UNIVERSITY OF GHANA

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PROXIMAL FEMUR INDICES OF ADULTS IN GHANA

BY

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DECLARATION

DECLARATION BY THE CANDIDATE

I hereby declare that this is the product of my own research undertaken under supervision and has neither been presented in whole or in part for another degree elsewhere. I am solely responsible for any residual flaws in the work.

Signature…………………………………………Date…………………………..

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DECLARATION BY SUPERVISORS

We hereby declare that the practical work and presentation of the thesis were supervised by us in accordance with guidelines on supervision of thesis laid down by the University of Ghana.

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ABSTRACT

Background: Definite knowledge of the anatomical indices of adult proximal femur of indigenous Ghanaians will better inform procurement of best-fit prostheses imported from abroad, where these are made for populations with different anthropological indices. This development should forestall the occurrence of misfit femoral prostheses and attendant health hazards in Ghana.

AIM: This study generated clinically relevant anatomical dimensions of the proximal femur in Ghanaian adults for possible use in prosthesis manufacture for replacement surgery in indigenous Ghanaians.

Method: Four dimensional variables of the proximal femur, namely; the head diameter, the neck diameter, the hip axis length, and the neck shaft angle were measured bilaterally using archived anteroposterior radiographs of the pelvis of 125 adult patients. There were 74 males and 51 females, aged 31 to 82 years who had accessed services at the Radiology Unit of Korle-Bu Teaching Hospital from April 2017 – May 2018. The obtained data were analyzed using SPSS version 20.0.

Results: Females had significantly greater femoral head diameter than males, with means of 5.06 cm (females) and 4.84 cm (males), (P = 0.020) on the left side and 5.15 cm (females), and 4.92 cm (males), (P = 0.021) on the right side. Similarly, females’ femoral neck diameter was significantly wider than in males. Mean Neck diameter was 3.96 cm (females) and 3.74 cm (males), (P = 0.043) on the left side; and 4.00 cm (females) and 3.82 cm (males), (P = 0.018) on the right side. Right side values for both femoral head and neck diameters were significantly greater than left in both sexes. The mean femoral neck shaft angle did not show any statistical difference between the females and males with means of 131.43° (females), and 131.82° (males), (P – 0.790) for the left side and 132.22° (females) and 132.34° (males), (P – 0.457) for the right side.
Conclusion: Significant sexual dimorphism and laterality were demonstrated in adult proximal femoral indices in the Ghanaian population. The indices were significantly greater in females than in males, and on the right side than the left side. This may reflect the greater hip dimensions in females than males and predominance of right-handedness in the Ghanaian population. It is proposed that the generated data should provide reference values for surgeons to advice manufacturers of hip prostheses for adult Ghanaians.
DEDICATION

This work is dedicated to my wife, Adams Salamatu for the love, support and patience she showed me throughout my study. Also, to my son Faiz Sabari whom I love so much.
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My sincere gratitude goes to Allah for the grace and strength to go through this program successfully.

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To the Secretary of the Department of Anatomy Mrs. Monica Dzikunu, thank you.
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<tr>
<td>AP</td>
<td>Anteroposterior</td>
</tr>
<tr>
<td>DHS</td>
<td>Dynamic hip screw</td>
</tr>
<tr>
<td>HDL</td>
<td>Head diameter left</td>
</tr>
<tr>
<td>HDR</td>
<td>Head diameter right</td>
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<tr>
<td>HALL</td>
<td>Hip axis length left</td>
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<tr>
<td>HALR</td>
<td>Hip axis length right</td>
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<tr>
<td>KBTH</td>
<td>Korle-Bu Teaching Hospital</td>
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<tr>
<td>NDL</td>
<td>Neck diameter left</td>
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<td>NDR</td>
<td>Neck diameter right</td>
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<td>NSAL</td>
<td>Neck shaft angle left</td>
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<td>NSAR</td>
<td>Neck shaft angle right</td>
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<td>PFI</td>
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CHAPTER ONE

INTRODUCTION

1.0 BACKGROUND OF STUDY

The femur is the longest and one of the strongest bones that have been thoroughly studied anatomically. It has three parts; the proximal end, a distal end and a long shaft (Kalamullah & Akbar, 2015)

The femur is ossified from one primary center for the shaft, three secondary centers of ossification for the upper end, one each for head, greater trochanter and lesser trochanter and one secondary center for lower end. The primary center appears in the middle of the shaft at about 7th week of intrauterine life. The center for the head appears at about 6th month to 1 year after birth, that for the greater trochanter about 4th year, and for lesser trochanter at about 14th year. The lesser trochanter unites with diaphysis during 16th year, the greater trochanter at 17th year, and the head at about 18th year. The neck is derived from the primary center as an extension of shaft. The epiphyseal plate between the head and neck is initially horizontal and becomes oblique by the age of 8 to 12 years. Therefore, the lower end is growing end of femur. The head and lower end are pressure epiphyses, whereas the greater and lesser trochanters are traction epiphyses (Pillai et al., 2014)

The proximal rounded head articulates with the acetabulum of the hip bone which is formed by the fusion of ischium, ilium, and pubis in the fetal period. A roughened, shallow pit called the fovea capitis is in the lower center of the head of the femur. The constricted region supporting the head is called the neck and it is a common site for fractures. On the proximo-lateral side of the shaft is the greater trochanter and on the medial side is the lesser trochanter. On the posterior side
between the trochanters is the intertrochanteric crest and on the anterior side is the intertrochanteric line. The linea aspera is a vertical ridge on the posterior surface of the shaft. The distal end of the femur is expanded for the articulation with the tibia. The lateral and medial epicondyles are the articulating processes (Kent, 1992).

According to Lunn et al., 2016, the hip joint is unique physiologically, anatomically and developmentally; therefore appreciating the fundamental structure and biomechanics of the hip is essential for clinicians, physiotherapists and engineers alike. Classically the hip joint is a synovial joint. The articulating bones are the head of femur and the acetabulum (which is formed by fusion of ilium, ischium, and pubis in the fetal period). It is a true ball-and-socket joint surrounded by powerful and well-balanced muscles, enabling a wide range of motions in several physical planes whilst also exhibiting remarkable stability).

This hip joint provides the stability and load-bearing requirement but at a cost of a severe limitation in the range of motions. This restriction is greatly compounded by the angulation and length of the femoral neck. The angulation in relation to the vertical axis of the shaft is 125° in the adult. It tends to be greater in children (Balderston et al., 1992). Figure 1.0 shows a typical proximal femur.
Figure 1: A Photograph of the proximal femur: Obtained from Teaching Collection: University of Ghana, Legon. Department of Anatomy
The neck of the femur in humans is an important functional modification after man attained an erect bipedal posture (Ravichandran et al., 2011). Proximal femur geometry is the morphological features of the proximal femur (Baharuddin et al., 2011). These include femoral neck axis length, femoral neck diameter, femoral head diameter, neck shaft angle and intertrochanteric length (Adjei, 2015).

Many studies have been conducted using MRI, computerized tomography and radiography on dry bone on the proximal femoral geometry, which showed substantial variations of these parameters among populations of different geographic regions and races (Toplumunda et al., 2017, Rubin et al., 1992, Mitra et al., 2014, Gilligan, Chandraphak, & Mahakkanukrauh, 2013, Baharuddin et al., 2011). Moreover, examination and statistical analysis of femoral anthropometry among different populations reveal a great amount of variation explicable by 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 lifestyle (Pillai et al., 2014). Different races have different genetic predisposition whilst bone density is under strong genetics and familial influence (Kelly et al., 1990). The Ghanaian physique and body built are not the same as other races because of genes, cultural habits (eating and the type of foods) and activities (Adjei, 2015). Unique features of most Ghanaian diets in quantity and composition has been reported (Ashigbie, 2015), as food is mostly served in plenty with greater of the served food being carbohydrates.

It is also known that Proximal femoral geometry is affected by different factors such as ethnicity, genetics and environmental conditions (Kalamullah & Akbar, 2015). There is substantial evidence suggesting that femoral geometry is largely determined by genes in both humans and other animals (Karasik et al., 2007). The genetic makeup of black Africans including Ghanaians is different from
their Western and Asian counterpart. Ghanaians are more stoutly built than Asians in general but are however less massive than the Caucasians from the West (Elvis, Thomas, & Thomas, 2018).

The following studies demonstrated differences of the anthropometry of the proximal femur between ethnic groups which are due to differences in lifestyle, physique, genetics, applied force and their distribution in the Western and Eastern populations, (Hoaglund & Low, 1980; Gnudi et al., 2004; Calis et al., 2004; Igbigbi & Msamati, 2002; Mahaisavariya et al., 2002; De Sousa et al., 2010; Mishra et al., 2009; Caetano et al., 2007; Da Silva et al., 2003)

The proximal femur indices of men and women could be different based on the activities of the gender involved (Looker, Beck, & Orwoll, 2001). In Ghana, men tend to be more musculously built than women, whereas women tend to be more overweight and obese than men (Ashigbie, 2015; Adu & Adu 2015). The overweight of the torso of women acting on the femur could physiologically make the femur stronger and also women carry a lot of heavy loads and walk far distances that would have the above effect on the proximal femur (Nurzenski et al., 2007). These activities and body built could result in different femur indices (Duda et al., 1997; Nieves et al., 2005)

According to Ruff, 1987, the structure of the proximal femur of females varies from males because of a greater pelvic width in the ability to bear children. The wider interacetabular distance of females would result in greater mediolateral bending of the subtrochanteric region, causing a difference in their measurement (Lynn Brown, 2006).

Recent studies (Bergot et al., 2002; Aly, 2017), suggest that variations in Proximal Femoral Indices also contribute to the etiology of hip fractures. “The characteristic morphology of the proximal extremity of the femur and the muscle balance of the hip are factors that make weight-bearing possible among patients. Recent study has been conducted with the intention of showing the
relationship between the fracture of the proximal extremity of the femur and the anatomical configuration of the hip (Aly, 2017).

Femoral neck-shaft angles (NSA) show considerable variation within human populations (Pathak et al., 2016). The average individuals are found to have from around 110° to almost 150° (Kaur, Mathew, & George, 2013). However, measurement problems and sampling limitations have precluded the identification of factors contributing to its variation at the population level. Potential sources of variation include sex, age, side (left or right), regional differences in body shape due to climatic adaptation, and the effects of habitual activity patterns (Gilligan et al., 2013). The development of bones depends on the applied forces that are exerted on the bone (Lynn Brown, 2006). The laterality or handedness of a person could influence the development of the bone based on activities the person is engaged in. All people are not the same in the use of a limb, therefore there are those who are right-handed and others whose handedness are left. The more one uses the predominant handedness the more it development from the other (Verlagsbuchhandlung, 2019). In his work, Steele (2000), studies assume that the association between behavioral and morphological asymmetry is through mechanically driven bone growth and remodeling.

An increase in the elderly population has resulted in raising the incidence of hip fractures in many parts of the world. Increased longevity, coupled with osteoporosis and muscular insufficiency in the aged, could explain the increasing number of clients with hip fractures (Aly, 2017). Evidence postulated that variations in Proximal Femoral Indices (PFI) also play an important role in hip fracture etiology (Cummings et al., 1993). The Study of Osteoporotic Fractures demonstrated that increased Hip Axis Length (HAL) is associated with increased hip fracture risk, independent of age and bone density (Patton et al., 2006). Evidence to date suggests an association between longer neck length and intracapsular fractures, as opposed to extracapsular fracture (Gao et al., 2008).
In the USA white women have twice the risk of fractures in comparison with black women (Ramalho et al., 2001). In a study of hip fractures in a region of Santiago, Chile, women showed 1.5 times greater incidence than men. In comparison with Caucasians rates, the Chilean rates are six times lower in women and three times lower in men (Ramalho et al., 2001). The Chilean women have shorter hip axis length compare to the Caucasians women which is a predictor of hip fracture (Glüer et al., 1994). These women of different continent showed very varied predisposition to hip fractures because of different proximal femur indices which can be attributed to genetic variation, geographical location, habitual activities and lifestyle (Cummings et al., 2005). These differences demonstrate the importance of evaluating the epidemiological features of proximal femur fracture in different countries.

In India, with a population of about 1.21 billion people, approximately 6 million people are osteoporotic and 2.3 million people are being added to the list every year (Bergot et al., 2002). One out of three women and one out of eight men are suffering from the osteoporotic bone fracture (Cummings et al., 1993). These fractures are associated with increasing age, menopause and decreased the amount of estrogen produced by the body. Nearly 75% of all hip fractures occur in women and about 25% of hip fractures in people over 50 years occur in men (Chie et al., 2004). A 50-year-old woman has a 2.8% risk of death related to hip fracture during her remaining lifetime, equivalent to her risk of death from breast cancer and 4 times higher than that from endometrial cancer (Gnudi et al., 1999). Approximately 1.6 million (0.024% of the present population of the earth) hip fractures occur worldwide every year and by 2050 this number could reach between 4.5 million and 6.3 million (Sakaki et al., 2004)

Early operative treatment (open anatomical reduction and internal fixation) is the treatment of choice for virtually all trochanteric fractures because it allows early rehabilitation and offers the
patient the best chance for functional recovery. This is the best option to reduce the risk of complications like non-union and avascular necrosis in treating fracture of the neck of femurs (Mittal & Banerjee, 2012). Intertrochanteric fractures usually unite if reduction and fixation are adequate, and late complications are infrequent. These procedures require insertion of appropriate implants. The success depends on the precise match between the dimensions of the implants and the femur (Ravichandran et al., 2011).

The morphology of the proximal femur is an essential parameter in the design and development of implant for total hip replacement. Inappropriate implant design and size could affect the outcome of the surgery with reported complications such as stress shielding, micromotion and loosening (Dewo et al., 2016). Most of these implants are designed and manufactured from the European and North American region which presumably are based on the anthropometric data of their respective populations (Ravichandran et al., 2011). The use of such implants in other regions such as Ghana may not be appropriate as the design may not take into consideration the morphology of the local population (Khan & Saheb, 2014; Toplumunda et al., 2017).

Because of the great variation of femoral anatomy in the normal population, the precise bone-implant fit is difficult to achieve and there have been few detailed studies of the geometry of the femur (Rubin et al., 1992). Many studies have been conducted using computerized tomography and radiography on dry bone on the proximal femoral geometry, showed substantial variations in these parameters among populations of different geographic regions (Toplumunda et al., 2017).

In the Ghanaian population, there is scarce or no published data on the proximal femur indices and as such rely on the prosthesis that were produced using different population indices. There is a rise in the incidence of hip fractures in the country. Procurement of appropriate and best –fit prostheses would be achieved if the indices of the Ghanaian population data is available to the procuring
authorities. It would also aid surgeons to make informed decisions (best-fit prostheses) pre-operatively. It would also help authorities to manage available resources.

1.1 PROBLEM STATEMENT

The incidence of hip pathology is increasing in Ghana, to ensure that scarce resources are not wasted, local data concerning the femoral anthropometric measurements of the Ghanaian adult is necessary to ensure best-fit prosthetics, implants, etc. are procured to manage and/or treat hip pathology.

1.2 JUSTIFICATION OF THE STUDY

While data regarding adult femur anthropometric indices is available for Western and Asia population, the same cannot be said about the Ghanaian population. This study sought to generate primary data on the indices of the adult proximal femur in Ghanaians. Personal communication with Orthopaedic Surgeons in Ghana suggests an increasing occurrence of mismatch of hip prosthetics. Currently, prosthetics are imported from Europe or Asia which are made for their population whose built, physique, habits, genetic make-up and personal lifestyle are different from those of Ghana. (Mishra et al., 2009). Manufacturers of proximal femur implants need reliable data to guide them in designing prostheses to be used for patients in Ghana.

This study will also provide a relevant database that will guide the procurement of appropriate size implants and guide surgeons in choosing the right implant for total hip arthroplasty.
1.4 AIM

To generate clinically relevant anatomical dimensions of proximal femur in Ghanaian adults by measuring proximal femur geometric indices in Ghanaian adults.

1.5 SPECIFIC OBJECTIVES

The following will be the specific objectives of the study:

- To measure the femoral neck diameter, the neck shaft angle, femoral head diameter, and femoral hip axis length in Ghanaian adults.
- To determine if any of these indices demonstrate sexual dimorphism.
- To determine whether there are differences between the right and left dimensions.
- To determine age-dependent variations in these variable.
CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 OSTEOLOGY OF THE HUMAN FEMUR

The femur is the longest, heaviest, and strongest bone in the body. The parts of this bone are shown in Fig. 2.1 below. The proximal rounded head articulates with the acetabulum of the os coxae. A roughened, shallow pit called the fovea capitis is in the lower center of the head of the femur. The constricted region supporting the head is called the neck and it is a common site for fractures. On the proximo-lateral side of the shaft is the greater trochanter and on the medial side is the lesser trochanter. On the posterior aspect there is a prominent ridge between the trochanters along the line of attachment between the posterior surface of the neck and the shaft, called the intertrochanteric crest and on the anterior side is the intertrochanteric line. The linea aspera is a vertical ridge on the posterior surface of the shaft. The distal end of the femur is expanded for the articulation with the tibia. The lateral and medial epicondyles are the articulating processes (Kent, 1992).

The femur is ossified from one primary center for the shaft, three secondary centers for the upper end and one for the distal end. The primary center appears in the middle of the shaft at about 7th week of intrauterine life. The secondary ossification centers for the upper end are for the head, greater trochanter, and lesser trochanter. The center for the head appears at about 6th month to 1 year after birth, that for the greater trochanter about 4th year, and for lesser trochanter at about 14th year. The lesser trochanter unites with diaphysis during the 16th year, the greater trochanter unites with diaphysis during 16th year, the greater trochanter at 17th year and the head at about 18th
year. The neck is derived from the primary center as an extension of the shaft. The epiphyseal plate between the head and neck is initially horizontal and becomes oblique by the age of 8 to 12 years. Therefore, the lower end is growing end of the femur. The head and lower end are pressure epiphyses, whereas the greater and lesser trochanters are traction epiphyses (Pillai et al., 2014).

Consistent with its weight-bearing requirements, the proximal femur has the thickest and strongest shaft of all long bones (Balderston et al., 1992). It receives the nearly vertical thrust from the pelvis through it angulated and uniquely configured upper end. This consists of a globular head affixed to a superiorly, anteriorly, and medially directed neck that is distally related to two muscular processes, the lateral greater trochanter, and the posterior medial lesser trochanter. The femoral head is deeply and securely engaged in the acetabulum and his provides the stability and load-bearing requirement but at a cost of a severe limitation in the range of motion. This restriction is greatly compounded by the angulation and length of the femoral neck. The angulation in relation to the shaft is 125 degrees in the adult and tends to increase in long femora and in the child and decrease in shorter bones and females (Balderston et al., 1992).

The downward thrust of the body upon the head of the femur and the resistance through the shaft produce displaced parallel lines of force that tend to shear the neck, a risk that is much increased in the demineralized bone of the aged. The morphology of the proximal femur, specifically the relationships among the head, neck, and proximal shaft has been a subject of interest and debate in orthopedic literature dating back to at least the middle of the 19th century (Skalak et al., 2009).
2.1.1 THE FEMORAL HEAD
The femoral head is covered with a corresponding articular cartilage beyond the reaches of the acetabular brim to accommodate the full range of motion. The covered region forms approximately 60 to 70% of a sphere. There is an uncovered area on the central area of the femoral head – the fovea capitis – for the femoral insertion of the ligamentum teres. The ligamentum teres femoris, while containing a blood supply does not contribute to the stability of the joint. The vascular supply to the femoral head has been well studied due to the risk of vascular necrosis of the head when it is disrupted, particularly in fractures of the femoral neck or dislocation of the hip. Three sources are noted: a small vessel found within the ligamentum teres, a supply from the medullary canal and an anastomosis of vessels creeping around the femoral neck (Lunn et al., 2016).

2.1.2 THE FEMORAL NECK
The head of the femur is attached to the femoral shaft by the femoral neck, which varies in length depending on body size. The neck-shaft angle is usually 125±5° in the normal adult, with coxa valga being the condition when this value exceeds 130° and coxa vara when the inclination is less than 120 (Lunn et al., 2016). The neck of the proximal femur is susceptible to fractures, especially in osteoporotic patients. The neck-shaft angle steadily decreases from 150° after birth to 125° in the adult due to remodeling of bone in response to changing stress patterns. The femoral neck in the average person is also rotated slightly anterior to the coronal plane. This medial rotation is referred to as femoral anteversion. The angle of anteversion is measured as the angle between a mediolateral line through the knee and a line through the femoral head and shaft. The average range for femoral anteversion is from 15 to 20° (Lunn et al., 2016)
The proximal femur acts as a brace, and its biomechanical properties depend on the width and length of the femoral neck (Kaur P et al., 2013). Figure 2 below shows a labeled diagram of the anterior and posterior view of the human femur.

Figure 2: Anterior and posterior view of the human femur
Obtained from Teaching Collection: University of Ghana, Legon. Department of Anatomy
2.2 PROXIMAL FEMUR GEOMETRY

Proximal femur indices are dimensions of the morphological features of the proximal end of the femur. The parameters include femoral head diameter, neck diameter, neck length, and neck shaft angle (Fig. 2.2). The head diameter (measured the distance between the widest parts of the femoral head), the neck diameter (measured the distance across the neck of the femur), Hip axis length (measured the distance between the inner and highest part of the tip of the femoral head to the inferior borders of the lesser trochanter), and the neck shaft angle (is the angle made by the axis of the shaft with the axis of the upper neck). The above variables are known to demonstrate variations among populations of different geographic regions using different methods of measurement (Mishra et al., 2009; Umer et al., 2010; Toplumunda et al., 2017; Ravichandran et al., 2011; Cho et al., 2015). The skull and the femur bones are considered to be the most dimorphic parts of the human skeleton (Srivastava et al., 2012) There has not been consensus on whether the geometric parameters demonstrate variation when the right and left limbs are compared (Kanchan et al., 2008). While some authors reported variation (Verma et al., 2017; Kaur P et al., 2013) in the dimensions between the right and left limbs, other studies did not find significant statistical differences to demonstrate variation in laterality (Saheb, & Joseph N, 2016). The development of bones is dependent on forces applied to the bones. The dominant use of a particular limb (handedness) results in that limb developing stronger than the other limb and could appear slightly bigger than the other limb (Verlagsbuchhandlung, 2019). An example is a paralyzed limb which is not used most of the time. It has also been shown from other studies that neck shaft angle differs with gender and with sides left and right (Akbar et al., 2015). The neck shaft angle is found to differ in gender because the anteversion of the femur in females is higher because of the nature of the pelvis (gynaecoid). The baby-carrying possibility of the female pelvis makes the angulation of
the female femur differ from the males. A study on Korean femurs revealed that proximal geometric parameter that were estimated found out that the male participants had a greater recorded value than females participants (Cho et al., 2015).

Hip axis length, and neck length: neck width ratio are significantly different between patients with intracapsular and extracapsular Proximal Femoral Fractures (Duthie et al., 2006). The anatomical knowledge of different dimensions of the femur is very essential in anthropological and medico-legal practice for sex determination and as well as to radiologists, rheumatologists and orthopedic surgeons for diagnosis and planning of treatment (Mohamad Khan & Shaik, 2014). These would ensure adequate planning and proper utilization of resources available. The patience would also encounter less intra-operative and post-operative complications.

The proximal femur measurements that are set to be carried out can be seen in figure 3, below.
Figure 3: Proximal femur indices. A-B ----- Hip Axis Length, C-D ------ Femoral Head Diameter, E-F ------ Neck Diameter, and AOG ---- Neck Shaft Angle. Obtained from Teaching Collection: University of Ghana, Legon. Department of Anatomy

2.3 SEXUAL DIMORPHISM AND BONE LATERALITY

There are a number of differences between males and females, such as physiological, hormonal and skeletal, which in total correspond to what is known as sexual dimorphism (Papaloucas, Fiska, & Demetriou, 2008). Skeletal structure is a very important element of sex differentiation. The most prominent skeletal variations between sexes are the ones of the bony pelvis and adjoining bones especially those contributing to the formation of the hip joint, i.e. the acetabulum and the head of the femur (Nieves et al., 2005). Sexual dimorphism can also be recognized as a consequence of
three factors, namely reproductive function as expressed in the morphology of the pelvis, genetic differences that influence body size and proportions, and lastly differences in musculature between the sexes (Srivastava et al., 2012). Sexual dimorphism of the femur has been very well studied in different populations with diverse and interesting outcomes (Kranioti et al., 2009; Sakaue K, 2004). The femur is dimorphic within the same population and very useful in sexing skeletal remains (Curate et al., 2016). Male and female disparities in the skeletal remains can be of use from many aspects to medical scientists, forensic investigations archaeological and anthropological studies. Vertical diameter of head, Neck-shaft angle and Transverse diameter of head can be used to predict gender with 75-80% degree of accuracy (Pillai et al., 2014)

Laterality differences in bone geometry and density as a function of subject activity have been documented (Pierre et al., 2010). Absolute left – right differences for individuals in the population can be significant (Pierre et al., 2010). Sometimes it cannot be assumed that the indices of one leg can be used for the contralateral leg (Kranioti et al., 2009). The variation in bilateral symmetry was demonstrated to be considerable in the humeral shaft of tennis players (Haapasalo et al., 1998), where the BMD and BMC of the dominant hand increased by 25% and 29%, respectively (Kannus et al., 1994). Similar results were found for the dominant femur of female soccer players (Alfredson et al., 1996). Additional studies have shown a correlation between BMD and BMC and right or left-handedness (Yang et al., 1997; Gumustekin et al., 2004; Plochocki, 2004; Vrahoriti et al., 2004).
2.4 PROXIMAL FEMUR INDICES STUDIES IN OTHER POPULATION

Statistical analysis of femoral Anthropometry among different populations reveals a great amount of variation due to the fact that the femoral anthropology measurements from different countries are likely to be affected by racial variations in diet, heredity, climate and other geographical factors (Pillai et al., 2014).

Khan et al., (2014) studies showed a significant difference between right and left femurs measurements in the Indian population using 250 femurs. Other studies by Akbar et al., (2015), showed a significant difference between males and females and also left side and right side in the Pakistan population using plain radiographs to measure the neck shaft angle.

Verma et al., (2017) investigates the morphometry of proximal femur in the Indian populations using an anteroposterior digital photograph on ninety-one dry bones (44 left and 47 right). There was a significant difference between right and left side of femoral neck diameter and neck shaft angle.

On the contrary, Kaur et al., (2013), in a study of the neck concluded that there was no statistical difference between males and females and also between left and right side. It was a retrospective study on the pelvic radiographs of 280 patients. Individuals between 20-50 years of age who would be undergoing pelvic x-ray AP view in the supine position with radiologically normal x-rays were used.
Veldman, (2004) studied the morphology of the proximal femur in the very elderly, the study was a retrospective using ninety (90) very elderly subjects using CT scan. The study showed no notable differences between males and females.

Saheb et al., (2016). This was a study to find out the measurements of neck shaft angle, femoral length and neck length of the femur. The study used 592 femurs from different colleges in south India. There was no significant difference between right and left femur measurements.

De Sousa et al., (2010) investigated the morphometric study of the proximal femur extremity in Brazilians. The study was a retrospective study of dry adult Brazilians human femurs of both males and females. The femurs were radiographed and subsequently scanned and transfer to a computer. The study revealed that the cervico-diaphyseal angle average variations did not show any statistical significance.

Cho et al., (2015) investigated the morphometric evaluation of Koreans femurs by geometric computation: comparisons of the sex and the population. The study measured 28 parameters of 202 femurs from Koreans by an automated geometric computation program using 3D models generated from computed tomography images. The measurement parameters were selected with reference to physical and forensic anthropology studies as well as orthopedic implant design studies. The results show that most parameters were larger in males than in females. Moreover, 14 variables differed statistically between Koreans and other populations.

Umer et al., (2010), conducted a study to measure the morphology of the proximal femur in a Pakistani population. A standardized anteroposterior pelvic radiograph of 116 male and 20 female healthy volunteers aged 20 to 50 years were taken. Morphologic dimensions of the proximal femur were measured; including canal flare index (CFI), morphological cortical index (MCI), femoral head offset, femoral head diameter, and femoral head position. The study revealed the morphology
of the proximal femur in the Pakistani population differed significantly from those in western populations.

Mishra et al., (2009), in his work, the proximal femur- a second look at rationale of implant design, twenty five pairs (50 bones) of cadaveric femora were studied morphologically and radiologically using standardized techniques to obtain anthropometric data to evaluate the applicability of internationally designed implant and to generate a database for proximal femur to help in design for future implant if these were found unsuitable. The results were compared with those reported in the literature for Hong Kong, Chinese, and Caucasians and were found to be different.

Ravichandran et al., (2011), in their work, proximal femoral geometry in Indians and its clinical applications, five hundred and seventy-eight (578) unpaired femora were used. The study showed that the Indians dimension of proximal femur are obviously lesser than the western standards.

Rawal et al., (2012) studies compare the differences in dimensions between femurs of elderly Indians and those of populations from other regions in order to solve the problem of a possible geometric mismatch between a selected implant and the hip joint as far as Indian patients are concerned. Measurements were made using computer-aided design techniques on computed tomography (CT) scanned images of 98 femurs (56 left and 42 right). This study indicates a need for a redesign of femoral stems.

Unnanuntana et al., (2010) investigates the evaluation of proximal femur geometry using photographs. The study used digital photographs to compare 200 cadaveric femora in individuals who died prior to 40 years of age: 25 African- American males, 25 African-American females, 25 Caucasian males, 25 Caucasian females. There were small, but statistically significant differences, between males and females in neck-shaft angle, neck inclination, and absolute horizontal and vertical offset. Females in his work showed a lower neck-shaft angle and more neck inclination.
In summary, a survey of the literature reveals that the human proximal femur indices can differ from one population to the other because of racial variations in diet, heredity, lifestyle, climate and other geographical factors. Further studies revealed that the proximal femur indices when compared males to females can differ while other studies hold a contrary view. In addition, asymmetry of the limbs (left and right) in some studies showed statistical difference and other works do not. Authors from the above literature revealed differences that were observed when one population was compared to another population. There is a paucity of data of proximal femur indices of the Ghanaian population. Available Ghanaian proximal femur indices data could help manufacturers, procurement institution and surgeons in procurement and selection of appropriate prostheses to prevent post-operative complications of mismatch (prosthesis-femur) and wastage of scarce resources.

2.5 PROXIMAL FEMUR FRACTURES

Proximal femoral fractures are a subset of fractures that occur in the hip region. They tend to occur in older patients, and in those who have osteoporosis. In this group of patients, the fracture is usually the result of low-impact trauma. Younger patients are usually victims of high-impact trauma, usually during a road traffic accidents (Kazemi et al., 2016)

The fracture of the proximal femur is a common and important cause of mortality and functional loss. The increasing incidence of this type of fracture with age is due mainly to the increase in the number of falls associated with a larger osteoporosis prevalence. It is more commonly related with senior females, resident in the urban areas and institutionalized patients (Sakaki et al., 2004). In the case of a senior females, it has to do with the increased bone resorption and decreased
production of estrogen (menopause) and likely osteoporosis that makes their bone brittle and easily fractured (Sieva, Beck, & Kannus, 2008). Institutionalized patients have decrease levels of calcium as a result of less exposure to sun which is a precursor for the metabolism of calcium and lesser exercise time to keep bones active and strong (Ja, 2006, Compston, et al., 1992).

These fractures account for a large proportion of hospitalization among trauma cases. An overwhelming majority of these patients (>90%) are aged above 50 years. The incidence of these fractures is 2 to 3 times more in females as compared to the male population.

The incidence of trochanteric femoral fractures has increased significantly during recent decades, and this tendency will probably continue in the near future due to the rising age of the population. The goal of the treatment of these fractures is a stable fixation, after open reduction which allows early mobilization of the patient (Mittal & Banerjee, 2012)

### 2.6 CLASSIFICATION OF PROXIMAL FEMUR FRACTURES

Proximal femur fracture is classified anatomically as intracapsular or extracapsular fractures (Sheehan et al., 2015). They are classified based on the anatomical location of the fracture into neck of femur fracture, intertrochanteric fracture, and subtrochanteric fracture. There has been no comprehensive, reliable and universally accepted method of classification of intracapsular fractures of the proximal femur since Waldenström described a simple division into stable (undisplaced) and unstable (displaced) fractures (Blundell et al., 1998).

Intertrochanteric fractures occur in the transitional bone between the femoral neck and the femoral shaft. These fractures may involve both the greater and the lesser trochanters. Transitional bone is composed of cortical and trabecular bone. These bone types form the calcar femoral
posteromedially, which provides the strength to distribute the stresses of weight-bearing. Consequently, the stability of intertrochanteric fractures depends on the preservation of the posteromedial cortical buttress (Evans & McGrory, 2002)

Subtrochanteric fractures are fractures occurring between the lesser trochanter and isthmus of the shaft of the femur. The frequency of these fractures is less than that of neck femur and intertrochanteric fractures. Subtrochanteric fractures constitute 30% of all hip fractures. These fractures usually unite with primary cortical healing. They are however notorious for the intraoperative difficulty in reduction and postoperative complications like non-union and malunion (Mittal & Banerjee, 2012).

Several classification systems are in place to categorize and help in choosing the best possible method of treatment viz. Garden’s, Pauwel’s and AO classification.

**Garden’s classification**

These classifications categorizes femoral neck fractures into 4 groups based on the alignment of bony trabeculae:

Type I: incomplete fracture (impacted valgus fracture)

Type II: complete fracture without displacement

Type III: complete fracture with partial displacement

Type IV: complete fracture with complete displacement Garden’s classification is the most widely used system, although there is much interobserver variation with regard to fracture grading” (Mittal & Banerjee, 2012).
Pauwel’s classification: 

This classification is based on the obliquity of the fracture line, Pauwel’s classified femoral neck fractures into three types:

Type 1: with the obliquity of 0 to 30 degrees.

Type 2: with the obliquity of 30 to 50 degrees.

Type 3: with the obliquity of 70 degrees more.

Pauwel’s classification has good interobserver reproducibility but has been found to be of limited use in predicting the clinical outcome or the rate of complications in the various fracture subtypes (Mittal & Banerjee, 2012).

AO classification: 

It is a comprehensive classification which groups femoral neck fractures in the 31. B group and further subdivides it into three types based on the location of the fracture line and displacement.

31B1: subcapital fractures with minimal displacement.


31B3: displaced subcapital fractures” (Mittal & Banerjee, 2012).
Figure 4: Classification of Garden’s fractures (Blundell et al., 1998)

B1.1, B1.2 and B1.3 – Undisplaced fracture

B2.1 – Basal fracture

B2.2, B2.3, B3.1, B3.2 and B3.3 – Displaced fracture
**2.7 PRESENTATION AND MANAGEMENT OF PROXIMAL FEMUR FRACTURE**

Patients of proximal femur fracture report to the hospital with a history of a fall or involvement in a road traffic accident. Symptoms include pain in the hip, groin, and knee, and difficulty and inability to walk. Physical examination reveals shortening of the leg on the affected side, lateral rotation of the leg, straight leg raised will be impaired. Plain X-ray normally confirms the diagnosis (Blundell et al., 1998).

Patients who suffer proximal femur fractures are resuscitated after the initial assessment. Immobilization and surgery are required in the management of hip fractures. Management of hip fractures depends on the type of fracture and the age of the patient. Mostly open reduction and hip replacement with femoral prostheses which come in different sizes and designs (Ravichandran et al., 2011) are done to avoid delayed healing and non-union.

The clinical importance of neck shaft angle of the femur lies in the management of the fractures of the extremities including diagnosis, treatment, and follow-up of fractures of the neck of the femur. The commonly used implants for surgical treatment of proximal fractures such as dynamic hip screws, ASNIS screws, cancellous screws, blade plates, etc. are designed primarily for the western population who’s constitutional and biomechanical factors vary from those of Indian population (Ravichandran et al., 2011).
2.8 PROSTHESIS OF THE PROXIMAL FEMUR

A large proportion of proximal femur implants are usually supplied by the manufacturers which come in standard sizes. If the used prosthesis or fixation implants do not match the proximal femoral geometry, then improper load distribution will result in great patient discomfort and aseptic loosening. A consensus has been reached among many surgeons that close adaptation of prosthesis and the internal fixation implants to the proximal femoral bone geometry is necessary to achieve an optimal primary stability and secondary biologic fixation (Toplumunda et al., 2017). These would offer the best fit prosthetics for most local populations and reduce both intra-operative and post-operative complications. If proximal femur geometry data are available, it would make the work of biomedical engineers and surgeons less cumbersome in the manufacturing of best-fit prosthetics design and in the operation rooms. Some proximal femur prostheses are discussed below.

Treatment of femoral neck fractures is still an important and challenging problem. The most widely used prosthesis is the multiple and compression screws for internal fixation of femoral neck fractures (Holmes et al., 1993).

For intertrochanteric hip fracture, dynamic hip screw (DHS) has been the best standard of treatment. DHS is based on the concept of allowing fracture fragments to impact, thereby achieving bone-on-bone stability, and decreasing the probability of implant failure (Siwach 2003). The neck shaft angle and the hip axis length are important indices to consider when selecting the dynamic hip screw (DHS). The Dynamic hip screw (DHS) had been the standard and the best-documented implant in treating intertrochanteric fractures and in several randomized trials, it has been associated with lower complications (Aly, 2017).
Other prostheses that are used include the ASNIS screws (Figure 2.2) and the Austin Moore prosthesis (Figure 2.3) which takes into consideration the indices of the head of the femur, the neck-shaft angle and the also the medullary canal.

Figure 5: Shows a picture and an X’ ray of a Dynamic hip screwed into the proximal femur

Adapted from: https://i.pinimg.com/236x/b9/4b/5c/b94b5cfe4d556d539b8ca043bea51833.jpg
Figure 6: shows an ASNIS Screws through a fractured proximal femur
Adapted from

Figure 7: shows an Austin Moore Prosthesis
In conclusion, data from the studies above show the increasing nature of hip fractures globally and the use of proximal femur prostheses for its management (Kim et al., 2015). There have been series of studies conducted in different populations that showed variation in the proximal femur indices results recorded due to genetics, lifestyle, habits and geological locations although some populations shared similar results (Toplumunda et al., 2017; Rubin et al., 1992; Mitra et al., 2014; Gilligan, Chandrapahk, & Mahakkanukrauh, 2013; Baharuddin et al., 2011). It is therefore paramount for every population to have data on its proximal femur indices that manufacturers and surgeons can rely on and appreciate in manufacturing of prostheses and choosing right prostheses.
for patients respectively. These should be done to prevent complication associated with mismatched prostheses which include; pain, loosening, micromotion, mal-union and aunion and moreso the management of scarce resources of a developing country like Ghana.
CHAPTER THREE

RESEARCH METHODOLOGY

3.1 STUDY DESIGN

The study was a retrospective study examining the anteroposterior pelvic radiographs.

3.2 STUDY SITE

The research was conducted at the Radiology Department of the Korle-Bu Teaching Hospital (KBTH) in Accra, Ghana. The KBTH is a tertiary referral hospital located in the capital of Ghana.

3.3 RESEARCH POPULATION

The target populations were Ghanaian men and women (people born in Ghana and living in Ghana at the time of this study) whose anteroposterior (AP) plain X-rays were taken from April 2017 to May 2018 for various indications other than pelvic problems. The specified duration of one year was because the X-ray machine at the study site has a limited capacity with respect to how much patient data it could store. Periodically, old records of patients were deleted to make room for new data. The old images are then backed up at Picture Archiving and Communication System (PACS). The images were sorted, of which relevant ones relating to this study were sampled and appropriately utilized.
3.3.1 Inclusion criteria:
Plain X-rays with AP view of adults male and female in Ghana aged 30 years and above. This was to ensure that permanent bone structures were measured.

Images whose indications did not include any conditions such as tumors, trauma, and fractures of bones that could potentially affect the shape and dimension of the proximal femur were reviewed.

The radiographs were normal without distortions. Images were clear enough and had the required bony landmarks for the estimation of proximal femur indices.

3.3.2 Exclusion criteria:
Radiograph of patients with the following conditions were excluded: pelvic tumor, fracture/trauma, deformity of the proximal femur bone, evidence of malignancy or disease process.

In addition, images that were not clear which made it difficult to identify the landmarks and borders for the proximal femur were also excluded. Also, images without “ages” and “sexes” of the individual were excluded.

3.4 SAMPLE SIZE DETERMINATION
Purposive sampling was deployed to enable me to get as much data as possible to carry out this research.

3.5 MEASUREMENT OF FEMORAL INDICES
The proximal femur indices were measured in the Department of Radiology with the assistance from the Radiographers. The x-ray machine has an in-built software (AGFA NX model/version 2.0, type: 8900 SUI) for viewing the medical images. The machine also has inbuilt calibration tools, including ruler for both linear and angular measurement. The X-ray machine-stored
digitalized images were examined using the software to estimate the proximal femoral head diameter, the femoral neck diameter, the femoral neck-shaft angle, and the femoral hip axis length. The measurements were taken by two trained radiologists with each repeating the measurement three times and the averages were taken and recorded on a data sheet so as to reduce observer variability.

3.6. PROCEDURE USED TO MEASURE THE PROXIMAL FEMUR INDICES

The Radiographers took the x-rays using standard operation procedure for AP pelvic films which employ a 15 -20 degrees internal rotation of the hips in the supine position with a film distance of 100cm with the beams centered on the symphysis pubis (Pathak et al., 2016; Sousa & Fernandes, 2010; Toplumunda et al., 2017; Vaseenon et al., 2015; Umer et al., 2010; Kalamullah & Akbar, 2015; Kaur P et al., 2013; Mitra et al., 2014)

The radiographers assisted in the measurement of the proximal femoral indices of the following:

**The head diameter** - measured the distance between the widest parts of the femoral head as seen in Fig. 9 below.

**The neck diameter** - measured the distance across the neck of the femur as seen in Fig. 10 below.

**Hip axis length** - measured the distance between the inner and highest part of the tip of the femoral head to the inferior borders of the lesser trochanter as seen in Fig. 11 below.

**The neck shaft angle** - is the angle made by the axis of the shaft with the axis of the neck of the femur seen in Fig. 12 below.
Figure 9: An image of an x-ray of the AP view of the pelvis showing the femoral head diameter (Red line).
Figure 10: An image of an x-ray of the AP view of the pelvis showing the femoral neck diameter (Red line).
Figure 11: An image of an x-ray of the AP view of the pelvis showing the hip axis length (Red line).
Figure 12: An image of an x-ray of the AP view of the pelvis showing the femoral P-value angle (angle between red lines).
3.7 DATA ANALYSIS AND PRESENTATION

Results obtained from the proximal femur indices measurements were analyzed using the SPSS software package (version 20). Descriptive statistics of means, standard deviation, minimum and maximum values were used to summarize proximal femur indices. Paired T-test and independent T-test were applied to compare the means between men and women and also compare the sides of left and right. Data were normally distributed by using the Kolmogorov Smirnov test of normality, so T-test was applied for comparison between two groups (male and females and right and left). Regression analysis was done to look out for associations between variables. A p-value of 0.05 or less was considered for statistical significance.

3.8 ETHICAL CONSIDERATIONS

Ethical clearance was obtained from the Ethical and Protocol Review Committee, University of Ghana, College of Health Sciences. Permission was also obtained from the central administration of the Korle-Bu Teaching Hospital as well as the Head of the Radiology Department at the hospital to allow the collection of data from their facility. Confidentiality of information of participants was ensured at all times by safeguarding clients’ data on a password-protected computer.
CHAPTER FOUR

4.0 RESULTS

The results of the indices of the proximal femur of Ghanaians are reported in Tables and figures as below. The indices of femoral head diameter, femoral neck diameter, femoral neck shaft angle and hip axis length were measured using plain anteroposterior radiographs of males and females on both left and right.

4.1 STATISTICS ON NUMBER OF IMAGES SAMPLED

A search through the patient record for anterior-posterior pelvic images showing proximal femur dimensions revealed two hundred and fifteen (215) images on the machine. Out of the 215 images, 40 images were not clear and 50 were excluded from the study because they had fractures, clients under 30 years or images had no identifiable gender or ages. Thus 125 images comprising 74 males and 51 females were used for the measurement.

4.2 AGE DISTRIBUTION

The age range of patients whose images were sampled for the measurement of the proximal femur indices was from 31 to 82 years with a mean of 53.90 (SD = 11.61) years as shown in Table 1. Most of the images (27.2%) of participants sampled belonged to the patients in the age group of 50-59 years. The age group which was least represented was 80 to 89 years (1.6%) and the most frequent age amongst the patients whose images were sample was age 54 years as shown in Table 2.
Table 1: Age Distribution of Patients

<table>
<thead>
<tr>
<th>Age (years)</th>
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<tbody>
<tr>
<td>Mean</td>
<td>53.90</td>
</tr>
<tr>
<td>Mode</td>
<td>54</td>
</tr>
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<td>Minimum</td>
<td>31</td>
</tr>
<tr>
<td>Maximum</td>
<td>82</td>
</tr>
</tbody>
</table>

Table 2: Frequency of age group

<table>
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<th>AGE RANGE</th>
<th>FREQUENCY</th>
<th>PERCENT (%)</th>
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</thead>
<tbody>
<tr>
<td>30-39</td>
<td>13</td>
<td>10.4</td>
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<tr>
<td>40-49</td>
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<td>26.4</td>
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<td>50-59</td>
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<td>60-69</td>
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<td>80-89</td>
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<td>1.6</td>
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<tr>
<td>TOTAL</td>
<td>125</td>
<td>100.0</td>
</tr>
</tbody>
</table>
Table 3: Regression of age of patients and femoral indices

<table>
<thead>
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<th>Age of patients</th>
<th>B</th>
<th>T</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head diameter left</td>
<td>0.009</td>
<td>2.037</td>
<td>0.044</td>
</tr>
<tr>
<td>Head diameter right</td>
<td>0.008</td>
<td>1.774</td>
<td>0.079</td>
</tr>
<tr>
<td>Neck diameter left</td>
<td>0.003</td>
<td>0.833</td>
<td>0.407</td>
</tr>
<tr>
<td>Neck diameter right</td>
<td>0.003</td>
<td>0.886</td>
<td>0.378</td>
</tr>
<tr>
<td>Neck shaft angle left</td>
<td>0.021</td>
<td>0.914</td>
<td>0.362</td>
</tr>
<tr>
<td>Neck shaft angle</td>
<td>0.035</td>
<td>1.759</td>
<td>0.081</td>
</tr>
<tr>
<td>Hip axis length left</td>
<td>0.019</td>
<td>2.335</td>
<td>0.021</td>
</tr>
<tr>
<td>Hip axis length right</td>
<td>0.019</td>
<td>2.368</td>
<td>0.019</td>
</tr>
</tbody>
</table>

Table 3 above shows the regression of age of patients and the femoral indices. The head diameter left, the hip axis on the left and right were statistically significant whilst the head diameter right, neck diameter left/right and neck shaft angle right/left were not statistically significant.
4.3 PROXIMAL FEMORAL INDICES

4.3.1 Femoral Head Diameter
The mean values of head diameter on the left (HDL) for males was 4.84 cm (SD = 0.52) and that of females being 5.06 cm (SD=0.56). The mean HDL for the sampled population (both and males and females) was 4.92 cm (SD = 0.55). The mean HDL was significantly greater in females (5.06 cm) compared to males (4.84 cm) \((F = 5.437; P\text{-value} = 0.021)\) as displayed in Table 5. The femoral head diameter on the right (HDR) for patients whose images were sampled for proximal femoral indices estimation range from 3.90 cm to 6.27 cm. The mean value of HDR for males was 4.92 (SD = 0.53) cm and that of females being 5.15 (SD = 0.56) cm. The mean for both males and females femoral head diameters on the right was 5.02 (SD = 0.55). There was statistically significant difference between the mean HDR of males and that of females \((f = 5.544; p\text{-value} = 0.021)\) as shown in Table 4. The mean femoral head diameter for the male sample demonstrated significant laterality with the femoral head diameter on the right wider than that of the left (paired t-test \(t = -6.150; p\text{-value} = .000\)) as in Table 6. Similarly, for the female sample, the head diameter is bilaterally different with the head diameter of the right femur significantly wider than the left (paired t-test, \(t = -5.390; p\text{-value}\) as displayed in Table 7 below.
Table 4: Descriptive statistics for femoral head diameter right of males and females

<table>
<thead>
<tr>
<th>Variable measured</th>
<th>Characteristic</th>
<th>Mean (SD)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Femoral head</td>
<td>Total population</td>
<td>5.02(0.55)</td>
<td></td>
</tr>
<tr>
<td>diameter right (cm)</td>
<td>Male</td>
<td>4.92(0.53)</td>
<td>0.021</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>5.15(0.56)</td>
<td></td>
</tr>
</tbody>
</table>

Table 5: Descriptive statistics for femoral head diameter left of males and females

<table>
<thead>
<tr>
<th>Variable measured</th>
<th>Characteristic</th>
<th>Mean (SD)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Femoral head</td>
<td>Total population</td>
<td>41.93(0.55)</td>
<td></td>
</tr>
<tr>
<td>diameter left (cm)</td>
<td>Male</td>
<td>4.84(0.052)</td>
<td>0.020</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>5.06(0.56)</td>
<td></td>
</tr>
</tbody>
</table>
Table 6: Paired sample t-test comparing the proximal femoral indices on the left with that for the right for male samples

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Standard deviation</th>
<th>T</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head diameter</td>
<td>-0.08392</td>
<td>0.11738</td>
<td>-6.150</td>
<td>0.000</td>
</tr>
<tr>
<td>Neck diameter</td>
<td>-0.07231</td>
<td>0.08101</td>
<td>-7.679</td>
<td>0.000</td>
</tr>
<tr>
<td>Neck shaft angle</td>
<td>-0.514</td>
<td>2.234</td>
<td>-1.977</td>
<td>0.052</td>
</tr>
<tr>
<td>Hip axis length</td>
<td>-0.03743</td>
<td>0.40441</td>
<td>-0.796</td>
<td>0.428</td>
</tr>
</tbody>
</table>
Table 7: Paired sample t-test comparing the proximal femoral indices on the left with that for the right for female samples

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Standard deviation</th>
<th>T</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head diameter</td>
<td>-0.08902</td>
<td>0.11795</td>
<td>-5.390</td>
<td>0.000</td>
</tr>
<tr>
<td>Neck diameter</td>
<td>-0.03804</td>
<td>0.10333</td>
<td>-2.629</td>
<td>0.011</td>
</tr>
<tr>
<td>Neck shaft angle</td>
<td>-0.784</td>
<td>1.641</td>
<td>-3.413</td>
<td>0.001</td>
</tr>
<tr>
<td>Hip axis length</td>
<td>-0.08882</td>
<td>0.11244</td>
<td>-5.642</td>
<td>0.000</td>
</tr>
</tbody>
</table>
4.3.2 Femoral Neck Diameter

Femoral Neck diameter on the left (NDL) for patients whose images were sampled for proximal indices estimation was from 2.99 cm to 5.21 cm. The mean values of NDL for males were 3.74 (SD = 0.48) cm and that of females being 3.96 (SD = 0.52) cm. The means NDL for the total population was 3.83 (SD = 0.50). There was a statistically significant difference between the mean NDL for males and that for females (p-value = 0.018) as in Table 9 below. The range of neck diameter on the right (NDR) for patients whose images were sampled was from 2.98 cm to 5.09 cm. The mean of NDR for males were 3.82 (SD = 0.46) cm and that of females being 4.00 (SD = 0.52) cm (Table 8 below). The combined mean neck diameter right for the sampled population was 3.89 (SD = 0.50) cm. The mean NDR for females was statistically wider than that for males (F = 4.201; p-value = 0.043).

The mean NDL and NDR for the male sample demonstrated significant laterality with the femoral neck diameter on the right wider than that of the left (paired t-test t = -7.679; p-value = .000) as reported in Table 6 above. Similarly, for the female sample, the neck diameter was bilaterally different with the neck diameter for the right femur significantly wider than the left (paired t-test, t = -2.629; p-value = 0.011) (Table 7) as depicted above.
### Table 8: Descriptive statistics for neck diameter right for males and females

<table>
<thead>
<tr>
<th>Variable measured</th>
<th>Characteristic</th>
<th>Mean (SD)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total population</td>
<td>Total population</td>
<td>3.90(0.50)</td>
<td></td>
</tr>
<tr>
<td>Femoral neck diameter</td>
<td>Male</td>
<td>3.82(0.46)</td>
<td>0.018</td>
</tr>
<tr>
<td>right (cm)</td>
<td>Female</td>
<td>4.00(0.53)</td>
<td></td>
</tr>
</tbody>
</table>

*P-value is the probability of two-sample t-test comparison between males and females.

### Table 9: Descriptive statistics for left femoral neck diameter for males and females

<table>
<thead>
<tr>
<th>Variable measured</th>
<th>Characteristic</th>
<th>Mean (SD)</th>
<th>*P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total population</td>
<td>Total population</td>
<td>3.38(0.50)</td>
<td></td>
</tr>
<tr>
<td>Femoral neck diameter</td>
<td>Male</td>
<td>3.74(0.45)</td>
<td>0.043</td>
</tr>
<tr>
<td>left (cm)</td>
<td>Female</td>
<td>3.96(0.52)</td>
<td></td>
</tr>
</tbody>
</table>

*P-value is the probability of two-sample t-test comparison between males and females.
4.3.3 Neck shaft angle

Neck shaft angle left (NSAL) for proximal indices estimation had the minimum of 123 ° and maximum of 139°. The mean NSAL for the total population (both males and female) was found to be 131.66° (SD = 2.89). The mean value for males was 131.82 ° (SD = 3.21) and that for females was 131.43 ° (SD = 2.36) as in Table 11. There was no significant difference between the mean NSAL for males and females (p-value = 0.457) as shown in Table 6 above.

The range of Neck shaft angle right (NSAR) for radiographs sampled for proximal indices estimation was from 124° to 137 °. The mean value of NSAR for males was 132.34° (SD = 2.56) and that for females was 132.22° (SD = 2.45). The mean NSAR values for the total population was found to be 132.29 ° (SD = 2.50) as displayed in Table 10 below. The means NSAR for males and females were not statistically different (p-value = 0.790).

The mean neck shaft angle was not significantly different between the right and left femur for the male samples (paired t-test t = -1.977; p-value = 0.052) (Table 6 above), but was significant for the females (paired t-test t = -3.413; p-value = 0.001) (Table 7 above).
Table 10: Descriptive statistics for right femur neck shaft angle

<table>
<thead>
<tr>
<th>Variable measured</th>
<th>Characteristic</th>
<th>Mean (SD)</th>
<th>*P - value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total population</td>
<td>132.29(2.50)</td>
<td></td>
</tr>
<tr>
<td>Femoral neck shaft angle</td>
<td>Male</td>
<td>132.34(2.56)</td>
<td>0.457</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>132.22(2.45)</td>
<td></td>
</tr>
</tbody>
</table>

*P-value is the probability of two-sample t-test comparison between males and females.

Table 11: Descriptive statistics for left femoral neck shaft angle

<table>
<thead>
<tr>
<th>Variable measured</th>
<th>Characteristic</th>
<th>Mean (SD)</th>
<th>*P - value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total population</td>
<td>131.66(2.89)</td>
<td></td>
</tr>
<tr>
<td>Femoral neck shaft angle</td>
<td>Male</td>
<td>131.82(3.21)</td>
<td>0.790</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>131.42(2.36)</td>
<td></td>
</tr>
</tbody>
</table>

*P-value is the probability of two-sample t-test comparison between males and females.
4.3.4 Hip axis length

Hip axis length on the left (HALL) for the sampled population ranged from 9.70 cm to 14.25 cm. The means for sampled population was found to be 11.59 cm (SD = 1.07) as shown in Table 13 below. The mean HALL for males was 11.49 cm (SD = 0.98) and that for females was 11.74 cm (SD = 1.15). There was no significant difference between the mean HALL of males and that of females (p-value = 0.185) (Table 6 above).

Hip axis length right (HALR) for patients whose images were sampled for proximal indices estimation was from 9.85 cm to 14.81 cm. The combined mean for both the male and female hip axis length right was 11.65 (SD = 1.07). The mean value of HALR for male population was 11.52 cm (SD = 0.99) and that of female is 11.83 cm (SD = 1.15) as recorded in Table 12. There was no significant difference between the mean HALR of males and that of females (p-value = 0.115). The mean hip axis length for the male samples was not significantly different between the left and right femur (paired t-test t = -0.796; p-value = 0.428) (Table 6 above). The mean hip axis length for females was however significantly different for the right and left femurs (paired t-test t = -5.642; p-value = 0.000) as in Table 7 above.
Table 12: Descriptive Statistics for right hip axis length

<table>
<thead>
<tr>
<th>Variable measured</th>
<th>Characteristic</th>
<th>Mean (SD)</th>
<th>*P - value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Femoral hip axis</td>
<td>Total population</td>
<td>11.65(1.07)</td>
<td></td>
</tr>
<tr>
<td>length (cm)</td>
<td>Male</td>
<td>11.52(0.99)</td>
<td>0.185</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>11.83(1.15)</td>
<td></td>
</tr>
</tbody>
</table>

*P-value is the probability of two-sample t-test comparison between males and females.

Table 13: Descriptive Statistics for left hip axis length

<table>
<thead>
<tr>
<th>Variable measured</th>
<th>Characteristic</th>
<th>Mean (SD)</th>
<th>*P - value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Femoral hip axis</td>
<td>Total population</td>
<td>11.59(1.10)</td>
<td></td>
</tr>
<tr>
<td>length (cm)</td>
<td>Male</td>
<td>11.49(0.98)</td>
<td>0.115</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>11.74(1.15)</td>
<td></td>
</tr>
</tbody>
</table>

*P-value is the probability of two-sample t-test comparison between males and females.
Figure 13: A line graph showing the average femoral head diameter for all study participants in decade-banded age groups.

The average head diameter measurements increase steadily and peaked at age group 60 – 69 years and steeply started declining to age group 80-89 years as can be seen in figure 13. The average right head diameter measurement was higher than the average left head diameter.
Figure 14: A line graph showing the average femoral neck diameter in all study participants in decade-banded age groups.

The above figure 14 shows an average neck diameter measurement which increases from 30-39 years and peaked at 50-59 years and declines to 80-89 years. Although following similar pattern the right recorded higher values than the left.
Figure 15: A line graph showing the average femoral neck shaft angle of all participants in decade-banded and age groups

The line graph shows an average neck shaft angle in the total population which sees slight increase from 30-39 years and peaked at 60-69 years and drops to sharply to 70-79 years and increase slightly to 80-89 years. The right neck shaft angle recorded higher values than the left although they follow similar pattern.
Figure 16: A line graph showing the average of hip axis length of all study participants in decade-banded.

The graph above shows a steady increase from 30-39 years to peak at 60-69 years age group and the declines to 70-79 years with a slight increase to 80-89 years in the total population sample as seen figure 16.
Figure 17: A line graph showing the average head diameter of male adult Ghanaians in decade-banded age groups.

The above figure 17 graph shows an average measurement of the head diameter in the male population which shows a decrease from 30-39 years to 40-49 years age group and rises to peak at 60-69 years and decline to 70-79 years.
Figure 18: A line graph showing the average head diameter of female adult Ghanaians in decade-banded age groups.

The above figure 18 shows a graph of an average measurement of the head diameter in the female population which increases sharply from 30-39 years and peaked at 40-49 years and then decreases slowly to 70-79 years. The right recorded higher values than the left but both follow similar patterns.
Figure 19: A line graph showing the average neck diameter of male Ghanaian adults in decade-banded age groups

The graph shows an average measurement of the neck diameter in the male population which increases slightly from 30-39 years to 40-49 and peaked age group 50-59 years and remained constant at age group 60-69 for the left neck diameter but decreases for the right until all sharply decline at 70-79 age group. Although both left and right follow similar patterns, the right recorded higher values than the left.
The average neck diameter measurement rises sharply from 30-39 and peaked at 50-59 years age group and then slowly decreases as seen in figure 20 above. The right neck diameter and the left diameter almost following similar pattern but the right recording higher values than the left.
Figure 21: A line graph showing the average neck shaft angle of the female adult Ghanaians in decade-banded age groups

The figure 22 above shows an average measurement of neck shaft angle which steady increase from 30-39 years and peaked at age group 50-59 years for the left neck shaft angle and 60-69 for right neck shaft angle, and then decreases sharply to 70-79 years. Although both left and right following almost similar pattern, the right recorded higher values than the left.
Figure 22: A line graph showing the average hip axis length of male Ghanaian adults in decade-banded age groups.

Figure 23 above shows an average measurement of hip axis length which decreases slightly from 30-39 years to 40-49 years and increases steadily to peak at the age group 60-69 years and sharply decrease at 70-79 year. The right hip axis length and the left hip axis length following similar pattern. The right hip axis length recording higher values than the left.
Figure 23: A line graph showing the average hip axis length of the female adult Ghanaians in decade-banded age groups

The graph rises to age group 40-49 and dip at slightly at the age group 50-59 and the increases steadily to 70-79 age group. The right hip axis length and the left hip axis length follow almost similar patterns with the right hip axis length recording higher values as can be seen in figure 24 above.
Table 14: Regression model for head diameter left

HDL = 4.095 + 0.009AP + 0.267GP

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Co-efficient</th>
<th>Std. Error</th>
<th>t - value</th>
<th>P - value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>4.095</td>
<td>0.290</td>
<td>14.101</td>
<td>0.000</td>
</tr>
<tr>
<td>Age of patients</td>
<td>0.009</td>
<td>0.004</td>
<td>2.037</td>
<td>0.044</td>
</tr>
<tr>
<td>Gender of patients</td>
<td>0.267</td>
<td>0.098</td>
<td>2.709</td>
<td>0.008</td>
</tr>
</tbody>
</table>

The variables age of patients (AP) and gender of patients (GP) both contribute in explaining the variation in Head diameter Left. This is because the Age of patients has a p-value of 0.044 whiles gender of patients has a p-value of 0.008 which are both significant since they are less than α value of 0.05. In addition, a unit change in age of patient gives a corresponding change of 0.009cm in Head diameter left whiles a unit change in gender of patients give a corresponding change of 0.267cm in Head diameter left.
Table 15: Regression model for head diameter right

\[ \text{HDR} = 4.233 + 0.008\text{AP} + 0.267\text{GP} \]

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Co – efficient</th>
<th>Std. Error</th>
<th>t - value</th>
<th>P - value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>4.233</td>
<td>0.295</td>
<td>14.338</td>
<td>0.000</td>
</tr>
<tr>
<td>Age of Patients</td>
<td>0.008</td>
<td>0.004</td>
<td>1.774</td>
<td>0.079</td>
</tr>
<tr>
<td>Gender of Patients</td>
<td>0.267</td>
<td>0.100</td>
<td>2.672</td>
<td>0.009</td>
</tr>
</tbody>
</table>

The variables age of patients (AP) and gender of patients (GP) both contribute in explaining the variation in Head diameter right. This is because Age of patients has a p-value of 0.079 which is not significant whiles gender of patients has a p-value of 0.009 which is significant since the \( \alpha \) value = 0.05. In addition, a unit change in age of patient give a corresponding change of 0.008cm in Head diameter right whiles a unit change in gender of patients give a corresponding change of 0.267cm in Head diameter left.
Table 16: Regression model for neck diameter left

\[ \text{NDL} = 3.332 + 0.003 \text{AP} + 0.232 \text{GP} \]

<table>
<thead>
<tr>
<th>Predictors</th>
<th>Co-efficient</th>
<th>Std. Error</th>
<th>t-value</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>3.332</td>
<td>0.272</td>
<td>12.263</td>
<td>0.000</td>
</tr>
<tr>
<td>Age of Patients</td>
<td>0.003</td>
<td>0.004</td>
<td>0.833</td>
<td>0.407</td>
</tr>
<tr>
<td>Gender of Patients</td>
<td>0.232</td>
<td>0.092</td>
<td>2.517</td>
<td>0.013</td>
</tr>
</tbody>
</table>

The variables age of patients (AP) and gender of patients (GP) both contribute in explaining the variation in neck diameter right. This is because Age of patients has a p-value of 0.407 which is not significant whiles gender of patients has a p-value of 0.013 which is significant since the \( \alpha \) value = 0.05. In addition, a unit change in age of patient give a corresponding change of 0.003cm in Neck diameter left whiles a unit change in gender of patients give a corresponding change of 0.232cm in Neck diameter left.
Table 17: Regression model for neck diameter right

NDR = 3.429 + 0.003AP + 0.198GP

<table>
<thead>
<tr>
<th>Predictors</th>
<th>Co-efficient</th>
<th>Std. Error</th>
<th>t-value</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>3.429</td>
<td>0.268</td>
<td>12.776</td>
<td>0.000</td>
</tr>
<tr>
<td>Age of Patients</td>
<td>0.003</td>
<td>0.004</td>
<td>0.886</td>
<td>0.378</td>
</tr>
<tr>
<td>Gender of Patients</td>
<td>0.198</td>
<td>0.091</td>
<td>2.180</td>
<td>0.031</td>
</tr>
</tbody>
</table>

The variables age of patients (AP) and gender of patients (GP) both contribute in explaining the variation in neck diameter right. This is because Age of patients has a p-value of 0.378 which is not significant whiles gender of patients has a p-value of 0.031 which is significant since the $\alpha$ value = 0.05. In addition, a unit change in age of patient give a corresponding change of 0.003cm in Neck diameter right whiles a unit change in gender of patients give a corresponding change of 0.198cm in Neck diameter right.
**Table 18: Regression model for neck shaft angle left**

\[ \text{NSAL} = 130.958 + 0.021\text{AP} - 0.298\text{GP} \]

<table>
<thead>
<tr>
<th>Predictors</th>
<th>Co – efficient</th>
<th>Std. Error</th>
<th>t - value</th>
<th>P - value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>130.958</td>
<td>1.586</td>
<td>82.581</td>
<td>0.000</td>
</tr>
<tr>
<td>Age of Patients</td>
<td>0.021</td>
<td>0.023</td>
<td>0.914</td>
<td>0.362</td>
</tr>
<tr>
<td>Gender of Patients</td>
<td>-0.298</td>
<td>0.537</td>
<td>-0.555</td>
<td>0.580</td>
</tr>
</tbody>
</table>

The variables age of patients (AP) and gender of patients (GP) both contribute in explaining the variation in neck shaft angle left. This is because Age of patients has a p-value of 0.362 whiles gender of patients has a p-value of 0.580 which are both not significant since they are more than \( \alpha \) value of 0.05. In addition, a unit change in age of patient give a corresponding change of 0.021 degrees in Neck shaft angle left whiles a unit change in gender of patients give a corresponding change of -0.298 degrees in Neck shaft angle left.
Table 19: Regression model for neck shaft angle right

\[
\text{NSAR} = 130.376 + 0.035\text{AP} + 0.034\text{GP}
\]

<table>
<thead>
<tr>
<th>Predictors</th>
<th>Co-efficient</th>
<th>Std. Error</th>
<th>t-value</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>130.376</td>
<td>1.364</td>
<td>95.569</td>
<td>0.000</td>
</tr>
<tr>
<td>Age of Patients</td>
<td>0.035</td>
<td>0.020</td>
<td>1.759</td>
<td>0.081</td>
</tr>
<tr>
<td>Gender of Patients</td>
<td>0.034</td>
<td>0.462</td>
<td>0.074</td>
<td>0.941</td>
</tr>
</tbody>
</table>

The variables age of patients (AP) and gender of patients (GP) both contribute in explaining the variation in neck shaft angle right. This is because Age of patients has a p-value of 0.081 whiles gender of patients has a p-value of 0.941 which are both not significant since they are more than \( \alpha \) value of 0.05. In addition, a unit change in age of patient give a corresponding change of 0.035 in Neck shaft angle right whiles a unit change in gender of patients give a corresponding change of 0.034 degrees in Neck shaft angle right.
### Table 20: Regression model for hip axis left

\[
\text{HALL} = 10.082 + 0.019 \text{AP} + 0.341 \text{GP}
\]

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Co-efficient</th>
<th>Std. Error</th>
<th>t – value</th>
<th>P - value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>10.082</td>
<td>0.566</td>
<td>17.805</td>
<td>0.000</td>
</tr>
<tr>
<td>Age of Patients</td>
<td>0.019</td>
<td>0.008</td>
<td>2.335</td>
<td>0.021</td>
</tr>
<tr>
<td>Gender of Patients</td>
<td>0.341</td>
<td>0.192</td>
<td>1.780</td>
<td>0.078</td>
</tr>
</tbody>
</table>

The variables age of patients (AP) and gender of patients (GP) both contribute in explaining the variation in hip axis length left. This is because Age of patients has a p-value of 0.021 which is significant whiles gender of patients has a p-value of 0.078 which is not significant since the \( \alpha \) value = 0.05. In addition, a unit change in age of patient give a corresponding change of 0.019cm in hip axis length left whiles a unit change in gender of patients give a corresponding change of 0.267cm in hip axis length left.
Table 21: Regression model for hip axis right

HALR = 10.044 + 0.019AP + 0.395 GP

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Co-efficient</th>
<th>Std. Error</th>
<th>t-value</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constants</td>
<td>10.044</td>
<td>0.570</td>
<td>17.619</td>
<td>0.000</td>
</tr>
<tr>
<td>Age of patient</td>
<td>0.019</td>
<td>0.008</td>
<td>2.368</td>
<td>0.019</td>
</tr>
<tr>
<td>Gender of patient</td>
<td>0.395</td>
<td>0.193</td>
<td>2.043</td>
<td>0.043</td>
</tr>
</tbody>
</table>

The variables age of patients (AP) and gender of patients (GP) both contribute in explaining the variation in hip axis length right. This is because Age of patients has a p-value of 0.019 whiles gender of patients has a p-value of 0.043 which are both significant since they are less than $\alpha$ value of 0.05. In addition, a unit change in age of patient give a corresponding change of 0.0.19cm in hip axis length right whiles a unit change in gender of patients give a corresponding change of 0.395cm in hip axis length right.
CHAPTER FIVE

DISCUSSION AND CONCLUSION

5.1 DISCUSSION

Geometric data on the proximal femur of adults in Ghana will facilitate the assessment of the fit between the component of hip prostheses and the proximal femur. Many studies have investigated various aspects of proximal femoral geometry using direct measurements from cadaveric bones, computed tomography (CT) scan, Magnetic resonance imaging (MRI) and direct radiographs. A well-suited implant will lead to a better outcome in hip replacement surgeries. It is, therefore, needful to generate data on femoral indices for designing custom made prosthesis based on specific population morphometry. Implants for replacement of diseased hip joint in Ghana are usually made by European and American manufacturers according to the morphology of their own population (Sabona & Nedunchezhiyan, 2019). These implants come in different sizes to suit the various sizes of their population. Inappropriate implant may not align with the bone properly and a mismatch between femoral bone and stem may result in micromotion which can lead to thigh pain, osteolysis and aseptic loosening (Reddy et al., 1999). There is no published data on the proximal femur morphological indices of the Ghanaian population. However, several studies showed variations amongst the Asian, Africans and Western population.

5.2 The Head Diameter

Proximal femur indices are important parameters that should be taken into consideration in the manufacture of prostheses of the proximal femur for total hip arthroplasty (Kokubu et al., 2003). The femoral head diameter is important to know because of the instrumentation of the bone with
screws which are used to hold the fracture in place in hip fractures. This study has demonstrated sexual dimorphism in the femoral head diameter with the females in this current study having wider femoral head diameter than the males bilaterally. According to Wolff’s law, bone dynamically adapts to the skeletal loads (such as weight-bearing), which lead to various osteogenic stimuli, by remodeling bone mass and architecture (Sun et al., 2006). According to Adu & Adu (2015), who investigated anthropometric dimensions of Ghanaian public workers, Ghanaian females were either overweight or obese more than the males. It may be proposed that the females in the Ghanaian population have predominantly heavily built upper body which put weight on the proximal femur. This may also be due to the nature of habitual activities of females in Ghana which involves carrying heavy loads on the head and traveling over long distances daily. The weight exerted by the load could also add to the perpendicular weight of the torso that the femur must bear. This could eventually lead to the strengthening of the proximal femur to withstand such applied force and hence an increase in the females measured indices.

This study also demonstrated laterality of geometric variables where significant statistical difference was observed between the right and the left femoral indices in both males and the females. The data showed that the right side proximal femoral anthropometric variables of the sampled population were greater than the left side. These findings could be as a result of handedness of the sample population (Auerbach & Ruff, 2006). The more one uses one particular lower extremity (left or right) over the other the more the difference in their sizes. There is a tendency for the skeleton of the overused leg to be different from the other leg. A study suggested that the association between behavioral and morphological asymmetry is through mechanically driven bone growth and remodeling (Steele, 2000). Modeling and remodeling modify the diaphysis of long bones in life resulting in change in diameter, shape, and thickness
in cortical bone that reflect the process and degree of biomechanical forces (Lynn Brown, 2006). The above could explain the laterality observed in the study. Studies have shown how asymmetry gradually diminishes when pre-industrial workers are compared to industrial workers to show how division of labour can result in greater development of most used limbs (Auerbach and Ruff 2006). The age group distribution of the variables showed an increasing average femur variable measurement which peaked at 50 – 59 and 60-69 years and start to decline. These may be due to decreasing levels of oestrogen in the women population (Nelson & Megyesi, 2004). The femur head diameter has been studied in different populations including Pakistan (Umer et al., (2010); France (Rubin et al., (1992); Chinese (Tang et al., 2015), Brazil (De souse et al., 2010); Nepalese (Mishra et al., (2009) and America (Unnanuntana et al., (2010). It is noted to demonstrate peculiar characteristics in each population studied. Racial variations in femoral head diameter were found in many populations studied.

Unnanuntana et al., (2010) studied femoral head diameter in the American population and their result was higher than the result of the present study. However, a similar result was obtained by Umer et al., (2010) amongst the Pakistan population. The Chinese, French, Nepal and the Brazilians studies recorded lower femoral head diameter than that of this current study, demonstrating a population-based variation of proximal femur head diameter. These variations may be attributed to genetics, habitual activities, and lifestyle. This data shows that Ghanaian adults have peculiar femoral indices.
5.3 Femur neck diameter

The femur neck diameter is of importance while fixing the fracture neck femur with screw. A large diameter screw may decancellate the neck to very large extent. Similarly, metal tamponade effect may ensue which can cause a vascular necrosis of femoral head, consequently resulting in non-union of fracture neck or a vascular necrosis (Kim et al., 2015). If the prostheses is smaller, the threads of a screw often fail to cross the fracture neck of the femora especially if the fracture is sub-capital (Mishra et al., 2009).

It has been demonstrated in this study that neck diameter demonstrated sexual dimorphism with the female sample recording statistically significant value over the males. It also exhibited laterality with the right side dominating over the left side. The indices of one limb cannot be assumed to be the same as the contralateral limb because of significant differences that can exist between them (Kranioti et al., 2009). This could be attributed to similar factors like genetic variation, lifestyles and activities that affect the head diameter (Kalamullah & Akbar, 2015). The age group distribution of the variables showed a peak at 50 – 59 years and followed by a decline. These may be due to decreasing levels of estrogen in the women population (Nelson & Megyesi, 2004). The in the male population showed a peak at 60- 69 years and begin to decline, these may be attributed to decrease muscle mass and activity that ensures bone maintenance and growth (Toplumunda et al., 2017)

The value of the femur neck diameter in the present study is similar to the works of De Sousa et al., (2010) who also evaluated the variables of proximal femur in Brazilian Population with Auto CAD 200 Software and compared it with other studies of different regions. The result is also similar to what Verma et al., (2017) found when they measured 91 cadaveric bones using digital photographs in the Indian population.
Other publishers of femur neck indices recorded values which are different from data obtained in this present study. Siwach and Dahiya (2003) compared the parameters of femur of Indian cadavers with those of western, Chinese and Hong Kong population. Ho Jung Cho et al., (2014) also observed the anatomic geometric differences of femur in Korean subjects from Americans and Japanese. Mishra et al, in Nepal, studied Twenty-five pairs (50 bones) of cadaveric femora morphologically and radiologically using standardized techniques to obtain anthropometric data to evaluate the applicability of internationally designed implant and to generate a database for Nepalese.

It is proposed that bone strain can directly or indirectly activate bone cells, which then respond with increased metabolism, gene activation, growth factors production and matrix synthesis Burger & Klien (1999). For example, mechanical stimulation of bone cells may induce elevated levels of IGF-I, which was found to promote bone formation and stimulate the differentiation of osteocytes from osteoblasts (Young et al., 2013)

5.4 Neck shaft angle

The studies on neck shaft angles have been done by different authors in different parts of the world. Variations in neck shaft angle have been demonstrated in this current study and this can be attributed to the unique level of activity, genetics, race, diet, and lifestyle of the study population (Kalamullah & Akbar, 2015). Bilateral variations in upper and lower limb bones are attributable to difference in mechanical stress and strain over different bones during its growth, and referred to as directional asymmetry (Kanchan et al., 2008). Despite a lot of research into the anatomic and biomechanical factors which influence the modality of treatment of orthopedic conditions, consideration of neck shaft angle gained importance in the assessment of hip biomechanics and preoperative planning (Miyamoto et al., 2013). The age group distribution of
the variable showed a peak at 50 – 59 years and a decline thereafter. These may be due to decreasing levels of estrogen in the women population (Nelson & Megyesi, 2004).

This present study is similar to previous study by Gilligan et al., (2013) who documented that NSA value of 132.3° for Chad, 130.8° for Mali, 132.5° for Senegal and 130.5° for Sudan. De Sousa et al., (2010) used 110 adult human cadaveric femurs in the Brazilian population by using a portable diagnostic model FNX 200, with Kodak-branded film to radiograph the femurs. Pathak et al., (2016) who used plain radiographs of 110 patients in the Indians population also recorded similar values. Other data that revealed contrary results to this present study are the works of Ravichandran et al., (2011) in their study of 578 dry femur found the mean neck shaft angle to be 126.55 degrees in Indians. Hoaglund and Low (1980) stated that the average neck shaft angle in Caucasian and Hong Kong Chinese people is 135degree. Togwood et al., (2008) published their work on 375 normal femurs and found the mean NSA as 129 degrees. Highest variation for the neck shaft angle was seen between western literature and Mongoloids. Saikia et al., (2008) in their study of 104 individuals concluded the neck shaft angle in the northeast population to be around 139.5 degrees. Kaur et al., (2013) also documented lesser values for neck shaft angle in the North-West Indians population (right 121.39⁰±2.46, left 121.13±2.44⁰). This can be explained in terms of the biomechanical demands. Owing to the greater breadth of the female pelvic inlet and, hence, interacetabular distance, combined with relatively shorter femora, the angle between shaft and condyles is usually greater in females than it is in males (Verlagsbuchhandlung, 2019).

With regards to bilateral symmetry, this current study showed statistically significant difference in the means of neck shaft angle of right and left side in either sex. Implants that are designed by considering anthropometric and biomechanical data will help in designing patient-specific
implants thereby minimizing the complications of surgeries and the management of scarce resources.

5.5 Hip axis length

Previous work that showed similar results to this present work (116.5 mm) is the works of Vaseenon et al., (2015) in the Thailand population where they study 48 plain radiographs of patients and Bergot et al., (2002), documented 11.52±0.43 cm in the French population when they investigated the hip axis length of 49 Caucasian women using a QDR 1000/W scanner. Contrary however to this present study is the work of O´Neil et al., (2006) who measured the femoral axis length and recorded a value of 136.2mm using radiographs in the American population. The differences in the values observed for the different populations may be as a result of the geographical location, genetic predisposition, habits or/and racial difference.

5.6 CONCLUSIONS

The present study has provided a normative data on proximal femoral indices in the Ghanaian adult. Femoral Head diameter and Femoral neck diameter were found to be sexually dimorphic among Ghanaian population with female having greater dimensions than male. This is a unique finding for this population since several studies done in other population reported the male as having greater proximal femoral dimensions. Hip axis length and the neck shaft angle on the other hand did not demonstrate sexual dimorphism. The proximal femoral indices also showed asymmetry on the left and right sides for the population studied.
This study may provide guidance for designing well-matched hip prosthesis for Ghanaian adults based on the dimensions obtained in this study. This study will significantly assist medical professionals’ especially orthopaedic Surgeons in choosing the right prostheses for patients in Ghana when planning for hip surgeries. The study has produced data for manufacturers and procurement institutions when manufacturing for and procuring for the Ghanaian market respectively.

5.7 LIMITATIONS

1. Choice of variables included in the study is limited since the x-ray machine does not input weight and height.

2. It was impossible to determine the effect of handedness on the differences between the femoral dimensions of left comparison to right of patients since data on the handedness of patients were unavailable.

3. It was very difficult determining the nationality of some patients. According to the radiographers, patients sometimes lied about their nationality (pretending to be Ghanaian when they are not) to enable them pay less charges on imaging procedure since non-Ghanaians pay double the fee paid by Ghanaians.
5.8 RECOMMENDATION

1. This study should be extended to other imaging centers in other regions of the country (Ghana). This will generate a broader data on the proximal femur indices of Ghanaians.

2. More proximal femur dimensions should be investigated for a comprehensive understanding and collation of a much comprehensive data on Ghanaians.

3. Other imaging techniques with clearer borders than radiographs can be employed for example MRI and CT scan for a detailed study/understanding of the proximal femur indices of Ghanaians.

4. Future studies of the Ghanaian adults’ femur indices should include healthy adults.

5. A study should be done prospectively to permit control of confounders such as weight, height, nationality and dominance of extremities.
REFERENCES


https://i.pinimg.com/236x/b9/4b/5c/b94b5cfe4d556d539b8ca043bea51833.jpg
Appendix i

Ethical clearance.
Appendix ii

Data collection sheet