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Original Research Article

Radiographic Assessment of the Proximal Femoral Anatomy in An Indigenous African Adult Population

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ABSTRACT

Background: Hip surgeries such as fracture fixation, corrective osteotomy, hemiarthroplasty, or total hip arthroplasty require accurate preoperative templating for a successful outcome. Such templating is done using the proximal femur and the acetabulum radiographs, depending on the planned surgery. Understanding the normal radiographic anatomy of the proximal femur is crucial to differentiate a normal from pathological anatomy. Proximal femoral anatomic indices include the femoral head diameter, femoral neck diameter, femoral neck length, femoral offset, femoral neck axis length and the femoral neck-shaft angle.

Aim: This study assesses and establishes the average values of the proximal femoral anatomy in an indigenous African adult population.

Method: This cross-sectional study examined 190 normal anteroposterior (AP) radiographs of the pelvis. The mean age, weight and height of the subjects were obtained. The following proximal femoral anatomic parameters were measured: femoral neck length (FNL), femoral neck diameter (FND), femoral head diameter (FHD), femoral neck-shaft angle (FNSA), femoral offset (FO) and femoral neck axis length (FNAL). The authors compared the mean difference of the parameters between the genders and the age categories and assessed the parameter correlations with the patients' weight and height.

Results: Males constituted 63 (33.2%) of the study population. The mean age of the subjects was 51.46 years (SD = 16.37). The mean weight was 76.13 kg, while the mean height was 1.62 m. The mean values of the proximal femoral parameters were as follows: FNL 4.52cm, FND 3.42cm, FHD 4.76cm, FNSA 132.96^0, FO 4.09cm, and FNAL 10.34cm. Males have a significantly higher mean value in all the parameters except the FO. None of the parameters showed any significant difference among the age categories except the FNL. A post-hoc analysis showed that the difference in the FNL lies between the young and the elderly age groups. The subjects' height correlated with all the parameters except FNSA, while the weight correlated with the FND, FNSA and FNAL.

Conclusion: The proximal femoral anatomy in Africans differed from those published in foreign literature. This knowledge is crucial for implant manufacturing companies and preoperative templating for hip surgeries.

KEY WORDS: Proximal femur, Anatomy, Black population.

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INTRODUCTION

Operations on the proximal femur are undertaken for several reasons. The indications may be traumatic such as fractures or dislocations, or non-traumatic, such as the sequelae of developmental dysplasia of the hip, Slipped upper femoral epiphysis, Perthes disease, Coxa vara and valga, Osteonecrosis or idiopathic Osteoarthritis. The anatomy of the proximal femur has implications in these operations. Proximal femoral anatomic indices that have surgical importance include the femoral head diameter (FND), femoral offset (FO) and femoral neck axis length (FNAL). Others are the femoral neck-shaft angle (FNSA), femoral neck length (FNL) and femoral neck diameter (FND) [1-5]. Femoral component head size is critical in total hip and hemiarthroplasty. A large femoral head size reduces dislocation rate, has an improved range of motion, and decreases cam-type impingement with consequent groin pain [3]. However, if the head is too large, it can result in excessive abductor muscle tension and increased liner wear.

The femoral offset is crucial in maintaining the abductor muscle tension. If the femoral stem offset is too short relative to the native hip, the abductor muscle tension is reduced and results in muscle weakness with a limp. Studies have shown that restoring the native hip offset during THR enhances range of motion, reduce limping and the need for crutches, decrease dislocation rates, cup strain and liner wear [6-9]. The role of the FNAL in hip fractures is unclear. While some studies have shown that a longer FNAL increases the risk of femoral neck fractures, others have not found any association [10,11]. Similarly, studies have shown that a larger FNSA increases the lever arm of the body weight, acting on the greater trochanter during a fall on the side [4,5]. Such impact could cause a hip fracture in those individuals. Surgeries that involve the placement of an implant into the femoral neck, such as DHS, pinning for femoral neck fractures or SUFE, require the knowledge of the FNL and FND to select the appropriate size of the implants.

In a developing economy such as Nigeria, implant and prostheses procurement are sometimes limited due to financial insufficiency. Therefore, it is vital to get prosthetic sizes that fit the majority of the population. Such a goal is possible when the average values of the proximal femoral parameters are known. Hence, this study assesses these parameters in individuals seen in a tertiary referral Orthopaedic centre in Nigeria.

METHODS

This research was a cross-sectional study conducted at the Orthopaedic department of the National Orthopaedic Hospital, Enugu, in South-East Nigeria. The hospital is the foremost tertiary Orthopaedic referral centre in the southern part of the country. The study was conducted for 24 months, from October 2018 to September 2020. The study protocol was explained to the radiographers with a research assistant present in the X-ray room to ensure the study protocol was followed. Ethical approval was received from the Hospital's Research and Ethics Committee, and verbal consent was obtained from all participants.

The required sample size was calculated with the formula $n = Z^2p\ (1-p)/d^2$, where Z is the standardised normal deviate which is 1.96 at a 95% confidence level. P is the proportion of normal pelvic x-rays, and q is 1-p. The denominator, d, is the precision which is set at 5%. Out of 812 pelvic X-rays done in 2017, 101 (12.4%) were free of any hip pathology. Substituting these values in the equation gives a minimum sample size of 167, which rounded off to 184 after adding a 10% attrition rate. The researchers used a final sample size of 190 normal pelvic radiographs.

After obtaining consent, the patient was placed supine, and the film-focus distance (FFD) was set at 100 cm. All x-rays are digital, and magnification was set at 100%, with the beam centred on the pubic symphysis. The lower limbs were internally rotated to 15^0 to neutralise the proximal femur anteversion. One of the researchers took two measurements of the parameters, and the average measurement was taken. The parameters measured are the femoral head diameter (FHD), femoral offset (FO), femoral neck axis length (FNAL), femoral neck-shaft angle (FNSA), femoral neck length (FNL) and femoral neck diameter (FND) (Fig. 1). Exclusion criteria include hip pathologies identified by the radiologist or the authors. The researchers weighed the patients and measured their heights.

The FHD is the transverse distance between the superior and inferior parts of the femoral head's broadest part. The FO is the horizontal distance between the femoral head centre of rotation and the femoral shaft's mid-diaphyseal line. The distance between the most lateral aspect of the greater trochanter and the end of the caput femoris is the FNAL. The FNSA is the angle subtended by the intersection of the neck mid-axis line and the shaft mid-diaphyseal. Similarly, the FNL is the distance between the intertrochanteric line and the head-neck junction. The FND is the distance between the superior and inferior borders of the narrowest part of the femoral neck.

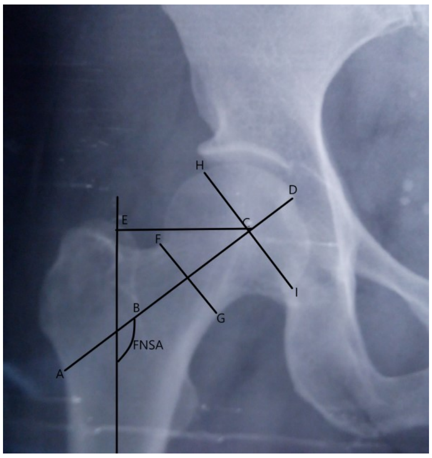

Fig. 1: The proximal femoral parameters measured: AD = FNAL, BC = FNL, EC = FO, FG = FND, HI = FHD. Also, note the FNSA.

ANOVA was used to test the parameters' difference among the age categories. A Pearson's bivariate correlation was run between the weight and height and the The authors presented the data as means and standard deviations for continuous variables and frequencies for categorical variables. An independent samples t-test was used to test the difference in the parameters between males and females. In contrast, a one-way parameters. All tests were 2- tailed, and a p-value of less than 0.05 was considered significant.

RESULTS

The researchers evaluated 190 x-rays of 63 males (33.2%) and 127 females (66.8%). The participants' mean age was 51.46 years (SD = 16.37). Their mean weight was 76.13 kg (SD = 15.53), while their average height was 1.62 m (SD = 0.09). Table 1 shows the age categories of the subjects.

Table 1: The participants' age categories, n = 190.

Age category (yrs)	n	%
< 45	69	36.3
45 - 65	60	31.6
>65	61	32.1
Total	190	100

The subjects' average values for the parameters are FNL 4.52cm (SD = 0.61), FND 3.42cm (SD = 0.31), FHD 4.76cm (0.21), FNSA 132.96^0 (SD = 5.49^0), FO 4.09cm (SD = 0.57), and FNAL 10.34cm (0.82). All the parameters differed significantly between the genders except the FO, with males showing consistent larger values than females (Table 2). None of the parameters differed significantly among the age categories except FNL (Table 3).

Table 2: Comparison of the average values of the proximal femoral parameters between the genders. Standard deviations of the means are enclosed in brackets, n =190.

Parameters	males	females	Mean difference	Std. error	t	p	95% CI
FNL (cm)	4.75 (0.58)	4.41 (0.60)	0.34	0.09	3.69	0.001	(0.16,0.52)
FND (cm)	3.60 (0.28)	3.33 (0.28)	0.27	0.04	6.13	0.001	(0.18,0.35)
FHD (cm)	4.85 (0.11)	4.71 (0.24)	0.14	0.03	4.38	0.001	(0.08,0.20)
FNSA (^{0})	134.08(5.51)	132.41(5.41)	1.67	0.84	2	0.001	(0.01,3.33)
FO (cm)	4.15 (0.63)	4.06 (0.54)	0.09	0.09	1.07	0.287	(-0.08,0.27)
FNAL (cm)	10.83 (0.85)	10.09 (0.67)	0.74	0.11	6.51	1	(0.52,0.97)

Table 3: Comparison of the average values of the proximal femoral parameters between the age categories. Standard deviations of the means are enclosed in brackets, n =190.

Parameters	<45 yrs.	45-65 yrs.	>65 yrs.	F	p
FNL (cm)	4.62 (0.68)	4.58 (0.61)	4.35 (0.49)	3.66	0.027
FND (cm)	3.37 (0.31)	3.45 (0.31)	3.41 (0.30)	0.89	0.96
FHD (cm)	4.87 (0.36)	4.99 (0. 39)	4.91(0.45)	1.52	0.305
FNSA (^{0})	133.29 (4.75)	132.28 (6.13)	133.40(5.40)	0.82	0.295
FO (cm)	4.09 (0.52)	4.14 (0.60)	4.01 (0.58)	0.83	0.166
FNAL (cm)	10.36 (0.74)	10.44 (0.87)	10.19 (0.81)	1.5	0.448

Table 4: The correlation between the participant's height and weight and the proximal femoral parameters, n = 190.

	parameter	r	p
Height	FNAL	.501*	<.001
	FND	.318*	<.001
	FNL	.314*	<.001
	FHD	.270*	<.001
	FO	.173*	0.042
	FNSA	0.092	0.205
Weight	FND	.225*	0.002
	FNSA	.205*	0.005
	FNAL	.159*	0.029
	FNL	-0.02	0.787
	FHD	0.027	0.706
	FO	0.042	0.567

*= significant correlation

A post-hoc analysis showed that the significant difference in FNL lies between the young adult (<45 yrs.) and older age (>65 yrs.) categories, p = .036. The patients' heights showed a moderate to strong correlation with all the proximal femoral parameters except the FNSA (Table 4). In contrast, the participants' weights showed only a small correlation with the FND, FNSA and FNAL (Table 4).

DISCUSSION

Population-based anthropometric studies are invaluable in understanding the subtle differences in the anatomic profiles of different races. This information has practical utility for both implant manufacturing companies, local hospital management and the surgeons. It helps the implant companies design implants and prosthesis that match the anatomic geometry of their target population. The knowledge also helps the local hospital management to procure implants that match the anatomy of the greater proportion of their patients. For the surgeons, preoperative planning and templating rely on knowledge of a normal parameter that this data provides. This study assessed the proximal femoral anatomy among subjects presenting to a tertiary Orthopaedic referral centre in South-East Nigeria.

The FHD has implications for hemiarthroplasty and total hip replacement. Larger head size is more stable and has a greater range of motion [3]. The average FHD in this study was 4.70cm, with males having a mean FHD of 4.85cm and females 4.71cm. Katchy et al. [2] studied 716 dry bone femora of Nigerians and documented an average transverse head diameter of 4.46cm. This difference of 2mm is not clinically significant since it is common practice to keep one prosthetic size larger and smaller than the templated one during hemiarthroplasty. Also, it is unclear if the preservation used to store cadaveric specimens could affect the parameters compared to a live one. Another dry bone study in France found a similar value to Katchy et al., of a mean FHD of 4.34cm [12]. In contrast, a study that utilised conventional radiographs in Bangladesh found an average FHD of 5.16cm in males and 4.57cm in females,[13] which is close to the index study's findings.

The FNSA has implications for hip fracture fixations. Implants such as dynamic hip screws, proximal femoral nails, and angled-blade plates have pre-set angles replicating the native FNSA. Also, surgeries such as proximal femoral valgus or varus osteotomies either for nonunion of femoral neck fractures or congenital coxa valga or vara relies on recreating the physiological FNSA. The FNSA has also been implicated in the aetiology of hip fractures[4]. The average FNSA in this work was 132.96^{0}, with males having a higher angle than females. This value is close to 132.15 found by Katchy et al. [2], and 130.77^{0} documented by Adekoya at al [14]. in South-West Nigeria and 131.04^{0} recorded by Iyidobi et al [5]. in South-East Nigeria. These values are higher than values recorded in western literature [1,12,15].

The hip abductor muscle tension is directly related to the FO. If the reconstructed hip's FO is shorter than the native hip, the abductors become functionally weak as their tension is decreased [6]. The mean FO in this study was 4.09cm, with an average male and female value of 4.15cm and 4.06cm, respectively. These values are smaller than the average values of 4.70cm and 4.44cm from a French and Brazilian study, respectively. This difference is expected because it makes sense that a femur with a larger FNSA will have a smaller horizontal FO than one with a smaller FNSA. The FNSA in Africans have consistently demonstrated higher neck-shaft angles than those in other climes [5,16].

The average FND was 3.42cm in this study compared to 3.27cm by Katchy et al. [2], 3.66cm by Pires et al. [1] and 3.75cm by de Farias et al. [15]. These differences might relate to the landmarks chosen to represent the superior and inferior points of the neck. Also, Katchy et al. used cadaveric specimens while the others used conventional radiographs. However, it is the FNL that showed the most significant discrepancy with other study findings. The mean FNL in this study was 4.52cm, while it was 3.19cm, 3.57cm and 3.65cm in other works [1,2,15]. In contrast, the FNAL showed the greatest similarity to other researchers' findings. The mean FNAL in this study was 10.34cm, while it was 10.48cm, 10.84cm and 11.34cm in other works.

All the cited works used conventional radiographs like the index study [1,15,17]. The reason for these observations may be that the FND and FNL measurements depend on the two points where the researchers chose to use for their measurements. These two points could be anywhere along the femoral neck and are subjective. However, the FNAL has a definition, and the landmarks are clearly defined, and the measurement is more objective than the former two parameters.

Except for the FNL, the parameters did not significantly differ among the age categories of young, middle, and older age. The FNL differed only between the young and older age groups. The exact reason is unknown; however, the femoral neck, like the vertebral body, is mainly cancellous in older subjects and may be subject to load-related height decrease as occurs in the osteoporotic spine. This observation needs further studies to elucidate the reason.

In contrast, all the parameters, except the FO, significantly differ between the genders. However, the differences are slight. This observation further buttresses why p-values should not be interpreted in isolation but should be evaluated with the effect size. A small effect size could be statistically significant if the sample size is large enough. On the contrary, a substantial effect could have a non-significant p-value because of a small sample size [18].

Other studies also documented higher proximal femoral parameter values for males. Iyidobi et al [5]. Found higher male values for the FNSA, although it was not statistically significant. Lee et al. [19] found that Malaysian males have a significantly greater average FHD than females. Their study showed that the gender difference in the FHD is 4mm, which is clinically significant. In comparison, the FHD gender difference in the index work is 1.4mm. Although the exact cause is unknown, the fact that African women are generally heavier than their Asian counterparts may cause the femoral head to become thicker and approximate that of the male value.

This study showed that the subjects' height correlated with all the parameters except the FNSA. In contrast, the weight correlated with only the FND, FNAL and FNSA. However, all the correlations were small to moderate, $r < .5$, except the FNAL, which correlates strongly ($r = .501$) with the subjects' height. Hence, a tall subject will require a longer screw or longer blade length for femoral neck fracture fixation.

CONCLUSION

The proximal femoral anatomy in Africans differed from those published in foreign literature. This information is crucial for implant manufacturing companies and preoperative templating for hip surgeries.

Conflicts of Interests: None

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