physical activity and where motor vehicle and *boda boda* as the main means of transport are prevalent. This is in agreement with the findings by Gilligan *et al.* of low activity in urban areas (Gilligan et al., 2013).

In this study 81(68.6%) of respondents reported to be feeding on food ingredients composed of a balanced diet only some times. This could be explained by the fact that most people in Kenya are engaged in low income economic activities and may not afford to finance regular meals composing a balanced diet. The variable eating habits in relation to culture such as the love for staple food may also explain this finding. Proper diets that contain three micronutrients (protein, carbohydrates and fats) minerals and vitamins are essential for bone development, growth and maintenance. Diets interact with other factors to ensure ideal bone health (Corwin et al., 2006; Heaney & Layman, 2008; Petrie et al., 2004; Rashighi & Harris, 2017; Sahni et al., 2008; Zernicke et al., 1995).

Morphometric Radiological measurements of Neck Shaft Angle and Femoral Head Diameter in Kenya Adult Patients at Moi Teaching and Referral Hospital, Eldoret, Kenya

Neck-Shaft Angle (NSA)

The overall mean NSA in the current study was 129.77° (3.31°). This finding is slightly lower but comparable to the mean reported by Gilligan *et al.* in their study involving multiple areas in the world and other tropical African countries like Chad, (132.8°), Mali (130.8°), and Sudan (130.5°) (Gilligan et al., 2013). In contrast, the mean obtained in this study was slightly higher than the 124.9° found in radiographic studies among Indians (Ravichandran et al., 2014). When the mean NSA in this study is compared to the most commonly available commercial implants for osteosynthesis in the proximal femur like the Dynamic Hip Screw (DHS), Proximal Femur Nails (PFN), Sign Nails and reconstruction nails, it is still slightly lower. Anecdotal evidence reveals that the most selected implant angles used for surgery range between 130°-135° with 135° being the most commonly used angle. The implication of the finding in this study is that, implants with higher angles may usually be implanted in femora with neck-shaft angles of less than 130º which may lead to possible malreduction and secondary displacement of reconstructed fragments in some cases.

Femoral Head Diameter (FHD)

The combined mean FHD obtained in the current study was 50.84 (3.59) mm. This is close to the mean of 52.09mm, obtained by Unnanuntana *et al.* in a study on American femora (Unnanuntana et al., 2010). It is however higher than the mean of 44.9mm and 42.6mm obtained in a Malaysian population (Lee et al., 2014). According to unpublished reports, the most locally used femoral head implant for monopolar and bipolar hemiarthroplasty range between 42mm- 44mm and 48mm-52mm for females and males respectively. These commonly used dimensions are slightly lower but comparable to the average dimensions of the female and male FHD found in this study. The implication of using inappropriate FHD dimensions is that it may be associated with complications such as accelerated wear, hip instability and gait disorders if implanted during orthopedic procedures.

Neck Shaft Angle and Femoral Head Diameter Dimensions in Relation to Gender and laterality in Kenyan Adult Patients at Moi Teaching and Referral Hospital, Eldoret, Kenya

This study revealed slightly larger mean NSA among males (mean= 129.98º (SD: 3.39º)) when compared to females (mean= 129.52º (SD: 3.23º)) although the difference was not statistically significant. This finding is in contrast with those in other previous studies (Adekoya-Cole et al., 2016; Otsianyi et al., 2011). The smaller angles in women have been attributed to a number of reasons including the wider pelvis, greater bi-condylar angle due to the obliquity of the shaft of the femur and shorter femur. However, this study findings differ from those of other studies where values of female NSA were higher than those in males (Akbar, 2015). The differences in sample size and study populations studied between this study and others may explain the observed difference in the findings.

This study found a slightly larger mean FHD in males (53.11(SD: 2.56) mm) than in females (48.42(SD: 2.90) mm), and this difference was statistically significant. This finding is in agreement with those in some other studies. For example, Baharuddin *et al.* in a radiographic study in a Malay population reported a smaller mean FHD in females than males(Baharuddin et al., 2011). Similar findings were also reported by Sanchita *et al.* and Unnanuntana *et al.* (Roy et al., 2014; Unnanuntana et al., 2010). The difference in the mean

FHD between males and females established in this study could be due to the fact that women generally and naturally have stature of pelvis that is wider than of men.

There was no lateral statistically significant difference between left and right NSA in this study. This finding concurs with those in other studies which documented no lateral variability of statistical significance (Kaur et al., 2013). However, the findings in this study contrast those of Nwoha and Gilligan *et al*. who found lateral differences between right and left sides which they attributed to right leg dominance (Gilligan et al., 2013; Nwoha, 1991). The differences in sample size and study populations studied between this study and others may explain the observed difference in the findings.

The findings of this study are also in agreement with those by several other researchers (Lakati, et al., 2017; Roy et al., 2014; Unnanuntana et al., 2010).

Factors Affecting the Neck Shaft Angle and Femoral Head Diameter in Kenyan Adult Patients at Moi Teaching and Referral Hospital, Eldoret, Kenya

Proximal Femur Morphometry in Relation to Sex

In this study, the sex factor for NSA and FHD dimensions were found to be greater in males than in females. Some authors (Adekoya-Cole et al., 2016; Otsianyi et al., 2011) had similar results. However, the results of this study were not statistically significant ($p>0.643$). There is in existence sexual dimorphism and this is supported by research showing NSA and FHD in males having larger dimensions than in females (Cho et al., 2015; Karakas & Harma, 2007; Lee et al., 2014; Srivastava et al., 2012; Zaki, et al., 2017) as well as for the contrary(Akbar, 2015).

Proximal Femur Morphometry in Relation to Age

In this study, age factor did not show statistically significant influence on the NSA and FHD ($p> 0.911$). This concurs with findings by some authors (Gilligan et al., 2013; Zaki, et al., 2017). However, in some studies, some authors (Gnudi et al., 1999; Nissen et al., 2005) have demonstrated that femoral head radius increased with age in both men and women.

The finding that increasing age does not seem to significantly influence the NSA and FHD dimensions in the population favours THA procedure increasingly being performed in younger patients with good success rate (Kurtz et al., 2009; Parvizi et al., 2004). What matters are: appropriate component location, and the prosthetic stem in an uncemented THA that fits well in the proximal femur (Lecerf et al., 2009; Ullmark, 2014) to facilitate and ensure that bony ingrowth into the prosthesis, leading to long-term attachment and stability.

Proximal Femur Morphometry in Relation to Level of Activity/ Lifestyle

In this study, the level of activity did not show statistically significant influence on the NSA and FHD. This is in agreement with a previous study where the level of activity did not have an influence on the NSA (Weaver, 2003). However, the findings in this study contrast with those by Gilligan *et al*. who reported a modest trend toward increasing NSA with decreasing level of activity. They attributed their findings to thermal insulation from cold weather by clothing and reduced movements of populations living in cold environment (Gilligan et al., 2013). A study done in Kenya by Otsianyi and colleagues reported interethnic differences in the value of femoral NSA due to level of activity. They reported nomads and groups that usually walked long distances tend to have higher values than the highland farmers (Otsianyi et al., 2011). The findings of the current study may be explained by the cosmopolitan composition of the study site and region. Researcher recommends nationwide research to document the NSA and FHD of all ethnic groups represented in Kenya.

Proximal Femur Morphometry in Relation to Environment (Region)

There was no statistically significant difference between the NSA or FHD and the region of origin in the current study. This may be due to the fact that although the different regions of the country have slightly different climate trends, Kenya is generally a tropical country. The small samples representing the various regions may also have influenced this finding. The mean found in this study is in agreement with that in the study findings by Gilligan *et al*. who documented that higher mean neck-shaft angles were found in the tropics and warmer regions when compared to cold regions (Gilligan et al., 2013). This finding is also in agreement with Bergmann's rule which proposes a possible variation in body and bone morphometric measurements and environment inhabited by the species (Bogin et al., 2022). Weaver also suggested that the lower NSA among cold climate groups reflected differing developmental forces on the femoral neck secondary to climate related differences in body proportions (Weaver, 2003). The Researcher recommends further studies with larger sample sizes for the different specific regions of Kenya.

Proximal Femur Morphometry in Relation to the Diet/ Nutrition

This study found diet to have a statistically significant association with proximal femur morphometry. This is in agreement with those in other studies that documented nutrition having a significant influence on bone build and strength (Heaney & Layman, 2008; Sahni et al., 2015). This is because proper nutrition is known to lead to generalized body build and health including bones. Researcher however recommends a more in-depth macro and micro nutrient study to explore this finding, given the possible seasonal variations in availability of different foodstuffs and the varying feeding behavior (staple food preference) of different populations in Kenya.

CONCLUSION AND RECOMMENDATIONS

Most participants in the study were over 40 years old, with Majority being women. There was a variation in Neck Shaft Angle (NSA) and Femoral Head Diameter (FHD) by gender, body side, and region, with higher values observed in men and participants from the Western region, who also showed the right femur being slightly larger than the left. There was a significant difference in FHD between males and females, with diet emerging as the only significant factor influencing both measurements. These variations are evidence of the importance of considering individual radio morphometric measurements during orthopedic surgeries involving the proximal femur and in implant design for Kenyan patients. Based on the findings of the study, it is recommended that; wider implant ranges based on these findings and calls for further research with larger samples, multiple centers, 3D imaging, and attention to ethnic and lifestyle differences.

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DISCLOSURE

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