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Morphometric Study of the Proximal Dry Femur And Its Potential Application in Prosthesis Designing in Tanzania

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Abstract

Background

Total hip arthroplasty and hemiarthroplast are currently common procedures in our setting, subluxation and periprosthetic fracture of the femur has been reported. This can be linked to undersize and oversize of the prosthesis since most of these prosthetics are western standardized. This is partly because of lacking data of the size of the proximal femur. The head of the femur articulates with the acetabulum in the pelvic bone forming the hip joint. Knowledge about the different diameters of the head, neck and length of femur is essential in orthopedic surgery, radiology and forensic medicine. These normative values are essential for plastic and reconstructive surgeons in their reconstruction and medical rehabilitation. However, the anatomical and anthropological statistical analysis of femoral anthropometry among different populations reveals a great variation for all human races. The present study aimed at determining morphometric measurements of proximal femur among Tanzania black people.

Materials and Methods

The study was done by evaluating 97 undamaged dry bones left femur 35, right femur 50 and 12 acetabula preserved in the anatomy laboratories at medical universities in Dar es Salaam, Tanzania. The parameters evaluated were femoral head diameter, femoral neck width, lateral and anteroposterior femoral neck length, femur length, acetabular diameter and height. They were measured using Vernier caliper, non-elastic thread and osteometric board.

Results

The femoral length had range of 400-520 mm with the mean of 454.1±30.3mm, head diameter had a range of 34-54mm with the mean of 44.4±3.8mm and neck width had the range of 25.2-40mm with the mean of 31.7±3.3. The anterior and postero-anterior neck length measure 15-36mm and 25-48mm with the mean values of 23.2±4.2 and 36.8±4.3mm respectively. The mean values of acetabula width and diameter were 52.3±2.93mm and 48.9±2.78mm respectively.

Conclusion

The proximal femoral and acetabula morphometric measurements varied compared to those in other populations. Therefore, the values obtained for Tanzania population should be considered on orthopedic decisions for implants to be used. However, more robust studies are needed to corroborate these findings.

Key words: *Femur head, neck, morphometric, acetabulum.*

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Background

The femur is the proximal bone of the lower limb. The head of the femur articulates with the acetabulum in the pelvic bone forming the hip joint, while the distal part of the femur articulates with the tibia and kneecap forming the knee joint. By most measures the femur is the strongest bone in the body. The femur is also the longest bone in the human body. The femur articulates above with the acetabulum to form the hip joint and below with the tibia and the patella to form the knee joint. The upper end of the femur has a head, a neck, greater and lesser trochanters (1)**.** The head forms about two thirds of a sphere and articulates with the acetabulum of the hip bone to form the hip joint. In the center of the head is a small depression, called the fovea capitis for the attachment of the ligament of the head. Part of the blood supply to the head of the femur from the obturator artery is conveyed along this ligament and enters the bone at the fovea. The neck, which connects the head to the shaft, passes downward, backward and laterally and makes an angle of about 125° (slightly less in the female) with the long axis of the shaft. The size of this angle can be altered by disease (2). The greater and lesser trochanters are large eminences situated at the junction of the neck and the shaft. Connecting the two trochanters the intertrochanteric line anteriorly, where the iliofemoral ligament is attached and a prominent intertrochanteric crest posteriorly, on which is the quadrate tubercle. The shaft of femur is smooth and rounded on its anterior surface but posteriorly has a ridge, the lineaaspera, to which are attached muscles and intramuscular septa. The margins of the lineaaspera diverge above and below. The medial margin continues below as the medial supracondylar ridge to the adductor tubercle on the medial condyle. The lateral margin becomes continuous below with the lateral supracondylar ridge.

On the posterior surface of the shaft below the greater trochanter is the gluteal tuberosity for the attachment of the gluteus maximums muscle. It is commonly accepted that the examination and statistical analysis of femoral anthropometry among different populations reveals a great amount of variation due to the fact that femoral anthropometric measurements from different countries are likely to be affected by racial variations in diet, heredity, climate and other geographical factors related to life style (3). Knowledge about the different diameters of the head, neck and length of femur is essential in orthopedic surgery for prosthesis, nail application and forensic studies. These normative values are essential for plastic and reconstructive surgeons in reconstruction and medical rehabilitation.

Also, these diameters are used in radiological practice to identify pathology of bone and for determination of age. Finally, morphometric data of femur help doctors and nutritionists to calculate body energy needed for normal individuals, sex identification and in forensic medicine (4). Operations on the proximal femur are very common in the practice of the orthopedic surgeon. These range from osteosynthesis for fractures, osteotomies, to hemi and total joint arthroplasty. These operations aim to restore the anatomy of the proximal femur to as near normal as possible, for optimal hip function. As such, a detailed knowledge of the anatomy of the proximal femur is required to achieve anatomical reduction with a stable fracture fixation, which helps bone union, and allow early mobilization. From the biomechanical point of view, a better contour fit between bone and plate is crucial to establish a stronger bone-plate construction and to stabilize the fracture fragments even with a locking compression plate may facilitate an appropriate placement of the plate intra operatively which saves time and prevents improper position of the proximal screw within femoral head because the screw is in the plate.

Different methods have been used in proximal femoral locked morphometric. The study done in Ile-Ife among Nigerians by Nwoha PU in 1990 using X-ray films discovered no significant difference between the right and left femoral dimensions ($p>0.05$), yet the dimensions for Nigerians reported to be larger than Caucasians, Indians and Chinese. Another study among Iran revealed that the calipers and ring gauge measurements are more reliable than the CT and X-ray methods and suggested for measurement of the femoral head diameter in the hip hemi arthroplasty and arthroplasty surgery. The sizes of the femoral head and femur components of prosthetics are produced in intervals of 2 mm, the range of direct error within the methods themselves were less than 2 mm would make each method as viable a solution as the others. (Vernier caliper 42.6mm-52.3mm, for X-ray 43.6-54.7mm and ring gauge measurement 42-53mm respectively. However, it was proved that the measurement with the Vernier caliper and ring gauge instruments are the most appropriate method to quantify the diameter of the femoral head (5). With increase of procedures involving the hip joint in our settings, the anatomy knowledge of articulating bones is very important. The study aimed at determining the morphometric measurements of proximal femur and therefore obtains baseline data for determination of the correct size of femoral prosthesis in Tanzania for surgical management of patients.

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Materials and Methods

Descriptive cross sectional study was conducted in the departments of anatomy at medical Schools in Dar es Salaam, Tanzania and data was collected by three trained staff. The study was conducted on dry adult femora. The femora were obtained from the bones collection preserved in the anatomy (cadaver) laboratory from the Anatomy Department. Dry undamaged femora were selected according to the convenient sample, and included left femur (n=35), right femur (n=50) and acetabula (n=12) for the study. The femora were of undetermined gender and age. Materials used for measurement of different parameters were; digital Vernier caliper, measuring scale, on-elastic acrylic thread, osteometric board and Fiberglass tape. Data collection involved three people, a researcher, one assistant, lab supervisor/senior expert. Each measurement was recorded in millimeters and detailed on standard data, upon completion; the data was transferred to SPSS for analysis.

Various parameters were recorded including the diameter of the neck of femur (DNF) which was measured at its narrowest part in a superoinferior direction by using carbon fiber composite digital vernier caliper gauge micrometer 100mm 4-inchLCD (Suzhou Tolsen Tools Co. Ltd., Jiangsu, China) (Figure 1A) (Figure 1B).The Length of the neck of the femur anterior aspect (LNFA); The distance between the base of the head and intertrochanteric line, measured along the line which is perpendicular to the intertrochanteric that divides anterior part of the neck into two equal parts (lower and upper), was measured with the Length of neck of femur on posterior aspect. (LNFP). It is the distance between the base of the head and intertrochanteric crest that was measured along the line that is perpendicular to the intertrochanteric crest, which divides the posterior part of the neck into two equal halves (upper and lower) parts. Acetabula width and diameter were also measured with the help of a non-elastic acrylic thread and femur length (Figure 1C) was measured using osteometric board.

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Figure 1A

Figure 1B

Figure 1C

Figure 1A: Femur morphometric measurement using carbon fiber composite digital vernier caliper; **Figure 1B:** Femoral neck length measurement; **Figure 1C:** MAC– maximum distance between adductor Tubercle to the lower most point on articular surface.

Results

The study used 97 undamaged bones. Table 1, shows the bones used in the study. The bones were left femur 35, right femur 50 and acetabula 12. The mean length of femur was 454.1±30.3mm and mean head diameter of 44.4±3.8mm. The neck width was 31.7±3.3mm while anterior and posterior neck lengths were 23.2±4.2mm and 36.8±4.3mm respectively. The mean length of right femur was 454.9±30.5mm and mean head diameter of 44.6±4mm. The neck width was 32±3.6mm while anterior and posterior neck lengths were 23.7±4.1mm and 37.3±4.7mm respectively. The mean length of left femur was 452.9±30.5mm and mean head diameter of 44±3.5mm. The neck width was 31±2.7mm while anterior and posterior neck lengths were 22.3±4.3mm and 36.2±3.6mm respectively. Diameter of the acetabula

had range of 43-54mm with the mean of 48.9±2.78mm. The height had the range of 46-53mm with the mean of 52.3±2.93mm. Details of the morphometric measurements are summarized in Table 1 and 2.

Table 1: Morphometric measurements of proximal femur

Variable	Right (n=50)			Left (n=35)		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Head diameter	34	51.4	44.6±4	37.5	54	44±3.5
Neck width	25.2	40	32±3.6	26.3	38.5	31.3±2.7
Neck length	16	33	23.7±4.	15	36	22.3±4.3
Neck	25	48	37.3±4.	30	43	36.2±3.6
Femur Length	400	520	454.9±	400	520	452.9±30

Table 2: Morphometric measurements of the acetabula

	Values (mm)			
Measurements	**Maximum**	**Minimum**	**Mean**	**SD**
Diameter	54	43	48.9	2.78
Width	55	46	52.3	2.93

Discussion

The study was done to assess the morphometric measurements of the proximal femur by evaluation of 97 bones. These were right femur 50, left femur 35 and acetabula 12. Knowledge of femoral parameters is helpful for the clinician in the treatment of femoral fractures example by placing various correct implants in the reconstruction of femoral fragments. The study found femoral length had a range of 520-400mm with the mean value of 454.1±30.3mm. There was no significant deference between the measurements of both sides. The findings are consistent with the similar study done in India (6). The findings are significantly higher compared to the study done in Japan where right and left femur mean lengths were 420±30.9mm and 413±25.4 mm, respectively with the mean bilateral femoral length of 420±28.1mm (7). The findings were also higher compared to the study done in India where the right and left mean femoral lengths were 439.3mm and 440.9mm respectively (8).The difference in mean femoral length in between populations may possibly be a result of factors affecting bone morphology such as genetic constitution, diet, nutrition status, environment and physical activity (6).The femoral head diameter had the mean of

44.6±3.8mm. The mean values were almost equal for both the right and left sides. Similar results were found among Turkish where mean femoral head diameter was 45.8±4.17mm (9). The findings are slightly higher compared to the study done in India where the mean femoral head diameter was 42mm (8). The findings are significantly higher compared to the study in Kulasekharam where mean femoral head diameter were 33.3±3.79mm and 33.88±2.46mm for left and right side respectively(10). The study found femoral neck width of 25.2-40mm with the mean of 31.7±3.3mm. The measurements were similar for both sides. The mean femoral neck width for right and left femur was 32±3.6mm and 31.3±2.7mm respectively. Similarly the mean femoral neck width among Brazilians was 31.3 and 30.8mm for the right and left respectively(11). The results were slightly higher compared to the study done in Japan where the mean width were 29.5±2.8mm, 29.4±0.mm, and 29.4±3.0mm for right, left and bilateral femur respectively (7).

The results are significantly higher compared to the study done in Kulasekharam where the femoral neck width for both right and left side were 24.5±3.27mm and 25.7±3.31mm respectively (10).The difference of the results could be due to measurement techniques and accuracy of measurement devices in addition to environmental variation in between the populations. In males with increase in age, neck thickness is also increased, which contribute to the development of osteoarthritis by increasing cam impingement. This should therefore be considered on developing appropriate implants (8).The study found that anterior length of femoral neck ranged from 15-36mm with the mean of 23.2±4.2mm. The mean anterior length of femoral neck for the right and left were 23.7±4.1mm and 22.3±4.3mm respectively. The findings of the study are significantly lower compared to the Indian study in Mumbai where the mean anterior length of femoral neck was 33.42mm and 34.96mm for the left and right side respectively. The study found that poster-anterior length of femoral neck ranged from 25-48mm with the mean of 36.8±4.3mm. The poster-anterior length of neck for right and left femur had the mean of 37.3±4.7mm and 36.2±3.6mm respectively. The findings of the study are slightly lower compared to the studies done in India where the mean were 40mm and 39.55mm for the left and right side respectively. The findings are higher compared to the study in India where the mean length was 33.68mm (13). Difference of femoral neck length correlates with difference in occurrence of neck fractures especially in postmenopausal women(14).The study found that diameter of the acetabula had range of 43-54mm with the mean of 48.9±2.78mm. The height had the range of 46-53mm with the

mean of 52.3±2.93mm. The findings are similar to the study done among Brazilians where the acetabula diameter and height had the mean of 49.1±2.3mm and 53.8±3.05mm (11). However the findings were higher compared to results among Indians (8) and Turkish (9).

Conclusion and recommendation

Following evaluation of the bones in this study and comparing with other studies in the literature there are apparent morphometric variations of the proximal femur parameters among Tanzanians versus most other studied populations. These preliminary findings may suggest a need to consider designing special sizes of femoral implants in hip joint replacement surgeries and prosthetic materials to fit the Tanzanian population. More robust studies are therefore needed to corroborate these findings.

Limitations

Artificial bones and bones from Caucasian were not included in our study because would yield different results from black population.

Ethics statement

Ethical clearance was obtained from the Senate Research and Ethics Committee of the Muhimbili University of Health and Allied Sciences.

Conflict of interest

Authors declared no conflict of interest.

Authors' contribution

SPM contributed to the conception and design of the study, acquired, analysed and interpreted the data, and drafted and revised the manuscript. DR contributed to the design of the study, data interpretation and critically revised the manuscript. BH contributed to the design of the study, data interpretation and critically revised the manuscript.

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Abbreviations

DNF	Diameter of The Neck of Femur
LNFP	Length of Neck of Femur On Posterior Aspect.
LNFA	Length of Neck of the Femur On Anterior Aspect
MAC	Maximum Distance Between Adductor Tubercle to the Lower Most Point on Articular Surface
MOI	Muhimbili Orthopaedic Institute
MUHAS	Muhimbili University of Health and Allied Health Sciences
SPSS	Statistical Package for Social Sciences

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