OSTEOMETRIC ASSESSMENT OF BONES OF GHANAIAN MALES

BY

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DECLARATION

I hereby declare that this thesis is my own work for MPhil. Reproductive Biology degree and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgment has been made in the text.

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ABSTRACT

Osteometric assessment of human skeletal remains for sex, age and stature estimation has been an important activity of forensic anthropologist and other skeletal biologists. The need for establishment of population-specific standards using osteometric methods has been emphasized due to intra-population and inter-population sexual dimorphism. While some populations have made several strides to standardize their samples, very little attempt has been made using Ghanaian samples. This study was carried out primarily to develop baseline data for sampled Ghanaian male skeletal remains, and also compare them with other samples for regional variation. A total of 300 different paired postcranial bones- femora, humeri, tibiae, radii, ulnae, fibulae, os coxae and articulated pelves housed at the Department of Anatomy, School of Medical Sciences (SMS), Kwame Nkrumah University of Science and Technology (KNUST) were measured for various osteometric indices using a sliding caliper, measuring tape, a pair of dividers and a flat wooden board. The Ghanaian male femoral length was significantly higher ($p<0.05$) than that of Thais, Chinese, Indians and Hong Kong Chinese. Humeral epicondylar breadth was also significantly different from Thais, Hong Kong Chinese, South African Whites and South African Blacks. However, the Ghanaian sample was similar ($p>0.05$) to Thai, Hong Kong and South African black males and females in innomate height and iliac breadth. Based on the studied sample, the ulna was dissimilar from the comparative sample populations in all its measured variables. The findings of this study further suggest that regional osteometric variation exists. Osteometric isolation of skeletal remains of Ghanaian males would be best achieved by combination several variables of a particular bone or by femoral, radial and ulna lengths as well as tibial proximal breadth, humeral epicondylar breadth and acetabular diameter.

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LIST OF ABBREVIATIONS

ABBREVIATION	NAME
ML	Maximum length of femur
MHD	Maximum head diameter of femur
EpBr	Epicondylar breadth of femur
MSCir	Midshaft circumference
MAPD	Midshaft anterior-posterior diameter
MMLD	Midshaft medial-lateral (transverse) diameter
TL	Tibial length
MPEB	Maximum proximal epiphyseal breadth of tibia
MTD	Midshaft transverse diameter of tibia
HML	Humeral maximum length
VHD	Vertical head diameter of humerus
HEpBr	Humeral epicondylar breadth
HAPD	Humeral midshaft anterior-posterior diameter
HMMD	Humeral midshaft Medial-Lateral diameter
HMSCir	Humeral midshaft circumference
RML	Radial maximum length
RMHD	Radial maximum head diameter
RAPD	Radial midshaft anterior-posterior diameter
RMMD	Radial midshaft medial-lateral diameter
RMSCir	Radial midshaft circumference

UML	Ulna maximum length
UPL	Ulna physiological length
UAPD	Ulna anterior-posterior (dorso-volar) diameter
UMLD	Ulna medial-lateral (transverse) diameter
FML	Fibula maximum length
FMSD	Fibula maximum midshaft diameter
FMSCir	Fibula midshaft circumference
TIH	Total innominate height
AD	Acetabular diameter
IL	Ischial length
PL	Pubic length
GSNW	Greater sciatic notch (breadth) width
IB	Iliac breadth
CJD	Conjugate diameter of pelvic inlet
OD	Oblique diameter of pelvic inlet
TD	Transverse diameter of pelvic inlet
HPS	Height of pubic symphysis
SA	Subpubic angle
ASBB	Anterior-superior bispinous breadth
AIBB	Anterior-inferior bispinous Breadth

DEDICATION

I dedicate this work to my mother Madam Mary Osei, my siblings, my uncles Messrs Moses Nkrumah and Atuahene Nkrumah-Ababio, and to my family as a whole.

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CHAPTER ONE

INTRODUCTION

1.0 Background

The importance of studying animal, and for that matter human skeleton, has well been documented. In forensic science, physical anthropology, paleontology, paleoarcheology and demography, knowledge of the human skeleton is imperative. Forensic anthropology has been very important field of traditional biological anthropology in modern science. There has been an unprecedented research growth in forensic anthropology in the last three decades (Steyn and Iscan, 1999). Areas of forensic anthropology that have been considered by various researchers include the assessment of crime related factors like the scene where remains are found, taphonomy, time since death, burned bones, and animal effects on bones (Iscan, 1998).

The role of skeleton in determining sex was adumbrated way back in 1917 by Pearson. Iscan (1998) notes that scientific research in traditional areas such as the assessment of variation in sex and population differences, age and stature has remained essentially the most important activity. Currently, it is axiomatic among skeletal biology researchers that in addition to sex determination, age and stature estimation, whole or part of human skeletal remains may be used to predict to some reasonable degree, occupation, lifestyles of individuals or populations from the past; and other human activities. Also studies on human skeletal samples may furnish an invaluable source of information on diseases of ancient times. Perhaps, sex determination becomes the first step in the identification of human skeletal remains, more so considering the existence of sexual dimorphism within and between populations in the world.

Traditional methods of sex determination in the human skeleton employ morphologic, metric and non-metric analysis of different bones in the human body. Visual inspection of morphologic traits is easier to make but difficult to judge; also, more morphological features depend on nutrition, occupation, race and geographical regions, thus their reliability is arguable since these information is nearly never available (Kranioti et al., 2008) for unknown skeletal remains. In this vein, metric studies have been demonstrated that it may provide certain advantages, appearing as a more objective way of obtaining data (Walrath et al., 2004). It is necessary to be underscored that sex determination of unknown skeletal materials from osteometric techniques in many literature as those found in this work, has relied greatly on various statistical analysis.

1.1 Sexual Dimorphism

There exists intra-population and inter-population sexual differences. Sexual dimorphism may be depicted in form and stature. An understanding of sexual differences between males and females within and between groups is important for sex identification. According to King (1997), sexual dimorphism in the human skeleton and dentition has been studied extensively by authors like Loth (1990; 1996), as well as Iscan et al. (1998).

The importance of studying sexual dimorphism includes understanding the magnitude of differences between males and females between or within populations. It can also give relevant clues to understanding growth and the factors that modify growth patterns (Ji and Ohsawa, 1992). The cardinal principle of sexual dimorphism is that size, along with other morphologic and metric traits, of each population changes over time (King, 1997).

There are numerous factors that make a population different from another (Steyn and Iscan.1999). A population may go through secular change as a result of changes in nutrition and genetic constitution (Steyn and Iscan, 1997). Cultural factors have also been underscored to be also important in influencing sexual dimorphism (King 1997). Steyn and Iscan (1999) note that protein deficiency can reduce sexual dimorphism and males may become less robust. Bone shape, size and other morphological traits may be related to robustness. According to King (1997), Gray and Wolf (1980) expressed that low mean height and low degree of sexual dimorphism in stature are characteristic of societies with poor protein availability. Also, extreme division of labor may enhance or reduce musculoskeletal development and in turn sexual dimorphism (Ruff, 1987). Changes in socioeconomic status and technology are also known factors modifying sexual dimorphism (Steyn and Iscan, 1999).

1.2 Sex Determination

Determining sex is one of the most important steps in identification of human beings. Perhaps, it is the first step in classifying whole or part of human skeletal remains. This is necessary for the settlement of crime-related cases that call for human identification in medico-legal investigation. Also, sex determination is important for the establishment of accurate demographic profiles. Osteometric analysis of human skeletal remains has been useful even in the assessment of race.

Interestingly, a recent study by Kanchan and Rastogi (2009) attempted to assess the utility of morphometric dimensions of the hand for sexing North and South Indian population. They found that the morphometric parameters of the hand showed considerable sexual dimorphism in the studied population. This should be a useful direction in identification of the sex of mutilated or dismembered gross human parts at accident scenes. Also, this is another giant step toward enhancing accurate identification of individuals in medical and legal investigation for the settlement of murder-related crimes.

Nearly all bones are known to show some form of metric and morphological sexual dimorphism. The cranium and the pelvis, however, are established to be highly dimorphic. The most commonly used bones for the purpose of sexing were the cranium and the pelvis (Steyn and Iscan, 1999), with the pelvis regarded as the most obvious anatomic site for sex determination. Krogman and Iscan (1986) have reported the utility of a complete pelvis for sexing with 95% accuracy, although Bruzek (2002) has reported 96% accuracy. For the skull accuracies of 90-92% have been reported (Krogman and Iscan, 1986). Pelvis and skull used in combination, sex was correctly assigned with 98% accuracy in a collection of 750 skeletons (Krogman and Iscan, 1986).

Considering the skull, relatively more recent studies include the face and neurocranium studied by authors like Loth (1996) and Steyn and Iscan (1997). Duric et al. (2005) have reported on usefulness and accuracy of various morphological traits of the cranium in estimating sex of a

Balkan population, using nine common visual indicators of sex, such as sharpness of supraorbital margin, size of mastoid process, size of occipital protuberance, supercilliary arch form, robustness of the mandible, size of mental eminence, size of frontal tuber etc; sex was correctly assigned in about 70% of cases. Cranioti et al. (2008) also studied sixteen standard metric dimension of the cranium some of which include maximum skull length, basion-bregma height, nasion-prosthion height, bizygomatic breath, maximum vault breadth, basion-nasion length, mastoid height and others in 178 adult skulls of Cretan origin.

In Krogman and Iscan's (1986) submission, the pelvis was not always 100% accurate nor was it always present or intact; thus the need for other standards has led to research on nearly every bone in the body. Besides, forensic anthropologists and other skeletal biologists have encountered other fragmented skeletal material. Quantitatively, previous research has shown to varying degree the effectiveness of using long bones in determining the sex of an unknown individual (Campbell and More-Jansen, 2005). Long bones are particularly suitable for metric analysis because they have no easily recognizable morphologic indicators of sex (King et al., 1998).

Some bones of the skeleton that have been worked on generally for the purpose of sexing, include the femur (Iscan and Miller-Shaivitz, 1984; King et al, 1998; Purkait and Chandra, 2004; Asala et al., 2004), tibia (Iscan and Miller-Shaivitz, 1984; Iscan et al., 1994; Kirici and Ozan, 1999 and Sakaue, 2004), humerus (Steyn, and Iscan 1999; Mall et al., 2001; Frutos, 2004) radius (Allen et al., 1987; Berrizbeitia, 1989; Darryl and Kenneth, 1991; Mall et al., 2001; Barrier and L'Abbe 2008), ulna (King, 1997; Sakaue, 2004; Barrier and L'Abbe 2008), fibula (Akihiko and Toshiko, 2005), talus (Bidmos and Dayal, 2004) and the ribs (Iscan, Loth and Wright, 1985; Dupras and Pfeiffer, 1996).

1.3 Age Determination

Age determination is also an important phenomenon in forensic anthropology. It is one of the necessary steps toward identifying whole, part or fragmented human skeletal material. Age is an extremely vital parameter in personal identity of living subjects as well as skeletonised dead bodies. Determination of age from skeletal remains has been studied and analyzed by many workers.

Previous attempts on the determination of age from bones relied more on morphological methods. This approach probably achieved increased accuracies with whole and intact bones but no fragmented skeletal material. Also skeletal biologists and forensic anthropologists in many instances have been confronted with parts of bones. These might have informed and sparked interest in histological age diagnosis. In a report by Han et al. (2009), it is highlighted that, microscopic age estimation of unidentified skeletal remains is accepted as a reliable technique (Stout, 1988) and has been developed from a variety of bones such as the tibia (Thompson and Garvin, 1983), humerus (Yoshino et al., 1994), radius (Stout and Stanley, 1991), and ribs (Stout et al., 1994; Cho and Stout, 2002; Kim et al. 2007).

Currently, Cattaneo et al. (2009) in a technical note indicated that a frequently encountered task in the forensic scenario is verification of the human origin of severely degraded fragments of bone. This perhaps precedes all means of skeletal identification.

1.4 Stature Estimation

Skeletal characteristics are also useful in predicting the stature of a dismembered or fragmented human skeletal remain. The estimation of stature from bones play an important role in identifying unknown bodies, parts of bodies or skeletal remains (Mall et al. 2001). According to Celbis and Agritmis (2006), Rollet conducted the first serious research on the subject of stature forecasting from skeletal studies, by measuring long bones of 50 male and 50 female corpses in 1888.

Bidmos (2008) records that intact long bones of the upper and lower extremities have been subjected to this analysis in Americans, South Africans (Lundy and Feldesman, 1987; Dayal, 2002), Portuguese (De Medonca,2000), Germans (Mall et al., 2001), Bulgarians (Radoinova, 2002) and Turks (Celbis and Agritmis 2006) for the purpose of stature estimation. Currently, skeletal biologists have explored the possibility of using percutaneous bones (Ozaslan et al., 2003) and even dimensions of the foot and shoe (Ozden et al., 2005), hands, feet and foot prints (Krishan and Sharma, 2007). Agnihotri et al. in 2009 studied a Mauritian population to predict stature using percutaneous length of tibia and ulna. Also, Bidmos (2008) reported on using metatarsals to estimate stature of South Africans. Roman et al. (2005) have also published work on stature estimation from femoral measurements of Polish origin. Didia et al (2009) have submitted that attempts have also been made to estimate stature from other bones including metacarpals (Meadows and Jantz, 1992), cervical, thoracic and lumbar vertebrae segments (Jason and Taylor, 1995). Stature estimation formulae have been developed from tibial length for Nigerians by Didia et al. (reported in 2009).

1.5 Population Specific Standards

Several studies have shown that osteometric differences exist between different population groups (Bidmos and Dayal, 2004) and also within a population group (King, 1997). Thus the need for the establishment of population- specific standards for improved forensic analysis of skeletal remains has been emphasized by contemporary skeletal biologists and researchers. It is important to gain data on sexual dimorphism of many bone dimensions in order to be able to assess sex in case only parts of corpses are found (Mall et al., 2001).

Some work has been done using long and pelvic bones of different European populations. Reports have been presented on the utility of the femur, for instance, for sexing populations like Spaniards (Trancho et al., 1997) and Alluni-Peret et al. (2008). Mall et al. (2001) worked on long bones of the arm using German samples. Allen et al. (1987) assessed the sex discriminatory capacity of radius from Dutch collection.

North America, in particular, the United States seems to have done the most extensive work on osteometric analysis of different bones for sexing individuals and race-black and whites. Standards have been set for various bones, especially the cranium, pelvic and long bones of

American skeletal collections. For long bones, some published works include the femur (Iscan and Miller-Shaivitz, 1984) and long bones of the arm (Darryl and Kenneth, 1991).

In Asia, some reports have been submitted for populations of Thais (King et al., 1998), Japanese (Iscan et al., 1994; Sakaue, 2004), Chinese (Wu, 1989; Iscan and Shishai, 1995) and India (Leelavathy et al., 2000; Purkait and Chandra, 2002).

In Africa, South Africa perhaps have done more studies on their skeletal collections than other populations and set standards for sexing different bones in their black and white population. Several osteometric studies have been conducted on the cranium, pelvis, humerus, patella, femur, and calcaneus of black South Africans with varying rates of accuracy (Barrier and L'Abbe, 2008). Asala et.al (1998) have published work on osteometric indices for sexing using Nigerian samples.

Unfortunately, in Ghana, there are no reports on osteometric assessment for sexing males and females using any bones of Ghanaian skeletal remains. Since it is generally accepted by skeletal biologists that sexual dimorphism exist in any population and population show temporal changes, the need for the establishment of some standards for facilitating the classification of unidentified skeletal remains is crucial for forensic analysis and research in present-day Ghana. Only from assessment of known skeletal series can standards be established to interpret remains from the past and identify forensic cases of today and tomorrow (King 1997).

!.6 Purpose of Study

This study was carried out primarily to develop baseline data for sampled Ghanaian male skeletal remains housed at the Department of Anatomy, School of Medical Sciences, KNUST, using pelvic and long bones.

Specifically, the study sought to:

(1) Take measurements of standard anthropometric indices for the Os coxae, femur, tibia, fibula, humerus, radius and ulna.

(2) Compare the obtained data with that of other populations in order to assess regional variability.

(3) Suggest which osteometric indices may be useful for separating the Ghanaian and comparative samples.

CHAPTER TWO

LITERATURE REVIEW

2.0 Skeletal Identification

Research by various forensic anthropologists has shown that sex of adult skeletal remains can be assessed with accuracy near 100%. However, the degree of accuracy is dependent on the part of the human skeleton that is recovered. The techniques used in sex determination have been primarily focused on the pelvis where reproductive difference is best seen and the cranium where the size and morphology are varied and best represented (Iscan, 2005).

The intact cranium when present can be visually assessed and the sex of an unidentified skeleton predicted with high level of confidence before any further confirmation of sex may be executed by quantitative metric analysis. Beyond the cranium, several postcranial bones have proven useful in sex determination. In many cases, particularly those involving intact pelvis, qualitative morphological observations are sufficient for accurate sex attribution (Darryl and Kenneth, 1991). In other cases, intact cranium or pelvis may not be available for qualitative or quantitative analysis, making the task of sexing skeletal remains very challenging. Under this circumstance where incomplete or fragments of skeleton may be found, metric assessment of these parts becomes good alternative. These skeletal parts may be dismembered intact long bones, separate cranial or pelvic bones, or fragments of these bones.

Long bones have played an important role in the determination of sex (Iscan and Mille-Shaivitz 1984). Of these, both upper and lower limb bones have been studied in different populations for this purpose. The femur, tibia and fibula, humerus, radius and ulna of the lower limb, from different regions have commonly been metrically analyzed to distinguish males from males.

2.1 Sexing of femora

The femur is one of the important body parts that forensic anthropologists have found to be sexually dimorphic. The studies on sexual dimorphism is based on the simple principle that the axial skeleton weight of the male is relatively and absolutely heavier than that of the female and the first brunt of this weight is borne by the femur in transmission of the body weight (Purkait and Chandra, 2004). Another factor which makes its indentation on the femur is the modification of the female pelvis with respect to its specialized function of reproduction; therefore the stress and strain experienced by the femur is different in male and female (Purkait and Chandra, 2004).

It is vital to be able to assess sex from many skeletal parts of the human body for the obvious reason that, one may not have complete pelvis or skull (Iscan, 2005); these are the first bones of choice in matters of sex diagnosis when complete or dismembered skeleton is encountered. Since isolated long bones are frequently found, many studies have produced osteometric standard for sex determination (Iscan and Shishai, 1995). The femur has probably been the most analyzed long bone of the human skeleton populations (Iscan, 2005). Since a long time, by virtue of its strategic position in human anatomy the femur has attracted the attention of researchers from all over the world (Purkait and Chandra, 2004).

The trend to study this bone has pervaded many different nations and populations. The femur has been evaluated for sex prediction in several populations such as American Indians, American Blacks, American Whites, Asian Indians, British, Czechs, French, Italians, Japanese, Chinese, New Zealanders and South Africans. These studies have clearly depicted that there are considerable size differences between populations and thus specific metric standards must be developed for each group.

It is commonly accepted that the examination and statistical analysis of femoral anthropometry among different populations reveals great amount of variation due to the fact that femoral anthropometric measurement from different countries are likely to be affected by racial variation in diet, heredity, climate and other geographical factors related to life style (Asala et al., 1998; Ziylan and Murshid, 2002).

Interestingly, of the many different standard anthropometric femoral indices that various researchers have utilized in identifying males from females in different populations, it has been recognized that, dimensions with the highest degree of sexual dimorphism vary from one population to another. Also, the magnitude of the differences even in various portions of the same bone differs by population (Iscan and Shishai 1995). Among the standard osteological variables, it has been commonly discovered that proximal and distal features wield higher classification potential than shaft indices and length. Femoral head indices and epicondylar breadth have stood atop as the best discriminators in many studied groups (King et al. 1998; Asala et al., 2004; Murphy 2005).

In a study by Iscan and Miller-Shaivitz (1984) on population of American Whites and Blacks, as highlighted by Iscan and Shishai (1995), head diameter was the highest dimorphic feature among the tested dimensions with accuracy of sex determination being 90.1% in Whites and 90% in Blacks. However, Iscan and Shishai (1995) assessing six standard femoral measurements for sex classification of Chinese sample discovered that distal epiphyseal (epicondylar, bicondylar) breadth was the highest sex discriminator for that population, with accuracy of classification being 94.9%. They further found that, by comparing the Chinese, American Whites and the Blacks, midshaft circumference was the least dimorphic in all these populations. King et al. (1998) have also underscored epicondylar breadth to be about 93% accurate as sex identifier in their study of Thai population.

According the findings of Purkait and Chandra (2004) in working on 124 femora from central India by measuring 11 anthropometric variables, head diameter could ascribe sex to males and females of this population with an accuracy of about 93.5%. Epicondylar breadth was the next single best sex discriminator in this group, recording accuracy of 90.3%. In their study, subtrochanteric anterior-posterior diameter was the least dimorphic variable.

In a recent study on French contemporary samples by Alunni-Perret et al. (2008) in assessing the reliability of bicondylar breadth as one of the best sex discriminators in many populations as postulated by many researchers, they found that it can be about 95% accurate in distinguish males and females of that population. Murphy (2005) reported accuracy of 80.9%-82.4% in sexing prehistoric New Zealand Polynesian skeletal remains using three femoral head indices.

South Africa seems to have made important strides in Sub-Saharan Africa terms of work on the utility of femoral variables as a diagnostic tool for sex classification. Asala (2001) and Asala et al. (2004) have established the reliability of upper and lower femoral features as sex indicators in White and Black South Africans. Steyn and Iscan (1997) have also quantified the importance of using dimensions of the femur in sexing White South African population. In all these research findings with samples from Raymond Dart Skeletal Collections and University of Pretoria Medical School, it became evident that features from the upper and lower extremities of femur contributed greatly to optimal sex discrimination, unlike those of the diaphysis.

Mall et al. (2000) reported that in their study of 170 femora of German descent, and of six easily accessible anthropometric dimensions measured, they observed varied degrees of accurate sex prediction using the individual femoral features alone. Maximum length alone was 72.4% precise, maximum midshaft diameter 81.4%, condylar width 86.8% , vertical head diameter, 87.7% , head circumference and transverse head diameter 89.6%

2.2 Sex Diagnosis of Tibia

The tibia is one of the important long bones of the human body. Anatomically located between the knee and the ankle, it transmits upper body weight from the pelvis and femur to the foot. Work on the tibia for sex determination in a variety of populations has been phenomenal.

Iscan (2005) writing on some of the useful researches on the tibia said, Slaus and Tomicic studied 7th century tibial remains collected from several medieval cemeteries (3rd–13th centuries) in Croatia and the eastern Adriatic coast. Their study was composed of 96 males and 84 females. Following the technique carried out by Iscan and Miller-Shaivitz, the authors recorded the tibial length and five epiphysis dimensions in order to determine sex from the complete as well as fragmentary bones. They found that sex determination was possible with an accuracy of 93% when all six dimensions were used. The percentage dropped considerably to a low of 75% when a single dimension in a presumably fragmented condition was used in the discriminant analysis. The accuracy as such is compatible with studies on contemporary populations. As the authors (Slaus and Tomicic) noted, archaeological populations are now better understood when the remains of that period are assessed with contemporary forensic techniques.

Iscan and Miller-Shaivitz (1984) studying 159 American Black and White tibiae from Terry Collection, established the utility of this bone in indentifying sex in that population. They measured four dimensions of the tibia-length and at the level of the nutrient foramen, anterposterior diameter and transverse (mediolateral) diameter. In their research, the tibial circumference alone predicted the sex with 77% accuracy for whites and 80% for blacks, and the length alone was accurate at 66% for whites and 81% for blacks. They further submitted that comparing their findings with that of the femur assessed by DiBennardo and Taylor (1979, 1982), sexual difference in blacks was somewhat better assessed from the tibia than from the femur.

In South Africa, Steyn and Iscan (1997) noted that Kieser et al. (1992) were the first to develop standards for sex determination from the proximal tibia in South African populations. In their own studies of assessing seven standard osteological variables from 106 tibiae of South African White descent, they recognized that proximal epiphyseal breadth alone can allocate sex in this group with accuracy of approximately 87%. Distal breadth in isolation can distinguish between the males and females with about 89% precision. In terms of dual features, distal breadth and proximal epiphyseal breadth were the most discriminative.

Some work done in Japan in using the tibia to differentiate between the male and females of that population include that of Sakaue (2004) who was interested in providing a basis from which one might choose a variable of a long bone that is most suitable for sex diagnosis. After investigating the tibiae of 64 modern Japanese, he submitted on record that proximal epiphyseal breadth was useful among the analyzed tibial indices. Sakaue's findings probably agreed with and for that matter corroborated ealier observations by Iscan et al. (1994) who after studying seven tibial measurements of 84 contemporary Japanese skeletons, found that among the studied males and females, proximal epiphyseal breadth can separate the two sexes with an average accuracy of 89% whiles minimum shaft circumference was the least discriminative, being 80% correct sex indicator.

2.2 Humerus for Sex Classification

The humerus which for anatomic purposes forms an integral component of the shoulder and the elbow has also been subjected to several tests in different populations to assess its capability as sex determiner. Like other long bones, different traits of the proximal shaft and distal parts have been enumerated for this motive. A common point of convergence from these studies is the fact that, end features of long bones tend to be the most sexually dimorphic.

Frutos (2005) addressed the question of the absence of population specific standards for sex determination using the Humerii from Guatemala. The skeletal remains were exhumed from individuals who were killed during an internal armed conflict that took place in the country. The maximum length, head diameter, mid-shaft circumference, mid-shaft maximum and minimum diameters, and epicondylar breadth measurements were taken from a total of 118 complete humerii involving 68 males and 50 females. From the survey, he obtained an accuracy rate of nearly 96% in separating one sex from another from the head diameter and 77% from the mid-shaft diameters. In Frutos' (2005) report, Augilera et al. (2000) made known that in a Spanish sample and based on the same three dimension of the humerus in that group, head diameter could distinguish females 100% and males, 70%. Epicondylar breadth could also assign sex in the Spaniards with accuracies of nearly 86% and 98% in males and females respectively

German humeral samples have also been investigated Mall et al. (2001). In this study, humerii were obtained from 143 individuals comprising 64 males and 79 females. The osteological variables assessed were maximum length, vertical head diameter and epicondylar width. From their work, they observed that among the three humeral indices, vertical head diameter gave the best distinction between the sexes with sex allocation accuracy of about 90%. Humeral length though the least dimorphic among the three investigated dimensions, could attribute sex with precision of about 81%.

A study by King (1997) has further demonstrated that the humerus is good for sex attribution in Thai individuals. King analyzed eight humeral indices from 104 subjects and reported that accuracies for correctly distinguishing males and females of that population ranged between approximately 88% and 97%. Further accentuating the claim that end traits of long bones are the best sex indicators, he noted epicondylar breadth had classification accuracy of 93%, followed by vertical head diameter having 90%.

Steyn and Iscan (1999), in one of their publications on sexual dimorphism in South Africans assayed osteometric variation in the humerus. Their sample was generated from skeletons 104 whites and 88 Blacks. They analyzed six humeral dimensions including vertical head diameter, deltoid tuberosity circumference, minimum and maximum midshaft diameters maximum length and epicodylar breadth. Their results showed that the head and epicondylar diameters were the best to differentiate sex in Whites whiles head diameter and maximum length represented the best indicators in the Blacks. Accuracy of correct sex classification was 96% and 95% in whites and Blacks respectively.

Iscan et al. (1998) made a comparative analysis of sexual dimorphism in the humerus from Japanese, Thais and Chinese. The sample comprised of 87 adult skeletons of recent Chinese, 90 contemporary Japanese skeletons and 104 modern Thai skeletons. A total of six humeral dimensions were taken. Measurements included maximum length, vertical head diameter, minimum midshaft diameter, maximum midshaft diameter, midshaft circumference, epicondylar breadth.

Though long bone lengths have been established to be less useful in metric sex determination, Darryl and Kenneth (1991) demonstrated humeral length may allocate sex with an accuracy of about 82% and 84% in American (Black and White) males and females respectively. It must however be noted this humeral osteometric index becomes adopted only as a last resort.

2.3 Sex Diagnosis of Radius

The radius is an equally vital long bone whose sex identification potential has been explored in several populations. In some populations, it may be the first bone of choice in employing forearm bones for sex determination when investigators are confronted with comingled skeletal remains.

Berrizbeitia (1989) analyzed a sample of 1108 radii from 567 black and White North Americans obtained from Terry Collection. The study showed that the diameter of the radial head is an accurate sex discriminator for human remains. Berrizbeitia's work submitted that radial head diameter alone can ascribe sex to unknown skeletal remains emanating from that population, with an accuracy of 96%. Darryl and Kenneth (1991) in their studies on sex determination from arm bone measurements took a set of five measurements from each of 302 adult American skeletons. They note that among the indices which included humeral length, radial semibistyloid breadth (distal breadth), ulna semibistyloid breadth, radial length and ulna length; the distal breadth index was the most biologically significant indicator of sexual dimorphism than any of the other four variables. Correct sexing accuracies (in parenthesis) were black males (84%), black females (88%), white males (92.3%) and white females (84.6%).

Celbis and Agritmis (2006) attempted to assess sex and stature from long bones of the forearm using recently deceased forensic cases in Istanbul, Turkey. The sample composed of 80 males and 47 females, and radial and ulna lengths were analyzed to know their sex determination efficacy. From the studies, it became evident that ulna length can correctly identify the sex of an unknown bone with an accuracy of approximately 91% in both males and females of that population, while radial length was 90.6 %. Interestingly, these individual accuracies are similar to the combined accuracy of both radial and ulna lengths in that group.

Barrier and L'Abbe (2008) reported the first study ever conducted to investigate the sexing potential of the forearm (radius and ulna) among black South Africans. Their sample consisted of 200 male and 200 female skeletons from the Pretoria Bone and Raymond Dart collections and they took sixteen standard anthropometric measurements; nine from the radius and seven from the ulna. Distal breadth, minimum mid-shaft diameter and maximum head diameter were the best discriminators of sex for the radius in blacks of South Africa. Classification accuracies ranged between 82 % and 88%. The authors reckoned the radius as a moderate indicator of sex in that racial group based on comparison with studies on other long bones (femur and tibia) of that race of South Africans as well as even other populations.

From Mall et al.'s (2001) report on their studies on sex determination and estimation of stature from the long bones of the arm, which included analysis of maximum length, maximum head diameter and distal width of the radius of German skeletal remains, a percentage of 95% of cases were correctly classified when all measures of the radius were applied jointly. This represented the highest accuracy among the all the long bones when combined traits of each bone was used for sex prediction. Furthermore, radial length gave an accuracy of 89%, even higher than humeral epicondylar width (88.5%), comparing their efficacy for sex attribution.

2.4 Ulna for Sex Identification

The utility of the ulna as a sex diagnostic tool for skeletal remains has been studied in some populations. Mall et al. (2001) observed from their study on German remains that when maximum ulna length, maximum proximal width and maximum distal width were combined for sex prediction in that group, accuracy of 90.58% could be attained.

Barrier and L'Abbe (2008) have noted minimum mid-shaft diameter and olecranon breadth as the best sex indicators among seven standard osteological standards analyzed, namely, maximum length of the ulna, anterior–posterior diameter, medial-lateral diameter, minimum circumference, olecranon breadth, minimum olecranon breadth and height of the olecranon. Accuracies for solitary and combined variables ranged between 83% and 88% for both males and females.

Celbis and Agritmis (2006) have also demonstrated that ulna length could be adopted to classify sex of unknown skeletal remains of Turkish descent with an accuracy of 91.3%. They made this observation from their analysis of skeletal remains of 127 individuals.

2.5 Pelvis

The bony pelvis consists of two innomates (hip bones, Os Coxae) and the sacrum with its coccyx. Each hip bone in turn comprises three fused bones, the ilium, ischium and pubis. Before that advent of metric analysis of bones for sex determination, individual skeletons were classified as either male or female based morphological traits. Studies had established that sexual dimorphism was prominent in the pelvis of males and females ostensibly owing to adaptation for child bearing. Each of the components of the pelvis is known to possess varied morphological indicators of sex. However, some of these indicators may only need to be metrically assessed and ascertained before any definite sex identification could be made. For example, males are known to have narrower sacrum and more curved coccyx than females. Also females tend have shallower acetabular depths than males. Visual assessment and/or metric quantification of the bony pelvis en bloc have also demonstrated marked sexual differences.

Before the common use of osteometric technique and discriminant function analysis, most anthropologists preferred the morphological variation in the skeletal system to determine the sex (Iscan, 2005). Current opinion regards the hip bone (os coxae) as providing the highest accuracy levels for sex determination; however, "simple" observations of the hip bone without any scoring of related traits should not be normally considered proper, despite the fact that the results may be surprisingly accurate (Bruzek, 2002).

In Bruzek's (2002) report, three techniques for the visual evaluation of traits of the hip bone are: 1) the method of Phenice (1969), which uses three traits on the pubis, 2) the method of Iscan and Derrick (1984) using the posterior pelvis, and 3) the method of Ferembach et al. (1980) of sexing the entire pelvis through an evaluation of eleven traits. Owing to some drawbacks in these methods identified by Bruzek as frequently cited, his work proposed a new method for visual sex determination that emphasizes four aspects insufficiently considered in previous studies. First, there is a reduction of observer subjectivity during the evaluation of selected traits by using only three possible scores (present, indeterminate, absent), contrary to ordinal scoring in which it is always difficult to make a decision between two neighboring categories. Second, the method eliminates confusion between traits (e.g., the preauricular and paraglenoid grooves, which represent separate elements; Kurihara et al., 1996). Third, when necessary for complex characters, it uses a rigorous evaluation of three relatively independent characters reflecting the sex of the individual. When at least two of these elements lead in the same direction, it is possible to decide whether a determination is possible. A reliable male or female diagnosis is considered possible when at least two variables are concordant. This approach is the opposite to one attempting to score a primary sexual characteristic, thereby anticipating the presence or absence of its secondary manifestations. And fourth, this method can be applied to damaged or incomplete hip bones.

Five characters of the hip bone adopted in Bruzek's method are: (1) aspects of the preauricular surface (2) aspects of the greater sciatic notch (3) the form of the composite arch (4) the morphology of the inferior pelvis and (5) ischiopubic proportions.

Though high degree of observer subjectivity; a lack of consistency in the evaluation of traits and a strong dependence on the results of previous experiences of the observer were enumerated as the major inefficiencies of the three previous techniques, Bruzek concedes that there is an advantage in visual techniques, which emanate from their rapidity of use as well as their ability to be used when damage does not allow complete set if measurements.

Bruzek established that from the new method, and upon testing 402 adult skeletons of French and Portuguese origins, the five characters combined yielded correct sex diagnosis of 95% in all cases.

One of the areas where attention was least focused was in determining sex metrically from the pelvis (Iscan, 2005). Nonetheless, impressive strides have been made from several studies.

Patriquin et al. (2005) analyzed metric characteristics of South African white and black os coxae in 400 individuals from the Dart and Pretoria collections. They used a number of anthropometric dimensions (e.g., acetabular diameter, width of the sciatic notch and pubis, and total lengths of the os coxae, pubis and ischium). Using the standard SPSS discriminant function analysis subroutine, they observed that sex determination is possible with high accuracy (91%) if the entire bone is present and all measurements are available. In order to solve the problem of fragmented remains, the authors devised a number of stepwise analyses. From individual bones, direct functions gave 80% for the coxal length, 85% for the ischial, only 73% for the sciatic notch and 77% acetabular diameter. Preceding the work Patriquin and associates on South African samples, was the pioneering work of Washburn who reported accuracy of 96.1% for 152 Bantu skeletons when he applied ischium-pubis index for sexing the sample.

Duric and co-workers attempted to develop sex determination model from the skull (N = 180) and pelvis (N = 262) using Albanian victims from Kosova found in two mass graves in Serbia (Iscan, 2005). Among the indices were the sub-pubic angle, ischiopubic ridge and preauricular sulcus from the pelvis. The authors observed that the accuracy rate was as much as 100% from the sub-pubic angle. Of the pelvis, the greater sciatic notch width had the lowest accuracy of 71% while the sub-pubic angle has the highest at 98%.

Luo (1995) studied one hundred and twenty-two (66 males, 56 females) adult pubes of known sex from the Human Identification Laboratory, University of Arizona. Two angles and two distances were measured as follows: the angle formed by the middle line of the superior ramus and inferior ramus of pubis, subpubic angle, the minimum distance from the symphyseal surface to the obturator and the minimum thickness of ischiopubic ramus. Luo reported accuracies ranging from 84.4% to 96.5%. Subpubic angle when applied singly was able to identify sex with an accuracy of approximately 97% in the studied sample.

Steyn and Iscan (2008) published their work on modern Greek skeletal remains. Their study sample consisted of 97 males and 95 females, and seventeen standard anthropometric variables were assessed. Sex classification based on variables from single innomates ranged from nearly 80% to 94%. They further observed that measurement from articulated pelvis yielded poorer results than those from single os coxae. From their analysis, the diameter of the acetabulum was the single most dimorphic characteristic, providing on average 83.9% accuracy when used in isolation.

Igbigbi and Igbigbi-Nanono (2008), determined the sex and race of 205 adult Ugandans from the anteroposterior radiographs of the pelvis by measuring their subpubic angles. The angle ranged from 50 to 140 degrees with a mean of 93.86 degrees and standard deviation (SD) of 21.12 degrees for males and 75 to 155 degrees with a mean of 116.11 degrees (SD, 17.79 degrees) for females. The angle was significantly wider in women than men ($P < 0.05$), as indeed has previously been shown in other population groups studied.

It has been suggested that dimensions of pelvic inlet and outlet vary among males and females. The approximate dimensions of the female pelvic inlet are as follows: anterior-posterior diameter, 11cm; transverse diameter, 13. Male pelvic inlet dimensions have been established to be slightly shorter than that of females.

CHAPTER THREE

MATERIALS AND METHODS

3.0 Sample Collection

A total of 300 different paired bones were available for the study. However, 50 femora, 38 humeri, 47 tibiae, 31 radii, 31 ulnae, 30 fibulae, 20 os coxae and 10 complete pelves were used in the study. The rejected bones were either incomplete or had pathological conditions or lesions, deformations, or fractures or had parts that were putrefied and disintegrated and so did not make them suitable for the study. Samples were obtained from the Department of Anatomy, School of Medical Sciences (SMS), Kwame Nkrumah University of Science and Technology (KNUST). Samples were prepared using collections from student cadavers. Specimens were of known sex and age between 21 and 65.

3.1 Sample Preparation

Samples were prepared using cadavers from student collection at the dissection hall of the Department of Anatomy, SMS-KNUST. Cadavers were laid on dissection or autopsy tables and the pelvis and various appendages disarticulated. The dismembered parts were then subjected to first series of defleshing using scalpels. The individual bones still having tiny soft tissues on them were air-dried for about four weeks and then a final series of mechanical removal of tissues carried out to rid the relatively dry tiny bits of soft tissues. The bones were again placed on plastic sheets and air-dried for some two weeks, and chemical treated to prevent insect infestation, after which they were ready for measurement.

3.2 Sample Measurement

A sliding caliper (Starrett, USA), a locally manufactured measuring tape, a pair of dividers and a flat wooden board were used in taking measurements of the various anthropometric variables of the individual bones. The measuring tape was checked with a well calibrated steel tape (Starrett, USA) to correct for measuring errors. All measurements were taken in millimeters.

A preliminary set of 80 bones were randomly selected, measured and subjected to student's t-test to find out if there were any statistical differences in then the prospective variables of the individual bones from the left and right sides. No statistically significant differences were observed with regard to the laterality of the bones. Thus, either left or right side of these postcranial bones was included in the study. Each variable was measured twice and the average recorded for the original data.

3.3 Osteological Indices

The anthropometric variables were carefully chosen based on one or combination of the following reasons:

1) recommended (traditional) standard anthropometric indices

2) easily accessible and identifiable features

3) frequently encountered or preserved bone parts

Femoral, tibial, fibula, humeral, radial and ulnal indices were adopted and measured according to the prescription enshrined in ***Standards For Data Collection From Human Skeletal Remains*** (Buikstra and Uberlaker, 1994). Pelvic variables were measured as according to Steyn and Iscan, 2008. Two new dimensions were introduced for the articulated pelvis; anterior-superior bispinous breadth and anterior-inferior bispinous breadth. These innovative measurements are important and useful for data collection from different parts and/or segments, of the bone.

The following femoral dimensions were measured:

Maximum Length (ML): The distance from the most superior point on the head of the femur to the most inferior point on the distal condyles. The most inferior point usually occurs on the medial condyle.

Maximum Head Diameter (MHD): The maximum diameter of the head of the femur, wherever it occurs. This can be obtained by carefully rotating the femoral head through the teeth of the caliper.

Epicondylar Breadth (EpBr): The distance between the two most laterally projecting points on the epicondyles (Figure 1).

Midshaft Circumference (MSCir): This is measured as the circumference at the midpoint of the diaphysis. The steel tape goes round this point while in contact with the bone.

Midshaft Anterior-Posterior (Saggital) Diameter (MAPD): The distance between the anterior and posterior surfaces measured approximately at the midpoint of the diaphysis, at the highest elevation of the linea aspera.

Midshaft Medial-Lateral (Transverse) Diameter (MMLD: The distance between the medial and lateral surfaces at the midshaft, measured perpendicular to the anterior-posterior diameter.

Figure 1. Measurement of epicondylar breadth

For the tibia, the following variables were measured and analyzed:

Tibial Length (TL): The distance from the superior articular surface of the lateral condyle to the tip of the medial malleolus.

Maximum Proximal Epiphyseal Breadth (MPEB): The maximum distance between the two most laterally projecting points on the medial and lateral condyles of the proximal articular region.

Midshaft Circumference (MSCir): This is measured as the circumference at the midpoint of the diaphysis. The steel tape follows contour of the bone (Figure 2).

Midshaft Anterior-Posterior Diameter (MAPD): The distance between the anterior border crest and the highest point of the posterior surface measured approximately at the midpoint of the diaphysis.

Midshaft Transverse Diameter (MTD: The distance between the medial and lateral surfaces at the midshaft, measured perpendicular to the anterior-posterior diameter.

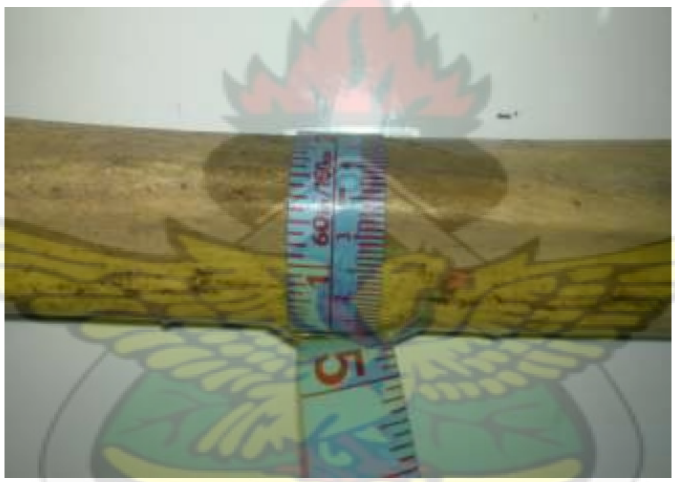

Figure 2. Measurement of midshaft circumference

Standard anthropometric dimensions of the humerus measured in the study are as follows:

Maximum Length (HML): The direct distance from the most superior point on the head of the humerus to the most inferior point on the trochlea (Figure 3).

Vertical Head Diameter (VHD): The direct distance between the most superior and inferior points on the border of the articular surface of the head (Figure 4).

Epicondylar Breadth (HEpBr): The distance of the most laterally protruding point on the lateral epicondyle from the corresponding projection of the medial epicondyle. Measurement should be taken with the bone resting on its posterior surface.

Midshaft Anterior-Posterior (Maximum) Diameter (HAPD): The distance between the anterior and posterior surfaces measured approximately at the midpoint of the diaphysis.

Midshaft Medial-Lateral (Minimum) Diameter (HMMD): The distance between the medial and lateral surfaces at the midshaft, measured perpendicular to the anterior-posterior diameter.

Midshaft Circumference (HMSCir):This is measured as the circumference at the midpoint of the diaphysis. The steel tape follows the contour of the bone.

Figure 3.Humeral length measurement

Figure 4.Measurement of VHD of humerus

For the radius, below are the osteological dimensions measured:

Maximum Length (RML): The distance from the most proximally positioned point on the head of the radius to the tip of the styloid process.

Maximum Head Diameter (RMHD): The greatest diameter of the head of radius wherever it occurs. The head of the radius is carefully rotated through the teeth of caliper to obtain the maximum diameter (Figure 5).

Midshaft Anterior-Posterior (Saggital) Diameter (RAPD): The distance between the anterior and posterior surfaces measured approximately at the midpoint of the diaphysis.

Midshaft Medial-Lateral (Transverse) Diameter (RMMD): The distance between the medial and lateral surfaces at the midshaft, measured perpendicular to the anterior-posterior diameter.

Midshaft Circumference (RMSCir):This is measured as the circumference at the midpoint of the diaphysis. The steel tape goes round this point while in contact with the bone.

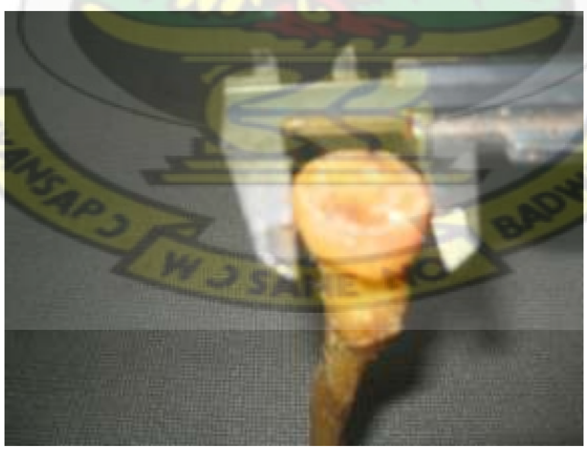

Figure 5. Measurement of radial head diameter

Anthropometric indices that were measured from the ulna are:

Maximum Length (UML): The distance from the most superior point on the olecranon to the most inferior point on the styloid process (Figure 6).

Physiological Length (UPL): The distance between the most distal point on the surface of the coronoid process and the most distal point on the inferior surface of the distal head of the ulna.

Anterior-Posterior (Dorso-Volar) Diameter (UAPD): The maximum diameter of the diaphysis where the crest exhibits the greatest development in anterior-posterior plane.

Medial-Lateral (Transverse) Diameter (UMLD): The distance between the medial and lateral surfaces at the level of greatest crest development; measured perpendicular to the anterior-posterior diameter.

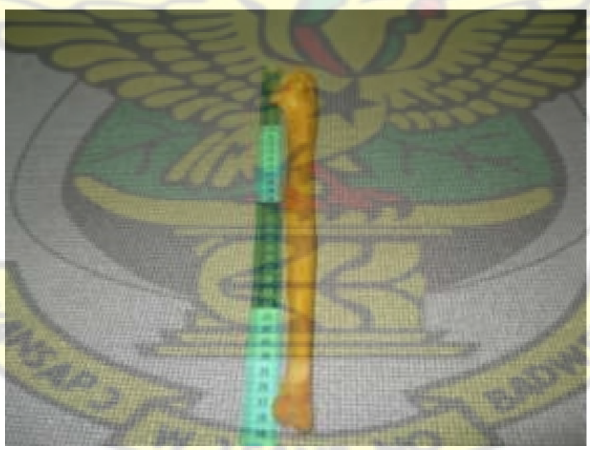

Figure 6.Measurement of maximum length of ulna

The three variables studied for the fibula include the maximum length, maximum diameter at mid shaft and the circumference at the mid shaft.

Maximum Length (FML): The maximum distance between the most superior point on the head of the fibula and the most distal point on the lateral malleolus (Figure 7).

Maximum Midshaft Diameter (FMSD): This measured as the maximum diameter at the midshaft; commonly located between the anterior and lateral crests. The diaphysis of the bone is placed between the two branches (teeth) of the caliper and it turned gently to obtain the maximum diameter.

Midshaft Circumference (FMSCir): This is measured as the circumference at the midpoint of the diaphysis. The steel tape goes round this point while in contact with the bone.

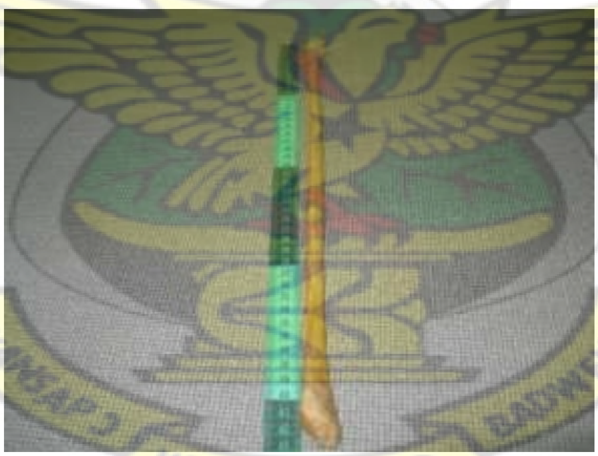

Figure 7. Measurement of fibula maximum length

Coxal bone (Os coxa) dimensions measured in the study comprised of the following:

Total Innominate Height (TIH): The greatest distance from the most superior point on the iliac crest to the most inferior point of the ischial tuberosity.

Acetabular Diameter (AD): The maximum diameter of the acetabulum measured in a superior-inferior direction (Figure 8).

Ischial Length (IL): The distance from the superior ridge of acetabulum at the center of origin (the point where the three elements of the os coxa meet) of the iliac blade to the deepest point on the ischial tuberosity.

Pubic Length (PL): The distance from the superior ridge of acetabulum at the center of origin (the point where the three elements of the os coxa meet) of the iliac blade to the most superior and medial point on the pubic crest (the upper end of the pubic symphysis). This measurement is perpendicular to ischial length.

Greater Sciatic Notch (Breadth) /Width (GSNW): The distance from the base of the ischial spine to the posterior inferior iliac spine, stopping at the point before the curvature of the spine angles towards the posterior.

Iliac Breadth (IB): the distance from the anterior superior iliac spine to the posterior superior iliac spine.

From the articulated pelvis 7 indices including conjugate, transverse and oblique diameters , were measured.

Conjugate Diameter (CJD): This is the anterior posterior diameter of the pelvic inlet measured from the deepest point of the sacral promontory to the pubic symphysis (Figure 9).

Oblique Diameter (OD): The greatest distance of the pelvic inlet measured diagonally from the sacroiliac joint to arcuate line.

Transverse Diameter (TD): the maximum distance between the arcuate lines of the two innomates.

Height of Pubic Symphysis (HPS): The distance from the most superior point to the most inferior point on the pubic symphysis.

Subpubic Angle (SA): The angle between the ischiopubic ramii of the two coxal bones.

Anterior-Superior Bispinous Breadth (ASBB): The distance between the two anterior-superior iliac spines of the articulated pelvis (Figure 10).

Anterior-Inferior Bispinous Breadth (AIBB): The distance between the two anterior-inferior iliac spines of the articulated pelvis.

Figure 8. Measurement of acetabular diameter

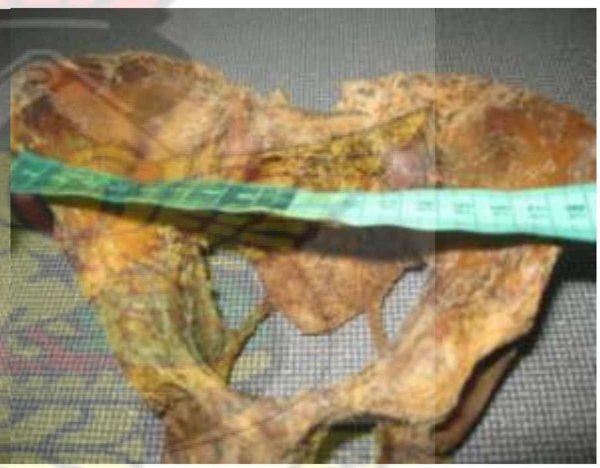

Figure 9. Measurement of conjugate diameter

Figure 10 Measurement of ASBB

3.4 Data Analysis

The collected data was analyzed using Graph Pad Prism statistical software for its ability to compare a theoretical mean with the mean of an original data. Descriptive statistics of the different variables has been presented as well as various comparisons drawn from different published populations. To be certain in identification, calculated range has to be considered, which is worked out by adding and subtracting three (3) standard deviations (3 x SD) to and from the mean of any parameter (Asala, 2001; Mishra et al., 2003). Therefore calculated ranges for the osteological variables of the individual bones were also presented.

CHAPTER FOUR

RESULTS

4.0 Femur

For the six anthropometric dimensions analyzed for the femur from the studied sample population, maximum length recorded mean (standard deviation) of 472.50 mm (20.69 mm) with a range of 435.00 mm-516.00 mm; that of maximum head diameter was 46.08 mm (2.57 mm) and range, 40.80 mm-53.20 mm. For epicondylar breadth, the mean was 80.29 mm with standard deviation, 4.39 mm and range of 71.40 mm-92.10 mm. Midshaft circumference had mean (standard deviation) of 89.56 mm (6.16 mm) and range of 75 mm-105 mm. The rest were midshaft anterior-posterior diameter with mean of 29.69 mm, standard deviation of 2.90 mm and range of 23.00 mm-36.20 mm as well as medial-lateral diameter at midshaft that had mean (standard deviation) of 25.95 mm (1.86 mm) with a range of 21.80 mm-30.50 mm. See table 1 below.

Table 1. Descriptive statistics of femoral indices (N=50)

Parameter (mm)	ML	MHD	EpBr	MSCir	MAPD	MMLD
Minimum	435.00	40.80	71.40	75.00	23.00	21.80
Maximum	516.00	53.20	92.10	105.00	36.20	30.50
Mean	472.50	46.08	80.29	89.56	29.69	25.95
Std. Deviation	20.69	2.57	4.39	6.16	2.90	1.86
Std. Error	2.93	0.36	0.62	0.87	0.41	0.26
Coefficient of Variation	4.38%	5.57%	5.46%	6.88%	9.77%	7.16%

Std. –Standard Deviation N-sample size ML-maximum length MHD-maximum head diameter EpBr-epicondylar breadth MSCir-midshaft circumference MAPD-midshaft anterior-posterior diameter MMLD-midshaft medial-lateral diameter

From table 2, and based on the mean obtained from the studied sample, the Ghanaian males apparently differed significantly (at p<0.0001) from the means reported for Thais (King et al., 1998) and Hong Kong (King, 1997) and Indian (Purkait and Chandra, 2004) but not South African White (Steyn and Iscan, 1998) males in their femoral length. However, the Ghanaian sample significantly differed from that of White South Africans in maximum head diameter at p<0.0001. The studied sample also varied greatly at p=0.0092 from Thai (King et al., 1998) sample for the same variable (maximum head diameter) but not Hong Kong and Indian male samples.

Table 2. Descriptive statistics and comparison between the means of Ghanaian males and other male populations.

Variable (mm)	**N**	**Mean**	**S.D**	**t**	**p-value**
ML					
Ghanaian	50	472.50	20.69		
Thais (King et. al, 1998)	70	429.40	21.38	15.00	<0.0001**
Hong Kong (King, 1997)	53	429.80	20.33	14.58	<0.0001**
South African Whites (Steyn and Iscan, 1997)	56	469.68	27.97	0.95	0.3466
Indians (Purkait and Chandra, 2004)	80	450.11	21.15	7.60	<0.0001**
MHD					
Ghanaian	50	46.08	2.57		
Thais (King et al., 1998)	70	45.10	1.98	2.70	0.0092**
Hong Kong (King, 1997)	53	45.60	1.96	1.33	0.1884
South African Whites (Steyn and Iscan, 1997)	56	48.46	2.65	6.50	<0.0001**
Indians (Purkait and Chandra, 2004)	80	46.18	2.39	0.27	0.7924

M L- maximum length ***MHD-maximum head diameter*** ***SD-standard deviation*** ***t-t value***

P value**-difference significant ***N-sample size***

Table 3. Descriptive statistics and comparison between the means of Ghanaian males and other male populations.

Variable (mm)	N	Mean	S.D	t	p-value
Epi. Br					
Ghanaian	50	80.29	4.39		
Thais (King et al., 1998)	70	79.70	3.83	0.96	0.3429
Hong Kong (King, 1997)	53	78.40	3.51	3.05	0.0036**
South African Whites (Steyn and Iscan, 1997)	56	84.63	4.63	7.00	<0.0001**
Indians (Purkait and Chandra, 2004)	80	78.74	4.51	2.51	0.0156**
MSCir					
Ghanaian	50	89.56	6.16		
Thais (King et al., 1998)	70	83.70	4.70	6.73	<0.0001**
Hong Kong (King, 1997)	53	84.70	4.55	5.60	<0.0001**
South African Whites (Steyn and Iscan, 1997)	56	93.18	6.10	4.20	0.0001**
Indians (Purkait and Chandra, 2004)	80	81.44	5.79	9.32	<0.0001**

Epi Br-epicondylar breadth MSCir-midshaft circumference SD-standard deviation

t-t value P value**-difference significant N-sample size

Considering epicondylar breadth, the Ghanaian sample mean was significantly greater than the sample means of Hong Kong (King, 1997) and Indian (Purkait and Chandra, 2004) males, yet also appreciably lower than that of South African Whites (Steyn and Iscan, 1997). However, the value was not significantly different from that of Thais (King et al., 1998), making the Ghanaian sample appears to be similar to the Thai sample in epicondylar breadth. For circumference at midshaft, the studied sample mean was significantly different ($p<0.0001$) from that of all compared samples. Also, the numerical value was higher than that of Thai, India and Hong Kong but not South African Whites. See table 3.

From the results, it also appeared that femoral midshaft diameters were also significantly disparate between the sampled Ghanaian males and the comparative sampled. The mean medial-lateral diameter obtained for the studied sample was significantly higher than values of Thai and Hong Kongers (King, 1997; King et al., 1998) as well as Indians (Purkait and Chandra, 2004) but lower than Steyn and Iscan's (1997) mean for South African Whites; likewise, similar observation was also made that the mean anterior-posterior diameter at midshaft for the Ghanaians was significantly higher than the values of the Asian males-Thais, Hong Kong and Indians-but lower than that of South African Whites (table 4).

Table 4. Descriptive statistics and comparison between the means of Ghanaian males and other male populations.

Variable (mm)	N	Mean	S.D	t	p-value
MMLD					
Ghanaian	50	25.95	1.86		
Thais (King et al., 1998)	70	25.30	2.00	2.50	0.0175**
Hong Kong (King, 1997)	53	25.10	2.46	3.22	0.0023**
South African Whites (Steyn and Iscan, 1997)	56	29.11	2.20	12.00	<0.0001**
Indians (Purkait and Chandra, 2004)	80	25.38	3.61	2.20	0.0361**
MAPD					
Ghanaian	50	29.69	2.90		
Thais (King et al., 1998)	70	27.80	2.44	4.60	<0.0001**
Hong Kong (King 1997)	53	28.00	2.06	4.10	0.0001**
South African Whites (Steyn and Iscan, 1997)	56	31.29	2.61	3.91	0.0003**
Indians (Purkait and Chandra, 2004)	80	26.01	2.30	9.00	<0.0001**

MMLD-midshaft medial-lateral diameter MAPD-midshaft anterior-posterior diameter
SD-standard deviation P value**-difference significant t-t value N-sample size

Table 5. Calculated ranges of the femoral parameters

Parameter (mm)	Mean	SD	Calculated Range (Mean ± 3SD)
ML	472.50	20.69	410.43-534.57
MHD	46.08	2.57	38.37-53.79
Epi Br	80.29	4.39	67.12-93.46
MAPD	29.69	2.90	20.99-38.39
MMLD	25.95	1.86	20.37-31.53
MSCir	89.56	6.16	71.08-108.04

Table 5 was presented to show the calculated ranges obtained for the femoral variables analyzed for the studied sample population. Femoral length recorded a value of 410.43 mm-534.57 mm; that of maximum head diameter, epicondylar breadth and midshaft circumference were 38.37 mm-53.79 mm, 67.12 mm-93.46 mm and 71.08 mm-108.04 mm respectively. The rest were, midshaft anterior-posterior diameter, 20.99 mm-38.39 mm and medial-lateral diameter at midshaft, 20.37 mm-31.53 mm.

4.1 Tibia

Out of the five standard osteological parameters studied from the tibia, mean (standard deviations) obtained for maximum length was 395.20 mm (23.42 mm) with a range of 335.00 mm-436.00 mm; midshaft transverse diameter recorded a mean of 22.09 mm and standard deviation of 2.66 mm, and 18.00 mm-31.20 mm as the range. Maximum proximal epiphyseal breadth recorded an average of 76.46 mm and standard deviation of 5.28 mm, its range was 61.50 mm-88.40 mm. Mean (standard deviation) of 29.64 mm (2.83 mm) and range of 22.00 mm-34.70 mm were realized for midshaft anterior-posterior diameter. For midshaft circumference, the mean was 85.68 mm with standard deviation and range of 7.37 mm and 70.00 mm-103.00 mm respectively (table 6).

Table 6 Descriptive statistics of the measured indices from the tibia (N=47)

VARIABLE	M L	MPEB	MAPD	MTD	MS Cir
Minimum	335.00	61.50	22.00	18.00	70.00
Maximum	436.00	88.40	34.70	31.20	103.00
Mean	395.20	76.46	29.64	22.09	85.68
Std. Deviation	23.42	5.28	2.83	2.66	7.37
Std. Error	3.42	0.77	0.41	0.39	1.08
Coefficient of variation	5.93%	6.91%	9.53%	12.03%	8.60%

Table 7 Descriptive statistic and comparison between the means of Ghanaian males and other male populations.

Variable (mm)	N	Mean	S.D	t	p-value
TL					
Ghanaian	47	395.20	23.42		
Thais (King, 1997)	68	357.42	20.78	11.19	<0.0001**
Hong Kong (King, 1997)	54	346.10	20.10	14.00	<0.0001**
Black Americans (Iscan and Miller-Shaivitz, 1984)	40	404.48	43.15	2.70	0.0095**
American Whites (Iscan and Miller-Shaivitz, 1984)	40	371.03	24.65	7.10	<0.0001**
MPEB					
Ghanaian	47	76.46	5.28		
Thais (King, 1997)	69	74.80	3.58	2.20	0.0361**
Hong Kong (King, 1997)	54	73.20	3.58	4.20	0.0001**
South African Whites (Steyn and Iscan, 1997)	56	79.13	4.88	3.46	0.0012**

SD-standard deviation   P value**-difference significant   t-t value
MPEB-maximum proximal epiphyseal breadth   TL-maximum length   N-sample size

From the table 7, the results showed that the mean tibial length for the Ghanaian sample population differed significantly from comparative sample males from Thailand and Hong Kong (King, 1997) and America Whites (Iscan and Miller-Shaivitz, 1984), all at $p<0.0001$; and Black Americans (Iscan and Miller-Shaivitz, 1984) at $p=0.0095$. Also, the results depicted the average Ghanaian (of the sample) as having longer tibia relative to those of the Thai, Hong Kong and American White samples. Considering maximum proximal epiphyseal breadth (MPEB), it was apparent that the Ghanaian sample was significantly different from King's (1997) Thai and Hong Kong samples as well as that of Steyn and Iscan (1997) for Whiter South Africans; and that the Ghanaian mean was higher in value than the two Asian samples but lower than Steyn and Iscan's South African mean.

Comparing anterior-posterior diameter at midshaft (MAPD of the Ghanaian and two Asian samples (Thai and Hong Kong) studied by King (1997), the Ghanaian mean was higher in numerical value than the Asians. However, the difference in means was not significant to make the Ghanaian sample entirely disparate from these Asian samples in tibial MAPD. Quite clearly, and as per the samples, the study suggested that the Ghanaians were similar to Thai and Hong Kong males MAPD of the tibia. Interestingly, in another feature of the same bone and for the same samples, the Ghanaian mean midshaft transverse diameter (MTD) of the tibia was significantly greater in value and also different from King's (1997) means for Thai and Hong Kong male samples. This gave the impression that the Ghanaian male sample varied greatly from the Thai and Hong Kong male samples when looking at midshaft transverse diameter of the tibia of the tibia. See table 8.

Table 8. Descriptive statistics and comparison between the means of Ghanaian males and other male populations.

Variable (mm)	N	Mean	S.D	t	p-value
MAPD					
Ghanaian	47	29.64	2.83		
Thais (King, 1997)	69	29.40	2.53	0.57	0.5695
Hong Kong (King, 1997)	54	29.40	2.58	0.57	0.5695
MTD					
Ghanaian	47	22.09	2.66		
Thais (King, 1997)	69	20.30	2.34	4.62	<0.0001**
Hong Kong (King, 1997)	54	20.50	2.29	4.10	0.0002**

SD-standard deviation P value**-difference significant t-t value MAPD-midshaft anterior-posterior diameter MTD-midshaft transverse diameter N-sample size

Table 9. Calculated ranges for tibial parameters (N=47)

Parameter (mm)	Mean	SD	Calculated Range (Mean ± 3SD)
TL	395.20	23.42	324.94-465.46
MPEB	76.46	5.28	60.62-92.30
MAPD	29.64	2.83	21.15-38.13
MTD	22.09	2.66	14.11-31.07
MSCir	85.68	7.37	63.57-107.79

The table above (table 9) was presented to show the calculated ranges obtained for the Ghanaian sample used in the study. Values observed for length of tibia was 324.94 mm-465.46 mm; that of MPEB was 60.62 mm-92.30 mm. For circumference at midshaft, 63.57 mm-107.79 mm was obtained. Transverse diameter at midshaft gave 14.11 mm-31.07 mm; and midshaft anterior-posterior diameter recorded 21.15 mm-38.13 mm.

4.2 Humerus

Table 10. Descriptive statistics of anthropometric variables of the humerus (N=38)

VARIABLE (mm)	HML	VHD	HEpi Br	HAPD	HMMD	HMS Cir
Minimum	294.00	39.70	54.50	18.20	13.10	59.00
Maximum	376.00	53.30	71.40	28.30	21.00	83.00
Mean	334.10	45.33	62.84	21.88	17.67	67.68
Std. Deviation	21.29	3.38	4.28	2.09	1.49	5.04
Std. Error	3.45	0.55	0.69	0.34	0.24	0.82
Coefficient of variation	6.37%	7.45%	6.81%	9.56%	8.42%	7.45%
95% CI of Discrepancy	327.10-341.10	44.22-46.44	61.43-64.25	21.19-22.57	17.18-18.16	66.03-69.34

Table 10 contains the descriptive statistics of the six anthropometric variables analyzed for the humerus. From the results, vertical head diameter recorded (VHD) a mean of 45.33 mm with standard deviation of 3.38 mm and range of 39.70 mm-53.30 mm; epicondylar breadth (HEpiBr) gave mean of.62.84 mm and standard deviation of 4.28 mm; its range was 54.50 mm-71.40 mm. Mean (standard deviation) and range for humeral maximum length (HML) were 334.10 mm (21.29 mm) and 294.00 mm-376.00 mm correspondingly. Midshaft anterior-posterior diameter (HAPD) also recorded mean (standard deviation) of 21.88 mm (2.09 mm) with a range of 18.20 mm-28.30 mm; that of medial-lateral diameter at midshaft (HMMD) was 17.67 mm (1.49 mm) and the range was 13.10 mm-21.00 mm. For midshaft circumference (HMSCir) the mean obtained was 67.68 mm with standard deviation of 5.04 mm; its range was 59.00 mm-83.00 mm.

Table 11. Descriptive statistics and comparison between the means of Ghanaian males and other male populations.

Variable (mm)	N	Mean	S.D	t	p-value
HML					
Ghanaian	38	334.10	21.29		
Thais (King, 1997)	70	300.60	15.65	9.70	<0.0001**
Hong Kong (King, 1997)	53	305.00	16.61	8.40	<0.0001**
Black Americans (Darryl and Kenneth, 1991)	50	339.05	19.79	1.45	0.1562
American Whites (Darryl and Kenneth, 1991)	50	326.21	18.06	2.27	0.0290**
South African Blacks (Steyn and Iscan, 1999)	40	328.00	14.80	1.75	0.0879
VHD					
Ghanaian	38	45.33	3.38		
Thais (King, 1997)	70	44.40	2.11	1.70	0.0991
Hong Kong (King, 1997)	53	44.90	2.33	0.78	0.4411
South African Blacks (Steyn and Iscan, 1999)	40	43.70	2.10	2.97	0.0052**
HEpBr					
Ghanaian	38	62.84	4.28		
Thais (King, 1997)	70	60.30	2.97	3.66	0.0008**
Hong Kong (King, 1997)	54	58.70	3.68	5.96	<0.0001**
South African Blacks (Steyn and Iscan, 1999)	40	61.40	6.20	2.07	0.0451**
South African Whites (Steyn and Iscan, 1999)	55	64.30	3.90	2.10	0.0422**

SD-standard deviation P value**-significant differences t-t value HEpBr-humerus epicondylar breadth VHD-vertical head diameter HML- humerus maximum length of N-sample size

From the results of the study (table 11), mean length of the Ghanaian humeri sample obtained was significantly greater and different from that of Thai and Hong Kong (King, 1997) male samples at p<0.0001 and American Whites (Darryl and Kenneth, 1991) at p=0.0290 but not Black Americans (Darryl and Kenneth, 1991) and South African Blacks (Steyn and Iscan, 1999).

However, whiles the Ghanaian sample appeared similar to Black South Africans in HML, apparent significant difference was at p=0.0052 between mean vertical head diameter (VHD) reported by Steyn and Iscan (1999) for the Black South Africans and that obtained in this study. In another perspective, there appeared no significant difference in mean VHD observed by King (1997) for Thai and Kong samples and the Ghanaian sample mean obtained from the study. Inarguably, one of the reportedly highly dimorphic features of the humerus, epicondylar breadth, seemingly presented similar findings, with the current study sample mean being significantly different from means of all comparative samples (table 11).

Calculated ranges observed for the humeral sample used in this study were length of humerus, 270.23 mm-397.97 mm; 50.00 mm-75.68 mm for humeral epicondylar breadth and 52.56 mm-82.80 mm for midshaft circumference. Others were midshaft medial-lateral diameter, 13.20 mm-22.14 mm; vertical head diameter, 35.19 mm-55.47 mm and anterior-posterior diameter at midshaft, 15.61 mm-28.15 mm. See table 12 below.

Table 12 Calculated ranges for parameters of the humerus

Parameter (mm)	Mean	SD	Calculated Range (Mean ± 3SD)
HML	334.10	21.29	270.23-397.97
VHD	45.33	3.38	35.19-55.47
HEpBr	62.84	4.28	50.00-75.68
HAPD	21.88	2.09	15.61-28.15
HMMD	17.67	1.49	13.20-22.14
HMSCir	67.68	5.04	52.56-82.80

4.3 Radius

Five osteological indices were analyzed for the radius. Mean radial maximum length (RML) obtained was 270.70 mm with standard deviation and range of 13.17 mm and 236 mm-302.00 mm respectively. Maximum head diameter of radius (RMHD) recorded mean ± standard deviation of 23.25±1.86 mm and range of 20.40 mm-28.00 mm. Mean (standard deviation) obtained from this study for midshaft anterior-posterior diameter (RAPD) was 12.53 mm (1.13 mm) with 10.20 mm-15.00mm as the range. For midshaft medial-lateral diameter (RMMD), the mean (standard deviation) observed was 15.06 mm (1.60 mm) and the range was 11.90 mm-18.20 mm; that circumference at midshaft (RMSCir) were 45.94 mm as the mean with 3.04 mm as the standard deviation and 42.00 mm-53.00 mm as the range. See table 13.

Table 13 Descriptive statistics of radial anthropometric variables (N=31)

VARIABLE (mm)	RML	RMHD	RAPD	RMMD	RMSCir
Minimum	236.00	20.40	10.20	11.90	42.00
Maximum	302.00	28.00	15.00	18.20	53.00
Mean	270.70	23.25	12.53	15.06	45.94
Std. Deviation	13.17	1.86	1.13	1.60	3.04
Std. Error	2.37	0.33	0.20	0.28	0.55
95% CI of discrepancy	265.90 - 275.50	22.57- 23.94	12.11 - 12.94	14.47 - 15.65	44.82 - 47.05
Coefficient of variation	4.86%	8.02%	9.03%	10.65%	6.63%

Std.- Standard RML- radius maximum length RMHD- radius maximum head diameter RAPD- radius midshaft anterior-posterior diamete RMMD- radius midshaft medial-lateral diameter RMSCir- radius midshaft circumference N-sample size

Comparing the observed means of the variables measured in this study with means obtained from comparative samples, the study sample average radial length (RML) was significantly different from that of Thai and Hong Kong (King, 1997), South African Black (Barrier and L'Abbe, 2008), German (Mall et al., 2001) and American Whites (Darryl and Kenneth, 1991) male samples, at p<0.0001; and also Black Americans (Darryl and Kenneth, 1991) at p=0.0042. Mean maximum head diameter of radius (RMHD) also significantly varied from German (Mall et al., 2001) sample mean. However, the results showed that the Ghanaian sample was similar to Black South African sample studied by Barrier and L'Abbe (2008) in that the means obtained from these samples were not significantly different (table 14)

Table 14. Descriptive statistics and comparison between the means of Ghanaian males and other male populations.

Variable (mm)	N	Mean	S.D	t	p-value
RML					
Ghanaian	31	270.70	13.17		
Thais (King, 1997)	70	240.60	16.07	12.73	<0.0001**
Hong Kong (King, 1997)	51	236.10	18.13	14.63	<0.0001**
Black Americans (Darryl and Kenneth, 1991)	50	263.38	16.37	3.10	0.0042**
American Whites (Darryl and Kenneth, 1991)	50	243.59	14.26	11.47	<0.0001**
South African Blacks (Barrier and L'Abbe, 2008)	200	255.70	4.82	6.30	<0.0001**
Germans (Mall et al., 2001)	64	246.00	12.50	10.45	<0.0001**
RMHD					
Ghanaian	31	23.25	1.86		
South African Blacks (Barrier and L'Abbe, 2008)	200	23.17	1.49	0.24	0.8090
Germans (Mall et al., 2001)	64	26.00	1.70	8.21	<0.0001**

RML- radius maximum length   RMHD- radius maximum head diameter   t-t value
S.D-standard deviation   P value**- difference significant   N-sample size

Table 15. Descriptive statistics and comparison between the means of Ghanaian males and other male populations.

Variable (mm)	N	Mean	S.D	t	p-value
RAPD					
Ghanaian	31	12.53	1.13		
South African Blacks (Barrier and L'Abbe, 2008)	200	11.85	0.93	3.30	0.0023**
Thais (King, 1997)	70	12.00	1.16	2.59	0.0147**
Hong Kong (King, 1997)	54	11.90	0.93	3.08	0.0044**
RMMD					
Ghanaian	31	15.06	1.60		
South African Blacks (Barrier and L'Abbe, 2008)	200	15.58	1.54	1.81	0.0801
Thais (King, 1997)	70	14.80	1.42	0.90	0.3775
Hong Kong (King, 1997)	54	14.70	1.57	1.24	0.2236

RAPD- radius midshaft anterior-posterior diameter RMMD- radius midshaft medial-lateral diameter S.D-standard deviation N-sample size P value**- difference significant t-t value

Evident on table 15, the mean midshaft anterior-posterior diameter of radius (RAPD) obtained form the study sample was numerically lager and significantly distinct from sample means reported for Thai and Hong Kong males (King, 1997) as well as Black South Africans (Barrier and L'Abbe, 2008). For midshaft medial-lateral diameter of radius (RMMD), the observed mean for the Ghanaian sample was greater in value than those of Thai and Hong Kong (King, 1997) but less than that of Black South Africans (Barrier and L'Abbe, 2008). However, the variation in means was not significant, ostensibly hinting that as per the samples, the Ghanaians were similar to Hong Kong, Thai and South African Black males in RMMD (table 15).

From the study, the calculated range recorded for radial length was 231.19 mm-310.21 mm; that of midshaft circumference stood at 36.82 mm-55.06 mm. Maximum radial head diameter had 17.67 mm-28.83 mm; anterior-posterior diameter at midshaft gave 9.14 mm-15.92 mm and midshaft medial-lateral diameter, 10.26 mm-19.86 mm. The calculated ranges for the radial indices were presented on table 16 below.

Table 16. Calculated ranges for parameters of the radius

Parameter (mm)	Mean	SD	Calculated Range (Mean ± 3SD)
RML	270.70	13.17	231.19-310.21
RMHD	23.25	1.86	17.67-28.83
RAPD	12.53	1.13	9.14-15.92
RMMD	15.06	1.60	10.26-19.86
RMSCir	45.94	3.04	36.82-55.06

4.4 Ulna

Of the four anthropometric dimensions analyzed for the ulna from the studied population, the mean (standard deviation) for maximum ulna length (UML) was 294.20 mm (13.99mm)with arange of 274.00 mm-325.00 mm. Physiological length of ulna (UPL) registered a mean of 277.00 mm with standard deviation of 21.92 mm and 236.00 mm-315.00 mm as its range. Looking at anterior-posterior (dorso-volar) shaft diameter (UAPD) the mean obtained was 17.33 mm with 2.17 mm and 14.60 mm-23.20 mm as the standard deviation and range in that order. Ulna medial-lateral diameter (UMLD) gave a mean (standard deviation) of 14.19 mm (1.23 mm) with its range being 11.50 mm-17.00 mm. See table 17.

Table 17. Descriptive statistics of anthropometric variables of the ulna (N=31, except UML where N=19)

VARIABLE (mm)	UML	UPL	UAPD	UMLD
Minimum	274.00	236.00	14.60	11.50
Maximum	325.00	315.00	23.20	17.00
Mean	294.20	277.00	17.33	14.19
Std. Deviation	13.99	21.92	2.17	1.23
Std. Error	3.21	3.94	0.39	0.22
95% CI of discrepancy	287.50- 301.00	269.00- 285.10	16.53 -18.12	13.74 -14.64

UML- ulna maximum length UPL- ulna physiological length UAPD- ulna anterior-posterior diameter UMLD-ulna medial-lateral diameter N-sample size Std.-standard

Table 18 was presented to portray how the statistical means of the ulna dimensions of the studied Ghanaian males compare with different regions. Apparently, mean maximum length of ulna observed for the Ghanaian study sample significantly differed ($p<0.0001$) from sample means of Germans (Mall et al., 2001), Thais and Hong Kong males (King, 1997), American Whites (Darryl and Kenneth, 1991) and Black South Africans (Barrier and L'Abbe, 2008); as well as Black Americans (Darryl and Kenneth, 1991) at $p=0.0015$. Also, King's (1997) mean UPL and UAPD obtained for Thai and Hong Kong samples varied considerably from that observed in this study. Based on the samples, the Ghanaian males did not appear to be similar to any of the comparative sample populations in any of the measured parameters of the ulna assessed during the study. See table 18.

Table 18. Descriptive statistics and comparison between the means of Ghanaian males and other male populations.

Variable (mm)	N	Mean	S.D	t	p-value
UML					
Ghanaian	19	294.20	13.99		
Thais (King, 1997)	70	257.30	17.13	11.00	<0.0001**
Hong Kong (King, 1997)	50	251.60	20.24	13.00	<0.0001**
Black Americans (Darryl and Kenneth, 1991)	50	282.18	21.58	3.10	0.0015**
American Whites (Darryl and Kenneth, 1991)	50	260.44	13.70	11.00	<0.0001**
South African Blacks (Barrier and L'Abbe, 2008)	200	273.76	14.97	6.37	<0.0001**
Germans (Mall et al., 2001)	64	265.00	15.40	9.10	<0.0001**
UPL					
Ghanaian	31	277.00	21.92		
Thais (King, 1997)	70	231.60	20.69	11.54	<0.0001**
Hong Kong (King, 1997)	50	223.90	19.78	13.00	<0.0001**
UAPD					
Ghanaian	31	17.33	2.16		
Thais (King, 1997)	70	15.50	1.41	4.69	<0.0001**
Hong Kong (King, 1997)	54	15.80	1.47	3.92	0.0005**

UML- ulna maximum length UPL- ulna physiological length UAPD- ulna anterior-posterior diameter P value**-significant differences t-t value N-sample size S.D-standard deviation UMLD-ulna medial-lateral diameter

For the calculated range values obtained were maximum ulna length, 252.23 mm-336.17 mm; physiological length of ulna, 211.24 mm-342.76 mm; 10.50 mm-17.88 mm for ulna medial-lateral diameter at midshaft and anterior-posterior diameter at midshaft, 10.82 mm-23.84 mm (table 19).

Table 19. Calculated ranges for parameters of the ulna

Parameter (mm)	Mean	SD	Calculated Range (Mean ± 3SD)
UML	294.20	13.99	252.23-336.17
UPL	277.00	21.92	211.24-342.76
UAPD	17.33	2.17	10.82-23.84
UMLD	14.19	1.23	10.50-17.88

4.5 Fibula

From the study sample, mean and standard deviation for fibula length was 399.80 mm and 25.08 mm correspondingly, and the range was 350.00 mm-473.00 mm. Maximum diameter at midshaft of fibula recorded mean of 15.54 mm and standard deviation, 1.77 mm with 12.40 mm-19.20 mm as its range. Mean (standard deviation) for the circumference at midshaft of fibula was 47.17 mm (4.66 mm); it also had 39.00 mm-58.00 mm as the observed range. The descriptive statistics for the three fibula parameters analyzed in the study were presented in Table 20 below.

Table 20. Descriptive statistics of anthropometric variables of the fibula (N=30)

VARIABLE (mm)	FML	FMSD	FMSCir
Minimum	350.00	12.40	39.00
Maximum	473.00	19.20	58.00
Mean	399.80	15.54	47.17
Std. Deviation	25.08	1.77	4.66
Std. Error	4.58	0.32	0.85
95% CI of discrepancy	390.40- 409.10	14.88 - 16.20	45.43 - 48.91
Coefficient of variation	6.27%	11.36%	9.88%

Table 21. Calculated ranges for variables of the fibula

Variable (mm)	Mean	SD	Calculated Range (Mean ± 3SD)
FML	399.80	25.08	324.56-475.04
FMSD	15.54	1.77	10.23-20.85
FMSCir	47.17	4.66	33.19-61.15

From table 21 above, calculated ranges noted for the fibulae used in the study were maximum length, 324.56 mm-475.04 mm; maximum diameter at midshaft, 211.24 mm-20.85 mm and midshaft circumference, 33.19 mm-61.15 mm.

4.6 Os Coxae

From the analysis, mean total height (TIH) of the hip bone recorded for the studied population was 207.70 mm with standard deviation, 13.27 mm and a range of 187.00 mm-236.00 mm. Acetabulum diameter (AD) gave a mean of 47.62 mm and standard deviation 2.00 mm; its range was 44.60 mm-51. For ischial length (IL), mean (standard deviation) of 107.20 mm (7.64 mm) was obtained, with a range of 95.70 mm-120.00 mm. The rest were greater sciatic notch width (GSNW) which registered a mean of 37.33 mm with standard deviation and range of 4.52 mm and 26.50 mm-44.50 mm respectively; that of iliac breadth (IB) was 147.90 mm as the mean, with standard deviation of 15.04 mm and range of 123.00 mm-184.00 mm. Range observed for pubic length was 54.00 mm-86.60 mm, its mean was 69.82 mm with standard deviation of 7.91 mm. See table 22 which displays the descriptive statistical analysis of the six osteological variables studied for the hip bone.

Table 22. Descriptive statistics of anthropometric variables of the os coxae (N=20)

VARIABLE(mm)	TIH	AD	IL	GSNW	IB	PL
Minimum	187.00	44.60	95.70	26.50	123.00	54.00
Maximum	236.00	51.60	120.00	44.50	184.00	86.60
Mean	207.70	47.63	107.20	37.33	147.90	69.82
Std. Deviation	13.27	2.00	7.64	4.52	15.04	7.91
Std. Error	2.97	0.45	1.71	1.01	3.36	1.77
95% CI of discrepancy	201.50-213.90	46.69-48.57	103.60 110.80	35.21-39.45	140.90 154.90	66.12-73.52
Coefficient of variation	6.39%	4.20%	7.13%	12.12%	10.17%	11.33%

TIH-total innominate height AD-acetabular diameter IL-ischial length GSNW-greater sciatic notch width IB-iliac breadth PL-pubic length Std.-standard N-sample size

It is known that regional variation in anthropometric parameters of skeletal remains exists. Table 23 has been presented to compare results of the present study with some other findings, in respect of TIH and AD. From the table, the average Ghanaian hip bone height as per the study sample, varied significantly only from mean submitted by DiBernnado and Taylor (1983) for American White sample ($p<0.0001$) and that of Steyn and Iscan (2008) observed for Greek sample ($p=0.0309$). However, the Ghanaian sample appeared similar to males of the Thai and Hong Kong (King, 1997), Black American (DiBernnado and Taylor, 1983) and Black South African samples (Patriquin et al., 2005), with no statistically significant variation in observed means. With regard to acetabulum diameter (AD), variation in means was significant at $p<0.0001$ between the Ghanaians and all comparative samples (table 23).

Table 23. Descriptive statistics and comparison between the means of Ghanaian males and other male populations.

Variable (mm)	N	Mean	S.D	t	p-value
TIH					
Ghanaian	20	207.70	13.27		
Thais (King, 1997)	67	203.80	8.15	1.31	0.2045
Hong Kong (King, 1997)	41	208.00	16.20	0.10	0.9206
Black Americans (DiBernnado and Taylor, 1983)	65	210.90	10.20	1.08	0.2945
American Whites (DiBernnado and Taylor, 1983)	65	222.40	10.70	4.95	<0.0001**
South African Blacks (Patriquin et al., 2005)	100	203.93	9.64	1.27	0.2194
Greeks (Steyn and Iscan, 2008)	95	214.62	9.20	2.33	0.0309**
AD					
Ghanaian	20	47.63	2.00		
Black Americans (DiBernnado and Taylor, 1983)	65	55.10	2.80	16.70	<0.0001**
American Whites (DiBernnado and Taylor, 1983)	65	56.50	3.20	19.83	<0.0001**
South African Blacks (Patriquin et al., 2005)	100	54.59	2.76	15.56	<0.0001**
Greeks (Steyn and Iscan, 2008)	92	54.59	3.07	15.56	<0.0001**

TIH-total innominate height AD-acetabulum diameter P value**-difference significantt-t value N-sample size S.D-standard deviation

In another part, the mean ischial length recorded from the study sample was significantly different from that of Greeks (Steyn and Iscan, 2008) and King's (1997) Thai and Hong Kong male samples. The Ghanaian mean was apparently larger in value than those of all comparative samples Considering iliac breadth, only Steyn and Iscan's (2008) mean for Greeks appeared to differ significantly (p=0.0032) from that of the sampled Ghanaian males. See table 24.

Table 24. Descriptive statistics and comparison between the means of Ghanaian males and other male populations

Variable (mm)	N	Mean	S.D	t	p-value
IL					
Ghanaian	20	107.20	7.64		
South African Blacks (Patriquin et al., 2008)	100	104.36	4.78	1.67	0.1107
Greeks (Steyn and Iscan, 2005)	95	56.74	3.29	29.53	<0.0001**
Thais (King, 1997)	67	73.90	3.84	19.45	<0.0001**
Hong Kong (King, 1997)	42	73.80	3.89	29.84	<0.0001**
IB					
Ghanaian	20	147.90	15.04		
South African Blacks (Patriquin et al., 2008)	100	150.10	7.29	0.65	0.5208
Greeks (Steyn and Iscan, 2005)	94	159.26	7.52	3.38	0.0032**
Thais (King, 1997)	65	149.80	6.77	0.57	0.5787
Hong Kong (King, 1997)	34	151.40	7.75	1.04	0.3111

IL-ischial length IB-iliac breadth P value**-difference significant t-t value
N-sample size S.D-standard deviation

From table 25, statistical means observed by DiBernnado and Taylor (1983) for American (Black and White) samples as well as Steyn and Iscan's (2008) Greek mean also varied appreciably at p<0.0001 from this study's mean as per greater sciatic notch width (GSNW). Average pubic length (PL) reported for male samples of Black South African (Patriquin et al., 2005), American Whites (DiBernnado and Taylor, 1983) and that of King (1997) for Thai and Hong Kong was also significantly disparate from mean the obtained in this study. However the Ghanaian sample looked similar to Black South Africans in GSNW; and to Greeks and American Blacks in PL.

Table 25 Descriptive statistics and comparison between the means of Ghanaian males and other male populations

Variable (mm)	N	Mean	S.D	t	p-value
GSNW					
Ghanaian	20	37.33	4.52		
Black Americans (DiBernnado and Taylor, 1983)	65	44.70	4.20	7.29	<0.0001**
American Whites (DiBernnado and Taylor, 1983)	65	48.60	4.60	11.04	<0.0001**
South African Blacks (Patriquin et al., 2008)	100	36.96	4.62	0.37	0.7186
Greeks (Steyn and Iscan, 2008)	93	43.37	3.94	5.97	<0.0001**
PL					
Ghanaian	20	69.82	7.64		
South African Blacks (Patriquin et al., 2008)	100	93.26	4.69	13.26	<0.0001**
Greeks (Steyn and Iscan, 2008)	94	70.35	4.48	0.30	0.7676
American Blacks (DiBernnado and Taylor, 1983)	65	70.50	4.90	0.39	0.7048
American Whites (DiBernnado and Taylor, 1983)	65	75.50	5.00	3.21	0.0046**
Thais (King, 1997)	67	75.10	4.87	2.99	0.0076**
Hong Kong (King, 1997)	37	76.30	4.80	3.67	0.0016**

P value**-significant difference   t-t value   N-sample size S.D-standard deviation

PL-pubic length   GSNW- greater sciatic notch width

Table 26. Calculated ranges for the Os coxae parameters

Parameter (mm)	Mean	SD	Calculated Range (Mean ± 3SD)
TIH	207.70	13.27	167.89-247.51
AD	47.63	2.00	41.63-53.63
IL	107.20	7.64	84.28-130.12
IB	147.90	15.04	102.78-193.02
GSNW	37.33	4.52	23.77-50.89
PL	69.82	7.91	46.09-93.50

From the table 26, calculated ranges obtained from the study sample were total innominate height, 167.89 mm-247.51 mm; acetabulum diameter, 41.63 mm-53.63 mm and ischial length, 84.28 mm-130.12 mm. The rest were pubic length, 46.09 mm-93.55 mm; grater sciatic notch width, 23.77 mm-50.89 mm and iliac breadth, 102.78 mm-193.02 mm.

4.7 Articulated Pelvis

Following the analysis of the parameters of the bony pelvis, the mean (standard deviation) pelvic inlet diameters for the studied Ghanaian males were 103.10 mm (7.20 mm) with a range of 90.00 mm-113.00 mm for anterior-posterior (CJD); that of transverse diameters (TD) 106.00 mm (5.54 mm) with a range of 98.00 mm-112.00 mm . The mean value for the sub-pubic angle was 69^{o}. The standard deviation and range for subpubic angle were 12.98^{o} and 49.00-88.00 (in degrees) respectively. For anterior-superior bispinous breadth (ASBB), the mean (standard deviation) recorded was 198.90 mm (14.81 mm) with a range of 175 mm-221.00 mm; mean obtained for anterior-inferior bispinous breadth (AIBB) was 171.70 mm, its standard deviation and range were 9.02 mm and 157.00 mm-188.00 mm in that order. Considering pubic symphysis height (HPS), the mean (standard deviation) recorded was 47.17 mm (8.48 mm) with a range of 38.30 mm-69.20 mm. See table .27.

Table 27. Descriptive statistics for the variables of the bony pelvis (N=10)

VARIABLE (mm)	OD	CJD	T D	ASBB	AIBB	HPS	SA (degrees)
Minimum	99.00	90.00	98.00	175.00	157.00	38.30	49.00
Maximum	121.00	113.00	112.00	221.00	188.00	69.20	88.00
Mean	108.70	103.10	106.00	198.90	171.70	47.17	69.00
Std. Deviation	7.07	7.20	5.54	14.81	9.02	8.48	12.98
Std. Error	2.24	2.28	1.75	4.68	2.85	2.68	4.10
95% CI of discrepancy	103.60-113.80	97.95 - 108.30	102.00-110.00	188.30 209.50	165.20 178.20	41.10 53.24	59.72-78.28

OD-oblique (diagonal) diameter CJD-conjugate diameter TD-transverse diameter ASBB-anterior superior bispinous breadth AIBB-anterior-inferior bispinous breadth HPS-height of pubic symphysis SA-subpubic angle N-sample size

Table 28. Calculated ranges for the articulated pelvis

Parameter (mm)	Mean	SD	Calculated Range (Mean ± 3SD)
OD	108.70	7.07	87.49-129.91
CJD	103.10	7.20	81.50-124.70
TD	106.00	5.54	89.38-122.62
ASBB	198.90	14.81	154.47-243.33
AIBB	171.70	9.02	144.64-198.76
HPS	47.17	8.48	21.73-72.61
SA (degrees)	69.00	12.98	30.06-107.94

From the study, the following (in parenthesis) were the calculated ranges obtained from the analysis of the seven osteological variables of the articulated pelvis: transverse diameter of pelvic inlet (89.38 mm-122.62 mm); oblique diameter of pelvic brim (87.49 mm-129.91 mm); height of symphysis pubis (21.73 mm-72.61 mm), anterior inferior-bispinous breadth (144.64

mm-198.76 mm), anterior-superior bispinous breadth (154.47 mm-243.33 mm), conjugate vera (81.50 mm-124.70 mm) and subpubic angle (30.06-107.94 degrees). See table 28.

CHAPTER FIVE

DISCUSSION

5.1 Femur

5.1.0 Maximum Length

The mean maximum length of 472.50 mm was found to be significantly greater than four Asian populations, Thais, Hong Kong Chinese Chinese males, mainland Chinese and Indian males at p<0.0001. Similar observation was made by King et al. (1998) who realized there was significant difference in femoral length between Thais and non-Asian samples i.e South African Whites and American Blacks. The Ghanaian sample was also significantly different from German males at p=0.0057, based on mean (464.00 mm) recorded by Mall et al. (2000). However, compared with South African White males (mean, 469.68 mm), there was no significant difference in femoral length. Same observation was made for American blacks (mean, 477.70 mm). It has been found in many sample populations that male mean values were numerically larger than their corresponding female values for many osteological parameters. King et al (1998) reported mean of 397.00 mm for 34 Thai females; King (1997) observed 405.10 mm as mean for Hong Kong 20 females; and Iscan and Ding (1995) gave 401.00 mm as average for 39 Chinese females. Others are 434.00 mm submitted by Mall et al. (2000) as mean for 70 German females; 437.62 mm from Steyn and Iscan (1997) as mean for 50 South African White females and Iscan and Miller-Shaivitz's (1984) mean of 437.30 mm noted for 51 American Black females. Interestingly, though the Ghanaian males were of a different origin, the observed sample mean as per these highlighted comparative populations' female means, was numerically and significantly larger.

Apparently, Ghanaian males were similar in their femoral length to South African White and American Black males but not the Asian males or Germans males. The apparent significant differences observed might be attributable to racial divergence; as the four Asian samples are mongoloids; the Germans, caucasians and the Ghanaians, central congoids. Sample size and the fact that South African Whites and American Blacks are of mixed races may have also contributed to the similarities.

5.1.1 Maximum Head Diameter

From the analysis, Ghanaian, Black South Africans, Hong Kong Chinese and Indian males were not significantly different considering maximum diameter of the head of the femur; these populations have recorded means ± standard deviations of 46.08 ± 2.57 mm, 45.40±2.55 mm, 45.60±1.96 mm and 46.18 ± 2.39 mm respectively. However, there were significant variations between the means of the Ghanaians and Thais ($p=0.0092$) and South African Whites ($P<0.0001$). Also, mean ± standard deviation of 47.80±2.39 mm was reported for American Black males by Iscan and Miller-Shaivitz (1984). This value was significantly higher than that of the Ghanaian males at $p<0.0001$. Mall et al. (2000) observed mean ± standard deviation of 49.00 ± 0.30 mm for some German males; higher than the Ghanaians at $p<0.0001$.

Following the above statistics, there was dimorphism in femoral head diameter between Ghanaian sample and their counterparts from America, Thailand, South Africa (Whites) and Germany but not those from India, Hong Kong Chinese and Black South Africans. This observation accentuates the existence of regional differences in osteological parameters submitted by various authors. According to Ziylan and Murshid (2002) great variation in femoral anthropometry over different time periods may likely be the results of variable factors such as nature of work, mode of life, continuous modifications that affect the characteristics of man as well as the effect of civilization on the composition of the human body in both positive and negative ways. These factors may equally be important in the creation of regional differences in anthropometric parameters.

5.1.2 Epicondylar Breadth

Breadth dimensions are known to be highly dimorphic, especially in differentiating sexes within many populations. In this study, significant epicondylar breadth (EpBr) differences were observed between the Ghanaian males and Hong Kongers (at p=0.0036), South African Whites (at p<0.0001) and Indians (at p=0.0156). There was no significant statistical difference between the studied population and Thai males (table 1).

Iscan and Ding (1995) recorded mean ± standard deviation of 80.30 ± 4.27 mm for Chinese sample; Iscan and Miller-Shaivitz (1984) realized mean ± standard deviation of 82.20 ±3.99 mm for American Blacks; Alunni-Perret et al. (2008) reported mean ± standard deviation of 84.30 ± 3.60 mm for their French study; Trancho et al. (1997) observed mean ± standard deviation of 80.60 ± 2.90mm in a Spanish population; and Mall et al. (2000) studying German sample recorded mean ± standard deviation of 84.00 ± 10.00 mm. In comparison with these populations, the Ghanaian males achieved lower mean value. However, significant differences occurred between Ghanaian males and Black Americans (at p=0.0035), French and Germans (at p<0.0001). An attempt to relate the mean of the studied population with those of females of the comparative populations also showed that the Ghanaian males were also significantly different in their Epi Br from all female samples as their corresponding male samples were already higher in numerical value. For example, corresponding female mean for samples of Spaniards, Chinese, Thais, American Blacks, French, South African Whites and Germans were 70.80 mm, 70.60 mm, 74.00 mm, 74.80 mm, 75.10 mm and 77.00 mm respectively. See table 3 for mean of the Ghanaian male sample.

Apparently, Ghanaian males metrically differed at their femoral epicondylii from Germans, French, Black Americans, South African Whites, Indians and Hong Kongers but not Spaniards, Thais and Chinese. Intra-population and inter-population variation in femoral osteological features as insinuated by Alunni-Perret et al. (2008) might be influenced by differences in height and robustness. There is correlation between epicondylar breadth and body size (Trancho et al., 1997). Also differences in racial origins and sample size may have added to some of the differences and similarities in the outcome of the comparison.

5.1.3 Midshaft Circumference

There seem to be that, with reference to the studied samples, Ghanaian males possessed wider femoral midshaft circumferential bone than males from four Asian populations-Thais, Hong Hongers, Indians (table 3) and Chinese (mean ± standard deviation, 85.30 mm ± 6.36 mm)-with mean value higher than the means of these populations. However, the mean of the Ghanaians was lower than that of South African Whites and American Blacks (mean ± standard deviation, 91.10 mm ± 6.08 mm). There was statistically significant difference between the Ghanaians and the Asian groups at p<0.0001 and South African Whites at p=0.0001 but not their Black American counterparts.

On the basis of femoral midshaft circumference the two black populations (Ghanaians and Americans) were similar and might be difficult to group bones of these two populations in an admixture using this feature alone. However, this variable might be valuable in combination with other features, for grouping Ghanaian male femora from the four Asian populations and White South Africans. It is important to be noted that genetic, racial and geographical differences have been underscored as some of the possible factors underlying osteometric inter-population dimorphism.

5.1.4 Midshaft Anterior-Posterior Diameter

This variable of the femur also demonstrated significant statistical difference between the Ghanaian sample and other regions, suggesting its utility for skeletal differentiation between groups. Values showing the degrees of significant variation (p-values) can be found on table 4.4. Additional comparison with American Blacks (mean ± standard deviation, 29.90 ± 3.07 mm) and Chinese (mean ± standard deviation, 28.00 ± 2.56 mm) revealed, midshaft anterior-posterior diameter (MAPD) might be useful for differentiating the original population (Ghanaian males) from Chinese as do Indians, Thais, Hong Kong males, and South African Whites but not Black Americans.

Iscan and Miller-Shaivitz (1984), Iscan and Ding (1995), Steyn and Iscan (1998) and some other authors have reported the utility of MAPD as diagnostic tool for sexing various populations when the femur is adopted for this purpose. The findings of this study also suggested that, like other femoral features, and in consonance with the fact that regional variation in osteological parameters exists, MAPD has the potential for separating bones from different regions. Nonetheless, it must be noted that its applicability is not generalized since in some other populations like Thais as observed by King et al. (1998), it was less discriminative a feature for distinguishing males and females of that sample population. Apparently, the Ghanaian sample MAPD (from a central congoid race) was dissimilar from the mongoloid Asian samples as well as White South Africans, who ostensibly are of mixed race.

5.1.5 Midshaft Medial-Lateral (Transverse) Diameter

In the study, population variation was also graphically demonstrated by the statistically significant difference in femoral transverse diameter between Ghanaians and the comparative samples (table 4). Iscan and Ding (1995) recorded mean ± standard deviation of 25.60 mm ± 2.76 mm for Chinese sample; Iscan and Miller-Shaivitz (1984) realized mean ± standard deviation of 28.20 mm ± 3.01 mm for American Blacks. Though the studied population showed significant difference from three Asian populations, -Thais, Hong Kongers and Indians- it seemed to bore resemblance to Chinese in this feature. However, the Ghanaian males recording mean value lower than that of the Americans, exhibited statistically significant difference from that group in their midshaft medial-lateral diameter (MMLD).

It was also observed that except South African White males, the Ghanaian sample mean was numerically greater than that of the Thai, Hong Kong and Indian males who themselves recorded higher means than their corresponding females. It therefore seems to suggest that the studied sample mean was appreciably disparate from Thai, Hong Kong and Indian female samples as well; as was the case. However, considering mean of 26.30 mm reported by Steyn and Iscan (1998) for 50 White South African females, the Ghanaian males were similar to South African White females in their mean MMLD. This suggests that if MMLD was considered as an osteometric index for grouping unknown femora and/or skeletons of mixed South African and Ghanaian descent, South African White females might be misclassified as Ghanaian males. Relative to the American Black and mongoloid Asian females, geographical location and mode of life might have had a bearing on this outcome, since South Africans were the closest test group.

5.2 Tibia

5.2.0 Tibial Length

Though length dimensions have been established by many authors to be less discriminative for separating sexes in many populations, it may be useful for inter-population differentiation of skeletal remains. From the present study, Ghanaians recorded mean TL value greater than Thai and Hong Kong males (King, 1997) as well as American Whites (Iscan and Miller-Shaivitz, 1984) but not Black Americans (Iscan and Miller-Shaivitz, 1984). See table 7. In the report of these authors, their corresponding female values were lower than the males; thus the Ghanaian sample mean was greater and highly different from female values from Thai, Hong Kong, American White as well as American Black (female mean, 365.63 mm) samples. Significant differences were realized between Ghanaians and three populations-Thais, Hong Kong males and

American Whites-at p<0.0001; between the original population and Black Americans, the variation was significant at p=0.0095.

Genetic, nutritional and environmental variations have all been underscored by authors such as Steyn and Iscan (1999) as influential on inter-population anthropometric differences.

5.2.1 Maximum Proximal Epiphyseal Breadth

Regional variation in tibial dimensions was also explicitly illustrated by the significant differences in maximum proximal epiphyseal breadth (MPEB) between Ghanaians and the comparative samples (table 7). As breadth features are known to be highly dimorphic within group and even race, it is also dimorphic with geographical differences. From the analysis, Ghanaian males were very different metrically in their MPEB from Thai males, Hong Kong males and South African White males. Quite clearly, once these different racial samples were as well in different geographical locations, there apparently will be differences in development. King et al. (1998) note that differential cortical development of bone has its maximum impact on breadth and circumference measurements.

5.2.2 Midshaft Anterior-Posterior diameter

Mean value of the anterior-posterior diameter at midshaft recorded from the Ghanaian sample was numerically higher than that reported by King (1997) for samples from Thai and Hong Kong males and females. Mean values recorded for females by same author were 26.10 mm for 34 Thai females and 26.00 mm for 21 Hong Kong females. However, the difference in means of these three male populations was not statistically significant, but significant ($p<0.0001$).between the Ghanaians and the Thai and Hong Kong females. This suggested that Ghanaian male sample metrically resembled these two Asian male samples in this part of their tibia. Though the Asians are mongoloids and the Ghanaians are central congoids, coupled with the fact that these populations are highly geographically sequestered, perhaps, lifestyle and activity patterns of the individuals in the sample populations as well as sample size may have influenced this outcome.

5.2.3 Midshaft Transvers Diameter

Though midshaft anterior-posterior diameter (MAPD) was not discriminative between the Ghanaian, Thailand and Hong Kong samples, tibial midshaft transverse diameter (MTD) recorded statistically significant differences between the means of these populations. Mean ± standard deviation recorded for the study sample was 22.09 mm ± 2.66 mm; that of Thais and Hong Kong males observed by King (1997) were 20.30 mm ± 2.34 mm and 20.50 mm ± 2.29 mm respectively. The difference was significant at $p<0.0001$ between the Ghanaian males and the Thais, and at $p=0.0002$ for the Ghanaian and Hong Kong male samples. In a way, this was quite expected as the assessed samples belonged to different races and environment.

5.3 Humerus

5.3.0 Humerus Maximum Length

The average maximum length of the humerus (HML) observed for the Ghanaians was higher than that of Thai and Hong Kong (King, 1997), South African Blacks (Steyn and Iscan, 1999) as well as American White males (Darryl and Kenneth, 1991); however, Ghanaian male sample appeared shorter in the length of their humerus relative American Black sample (Table 11). Differences in means of this variable for the original and comparative samples were significant between the Ghanaian males and American Whites, Thai and Hong Kong males at p=0.0290, p<0.0001and p<0.0001 respectively. Apparently, though there were numerical differences between the Ghanaian mean and that of their Black counterparts-South African Blacks and American Blacks-the difference was not statistically significant; a tacit expression of similarity in upper arm length between these three black population samples. This observation might not be surprising for the fact that some of South African Black population emanated from central congoid race as Ghanaians; and also the fact that most Black Americans originally trace their ancestry to sub-Saharan Africa.

Mall et al. (2001) reported mean ± standard deviation of 334.00 ± 15.80 mm for males of some German sample they worked on. Iscan et al. (1998) observed mean ± standard deviation of 313.70 mm ± 16.46 mm and 297.40 mm ± 10.42 mm for Chinese and Japanese male samples respectively. There was no statistically significant difference between the males of the original population and the German but there was between Ghanaians and these two East Asian populations at p<0.0001. The East Asians are mongoloids, the Ghanaians are congoids and the

Germans, Caucasians; somehow, the similarity between the Ghanaian and German sample in HML might be due to factors such as occupation and mode of life. It therefore, presents that humeral length might be metrically important for grouping male humeri of Ghanaians and American Whites and Asians-Thais, Hong Kong males, Chinese and Japanese-, but not Black Americans, Black South Africans and German Europeans.

5.3.1 Vertical Head Diameter

In terms of intra-population sexual dimorphism, vertical head diameter (VHD) has been shown by Mall et al. (2001) and Iscan et al. (1998) as the single most effective variable to separate sex in German and Chinese populations respectively. Though this study could not analyze sexual dimorphism within the Ghanaian population because female sample was not included for their inadequacy, marked geographical dimorphism between the study sample males and some comparative sample populations were demonstrated. There was significant difference between the statistical means of the Ghanaians and Black South Africans at p=0.0052; however, the Ghanaian males appeared metrically similar to Thais and Hong Kong males with the mean numerically greater than the means of these two comparative samples, with no statistically significant difference (table 7).

Mall et al. (2001) observed mean ± standard deviation of 50.00 mm ± 2 .90 mm for their German male sample; Iscan et al. (1998) recorded mean ± standard deviation of 44.90 mm ± 2.77 mm and 44.10 mm ± 1.75 mm for Chinese and Japanese populations respectively. Comparatively, there was significant variation in this variable between the study population and Germans at p<0.0001, and Japanese at p=0.0312 but not Chinese. Ostensibly, Ghanaians were disparate from

South African Blacks, Germans and Japanese in this feature but resembled Thai, Hong Kong and Chinese males. From the study, VHD seemingly expresses a diagnostic potency for distinguishing humeri from the dissimilar populations-Ghana, German, South Africa (Blacks) and Japan-though not valuable for the quantitatively congruent populations. Differences in environmental conditions and nutritional modifications may have contributed to the differences. However, the similarity between the VHD of the congoid Ghanaian and the mongoloid Asian samples might be as a result of similar activity patterns of the sampled individuals. King et al. (1998) also underscores that there are varying degrees of difference in different parts of the skeleton. Thus apparently whiles Ghanaian sample vary appreciably from these Asian samples in HML, they situation was not entirely so in VHD.

5.3.2 Humeral Epicondylar Breadth

Some authors have also established epicondylar breath (HEpBr) as the best single most discriminative variable of the humerus for distinguishing male and female bones of some populations. Such was the observation by Iscan et al. (1998) for Japanese and Thais when they made comparative analysis of sexual dimorphism in Thais, Japanese and Chinese. Steyn and Iscan (1999) also identified HEpBr as the most effective individual parameter of the humerus for sexing South African Whites. From the study, there seemed to be marked regional dimorphism between the Ghanaians and all four comparative populations-Thias, Hong Kong males, South African Blacks and Whites-with statistically significant differences between the means of the original and comparative samples. Iscan et al. (1998) observed mean ± standard deviation of 60.40 mm ± 8.65 mm and 59.80 mm ± 2.27 mm for Chinese and Japanese samples respectively;

Mall et al. (2001) reported mean ± standard deviation of 66.00 mm ± 4.50 mm for their German male sample. Relative to these groups, the average of this variable for the Ghanaian males significantly differed from Germans and Japanese at $p<0.0001$; and Chinese at $p=0.0012$.

From the analysis of the three commonly established most sexually dimorphic humeral parameters-HML,VHD and HEpBr- and in comparison with other populations, HEpBr came out also as the single most regionally dimorphic variable with the statistical mean of the Ghanaians been significantly different from all compared populations-Chinese, Japanese, Thais, Hong Kongers, Germans, South African Whites and Blacks. It's on record by Iscan et al. (1998) that proximal and distal measurements are likely to be more accurate (highly variable) for differentiating male and female bones because these areas are subjected to greater functional and occupational stress. Also with variation in racial origin, environmental conditions, cultural and probably life style habits, this observation was quite expected

5.4 Radius

5.4.0 Maximum Length of Radius

Though various dimensions of the radius have been established to be sexually dimorphic within many studied populations, maximum length has been reported not to be very useful for intra-population separation of sexes. However, Mall et al. (2001) noted that in their study on a German sample, RML appeared to be the best single criterion for sex discrimination in that population. Like metric sexual differences within groups on various skeletal parts, regional variation has also been documented by authors such as Iscan et al. (1998). The findings of this study further supported the existence of regional variation even in radial length alone.

Mean maximum radial length for the Ghanaians was numerically larger than mean of each comparative population (table 14). When the maximum length of the radius of the original and comparative samples was assessed to determine if the numerical differences in means were significant, it became evident that the Ghanaians significantly had longer radius than Thais, Hong Kong males, American Whites, South Africans and Germans, all at $p<0.0001$. However, the variation between the Ghanaians and American Blacks was significant at $p=0.0042$. Genetic variation and type of nourishment may be vital factors influencing this result. It has also been claimed that stature based sexual dimorphism peaks in societies that are at the extremes of protein consumption – both high and low (Gray and Wolfe, 1980). However, in the studied sample, the longer radial length might be largely attributed to occupation and lifestyle. Farming is the common occupation of indigenous Ghanaians, and from childhood the average Ghanaian would have been involved in one kind of farming activity or the other before reaching adulthood. Weeding, tree cutting and mound making are common farming practices. Such activities may have the tendency to stretch the epiphyseal plates and extremities of the radius in children giving them longer radius from tender age

5.4.1 Radius Maximum Head Diameter

Berrizbeitia (1989) obtained a mean maximum diameter of the radial head (RMHD) of 24.23 mm in males for white individuals from the Terry Collection. This mean was statistically different from the mean observed from this investigation, and the difference was significant at p=0.0065. The observed mean for the studied sample (Ghanaians) was similar to the mean observed by Barrier and L'Abbe (2008) for South Africans (table 9); though numerically larger than the South Africans, there difference was not statistically significant. However, the mean reported by Mall et al. (2001) for Germans was greater than the mean of the Ghanaians. The difference between the means of the Ghanaians and Germans was statistically significant at p<0.0001. From the studied and compared samples, it was apparent that Ghanaian males were dissimilar in their RMHD from Germans and American Whites but not South African Blacks based on the metric assessment. Perhaps, aside racial and territorial differences possibly underpinning this results, authors like DiBernnado and Taylor (1982) as well as Macho (1990) have all also suggested from somehow functional perspective, that greater sexual dimorphism in proximal and distal measurements may be so because functional demands of weight and musculature concentrate on these parts of the bone.

5.4.2 Radius Midshaft Anterior-Posterior Diameter

As documented by Barrier and L'Abbe (2008) mid-shaft variables of the forearm have been shown to be highly dimorphic in Japanese and Indian groups, however, they were less so among South Africans. From the study, dimorphism in radius anterior-posterior diameter was prominent between the Ghanaian sample and the comparative samples. From table 15 the numerical value of the Ghanaian mean was higher than that of Thai, Hong Kong and Black South African males. The difference in statistical means between the original and comparative samples was significant at p=0.0023, p=0.0044 and p=0.0147 for South African, Hong Kong and Thai males respectively. Apparently, this observation might also be the result of several factors such as racial variation, genetic and territorial differences.

5.4.3 Radius Midshaft Medial-Lateral Diameter

Though midshaft variables of the radius have been demonstrated by authors such as Barrier and L'Abbe (2008) to be dimorphic albeit to lesser extent for sexing Black South Africans; midshaft medial-lateral diameter of the radius (RMMD) appeared not useful at all for distinguishing Ghanaian males and Thai or Hong Kong or South African Black males. In terms of numerical strength, Ghanaians recorded mean RMMD less than that of South Africans but greater than the two Asian comparative populations-Thai and Hong Kong males. There was no statistically significant difference in the mean. Thus Ghanaians relative to Thai, Hong Kong and South African samples seemed metrically similar in this parameter of the radius. This hints that if RMMD was considered as feature for metric identification of unknown radii or skeleton from these sample populations, Thai, Hong Kong and Black South African males might be misclassified as Ghanaian males and vice versa. The similarity though somehow unexpected, may possibly be due to variation in sample size.

5.5 Ulna

Various dimensions of the ulna have been studied for intra-population separation sexes by authors such as Darryl and Kennett (1991), (King, 1997), Mall et al. (2001) and Barrier and

L'Abbe (2008) for Americans, Thais and Hong Kong males, Germans and South Africans respectively. From the study, mean maximum ulna length for the Ghanaian males was numerically greater the individual means of each of the comparative populations (table 18). The difference in means was statistically significant at $p<0.0001$ for Germans, American Whites, South Africans, Hong Kong males, and Thais. However, the statistical difference was significant between Ghanaian and American Black males at $p=0.0015$. Apparently, with reference to the study sample, the average Ghanaian male have longer ulna than the males in each of the comparative populations.

The mean ulna physiological length for the Ghanaian males was numerically higher than the means for Thai males and Hong Kong males. The variation in statistical means for the original sample and the two comparative populations was significant at $p<0.0001$. Based on this observation, Ghanaian males were metrically different from Thai males and Hong Kong males considering physiological length of the ulna.

From the investigation, anterior-posterior diameter of the ulna has further established the existence of regional dimorphism. King (1997) measured mean ± standard deviation of 15.50 mm ± 1.41 mm and 15.80mm ± 1.47 mm for Thai and Hong Kong males respectively. These values were lower than the Ghanaian mean. There was statistically significant difference in means between the Ghanaians and Thais at $p<0.0001$ and the Ghanaians and Hong Kong males at $p=0.0005$ (table 18).

Expectedly, all three ulna parameters assessed for the studied sample populations with disparate racial backgrounds- congoid, caucasian and mongoloid-and also different genetic and geographical conditions, depicted marked regional variations. It is also believed that the longer ulna length of the Ghanaian males may have been due to life style and occupation. Most local Ghanaians are into farming activities. Weeding for instance is a common activity of many indigenes including children. Such practice could possibly extend the extremities of the ulna and also impact on the epiphyseal plates as the children grow thereby promoting the development of longer ulnae in the sampled Ghanaian males.

5.6 Fibula

The fibula is one of the least studied bones for sexual and regional dimorphism. The few studies that have been conducted seem to have concentrated on distal features. Considering the Ghanaian male sample analyzed in this study, the mean ± standard deviation for the maximum length was 399.80 mm ± 25.08 mm. The statistical range for the maximum length was 350.00 mm-473.00 mm.

The recorded value mean ± standard deviation for the diameter at midshaft was 15.54 mm ± 1.77 mm; that for the circumference at midshaft was 47.17 mm ± 4.66 mm.. Though comparisons could not be made for the Ghanaian males and any other populations to assess regional dimorphism in fibula measurements, for virtual lack of expected data, this Ghanaian data for the fibula might serve as an important source of information for future re-evaluation and comparison. Since population differences in metric osteological values have been quantified, the

Ghanaian male population should be anticipated to present some metric variation relative to other populations.

5.7 Os Coxae

Metric analysis of the hip bone for the purposes of distinguishing male skeletons from females, and also race assessment seems to have been well conducted in some populations. Such was the work of authors like King (1997) for Thai and Hong Kong males; Patriquin et al. (2005) studied South African samples; and Steyn and Iscan (2008) analyzed os coxae of modern Greeks. DiBernnado and Taylor (1983) have also studied American innomates. This is probably so because of the importance of the pelvis in sex identification and also reproduction

5.7.0 Total Innomate Height (TIH)

From the analysis, the average innomate height of the Ghanaian sample was significantly lower than DiBernnado and Taylor's (1983) American White and Greek (Steyn and Iscan, 2008) male sample meansat $p<0.0001$ and $p=0.0309$ respectively. Though numerically higher than the means of Thai (King, 1997) and Black South African (Patriquin et al., 2005) male samples, it was less than those of American White and Black, Hong Kong and Greek males. Considering total height of the coxal bone, there was metric similarity between Ghanaian, Thai, Hong Kong, Black American and South African Black male samples. This observation might be so due to the relatively small sample size of the Ghanaians as well as perhaps, similar occupation and nourishment of the sampled individuals.

DiBernnado and Taylor (1983) reported a mean of 204.60 mm and 195.50 mm for female American White and Black samples respectively; King (1997) observed 186.90mm and 189.60mm as means for sampled Thai and Hong Kong females respectively; Patriquin et al. (2005) gave 190.87mm for some Black South African female sample and Steyn and Iscan (2008) submitted 199.86 mm as mean for a Greek female sample. Relating the Ghanaian male sample mean with these female mean values, the studied population sample had appreciably greater hip bone height than these comparative female samples. Against the backdrop of these samples having different genetic, environmental and racial backgrounds; this observation though across population, agrees with earlier findings of these authors that male innominates were higher than their corresponding females of the same population.

5.7.1 Acetabulum Diameter

Acetabulum diameter (AD) is one of the important dimensions of the pelvis because of its relationship to the head of the femur and therefore robusticity. Larger AD might reflect larger femoral head which also reflects a more robust bone and form. From the studies, AD was highly dimorphic in terms of numerical values and significance of differences between the Ghanaian and comparative male population means. The mean AD for the studied sample was smaller than the individual means of all four comparative samples (table 23). The variation in means was significant at $p<0.0001$ for the original and all the comparative populations. Apparently, on the average, the studied Ghanaian males were less robust than their sampled counterparts from America, South Africa or Greece.

Interestingly, the Ghanaian sampled males recorded lower mean values than sampled female American Whites (mean, 50.30 mm; N=65) and American Blacks (mean, 50.00 mm: N=65) documented by DiBernnado and Taylor (1983) as well as those of Black South Africans (mean, 49.23 mm; N=100) and Greeks (mean, 49.15; N=94) reported by Patriquin et al. (2005) and (Steyn and Iscan, 2008) respectively. Nonetheless, the Ghanaian males appeared significantly unique from these comparative (female) South African Blacks ($p=0.002$), Greeks ($p=0.003$), American Whites and Blacks ($p<0.0001$)

Given that the sampled populations varied in size, race, territory and perhaps occupation and mode of life, such an outcome might not be far-fetched.

5.7.2 Ischial Length

Mean value for the ischial length recorded for the Ghanaian male was higher than that of all comparative populations (table 24). With reference to the samples, Ghanaian male ischial length looked longer than that of Thai, Hong Kong and Greek samples. The variation in means between these samples was significant at $p<0.0001$. The mean value for South African Blacks as observed by Patriquin et al. (2005) was similar to the mean obtained for Ghanaians. Also, it appeared that the studied sample mean was also significantly different ($p<0.0001$) from the female sample means obtained by King (1997) for Thais (mean, 66.10 mm; N=32) and Hong Kongers (mean, 67.30 mm; N=16) together with those of Steyn and Iscan (2008) for Greeks (mean, 51.55 mm; N=92) and Patriquin et al. (2005) for Black South Africans (mean, 95.63 mm; N=100).

Ostensibly according to this observation, the sampled Ghanaian males were similar to the South African Black male sample, probably because some South African Blacks (those of the Natal) share similar race (Central Congoid) with the Ghanaians and for the fact that they are geographically the closest test group.

5.7.3 Iliac Breadth

Iliac breadth (IB) mean varied between populations as shown in table 24. However, the variation was not significant between the original sample and all the comparative samples except the Greek sample at p=0.0032. The mean obtained for the Ghanaians was numerically lower than that of Thais, Hong Kongers, South African Blacks and Greek populations as well as Black South Africans. Additionally, considering the corresponding female means of the comparative groups and the studied Ghanaian sample, though the mean was numerically higher than Thai (mean, 145.20 mm; N=32) and Hong Kong (mean, 142.5 mm; N=13) as well as that of Black South Africans (mean, 145.23 mm; N=100) but lower than Greeks (mean, 154.51 mm; N=91), the difference was not significant. It therefore suggested that as per the samples, and excluding Greek males, the Ghanaian males were similar in the breadth of their ilium to the compared Asians, Black South Africans and Greek females. According to this observation, it sounds that, if IB was considered as an osteological index for grouping unknown pelves of these sampled populations, Ghanaian males might be misclassified as Greek or Black South African or even Thai females. There seems that for these racially and genetically distinct samples, this similarity might have stemmed from factors like variation in sample size, nourishment, occupation or lifestyle.

5.7.4 Greater Sciatic Notch Width

DiBernnado and Taylor (1983) reported mean ± standard deviation of 44.70 mm ± 4.20 mm and 48.60 mm ± 4.60 mm for American Blacks and Whites respectively. These means were greater than the mean of the Ghanaians and also significantly different at $p<0.0001$. Thus, the studied sample population and the Americans were metrically different in the GSNW of the pelvis. The Greek sample average for GSNW obtained by Steyn and Iscan (2008) was higher than the Ghanaians, varying significantly at $p<0.0001$. The Ghanaians have similar greater sciatic notch breadth to Black South Africans since there was no statistically significant difference in means between these populations. It might seem difficult to distinguish pelves or skeletons from these two samples when applying GSNW measurement alone.

Greater sciatic notch width has been shown to be wider in females than in males especially for the same population, perhaps for parturition purposes. An attempt was made to make some trans-population comparison between the Ghanaian males and females of the comparative samples. Patriquin et al. (2005) obtained sample mean ± standard deviation of 43.35 mm ± 5.82 mm and 48.83 mm ± 5.78 mm for South African Black and White females respectively. Comparing, these female values were greater than that of their corresponding males as well as that of the Ghanaians (table 25). The difference between the Ghanaian male mean and the South African female means was significant at $p<0.001$. Greek female GSNW mean observed by Steyn and Iscan (2008) was 50.96 mm; that of American Black and White females noted by DiBernnado and Taylor (1983) was 49.30 mm and 51.7 mm respectively. All these female values were significantly larger and disparate from that of the Ghanaian males at p<0.0001, confirming earlier findings that females have wider GSNW than males.

5.7.5 Pubic Length

Pubic length (PL) is one dimension of the pelvis that is essential because of its implication in anterior-posterior diameter of the pelvic inlet. Greater pubic length might confer larger conjugate vera (anterior-posterior diameter) on the pelvis. Females are known to have longer pubis than males. Patriquin et al (2005) note that robusticity and childbearing modifications play a role in metric manifestations of sexual dimorphism. From the study, the Ghanaian male sample recorded shorter pubic length that all compared male samples (table 25). However, the numerical variation in pubic length between the original and comparative populations was only significant between the Ghanaians and American Whites, South African Blacks, Thais and Hong Kong males but not American Blacks and Greeks (Table 25).

Patriquin et al. (2005) recorded mean ± standarad deviation of 93.31 mm ± 5.43 mm for Black South African females; Steyn and Iscan (2008) reported mean ± standarad deviation of 73.21 mm ± 4.37 mm in Greek females; from Thai and Hong Kong female samples, King (1997) observed 76.30 mm ± 4.44 mm and 78.70 mm ± 4.48 mm respectively as the mean ± standard deviation. For samples of Black and White American females, DiBernnado and Taylor (1983) obtained mean ± standard deviation of 72.80 mm ± 4.70 mm and 79.00 mm ± 5.00 mm respectively. Comparatively, though the Ghanaian male mean PL was numerically lower than all compared female PL, the difference is only statistically significant at p=0.0016 in Thai females;

p<0.0001 for South African Black, American White and Hong Kong females. Somehow, the Ghanaian males were metrically similar in their pubic length to Greek and Black American females. From this perspective and based on the studied samples, if metric identification of unknown pelves from these groups were to be executed solely on PL, Greek and American Black females might be misclassified for Ghanaian males and vice-versa.

5.8 Articulated Pelvis

As documented by Igbigbi and Nanono-Igbigbi (2003) pelvic dimensions have been shown to be important in forensic medicine in that these measurements display individual and racial differences, which have been found to be greater in the inferior aperture than the brim. For the passage of foetal head during child birth, inlet and outlet dimensions of the pelvis must be commensurate with skull dimension.

From the study, pelvic brim dimensions-anterior posterior, diagonal and transverse diameters-were presented. Mean and standard deviation of anterior-posterior diameter (conjugate diameter, CJD) of pelvic inlet obtained for Greek males by Steyn and Iscan (2008) was 103.21 mm and 8.54 mm respectively; that of the females was 113.33 mm and 9.27 mm. For the transverse diameter, they observed 124.66 mm ± 7.79 mm and 130.69 mm ± 7.51 mm as mean ± standard deviation for males and females respectively. Comparing these values with that of the sampled Ghanaian males, the Ghanaian and Greek males were metrically similar in their Conjugate Diameter (CJD) with no statistically significant difference in means; however, the Greek females had significantly higher CJD than their own males (p=0.0001) as well as the Ghanaian males (p=0.0015). With regard to transverse diameter (TD), Ghanaian males had significantly lower TD than Greek males and females at p<0.0001. Indeed, this observation attests to earlier findings that within a population, females have larger pelvic inlet dimensions than males; and quite so even across populations.

Steyn and Iscan (2008) found that height of pubic symphysis (HPS) was not highly sexually discriminative; though symphyseal height was more in male than female Greeks. However, in Patriquin et al.'s (2005) observation HPS was a good discriminator of sex in South African Black and Whites, also with the same note that males had higher average values than females. Mean HPS for Ghanaian sample was 47.17 mm; this value was significantly higher than the mean (40.86 mm) of Greek males at p=0.0432 and South African Black males mean of 38.98 mm at p=0.0137. Apparently, it was also higher than the Greek and Black South African females' means.

Mean anterior-superior bispinous breadth (ASBB) and anterior-inferior bispinous breadth (AIBB) recorded for the study population was 198.90 mm and 171.70 mm respectively. Anterior iliac spine dimensions though have received little or no attention in standard forensic and anthropometric analysis, might be equally useful as other pelvic parameters for identification. Iliac spine dimensions may also correlate with foetal dimensions during pregnancy and also delivery in females. Additional attention might establish its anthropometric importance.

Tague (1992) showed that the subpubic angle is one of the most dimorphic dimensions of the pelvis, and it has also been established that females have greater subpubic angles than their corresponding males. In the study, comparative data for subpubic angle was extracted from a publication by Igbigbi and Nanono-Igbigbi in 2003, who analyzed subpubic angles from radiographs of Ugandan and Malawian subjects. The authors underscored that there was no significant differences in the subpubic angle measured from radiographs and skeletal materials; hence, radiographic and manually measured skeletal subpubic angles could be compared. They also established that there were significant differences in subpubic angle between races of both sexes.

As documented by Igbigbi and Nanono-Igbigbi (2003), the following were some values reported as mean ± standard deviation (values in degrees) for some populations. White Americans (Men, N= 50, 63.70 mm ± 7.80 mm; Women, N=50, 88.40 mm ± 8.50 mm); Black Americans (Men, N=50, 65.80 mm ± 8.70 mm; Women, N= 49, 85.20 mm ± 8.50 mm); Black Malawians (Men, N=73, 99.20 mm ± 15.70 mm; Women, N=46, 129.10 mm ± 14.60 mm) and Black Ugandans (Men, N=110, 93.86 mm ± 21.12 mm; Women, N=95, 116.11 mm ± 17.79 mm). Comparatively, there was no statistically significant difference in recorded means for the Ghanaian and the American (both Black and White) males, most probably because of the relatively smaller samples size of the Ghanaians used (table 27). On the other hand, Black Ugandan males had significantly wider subpubic angle than Ghanaian males ($p=0.0002$); likewise, Black Malawian males were significantly greater in this angle than the Ghanaians ($p<0.0001$). Clearly, there was regional variation in subpubic angle in Black subjects, apparently because of differences genetic and environmental factors that modulate development. Similar observation was made by Igbigbi and Nanono-Igbigbi for Black Ugandans and Malawians. They added that there was also significant variation even between races for both males and females, and that Blacks had wider subpubic angles than whites.

As Igbigbi and Igbigbi-Nanono (2003) highlight, presence of sexual, regional and racial variability of the subpubic angle could possibly be explained on genetic, dietary, and environmental factors; previous study on whites had also shown sexual differences in subpubic growth expressed in the subpubic angle, which was more acute in men than in women. In addition to these factors, socio-economic influences have also been implicated in osteological dimorphism within and between populations.

It is worthwhile noting again that various authors have underscored possible reasons for metric intra-population and inter-population variation in various skeletal indices; and more so why different segments of bones vary in their efficacy and accuracy in sex diagnosis and perhaps regional grouping of bones. Iscan et al. (1998) drawing from France's (1983) work, submitted that proximal and distal measurements are likely to be more accurate because these areas are subjected to greater functional or occupational stress. From a somewhat different viewpoint, Ruff (1987) noted that the cross sections of limb bones may be influenced by behavior more that bone length. It has also been claimed that stature based sexual dimorphism peaks in societies that are at the extremes of protein consumption – both high and low (Gray and Wolfe, 1980). Another possible explanation for this phenomenon was discussed by Black (1978), who proposed that differential bone remodeling exists between males and females. In addition, more cortical bone is developed during adolescence in males and the ratio remains essentially unchanged throughout adulthood. Others like DiBernnado and Taylor (1982) came to a similar conclusion in their study of black femora from the Terry collection. They suggested that shape measurements were of major significance for correct diagnosis of sex because functional demands of weight bearing and musculature affect circumferential measurements more than length.

Current populations are biologically more heterogeneous than more ancient populations, as a consequence of nutritional, socio-economical changes and the mixing of populations (Alunni-Peret et al. 2008). Better nutrition has led to increased height and weight across populations, and this in turn must be accompanied by increased bone robustness in order to maintain muscle function Trancho et al. (1997). The findings of this study have further underscored the need to re-evaluate bone measurements within and between contemporary populations.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

This study has confirmed that population variation exists in metric osteological parameters, hence the need for population specific standards. Preliminary osteological baseline data have been produced for Ghanaian males; and these data may be invaluable for preliminary classification of whole, part or fragmentary skeletal remains. With regard to identification of Ghanaian male postcranial bones, measured values outside the statistical and calculated ranges might suggest that the bone from which the measurement was taken might not be of Ghanaian male origin. However, it must be noted in using these ranges that the descriptive statistical ranges (minimum and maximum values) have more identification power than the calculated range. Also, it is important where available, that combination of variables are used in preliminary identification so as to optimize the accuracy of correct classification since no single variable of any bone is in itself 100% accurate in identification.

It is recommended that further studies are conducted using Ghanaian females and compared with the males when reasonably adequate sample size is available. Also because literature has underscored that intra-population modification occurs over time, it is important the data is built upon and new and enhanced techniques of metric analysis and identification of skeletal parts considered.

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