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Study of Morphometric Collo-Diaphyseal Angle of Femur in Homozygous Sickle Cell Nigerian Children

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Authors' contributions

This work was carried out in collaboration between all authors. Author EEBB was involved in conception & design of the study, collection of data and first manuscript writing, author TWJ did statistical analysis and interpretation of data. Author DSA performed final analysis of manuscript and literature searches. Author AA managed provision of study materials/Radiographs and selection of normal Radiographs and draft measurements procedure. All authors read and approved the final manuscript.

Research Article

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ABSTRACT

Aims: The aim is to investigate the neck-shaft angle or Collo-Diaphyseal Angle (CDA) of femur and the effect of homozygous sickle cell (HbSS) on the angle.
Study Design: A retrospective study.
Place and Duration of Study: Radiology Departments of two Hospitals in Maiduguri, namely Umaru Shehu Modern Hospital and University of Maiduguri Teaching Hospital (UMTH), between January, 2009 - December, 2010.
Methodology: Using plain radiographs of the femur, a total of 194 HbSS and 40 control

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(non-HbSS) children below 17 years of age were selected. The study samples whose clinical data had been excluded from any diseases that could modify the femur were studied. The Technical Error of Measurement (TEM) was performed by the evaluator. Ethical clearance for the study was obtained from the relevant body of these government hospitals.
Results: The TEM values obtained were less than 1 and were considered as a good measurement method for the evaluator performance. The CDA (mean ± standard deviations) were higher in males than females. The CDA in the left femur was greater than the right both for males and females, respectively. Furthermore, the study documents, probably for the first time that in few cases there was a reduction in the CDA of HbSS when compared with the control groups. The study revealed that there was sexually significant variation ($p<0.05$). The demarking points and index of sexual dimorphism of CDA show sex differences and can be used for sex determination.
Conclusion: The results from this study reveal that the mean CDA of femur of HbSS children of the study population were sexually dimorphic. The information from this study may aid forensic pathologists, orthopaedic surgeons and future research in evaluation of the femur.

Keywords: Femur; collo-diaphyseal angle; homozygous sickle cell; Maiduguri; Nigeria.

1. INTRODUCTION

The femur is the thigh bone. In the human, it is the longest, most voluminous and strongest bone. The neck-shaft angle and angle of inclination also known as collo-diaphyseal angle (CDA) of femur is the object of study, being that the values obtained, could be adopted as standards for the inhabitants of a region (Purkait, 1996). The angle of inclination that the long axis of the femoral neck makes with the femoral body varies with age, sex, and development of the femur (Keith and Arthur, 2006).

Sex determination from skeletal remains is an important component in human identification, especially when subjected to statistical and morphological analysis for the purpose of determining sex. The femur has peculiarities, the most conspicuous being the angulations of the neck which is a consequence of the evolution of erect posture and bipedalism in man among other structural modifications. The femora neck-shaft angulations results in structural weakness at this junction and hence this end of the femur has assumed great importance (Kate, 1970).

Reports from Chaurasia (1981) revealed that the femoral portions are also being used to differentiate the sex of unknown skeletons since a region was susceptible to alterations between men and women.

According to Carme et al. (2008) any femoral measurement was likely to serve as a useful source to estimate sub-adult age in both archeological and forensic samples. Archeological human bones specialists, osteoarchaeologist, physical/biological anthropologists or clinicians may find the use of radiologic metric analysis in the standardization of the skeleton for evaluation of abnormalities (Brothwell, 1981).

Anatomists are often called upon to give an expert opinion in medico legal cases pertaining to sex from the available skeleton of the deceased (Meshram et al., 2003).

The availability of basic geometric data describing the proximal femur allows assessment of the match between the shape of existing components and the proximal femur and allows guidelines to the development of new prosthetic designs (King et al., 1998).

It was estimated that a total of 37 million Nigerians suffer from sickle cell disease (Akinyanju, 1989).

Sickle cell disease is a chronic hemolytic disease and may cause insults of the blood supply to the femur producing radiographic changes. Its features are variable in different sexes and age groups in different populations. After the first report of radiological findings in sickle cell disease by Cooley (1927), diagnostic modalities relied initially on conventional radiography (Elizabeth et al., 2004).

The descriptions of skeletal changes sequelae of sickle cell disease are almost as old as the description of the sickling event itself (Jeffrey et al., 2006).

Ivan et al. (2007) showed that plain radiography of the extremities of sickle cell disease patients is useful in evaluating sub acute and chronic infarction and in assessing the number and severity of prior episodes of infarction. It is excellent for evaluating deformities and other complications of deformities in patients with this disease.

However, there is paucity of published work as at present on the morphometry of the femur in sickle cell patients in relation to age and sex in Nigeria, hence the need for this survey.

2. MATERIALS AND METHODS

Scope of Study: The retrospective study was conducted from January, 2009- December, 2010 on plain radiographs of the femur of patients with homozygous sickle cell anemia (HbSS) in Maiduguri, Nigeria.

Ethical Approval: The study received approval by the University of Maiduguri Teaching Hospital Research and Ethical Committee.

Patient Selection: A total of 194 (97 males and 97 females) children below 17 years of age were selected. The children were stratified into different age-groups each for males and females according to Behram et al., 2004 as follows: 3-7years (32), 8-12years (32) and 13-17years (33). Forty (40) control (non-HbSS) subjects were distributed into similar age-groups each for males and females, which include; 3-7years (4), 8-12years (8) and 13-17years (8) according to Elizabeth et al., 2004. The radiographs were collected from the Radiology departments of two hospitals in Maiduguri, namely Umaru Shehu Modern Hospital and University of Maiduguri Teaching Hospital (UMTH).

The study samples whose clinical data had been excluded from any diseases (fracture, osteoporosis or osteoarthrosis) that could modify the femur were studied. Patients with extensive areas of necrosis, previous surgeries and accidents with fracture of femoral head were excluded from the study.

2.1 Formations and Measurements of Collo-diaphyseal Angle

Each radiograph was placed horizontally on the surface of the illuminator box and measurements carried directly on the AP view as adopted by (Singh et al., 1986; Christopher et al., 1998; Tahir et al., 2001).

The CDA was measured on right and left femora in plain radiographs (exposing the hip joint) of HbSS patients using transparent graduated measuring rule (mm), calibrated protractor (00), illuminator box and HB pencil. At 2cm intervals, marked midpoints of three horizontal lines starting from the superior end of the lesser trochanter were connected vertically passing above and medial to the greater trochanter. Also a line was drawn from the fovea centralis of the head of the femur and distal end of the greater trochanter to cross/intersect the vertical line. The angle was formed and located immediately anterior to the intertrochanteric line of the upper end of the shaft. The calibrated protractor was placed directly on the radiograph already fixed on the illuminator box. The readings were taken and recorded.

2.2 Statistical Analysis

Data obtained from the measurements were subjected to statistical analyses using ANOVA (analysis of variance) with Instat 3 Graph Pad Guide (1998). Mean standard deviation and 95% confidence intervals (CI) for the collo-diaphyseal angle were calculated. A probability level was declared significant at $p<0.05$, 0.01 or 0.001 and not significant at $p>0.05$. The index of sex dimorphism (ISD) was analyzed adopting the formula: male mean÷female mean x 100% (Ilayperuma, 2011). Demarking points were calculated from the formula: Mean ± 3 x standard deviation (Singh and Gangrade, 1968). The Demarking Points (DP) (maximum and minimum limit) of the measurements was calculated in different sex and age groups.

2.3 Technical Error of Measurement (TEM)

It is necessary for anthropometrists to evaluate some degrees of error observed in the measurement of an object. In measuring same object for more than one occasion, the values obtained may differ. Thus giving rise to TEM (intra-observer or intra-evaluator). It is essentially the standard deviation between repeated measures (Geeta, et al., 2009). The TEM measurements were performed within the same group of volunteers [forty measurements (20 each for control and HbSS, respectively)] and both gender in the morning and afternoon of same day were measured using the method explained above. The difference between the 1st (beginner anthropometrist) and 2nd (beginner anthropometrist) measurements was determined and subjected to analysis using the formula, TEM (Ulijaszek and Lourie, 1994),

$$TEM = \sqrt{\frac{\sum D^2}{2N}}$$

Where:
D is the difference between measurements made on a given object on two occasions.
N is the total number of measurements made on those two occasions (N =40 in this study).

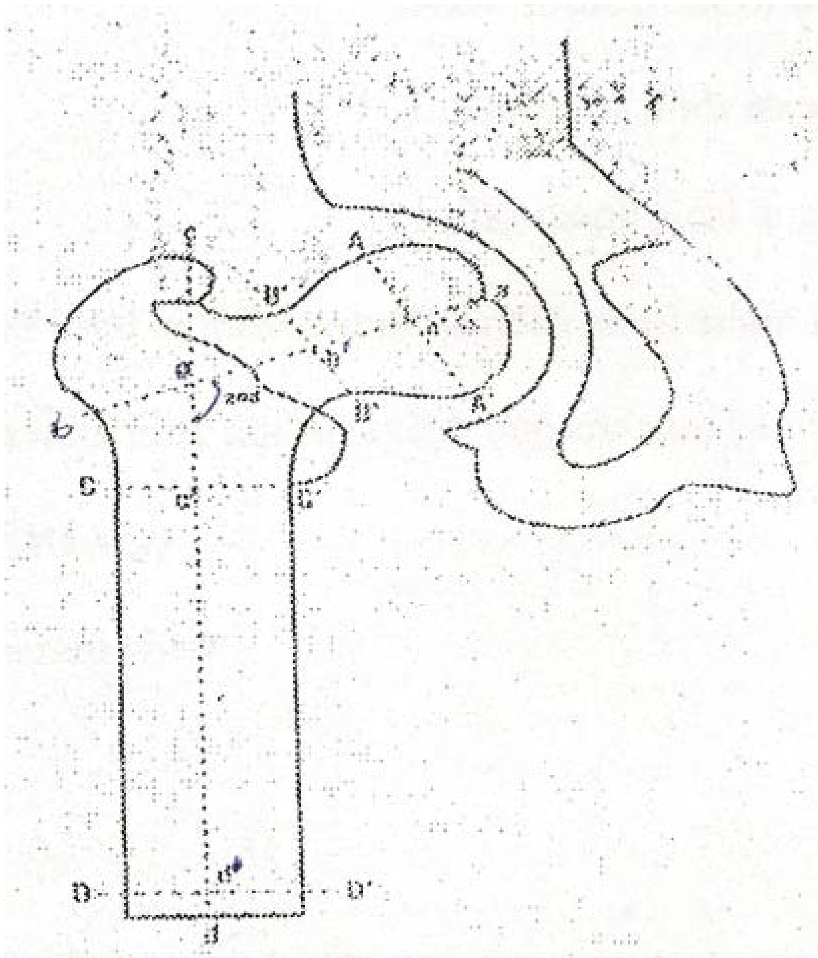

Fig. 1. Measurement of the collo-diaphyseal angle of the femur (Adopted from Tahir et al., 2001)

AA1: Maximum diameter of the head of the femur.
BB1: Minimum diameter of the neck of the femur.
a1: Midpoint of AA1.
b1: Midpoint of BB1.
CC1: Maximum diameter of the shaft of the femur just below the lesser trochanter.
c1: Midpoint of CC1.
DD1: Maximum diameter of the shaft of the femur away from its distal end.
d1: Midpoint of DD1
cd: Axis of the shaft of the femur
ab: Axis of the neck of the femur
o: Intersect of lines ab and cd
aod: Collo – diaphyseal angle of the femur

3. RESULTS

Table 1 show that the TEM of the control was higher than that of HbSS. This is because the measurements were taken with the control before the HbSS samples, though both of them were subjected to the same method and calculations stated above. All the values obtained were less than 1; the lower the values of TEM obtained, the better the accuracy of the evaluator in carrying out the measurement. Therefore, this suggests that our method of measurements was generally good for the evaluator performance. It is a common practice that many researchers have been reluctant to add to their findings the estimated TEM. This is likely due to the fact that many of them felt that the result obtained from their study may be undermined. Thus, workers need to appreciate the fact that TEM represents measurement quality and control dimension studies.

Table 1. TEM of average mean CDA of Control and HbSS patients (right side, female) in (º) = (degree)

	N = 40	
Age (yrs)	**Control**	**HbSS**
3-7	0.9	0.7
8-12	0.6	0.5
13-17	0.3	0.2

N = total number of measurements, yrs= years, HbSS= homozygous sickle cell, (º) = (degree)

Table 2 indicates that CDA was greater in males than females in the control and cohort study in the age category. In most cases, the CDA in the left femur was greater than that in the right for both males and females. However, the values in the HbSS patients were lower than those in the control. There were significant differences ($p<0.05$) between sexes.

The DP of mean CDA was higher in control and HbSS male than female; the values were mostly higher in HbSS patients than in the control (Table 3).

The mean ± SD of CDA was higher in the control and HbSS male than female; but the values were mostly higher in the control than HbSS subjects (Table 4).

Table 5 reveals that the demarking points of CDA were greater in the male than female in the control and cohort study age-groups. In most cases, the values in the male and female lefts were respectively greater than the rights.

Table 2. Mean ± SD of CDA of control and HbSS patients by age-group and sex (º)

	N= 194 (HbSS), N=40 (control)							
Age (yrs)	**Control Rt male**	**HbSS Rt male**	**Control Lt male**	**HbSS Lt male**	**Control Rt female**	**HbSS Rt female**	**Control Lt female**	**HbSS Lt female**
3-7	40.1±0.1	40.1±0.2	40.4±0.1	40.3±0.2	39.7±0.2	39.7±0.3	39.8±0.2	39.9±0.3
8-12	60.0±0.7	60.0±0.7	60.1±0.7	60.1±0.7	53.6±3.8	52.8±4.0	53.7±3.8	53.0±4.0
13-17	89.8±1.2	89.8±1.1	89.9±1.2	89.8±1.1	79.3±30	79.2±3.0	79.5±3.0	79.3±3.0

N = total number of measurements, CDA=collo-diaphyseal angle, yrs= years, Rt= right, Lt =left, SD =standard deviation, HbSS= homozygous sickle cell, (º) = (degree) p<0.05

Table 3. Demarking points of mean CDA of right and left male and female control and HbSS patients by age-group and sex (º)

Age(yrs)	Control (male)	HbSS (male)	Control (female)	HbSS (female)
3-7	>40.4	>40.7	<40.0	<40.4
8-12	>65.1	>65.3	<58.0	<58.0
13-17	>88.4	>88.3	<84.8	<85.0

CDA=collo-diaphyseal angle, yrs= years, HbSS= homozygous sickle cell, (º) = (degree)

Table 4. Mean±SD of CDA of right and left femur in males and females control and HbSS groups in each age-group and sex (º)

	N= 194 (HbSS), N=40 (control)			
Age(yrs)	**Control (male)**	**HbSS (male)**	**Control (female)**	**HbSS (female)**
3-7	40.3±0.1	40.2±0.2	39.8±0.2	39.8±0.3
8-12	60.1±0.7	60.1±0.7	53.7±3.8	53.3±4.0
13-17	88.4±1.2	88.3±1.1	79.4±3.0	79.3±3.0

N = total number of measurements, CDA=collo-diaphyseal angle, yrs= years, HbSS= homozygous sickle cell, (º) = (degree) p<0.05

Table 5. Demarking points of mean±SD CDA between control and HbSS patients (º)

Age (yrs)	*Control Rt male*	*HbSS Rt male*	*Control Lt male*	*HbSS Lt male*	*Control Rt female*	*HbSS Rt female*	*Control Lt female*	*HbSS Lt female*
3-7	>40.3	>40.6	>40.4	<40.8	< 38.9	<39.5	<40.1	<39.7
8-12	>65.0	>64.8	>65.1	<65.0	<57.9	<57.9	<58.0	<58.0
13-17	>88.3	>88.2	>88.5	>88.3	<86.2	<86.5	<86.3	<86.0

CDA=collo-diaphyseal angle, yrs= years, Rt= right, Lt =left, HbSS= homozygous sickle cell, < = Less than, >= Greater than, (º) = (degree) p<0.01.

The ISD increases with age but the values in the control were lower in most cases than in HbSS patients (Table 6).

Table 6. Index of Sexual Dimorphism of mean CDA between Control and HbSS Patients

Age (yrs)	**Control (%)**	**HbSS (%)**
3-7	1.2	1.0
8-12	10.7	11.9
13-17	11.6	11.7

CDA=collo-diaphyseal angle, yrs= years, HbSS= homozygous sickle cell. P<0.05

4. DISCUSSION

In the present study, femoral CDA were analysed in control and HbSS patients at different age-groups (3-7, 8-12 and 13-17 years), which are simple, reproducible and objective measurements.

Data obtained by CDA measurements of the male and female right and left femora indicated that in few cases the control groups were higher than the HbSS samples (Tables 2 & 4). This reduction in the HbSS samples could be due to repeated vasoocclusive crises suffered at the proximal femur. These available osteometric data correlations will help in clinical assessment of the comparison between the shape and size of the reduced angle and proximal femur in order to provide procedures to the development of durable prosthetic design for total hip arthroplasty (Bulent et al., 2007). The results of this study show that the femoral CDA gave higher classification accuracy (89.0 percent for control and 74.6 percent for HbSS).

Our study reaffirmed that the mean±SD CDA of the femur in the male was higher than that in the female, but the values in male and female left femur were higher than those in the right (Table 2). However, there was significant differences (p<0.05). This pattern of result is similar to other worker's findings in adult femoral CDA (Hoaglund et al., 1980; Nwoha, 1991; Cheng et al., 1997; Keith and Arthur, 2006; Ibrahim et al., 2009).

Sex difference may as a result of genetic factors, environmental factors affecting growth and development (nutrition, physical activity, and pathologies), or even interaction of these factors (Trancho et al., 1997). This variation shows that the average male skeleton is longer and more robust than that of the female, although the magnitude of difference varies from population to population. The increase in CDA in the left femur than the right is supported with the fact that the left femur is considered dominant, because most individuals use the left side as weight support (Isaac et al., 1997).

Also according to Ferrario et al. (1998), asymmetry between the sides is a common finding in normal femora of human beings; and that in human long bones there is weight, length and shape asymmetry when analyzed from a mathematical standpoint. Furthermore, the femur of the left side was reported to be larger and longer regardless of the sex. This sex difference can be the result of genetic or environmental factors affecting growth and development (nutrition, physical activity, and pathologies), or the interaction of these factors (Ruma and Heeresh, 2002). The angle is less in female because of the increased breadth of the lesser pelvis (true pelvis, or pelvis minor) and the greater obliquity of the body of the femur (Keith and Arthur, 2006).

Results from our findings revealed that CDA increases with age (Table 2 & 4). This trend is likely that at birth the neck is short, thick and increases in length as the bone grows (Edie et al., 2007). Therefore, the upper end of the femur, especially the head neck angle, assumed great importance in orthopaedic surgery.

The accuracy of demarking point is a measure that was used in sexing adult femur of South African whites and blacks (Asala, 2002). The demarking point in the male was greater than that of the female in the cohorts studied (Table 3 & 5). Sexual dimorphism is a vital component of the morphological variation among biological populations (Ilayperuma, 2011).
The values of ISD in all the age groups were 1.0% and above (Table 6). Therefore, demarking points and index of sexual dimorphism is sexually dimorphic and may be used for sex determination. These measures being used for sexual determination may be due to the fact that axial skeleton weight of the male was relatively and absolutely heavier than that of the female, and initial impact of this weight is borne by the femur in transmission of the body weight. Hence, the stress and strain experienced by the femur is different in male than it is in female (Ruma and Heeresh, 2002).

Clinically, knowledge on the CDA of the femur in HbSS children of a specific population is multifold. It may provide evidence in forensic examination and guidelines to the development of new prosthetic designs for internal fixation. This survey can also provide data pools for more research development.

5. CONCLUSION

The study has demonstrated significant differences in the morphometry of the femoral collo-diaphyseal angle in HbSS patients in all the age groups. This result is consistent with the control groups and reports from previous studies on normal adult femora in other population even though different methods were adopted to study these parameters. The angle increased with age. The male femoral collo-diaphyseal angle was greater than the female but the right male and female were lesser than the left male and female respectively. The angle in all the age groups demonstrated asymmetry between sexes and shows $P<0.05$. However, between right and left there were no significant differences ($P>0.05$). The demarking point and index of sexual dimorphism of CDA was sexually dimorphic and can be used for sex determination. Hence more studies on CDA are required to explore the racial and other pathological variations that exist.

CONSENT

All authors declare that 'written informed consent was obtained from the University of Maiduguri Teaching Hospital (UMTH) and Umaru Shehu Modern Hospital Departments of Radiology and Haematology for publication of this study.

ETHICAL APPROVAL

All authors hereby declare that all radiographs and measurement protocol have been examined and approved by the ethical committee of the University of Maiduguri Teaching Hospital (UMTH) and have therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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