ASSESSMENT OF PELVIC DIMENSIONS USING RADIOGRAPHS OF ADULT NIGERIANS

BY

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DECLARATION

I hereby declare that this work is the product of my research efforts undertaken under the supervision of Dr. M. H. MODIBBO and has not been presented anywhere for the award of a degree or certificate. All sources have been duly acknowledged.

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CERTIFICATION

This is to certify that this research work titled "Assessment of Pelvic Dimensions using Radiographs of Adult Nigerians" and the subsequent write up of ADAM NMA JIBRIL (SPS/15/MAN/00009), was carried out under my supervision.

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This research work titled "Assessment of Pelvic Dimensions using Radiographs of Adult Nigerians" has been examined and approved for the award of Master Degree in Anatomy.

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ABSTRACT

Identification of sex in human skeletal remains is an important component and frequently the starting point of many forensic anthropological investigations. In adults, the hip bone is the most reliable sex indicator because of its sexual dimorphism which can be used as best parameter for determination of sex. The aim of the study was to determine sex from human pelvis using radiographs of adult Nigerians. The study was a retrospective and cross sectional study design. Antero-posterior view of 500 radiographs was used, which composed of 250 females and 250 males with age range from 18-60 years. Radiographs were obtained from the record units of Radiology Department in Murtala Mohammad Specialist Hospital and National Orthopedic Hospital Dala, Kano. The measured variables were antero-posterior diameter of pelvic inlet, transverse diameter of pelvic inlet, oblique diameter, pubis length, ischium length, pelvic height, sub-pubic angle. Generated equations were used to analyse the sex determination in adult Nigerians, and Mann-Whitney test was used for sex differences. The results confirmed the well-established sexual dimorphism in the pelvic variables; the mean values of females were higher than their males' counterparts except the ischium length in males which was higher than the females. Sub-pubic angle of females were wider than the males, which was greater than 90^0. Among the female pelvis types, the anthropoid pelvis had the highest percentage of 49.20%. The gynaecoid and android pelvis were found to have 31.60%, and 18.00% respectively. The least was platypelloid with 1.20% of pelvis type. With regards to sex discrimination, sub-pubic angle was found to be the best predictor of sex among adult Nigerians with an accuracy of 98.4%. However, the percentage accuracy increased to 100% when the other variables (sub-pubic angle, pubic length, left pelvis height and ischial length) were considered. In conclusion, the pelvic

variables showed sex differences in adult Nigerians, and the pelvic bone diameters found in this study can be used for sex discrimination among the adult Nigerians.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

The pelvis is so called because of its resemblance to a basin. It is a bony ring, interposed between the movable vertebrae of the vertebral column which it supports, and the lower limbs upon which it rests. It is stronger and more massively constructed than the wall of the cranial or thoracic cavities. It is composed of four bones; the two hip bones laterally, then the sacrum and coccyx posteriorly. The pelvis is divided by an oblique plane passing through the prominence of the sacrum, the arcuate and the pectineal lines, the upper margin of the symphysis pubis, into the greater and the lesser pelvis. The circumference of this plane is termed the linea terminalis or pelvic brim. It contains, supports, and protects the pelvic viscera. The computed radiography is used to measure the variable distance between iliac crests, line joining the anterior superior iliac spine (ASIS), brim length, brim width, distance between acetabulum and pubic angle (Chung, 1996). The bony pelvis is separated by an inlet or brim into two parts which are false and true pelvis. The false pelvis is above the brim and does not have a significant function in childbirth. The true pelvis is below the brim, which is between the pelvic inlet and pelvic floor and has an intimate role in childbirth. This bony birth canal is made up of three planes, which are the inlet, mid pelvis, and outlet. The pelvic inlet is the upper border of the true pelvis, while the outlet is the lower border. The mid pelvis, or pelvic cavity, is bounded by the posterior part of the symphysis pubis, the ischium, ilium, sacrum, and coccyx (Lowdermilk, 2010).

The pelvis is an important structural and functional element influenced during an individual’s life time by various mechanical and physiological factors. It is a source of information about the contemporary (Kornafel, 1987) and extinct human groups and it is also an interesting object of anthropological studies (Jozwiak, 1984; Budnik & Jozwiak, 1985). Evolutionarily, the human pelvis has adapted to two processes which changed the morphology of its cavity. Primarily, the human pelvis was shaped by the erect posture and the bipedal locomotion (Schultz, 1949; Abitbol, 1987; Tague, 1992). Secondarily, the female pelvis was exposed to an additional selective pressure of the obstetric difficulties caused by the encephalization of a newborn (Tague, 1992). There are many factors which could have a negative influence on the pelvic anatomy and its function like injuries, diseases, overload and congenital abnormalities. Otherwise, change of the geometrical status of the human pelvis has its clinical impact through the alteration of physiological loads, pressures and forces acting on the human pelvis. Sex differences of the pelvic shape have also their clinical repercussions. Women have a higher hip joint pressure, which is the result of the smaller radius of femoral head, which could explain, at least partially a higher incidence of osteoarthritis in female population (Maquet, 1985).

In terms of sexual dimorphism related to body structure, an example would be that females have a notably wider pelvic canal in many species. The sexual dimorphism is also important because it may provide insight into the different functions of the pelvic region in humans. One function is that, only females give birth. Another function may be that females have different biomechanical requirements of locomotion than males, given that they have wider hips than males (Cutting *et al.*, 1978). This raises the question of whether sexual dimorphism in the human pelvis is primarily related to childbirth requirements or biomechanical ones. Many studies have tested the hypothesis that sexual dimorphism in the human pelvis is related to birthing (Badyaev, 2002; Betti, 2014). In the process of birthing, foetal rotation and the direction of the emergence of the newborn also allow humans to deliver large babies.

The head and torso of the neonate rotate to fit through the bony birth canal, and when they emerge, it is in the occipitoanterior position, which is facing away from the mother (Rosenberg & Trevathan, 1996). Rotation of the head and torso must occur because of the large size of the foetal head in relation to the pelvic canal. The larger back of the neonate's head moves to come in contact with the pubic symphysis, and then rotates around it. This rotation allows for the smallest diameter of the head to pass through the pelvis first. The occipitoanterior position takes advantage of the angles of the pelvis during childbirth by allowing the neonate's back to arch to fit the curves of the pelvis. The widest part of the infant's head also fits into the widest part of the pelvis. This mechanism, in combination with the anatomy of the female pelvis, aids in childbearing. Although the above mechanisms aid in childbirth, some features of the pelvis can hinder it, posing the idea that they serve other functions. The ischial spines that protrude into the pelvic midplane can present a challenge in birthing, given that they create the narrowest part of the birth canal (Trevathan, 2015). Women with spines too far apart are at risk for disorders such as pelvic organ prolapse, but closely spaced ones make birthing more difficult. The ischial spines play a negative role in birthing, suggesting their existence serves another more beneficial purpose. Another hypothesis for the implications of sexual dimorphism in the human pelvis focuses on locomotor biomechanics of walking and running. As an adaptation for childbirth, females have wider hips than males to accommodate a large neonate. Studies show that although females have wider hips, their locomotor efficiency is not compromised because of it (Warrener *et al.*, 2015). However, there may be shape and size dimorphisms between males and females based on locomotor biomechanical function. The false pelvis, which is above the bony birth canal, includes the ilium, which functions in stabilization (Barrett *et al.*, 2008). Possible changes in the shape or size of the ilium between males and females may be related to the way each sex walks and runs. In relation to non-human primates, humans have a much shorter ilium because of bipedalism (Lovejoy, 1988). Having a shorter ilium shortens the torso and brings the trunk closer to the hip joints, reducing exhaustion of the gluteal muscles. Lovejoy's study states that humans have outward flaring ilia to provide a wider lateral attachment for the abductor muscles that stabilize the bipedal pelvis when on one leg. It is known that females have a larger ratio of hip width to femoral length than to males, which may increase hip adduction (Chumanov, 2008). This wide pelvis can influence the joints below the pelvis and result in a greater knee joint valgus in women. These anatomical differences are believed to influence walking and running mechanics in males versus females. A study showed that while walking, females have greater hip flexion and less knee extension before initial contact and greater knee flexion pre-swinging of the legs, compared to males (Kerrigan *et al*., 1998). This greater valgus angle in women also makes them more prone to knee injuries, such as anterior cruciate ligament (ACL) tears (Russell *et al*., 2006). They demonstrated that during a single leg landing, women land in knee valgus when their leg makes contact with the ground, in contrast to men who tend to land in knee valgus. This tendency for women to stay in a greater valgus angle could explain why they are 2 to 4 times more likely to suffer ACL injuries. Although studies have found clear anatomical and biomechanical differences in the lower extremity between males and females, few have expanded these investigations to the pelvis to determine whether morphological differences in the pelvis play a role in obstetrics, locomotor biomechanics, or both.

Characterization of the female pelvis attracted the attention of researchers since the mid 1980's and it is of great importance to the Anatomist, Gynecologist, Anthropologist and the Radiographers among other professionals. A true knowledge of the female pelvis is essential to the understanding of the mechanism of labour (Ikamise, 2006). Pelvis imaging techniques such as the conventional radiography, the computed tomography and the Magnetic Resonance Image (MRI) have been very useful in the characterization of the pelvis into its various types which includes the Gynecoid pelvis, the Anthropoid pelvis, the Android pelvis and the platypelloid pelvis. In gynecoid pelvis the cavity of the pelvis is ample in all directions and it is found in 50% women, while the platypelloid pelvis is about 4.4% of women (Isadore & Saunders, 1978; Mcneely, 2013; Deborah 2016). The shape of the pelvis may become abnormal as a result of either congenital or of acquired disease. Congenital abnormality such as achandroplasia or osteomalacia may cause obstruction to labour (Ezea, 2005), and other problems associated with pelvis, are pelvic fractures and pelvic floor disorders. Pelvis fractures occur in 20% of all poly trauma cases (Jan, 1998; Ezea, 2005). Pelvic floor disorders involve prolapse of bladder, urethra, uterus and is common as women aged and this may require surgery (Mcneely, 2013).

Caesarean section is a surgical operation to deliver a baby or babies by means of an incision through the abdomen and uterus (Mutihir *et al*., 2005). Caesarean section rates have been raising progressively worldwide (Bragg *et al*., 2010) with a wide variability amongst various countries and regions (Althabe *et al*., 2006). This rises has been attributed to improvement of surgical techniques, innovation, technological development (Flores *et al*., 2008), changes in women's preferences and a growing proportion of women who have previously had a caesarean section (Karlstrom *et al*., 2011).

Cephalopelvic disproportion (CPD) in labour occurs when there is a mismatch between the size of the fetus and the dimensions of the maternal pelvis. The factors which mainly influence the outcome of the delivery can be summarized as the three “Ps” of the labour: passageway, passenger, and power of the uterus (Maharaj, 2010). The passageway component of this trinity has been investigated by pelvimetry which measures the maternal bony pelvic dimensions (Friedman, 1997), with very little emphasis on its shape or pelvic floor muscles. During the last decades, the use of pelvimetry has been discouraged (Pattinson, 2000), but at present, no replacing methods to evaluate the maternal pelvis have been introduced. The benefits of vaginal deliveries are well known when no risk factors are present (Liu *et al*., 2007) even after previous Cesarean section (CS) (Faranesh & Salim, 2011; Rozen *et al*., 2011). On the other side, unplanned interventions during labour such as acute or emergency cesarean sections as well as operative vaginal delivery increase both maternal and fetal morbidities (Wax, 2006), as does a prolonged second stage of the delivery (Altman & Lydon-Rochelle, 2006).

1.2 STATEMENT OF THE RESEARCH PROBLEM

Determination of identity is difficult and challenging in mass disasters, genocides and accidents. Long bones are often used to determine identity such sex of an individual and few studies determine sex using macerated bony pelvic. However, the use of pelvic radiographs in determination of sex received less attention among adult Nigerians. Proportions of female pelvis types contribute to difficulty in childbirth which increases the maternal death. And there is paucity of data on the distribution of different types of pelvis among female adult Nigerians.

1.3 JUSTIFICATION OF THE STUDY

The need to use pelvic radiographs to determine sex is highly desirable in order to establish reference value for sex determination for adult Nigerians. It may reduce the process of personal identification of human being. Available data in our locality is not enough for pelvic dimensions and the literatures of other nations could differ from our dimensions or measurements due to demographic, social and geographic variations. There is paucity of established baseline data on proportions of female pelvis types among female adult Nigerians.

1.4 AIM AND OBJECTIVES OF THE STUDY

1.4.1 Aim of the Study

The aim of this study is assessment of pelvic dimensions using anteroposterior radiographs of adult Nigerians.

1.4.2 Objectives of the Study

i. To determine the mean value of pelvic dimensions; [pelvic diameters (antero-posterior, oblique and transverse), pelvic lengths (ischial and pubic), height (pelvic) and angle (sub-pubic) of adult Nigerians.

ii. To determine the sexual dimorphism in pelvic dimensions; [pelvic diameters (antero-posterior, oblique and transverse), pelvic lengths (ischial and pubic), height (pelvic) and angle (sub-pubic) of adult Nigerians.

iii. To investigate the best sex discriminating features in [pelvic diameters (antero-posterior, oblique and transverse), pelvic lengths (ischial and pubic), height (pelvic) and angle (sub-pubic) of adult Nigerians.

iv. To determine the proportion of female pelvic types of female adult Nigerians.

v. To determine the sex differences in pelvic asymmetry of pelvic height of adult Nigerians.

1.5 SIGNIFICANCE OF THE STUDY

The findings may serve as a reference baseline data for anthropologists, forensic scientists and researchers. Provides evidence of population specific models for estimate of sex in disasters, which may be useful to anthropologists and forensic scientists. The result of the study may be helpful to gynecologists in knowing the female pelvis types and other clinicians. It provides statistical differences in some normal pelvic dimensions between age groups and sex. It provides data for clinical purposes either injuries or disorders and for obstetricians or urogenital specialist. It Provides evidence in sex discrimination in events of disasters, such as earthquake, plane crash and bomb blast for anthropologist. It may also be useful when obstetricians or surgical procedures in females are planned, for example, may impede visibility access and space for surgical excision. It may be used in establishment of personal identity for crime related forensic investigation.

CHAPTER TWO

LITERATURE REVIEW

2.1 SEXUAL DIMORPHISM

The pelvic girdle is the most accurate area from which to determine sex and methods using these elements tend to make successful predictions in 90 to 95 percent of individuals (Krogman & Işcan, 1986). Determination of sex is an integral first step in the development of the biological profile in human osteology. Sex determination is necessary to make age, ancestry and stature estimations, as the sex's age differently, exhibit some degree of variation in ancestry related morphology, and generally differ in height (Stewart, 1979). Nearly every region and element of the skeleton has been used to develop methods for sex estimation with varying degrees of success. The general anatomical regions used for sex determination are the pelvic girdle, the skull, and long bones, although other bones have also been utilized.

Sexual dimorphism in bony pelvis is mainly due to the changes that occur during adolescence to meet the requirements of childbirth in females (Singh & Potturi, 1978; Işcan & Derrick, 1984; Budinoff & Tague, 1990; Tague, 2007). The female pelvis grows more in width than height during adolescence, while the growth of the male pelvis maintains the morphological characteristics of both sexes before adolescence period (Coleman, 1969). Thus, a wide pelvic inlet, wide subpubic concavity and a wide greater sciatic notch are the hallmarks of the female pelvis, while the opposite characteristics are found in male pelvis.

The knowledge of sexual dimorphisms is important in many aspects of paleodemography and paleobiology. However, the different methodologies employed to estimate the degree of sexual dimorphism, made the comparison of the result remains difficult (Bruzek, 1996). Bruzek used eighteen (18) variables of the os coxae to evaluate the degree of sexual dimorphism. The data collected were employed to investigate the pelvis sexual dimorphism within a recent sample of known sex, and among the Afalou-bou Rhummel-Taforalt (Epipaleolithic of Northern Africa) and the Teviec-Hoedic samples (Mesolithic of France). A comparative analysis is applied to a few recent samples. The results indicate the stability of sexual dimorphism pattern in recent and past populations.

Gonzalez *et al*. (2007), carried out a research titled “Analysis of dimorphic structures of the human pelvis: its implications for sex estimation in samples without collections” they used geometric morphometric techniques based on semi landmarks in order to quantify shape variation of the greater sciatic notch and ischio--pubic region, and the greater sciatic notch of two unknown sex Amerindian samples from Argentina, and k-means clustering analysis was applied to detect two groups within each sample. One sample corresponds to hunter-gatherers from South Argentina (n = 29), whereas the other comprises farmers from Northwest Argentina (n = 30). The results obtained suggest that, the first relative warps axis obtained for both structures summarizes shape changes due to sexual dimorphism, the individuals grouped into clusters can be assigned as female or male based on their shape, sexual dimorphism is not equally expressed in both archaeological samples. The findings support the hypothesis that patterns of pelvis sexual dimorphism vary among human populations and thus, criteria for sexing are population-specific.

Ekanem *et al*. (2009), carried out a research titled on radiographic determination of sex differences in ischio-pubic index and measuring the pubic and ischial lengths in 214-ray films (114 males and 100 females) of Cross River State indigene. The ischio-pubic index was calculated by dividing the pubic length by ischial length and multiplying by 100. The sex differences of the pubic length, ischial length and ischio-pubic index were found to be statistically significant when male and female X-ray films were compared ($p<0.001$). The marking points of these parameters were worked out to determine sex. The demarking point of the ischiopubic index was more useful in sex determination assigning sex to 69% males and 81% females. The ischio-pubic index therefore is a useful parameter in sexing of the hip bone.

A study was based on the retrospective pelvimetry of three dimensional computed tomography of 176 live male and 212 female. Antero-posterior diameters and transverse diameters were measured in four planes, and their ratios were calculated in order to evaluate proportions and variances. The results confirmed well established sexual dimorphism in the pelvic linear measures, the anteroposterior diameters of the midplane and the outlet. In addition, the study identified higher variation in the transverse diameter of the inlet in females. The proportions demonstrated no differences in variation in all the planes but the mid-plane including bispinous diameter ($F=11.34$; $p<.01$). It seems important that the female pelvic cavity demonstrated lower variance than the male pelvic cavity in the mid-plane including bispinous. Their finding supports the view of selective pressure on the female pelvis and its intensity in the mid-plane (Kolesova & Vēstra, 2011).

Osunwoke *et al*. (2013), carried out a research study to document the determination of sex by discriminant formula using the pelvic radiographs of Nigerian adults. Pelvic radiographs of 500 adult Nigerians of known sex, age ranged 18-75 years (comprising 250 males and 250 females) were measured in the antero-posterior position using a digital vernier calliper. The data was analysed using Z-test. The results showed that the mean values for the ischial length and pubic length in males were 86.82±8.25mm and 76.41±8.91mm respectively while in females the ischial length and pubic length were 80.62±7.66mm and 84.58±8.80mm respectively. 4% males and 19% females were identified for ischial length and 15% males and 42% females were identified for pubic length. The mean value for pelvic height in males and females were 236.70±12.51mm and 223.02±12.18mm respectively, the demarking points identified 29% males and 32% females, while the mean value for mid-pubic width in males and females were 25.94±4.54mm and 30.09±3.67mm respectively, the demarking points identified 40% and 65% females. The mean values for ischio-pubic and pelvic height/mid-pubic width were statistically significant (P<0.05). The mean values of the pelvic height/mid-pubic index were 9.35±1.38 in males and 7.49±0.82 in females. The demarking points identified 72% males and 75% females. While the mean values of the ischio-pubic index in males and females were 88.46±9.26 in males and 114.67±99.28 in females, the demarking points identified 56% males and 84% females. They observed that the males had higher pelvic height and ischial length than females, while the females had longer pubic length and mid pubic width which contributed to the females having wider pelvis. The accurate determination of sex and race are important tools to forensic scientists and physical anthropologists.

A study was carried out to determine the ischio-pubic index and sexual dimorphism in ischio-pubic index among adults in Maiduguri, North-Eastern Nigeria (Attah *et al*., 2015). Anteroposterior radiographs of adult pelvis (age range, 18-60 years) were evaluated. One hundred and twenty (120) radiographs (60 males and 60 females) were used for the study. The morphological measurements were pubic length, ischial length and ischio-pubic index. The mean values of pubic length, ischial length and ischio-pubic index of males in Maiduguri North Eastern Nigeria population were

81.0mm, 91.7mm and 88.5, respectively while those of their females counterparts were 92.7mm, 87.1mm and 106.8, respectively. The mean pubic length was significantly longer in females than males in the population ($p<0.05$). The mean ischial length was significantly higher in males than in females ($p<0.05$). The ischio-pubic index of the females was significantly higher than that of the males ($p<0.05$). There was sexual dimorphism in the ischio-pubic index of North Eastern Nigerian population in their study. When the results were compared with other populations there were slight differences. An ischio-pubic index greater than ninety (90) will most probably be that of a female and less than ninety (90) will most probably be that of a male in North Eastern Nigeria population (Attah *et al.,* 2015).

A research study was carried out to determine the pubic length, ischial length and ischio-pubic index of the South-South people of Nigeria (Okoseimiema & Udoaka, 2013). Anteroposterior radiographs of adult pelvis (age range, 18-75 years) were evaluated. Five hundred and eighteen (518) radiographs (259 males and 259 females) were those of the south-South people of Nigeria. The morphological measurements were pubic length, ischial length and ischio-pubic index. The mean values of pubic length, ischial length and ischio-pubic index of male South-South Nigerians were 74.99 mm, 85.03mm and 88.65, respectively while those of their females were 84.48 mm, 79.52 mm and 106.45, respectively. The mean pubic length was significantly longer in females than males in the population ($p<0.05$). The mean ischial length was significantly higher in males than in females ($p<0.05$). The ischio-pubic index of the females was significantly higher than that of the males. Using the radiographs, sex could be assigned to 32.43% of males and 31.66% of females when using the formulae (Mean±3SD). But then, using the formulae (Mean±2SD), sex was assigned to 68.72% of South-South Nigerian males and 62.53% of South-South Nigerian females. When the results were compared with other races, there were racial differences. Thus, this study is important as it has provided the necessary data for the Nigerian population under investigation. An ischio-pubic index greater than (90) will most probably be that of a female and less than (90) will most probably be that of a male in South-South Nigeria. The data is recommended to obstetricians, physical anthropologists and forensic scientists.

2.2 PELVIC ASYMMETRY

Asymmetry in pelvic dimensions is one factor that may cause difficulties in childbirth. Pelvic asymmetry can also cause leg length asymmetry (Badii *et al.*, 2003), study of symmetry in iliac crest height found that asymmetry of greater than 5mm only occurred in 5.3% of the 323 pelvises evaluated; the authors measured distance between the iliac crest and acetabulum from CT scans and used every pelvic and abdominal CT scan taken in two months in one institution.

Campbell *et al.* (2011), found that significant amounts of asymmetry were present in several pelvic dimensions in young females but not in old ones. Their study involved 45 young females (18-24 years), 51 old females (25+ years), 16 young males (18- 24 years), and 48 old males (25+ years) from four archaeological Native American populations from New Mexico and Alaska. Measurements evaluated included greater sciatic notch width, iliac blade length, alar-pubis length, and sacral-ischial spine length. The young female group had significant amounts of asymmetry in greater sciatic notch width, alar-pubis length, and sacral-ischial spine length while old females did not have significant asymmetry in any dimension. They concluded that these differences suggest that the young female group may have suffered from greater stress levels during childhood and adolescence, which may contribute to both pelvic asymmetry and mortality; pelvic shape is affected by vitamin D deficiency, childhood nutritional status, and activity patterns in childhood and adolescence (Abitol, 1996; Greulich & Thoms, 1938). The differences may also suggest that the greater amount of pelvic asymmetry may have contributed to death in childbirth.

The human pelvis is extremely sexually dimorphic and growth patterns in males and females are accordingly very different. In females, pubic length, ischium height, biiliac diameter, inlet transverse diameter, and mid-plane transverse diameter have significant growth continuing after stature growth ceased (Moerman, 1981). Females show greater growth in ischium length, sacrum breadth, and outlet transverse diameter than males do, although these dimensions continue to grow after stature growth ceases in both sexes. Growth is greater in females than in males at all points on the pelvis between 9 and 18 years of age (Coleman, 1969). The pubis border also has different completion times as the inferior border of the pubis is generally complete by 18 years of age in females and males while the superior border may continue to grow in females between 20 and 30 years of age (Tague, 1994).

A research conducted by Boulay *et al*. (2006), was to assess pelvic asymmetry (that is to determine whether the right iliac bone and the right part of the sacrum are mirror images of the left), both quantitatively and qualitatively, using three-dimensional measurements. Pelvic symmetry was described osteologically using a common reference coordinate system for a large sample of pelvises. Landmarks were established on 12 anatomical specimens with an electromagnetic Fastrak system. Seventy-one paired variables were tested with a paired *t*-test and a non-parametric test (Wilcoxon). A Pearson correlation matrix between the right and left values of the same variable was applied exclusively to values that were significantly asymmetric in order to calculate a dimensionless asymmetry index, ABGi, for each variable. Fifteen variables were significantly asymmetric and correlated with the right versus left sides for the following anatomical regions: sacrum, iliac blades, iliac width, acetabulum and the superior lunate surface of the acetabulum. ABGi values above a threshold of ± 4.8% were considered significantly asymmetric in seven variables of the pelvic area. Total asymmetry involving the right and the left pelvis seems to follow a spiral path in the pelvis; in the upper part, the iliac blades rotate clockwise, and in the lower part, the pubic symphysis rotates anticlockwise. Thus, pelvic asymmetry may be evaluated in clinical examinations by measuring iliac crest orientation.

Tobolsky *et al*. (2016) carried out a research on patterns of directional asymmetry in the pelvic and pelvic canal. The human pelvis is unique among modern taxa for supporting both parturition of large brained young and obligate bipedalism. Though much work has focused on pelvic development and variation, little work has explored the presence or absence of asymmetry in the pelvis despite well-known patterns of asymmetry in other skeletal regions. The study investigated whether patterns of directional asymmetry (DA) could be observed in the pelvis or pelvic canal. Seventeen bilaterally paired osteo-metric measurements of the os coxae (34 measures in total) were taken from 128 skeletons (female n=565, male n=563) from recent human populations in five geographic regions. Paired sample t-tests and Mann–Whitney U-tests were used to investigate DA. Results from a pooled sample of all individuals showed that the pelvis exhibited a left-bias in DA. In contrast, the pelvic canal exhibited a pattern in which the anterior canal exhibited a right-bias and the posterior canal exhibited a left-bias. Neither sex nor population differences in DA were observed in the pelvis or pelvic canal. The varying patterns of asymmetry uncovered here accord with prior work and may indicate that loading from the trunk and legs place differing stresses on the pelvis and canal, yielding these unequal asymmetries. However, this is speculative and the possible influence of genetics, biomechanics, and nutritional status on the development of pelvic and canal asymmetry presents a rich area for future study. In addition, the potential influence of pelvic canal asymmetry on obstetric measures of pelvic capacity merits future research.

2.3 FEMALE PELVIS TYPES

A study was conducted in 2012 by Kolesova and Vētra on female pelvic types and age differences in their distribution and it shows statistics-based exploration of a typology of the female pelvis. The research sample was 172 females aged from 18 to 69. For measurements, the three dimensional CT images of pelvis were used. A cluster analysis was performed on anteroposterior and transverse diameters of the pelvic inlet and the midplane. The results revealed three clusters representing gynecoid, “narrow”, and intermediate types of female pelvis. The distribution of pelvic types in age groups indicates a tendency for the “narrow” pelvis to be presented more frequently in the group of younger females.

Bukar *et al*. (2013), determine the proportion of pelvic types as seen in a tropical setting. A retrospective review of preliminary films of hysterosalpingography of 400 women who underwent the study between January 2000 and December 2007 was reviewed to determine the pelvic typology, out of the 400 films reviewed, 361 (90.3%) were gynaecoid, 36 (9%) were android and 3 (0.8%) were andropoid. There was no platypelloid pelvis seen in the films reviewed and a mixed type pattern was not observed in their study. The proportion of pure gynaecoid pelvis seen in their reviewed was the highest reported in the literature.

Functional analysis of the true pelvis (defined as that portion lying below and including the pelvis brim) was undertaken on a sample of 588 females of reproductive age sent for an anterio-posterior examination of the pelvis from January 2005 to June 2009 in two hospitals from Jos metropolis in Plateau State, Nigeria. Standard radiographic measurement were taken and used in the characterization of the normal female pelvis living in this region to ascertain their pelvis type and percentages of their prevalence. The result was compared to that reported on a global scale and the result showed three (3) pelvis types, prevalent among the female population living in Jos Metropolis. These are the Gynecoid with 8% prevalent rate, Andriod pelvis type 39% and the platypelloid pelvis type with 53%. Each having an average index of 93%, 84% and 64% respectively. The research showed that Platypelloid pelvis was found to be the most common in the population with 53% prevalence rate, and calls for concern in the health sector since the capacity of female pelvis for child bearing is profoundly influenced by size and shape of the pelvis (Akpaniwo *et al*., 2016).

Fatima *et al*. (2013), conducted a research and establish standard measurement of Sudanese female pelvis and comparing the measurements with other nationalities in order to develop a Sudanese reference document. The study also aimed to describe the characteristic of Sudanese female pelvis, specially the birth canal, and to determine the prevalence of different anatomical variation in different parts of the Sudan. The result of study showed that there were two mains pelvic types in the Sudan, out of four known types in the world, the two types were: The anthropoid pelvis (oval birth canal) and the gynaeocoid pelvis (rounded birth canal). The other types of pelves were not common in Sudan. The two types presented as following: In North of Sudan 68% of cases were anthropoid while 32% of cases were gyneacoid. In South of Sudan, 30% of cases were anthropoid and 70% of cases were gyneacoid. In West of Sudan 49.3%

of cases were anthropoid and 50.7% of cases were gyneacoid. In East of Sudan, 22% of cases were anthropoid and 78% of cases are gyneacoid. In conclusion, the anthropoid and gynaecoid pelves are common in Sudan. While the platopelloid and android pelves are rare.

Ismail *et al*. (2016), conducted a research to determine the incidence of gynecoid pelvis by using classical criteria and measured parameters obtained from three-dimensional computed tomography (3D CT) pelvimetry in non-pregnant multiparous women who delivered vaginally and a retrospective study . All adult women who had undergone CT examination with routine abdominal protocols were identified. In the pelvic inlet, mid-pelvis, and pelvic outlet, classical criteria and measured parameters, both alone and in combination, were used to determine the presence of gynecoid pelvis. The 3D CT pelvimetry was performed on 226 women aged 23–65 years without any history of cephalopelvic disproportion and who had at least one delivery of an average fetal size (>2,500 g). The median parity was 4, and the mean (±SD) birth weight was 3,700 ± 498 g. Compared to the classical criteria, measured parameters and their combined use with the classical criteria significantly reduced the frequency of gynecoid pelvis (51.3 and 47.8%, respectively, versus 71.6%; $p = 0.001$). There was no significant difference between the measured parameters and their combined use with classical criteria with regard to the frequencies of gynecoid pelvis ($p > 0.05$). With the use of measured parameters of 3D CT pelvimetry, the incidence of gynecoid pelvis reduces to a more acceptable level (51.3%) in accordance with obstetric knowledge. Since there is no considerable decrease with the addition of classical criteria, 3D CT pelvimetry alone has merit for determining a woman's pelvic capacity for obstetric needs after the improvement and standardization of measured parameters.

A total of 1619 x-ray pelvimetries were analyzed to establish whether there are any differences in pelvic measurements between the four pelvic types. 1367 were analyzed to find out the relation between the capacity of each pelvic plane and maternal height. Of the 1619 cases, 564 (34.8%) were gynecoid. 330 (20.4%) anthropoid, 277 (17.1%) android and 448 (27.7%) platypellic. There were considerable differences in pelvic measurements among the four types; android pelves have smaller diameters than gynecoid and anthropoid pelves. Their findings suggest that pelvic types classified on the basis of impression alone may have a prognostic significance regarding the course of labor. Maternal height has a positive correlation with pelvic measurements; this correlation is greater at the inlet than at midplane and outlet and is, moreover, more evident in gynecoid and platypellic than in anthropoid and android pelves. If maternal height is less than 150 cm, there is great probability that inlet capacity will be less than average; if it is less than 145 cm, low borderline contraction is highly probable (Chen *et al*., 1982).

2.4 PELVIC DIMENSIONS

A research conducted by Ma'aji *et al.* (2007), on normal pelvic dimensions of Nigerian women in Ile-Ife by computed tomographic pelvimetry. A total of 100 pregnant women were used and the subjects' ages ranged from 24-45 years. The mean anteroposterior and transverse inlet pelvic diameters were 11.6 cm +/-SD 0.9 and 12.0 +/-SD 0.8 cm respectively. The range of anteroposterior and transverse diameters of the inlet were 8.4 cm-14.0 cm and 10-13.8 cm respectively. The mean outlet diameter was 11.5 cm +/-SD 1.2 cm. The mean bispinous diameter of the pelvis was 10.6 cm +/-SD 0.9 cm. There was significant positive correlation between anteroposterior diameter inlet and outlet as well as the bispinous diameters (1st, 4th - 6th pairs) p<0.001, here are significant variations in pelvic parameters of Nigerian women when compared with values from other countries of the world. These significant variations are anthropometric in origin.

Munabi *et al*. (2015), used 30 complete rearticulated adult pelvic bonesets of known sex for research. The some of the thirteen measurements made on each boneset included: Pelvis height, Sacral Anterior Orientation (SAO), pubic bone length, total pelvis height and inlet medial-lateral diameter. All measurements were taken thrice and the average used for comparisons with pelvis height. The non-parametric Mann-Whitney test and multilevel regression analysis test to control for gender was used. Pelvis height had significant associations with SAO (-0.36, P<0.01), pubic bone length (0.41, P<0.01), total pelvis height (0.21, P=0.04) and inlet medial-lateral diameter (0.46, P=0.02). Additional significant associations were observed with the diameters of the mid and outlet diameters of the birth canal. Pelvis height had significant associations with: total pelvis height and inlet medial-lateral diameter of the pelvis and the measurements related to the mid and outlet diameters of the birth canal. Their study provides initial evidence to support further evaluation of pelvis height as an additional tool for the assessment of the human birth canal.

Beric *et al*. (2011), conducted a research to know the relationship between anthropometric measurements and the size of the adult female bony pelvis. Three-dimensional points of all pertinent landmarks of 96 adult female bony pelvises were obtained and the true conjugate, interspinous distance, intertuberous distance, and pelvic inlet and outlet areas were calculated. The relationship between these measurements and height and multiple anthropometric measurements were evaluated using pearson’s correlation coefficient (r). Multiple anthropometric measurements were significantly correlated with the true conjugate and pelvic inlet and outlet areas, but not with the interspinous or intertuberous widths. Height had a greater correlation with pelvic areas than any other anthropometric measure considered, even after controlling for race. There were no significant differences in pelvic areas between races. They concluded that the height and other anthropometric measurements were significantly correlated with the true conjugate and pelvic inlet and outlet areas.

The values of pelvic dimensions three dimensional computed tomography (3DCT) were performed for non-obstetrical indications in non-pregnant multiparous women with a successful vaginal delivery and to evaluate the impact of maternal short stature on these parameters. A retrospectively study in 203 non-pregnant women selected consecutively if they had at least one singleton term delivery with head presentation and if there was no history of maternal or fetal birth trauma or cerebral palsy after childbirth. With standard sagittal and reformatted axial-oblique views, anteroposterior including three conjugates of pelvic inlet, transverse, posterior sagittal diameters of pelvic inlet, the plane of greatest diameter, the plane of least diameter, and pelvic outlet were measured. Selected obstetric parameters were collected. Overall, the pelvises had transverse oval appearance in inlet and size of the female pelvis. The diagonal conjugate was at least 15 mm longer than the obstetric conjugate. Women with short stature had lower maximal birth weight, and this was in accordance with their somewhat lower pelvic diameters. Their research present the reference values of the main planes of the true pelvis by 3D CT pelvimetry in a relatively large group of multiparous women who passed a trial of labor successfully. The pelvises had features of female pelvic bony structure although pelvic diameters were somewhat lower in multiparous women with short stature. The 3D pelvimetry with CT applications may be used as an adjunct to clinical and ultrasonographic examinations to rule out cephalopelvic dystocia in selected cases (Ismail *et al*., 2016).

A study was conducted on 175 women who underwent CT between March of 2006 and May of 2008. One specialist in obstetrics and gynecology measured the obstetrical conjugate, the true conjugate and the diagonal conjugate on the sagittal plane and the transverse diameter, the intertuberous diameter and the interspinous diameter on the coronal plane. A total of 175 Korean women were examined, and their ages ranged from 20 to 50 years. The mean age was 37.6 ± 7.4 years. The interspinous diameter that was measured on CT scans was 94.6 ± 7.8 mm in the vaginal delivery group (n=84) and this was 90.9 ± 6.6 mm in the cesarean section group (n=20). The difference reached statistical significance. The study examined the difference in the pelvic architecture with using CT and we found that the interspinous diameter can be the important determinant that affects normal vaginal delivery. Of these pelvimetric parameters, a wider interspinous diameter was significantly associated with vaginal delivery. Multi-displinary approaches are warranted to examine this relation with regard to the various factors that are involved in delivery (Sa-Jin *et al*., 2011).

A research was carried out by Michel *et al*. (2002), on the impact of supine and upright birthing positions on magnetic resonance (MR) pelvimetric dimensions. MR pelvimetry was performed in 35 non-pregnant female volunteers in an open 0.5-T MR imaging system with patients in the supine, hand-to-knee, and squatting positions. The obstetric conjugate; sagittal outlet; and interspinous, intertuberous, and transverse diameters were compared among positions. With patients in the hand-to-knee and squatting positions, the sagittal outlet (11.8 ± 1.3 cm and 11.7 ± 1.3 cm) exceeded that in the supine position (11.5 ± 1.3 cm; $p = 0.002$ and $p = 0.01$, respectively), as did the interspinous diameter (11.6 ± 1.1 cm and 11.7 ± 1.0 cm vs 11.0 ± 0.7 cm; $p < 0.0001$, in both cases). Intertuberous diameter was wider with patients in the squatting position than in the supine position (12.7 ± 0.8 cm Vs. 12.4 ± 1.1 cm; $p = 0.01$). Only the obstetric conjugate was smaller with patients in the upright squatting position than in the supine position (12.3 ± 0.8 cm Vs. 12.4 ± 0.9 cm; $p = 0.01$). Transverse diameter did not change significantly in any position. An upright birthing position significantly expands female pelvic bony dimensions, suggesting facilitation of labor and delivery.

Crespo *et al*. (2015) carried out research that provides data regarding the morphology of the pelvic girdle from a living Spanish sample. The material used comprises radiographic images (CT scans) from 74 adult individuals (39 ♂ and 35 ♀) in DICOM format. The variables recorded were the bi-iliac width and the antero-posterior and transverse diameters of the three anatomical planes of the birth canal, with the exception of the transverse diameter of the outlet. Indices of the inlet and mid-plane were also calculated. Statistical analysis of the data (Student’s t-test and principal component analysis) revealed that the variables which display sexual differences are the transverse diameter of the inlet, the antero-posterior and transverse diameters of the mid-plane and the mid-plane index. In particular, Spanish women have significantly higher values in the transverse diameter of the inlet and the antero-posterior and transverse diameter of the mid-plane than men; and Spanish men have significantly higher values in the mid-plane index than women. The results of their study are in accordance with those obtained in previous studies based on dry bone, which suggest considerable population variability in pelvic and birth canal geometry. The CT-based study of living populations may significantly enhance their understanding of population variation of pelvic morphology. The information can be useful to better understand the birth mechanism in Homo sapiens and the appearance of rotate birth in the Homo lineage through comparison with the other primates, living or fossil.

Oladipo *et al.* (2014), carried out a study that was designed to determine and compare the pubic length, ischial length and ischio-pubic indices amongst Urhobos and Itsekiris. The parameters were measured from radiographs obtained from the Radiology department of Delta State University Teaching Hospital (DELSUTH), Oghara and Capitol Hill Clinic, Warri both in Delta State, Nigeria. Anteroposterior radiographs of 93 adult pelvis (age range, 18 years and above) were evaluated. 66 of the radiographs were those of Urhobos (36 males and 30 females), while 27 were those of Itsekiris (13 males and 14 females). The morphological measurements were the pubic length, ischial length and ischio-pubic index. The mean values for pubic length, ischial length and ischio-pubic index for Urhobo males were 78.51±12.4mm, 85.58±11.6mm and 91.66±5.86 respectively while those of their females were 92.39±7.08mm, 81.97±12.00mm and 114.93±18.14 respectively. The mean values for pubic length, ischial length and ischio-pubic index for Itsekiri males were 82.20±10.62mm, 83.84±10.82mm and 98.40±9.37 respectively while those of their females were 92.05±6.36mm, 85.03±14.59mm and 111.03±18.37 respectively. There were significant data for male and female pubic length and ischio-pubic indices both in Urhobos and Itsekiris. The demarking point of ischio-pubic index was more useful in sex determination assigning sex to 78.6% Itsekiri females ($p<0.05$). The accurate determination of sex and race are important tools to forensic scientists and physical and clinical anthropologists. Thus, the study is important as it has provided the necessary data for Nigerian population under investigation.

A research study for sexing the sacra and sub-pubic angle of indigenes of Cross River and Akwa Ibom States was carried out using radiographic films of adults aged 18 -80 years (Isaac *et al*., 2014). The parameters that were assessed and measured included the length and width of the sacrum, the sacral index, and the sub-pubic angle. The measuring instruments used were a protractor for the sub-pubic angle and a ruler for the sacrum. The sex differences of the sacral length marked a greater mean in males but were not statistically significant ($P>0.05$) as it ranged from 92-126mm in males and 80-119mm in females. The sacral breadth marked a mean slightly higher in females than in males with insignificant statistical differences ($P>0.05$). It ranged from 99-134mm in males and 92-138mm in females. The sacral Index which was calculated as Width (maximum breadth) x 100 divided by maximum length was higher in females than in males with a significant statistical difference ($P<0.05$) ranging from 94.9 to 118.2mm and 97.6-124.4mm in male and female respectively. The sex difference of the sub-pubic angle was found to be statistically significant in females when male and female x-ray films were compared ($P<0.05$) with a range of 80-144^{o} in males and 96-142^{o} in females. The sacral index and sub-pubic angle are therefore useful parameters in sexing of the pelvic bone since they were found to be significant by statistical analysis.

A study conducted by Esraa *et al.* (2014), on characterize the Sudanese pelvis using computed radiography and compare the finding with age and BMI. The study was performed on 44 cases in both sexes during the period from May 2014 up to August 2014 at Antalya, Al-Nelaen center and Ibn al Hytham hospital. The study found that the distant between iliac crests was ±3.8, anterior superior inferior spine was ± 3.9, brim length was ± 2.4, brim width was ±1.7, distant between acetabulum was ± 3.0 and pubic angle was ±19.7. The study also revealed a linear relation between age and

BMI. A significance different between the two genders were noticed computed radiography is a good method for characterizing the pelvic. Sudanese pelvis is differed from what was mentioned in previous study.

Karakas *et al*. (2013), carried out a research titled on “the subpubic angle in sex determination: Anthropometric measurements and analyses on Antolian Caucasians using multidetector computed tomography datasets”. The subpubic angle was identified and measured on three-dimensional computed tomographic images of pelves. Data were obtained using 64-multidetector computed tomography (MDCT) with an isotrophic resolution of 500 mm. The sample included 66 males (41.6±14.9 years of age) and 43 females (41.1±14.2 years of age). Measurements were taken on a dedicated three-dimensional image analysis workstation. The subpubic angle was electronically measured. The subpubic angle for the study group and for both sexes was reported as minimum-maximum (mean± SD). The result shows that Intra-class correlation for the subpubic angle (0.990), TEM (1082), rTEM (1.492), and R (0.990) represented almost complete reliability and accuracy of the measurement method. The subpubic angle was between 48˚ and 81˚ (65.9˚±7.2˚) in males and was between 64˚ and 100˚ (82.6˚±7.7˚) in females. Statistically significant difference was found between males and females regarding the subpubic angle ($p<0.0001$). The subpubic angle was not significantly correlated with age in males ($p=0.953$), or in females ($r=0.975$). The accuracy of the subpubic angle in sex determination was 90.8%. With a cut-off value of 74˚, sensitivity of subpubic angle to detect female phenotype was 88% and its specificity was 95%. The subpubic angle is an accurate parameter in sex determination with high sensitivity and specificity.

A retrospective study on the anteroposterior X-ray films of the pelvis of 40 male, and 31 female Nigerians was undertaken to verify if there was any significant difference in the values of the transverse diameter of the inlet (TID), bicristal diameter (BCD), bituberal diameter (BTD), and subpubic angle (SA) between the male and the female, between the younger age group (21-45 years) and the older age group (46-70 years) in each sex, using the student's t-test. Results showed that TID, BTD and SA each was significantly greater in the female than in the male ($P < 0.001$). BCD showed no significant difference between the sexes ($P > 0.05$). SA was significantly greater in the older age group than in the younger age group ($P < 0.05$) while the other variable showed no significant difference. The TID showed significant positive correlation with BCD, and BTD in the female ($P < 0.05$), and with BCD, BTD, and SA in the male ($P < 0.05$). The value of SA in female is obtuse but overlaps between acute and obtuse in males. Ninety-three per cent of the female pelvis had subpubic angle above the 111.3 degrees demarking point (DP) but none of the male or female pelvis was marked out by the lower or upper demarking points of BCD, suggesting a relevance of DP of SA in sex discrimination. The mean ratio of TID to BTD was 1.5:1 in the male and 1.2:1 in the female suggesting a gynaecoid tendency in the latter. The study provided data that can be useful for clinical and radiological pelvimetry for use in obstetrical care of Nigerians women, and normal values for Nigerian male and female (Nwoha, 1995).

2.5 GROSS ANATOMY OF THE BONY PELVIS

The pelvis is the part of the trunk that is infero-posterior to the abdomen, and is the area of transition between the trunk and the lower limbs. The pelvic cavity is the inferior most part of the abdomino-pelvic cavity. Anatomically, the pelvis is the part of the body surrounded by the pelvic girdle (bony pelvis), part of the appendicular skeleton of the lower limb. The pelvis is subdivided into greater and lesser pelves. The greater pelvis is surrounded by the superior pelvic girdle. The greater pelvis is occupied by inferior abdominal viscera, affording them protection similar to the way the superior abdominal viscera are protected by the inferior thoracic cage. The lesser pelvis is surrounded by the inferior pelvic girdle, which provides the skeletal framework for both the pelvic cavity and the perineum compartments of the trunk separated by the musculofascial pelvic diaphragm. Externally, the pelvis is covered or overlapped by the inferior anterolateral abdominal wall anteriorly, the gluteal region of the lower limb posterolaterally, and the perineum inferiorly. The term perineum refers both to the area of the surface of the trunk between the thighs and the buttocks, extending from the coccyx to the pubis, and to the shallow compartment lying deep (superior) to this area but inferior to the pelvic diaphragm. The perineum includes the anus and external genitalia: the penis and scrotum of the male and the vulva of the female (Moore *et al*., 2014).

The pelvic girdle is a basin-shaped ring of bones that connects the vertebral column to the two femurs. The primary functions of the pelvic girdle are to bear the weight of the upper body when sitting and standing. Transfer weight from the axial to the lower appendicular skeleton for standing and walking. Provide attachment for the powerful muscles of locomotion and posture and those of the abdominal wall, withstanding the forces generated by their actions. Consequently, the pelvic girdle is strong and rigid, especially compared to the pectoral (shoulder) girdle. Other functions of the pelvic girdle are contain and protect the pelvic viscera (inferior parts of the urinary tracts and the internal reproductive organs) and the inferior abdominal viscera (intestines), while permitting passage of their terminal parts (and, in females, a full-term fetus) via the perineum. Provide support for the abdomino-pelvic viscera and gravid (pregnant) uterus. Provide attachment for the erectile bodies of the external genitalia. Provide attachment for the muscles and membranes that assist the functions listed above by forming the pelvic floor and filling gaps that exist in or around it (Moore *et al*., 2014). In mature individuals, the pelvic girdle is formed by three bones Right and left hip bones (coxal or pelvic bones): large, irregularly shaped bones, each of which develops from the fusion of three bones, the ilium, ischium, and pubis. Sacrum is formed by the fusion of five, originally separate, sacral vertebrae but in infants and children, the hip bones consist of three separate bones that are united by a triradiate cartilage at the acetabulum, the cup-like depression in the lateral surface of the hip bone, which articulates with the head of the femur. After puberty, the ilium, ischium, and pubis fuse to form the hip bone. The two hip bones are joined anteriorly at the pubic symphysis, a secondary cartilaginous joint. The hip bones articulate posteriorly with the sacrum at the sacro-iliac joints to form the pelvic girdle (Moore *et al*., 2014).

The ilium is the superior, fan-shaped part of the hip bone. The ala (wing) of the ilium represents the spread of the fan, and the body of the ilium, the handle of the fan. On its external aspect, the body participates in formation of the acetabulum. The iliac crest, the rim of the fan, has a curve that follows the contour of the ala between the anterior and posterior superior iliac spines. The anteromedial concave surface of the ala forms the iliac fossa. Posteriorly, the sacropelvic surface of the ilium features an auricular surface and an iliac tuberosity, for synovial and syndesmotic articulation with the sacrum, respectively (Moore *et al*., 2014).

The ischium has a body and ramus. The body of the ischium helps form the acetabulum and the ramus of the ischium forms part of the obturator foramen. The large postero-inferior protuberance of the ischium is the ischial tuberosity. The small pointed posteromedial projection near the junction of the ramus and body is the ischial spine. The concavity between the ischial spine and the ischial tuberosity is the lesser sciatic notch. The larger concavity, the greater sciatic notch, is superior to the ischial spine and is formed in part by the ilium (Moore *et al*., 2014).

The pubis is an angulated bone with a superior ramus, which helps form the acetabulum, and an inferior ramus, which helps form the obturator foramen. A thickening on the anterior part of the body of the pubis is the pubic crest, which ends laterally as a prominent swelling, the pubic tubercle. The lateral part of the superior pubic ramus has an oblique ridge, the pecten pubis (pectineal line of pubis) (Moore *et al*., 2014).

The pelvis is divided into greater (false) and lesser (true) pelves by the oblique plane of the pelvic inlet (superiorpelvic aperture). The bony edge (rim) surrounding and defining the pelvic inlet is the pelvic brim, formed by the: Promontory and ala of the sacrum (superior surface of its lateral part, adjacent to the body of the sacrum). A right and left linea terminalis (terminal line) together form a continuous oblique ridge consisting of the Arcuate line on the inner surface of the ilium. Pecten pubis (pectineal line) and pubic crest form the superior border of the superior ramus and body of the pubis (Moore *et al*., 2014).

The pubic arch is formed by the ischiopubic rami (conjoined inferior rami of the pubis and ischium) of the two sides. These rami meet at the pubic symphysis, their inferior borders defi ning the subpubic angle. The width of the subpubic angle is determined by the distance between the right and the left ischial tuberosities, which can be measured with the gloved fingers in the vagina during a pelvic examination. The pelvic outlet (inferior pelvic aperture) is bounded by the Pubic arch anteriorly, Ischial tuberosities laterally, Inferior margin of the sacrotuberous ligament (running between the coccyx and the ischial tuberosity) posterolaterally, Tip of the coccyx posteriorly. The greater pelvis (false pelvis) is the part of the pelvis, Superior to the pelvic inlet, Bounded by the iliac alae posterolaterally and the anterosuperior aspect of the S1 vertebra posteriorly, Occupied by abdominal viscera (e.g., the ileum and sigmoid colon). The lesser pelvis (true pelvis) is the part of the pelvis between the pelvic inlet and the pelvic outlet, bounded by the pelvic surfaces of the hip bones, sacrum, and coccyx and that includes the true pelvic cavity and the deep parts of the perineum (perineal compartment), specifically the ischio-anal fossae that is of major obstetrical and gynecological significance. The concave superior surface of the musculofascial pelvic diaphragm forms the floor of the true pelvic cavity, which is thus deepest centrally. The convex inferior surface of the pelvic diaphragm forms the roof of the perineum, which is therefore shallow centrally and deep peripherally. Its lateral parts (ischio-anal fossae) extending well up into the lesser pelvis. The terms pelvis, lesser pelvis, and pelvic cavity are commonly used incorrectly, as if they were synonymous terms (Moore *et al*., 2014).

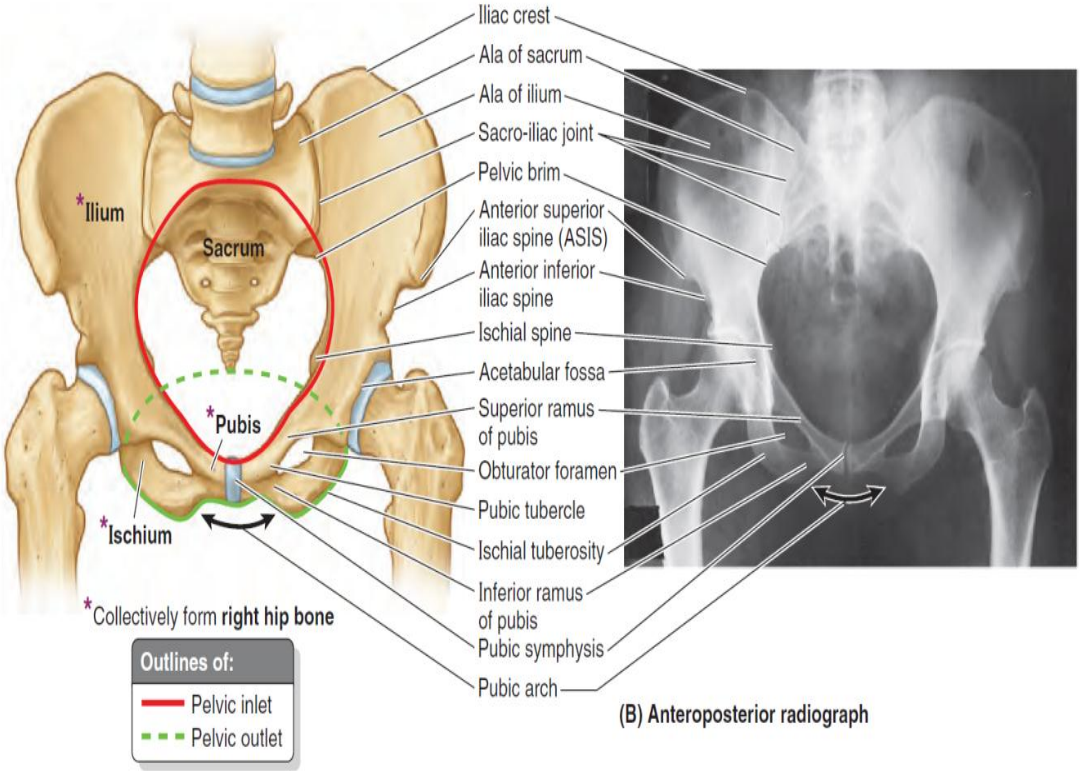

Plate I: Features of the Pelvic Girdle: Anatomical Drawing versus Radiographical Appearances (Source: Moore *et al.*, 2014).

The joints of the pelvis are the sacroiliac and sacrococcygeal joints and the pubic symphysis, while the chief ligaments of the pelvis (vertebropelvic ligaments) are the sacrotuberous, sacrospinous and iliolumbar. The sacroiliac joint is a synovial joint between the auricular surfaces of the ilium and sacrum. The articulating surfaces are jagged and there is very little movement. With increasing age fibrous adhesions and gradual obliteration of the joint cavity occur; earlier in males, after the menopause in females. The capsule is attached to the articular margins. Ligamentous bands surround the capsule. The anterior sacroiliac ligament is a flat band which joins the bones above and below the pelvic brim stronger in the female, it indents a preauricular groove on the female ilium just below the pelvic brim. A mass of ligaments attaches the sacrum to the ilium behind the joint. Most of them constitute the very strong interosseous sacroiliac ligament, whose fibres are attached to deep pits on the posterior surface of the lateral mass of the sacrum. The most superficial fibres form the posterior sacroiliac ligament. The posterior rami of the spinal nerves and vessels pass between the interosseous and posterior ligaments. The stability of the sacroiliac articulation depends entirely upon ligaments. Body weight transmitted through L5 vertebra tends to push the sacrum downwards and forwards towards the symphysis. Opposing any gliding movement of the joint surfaces are the interosseous sacroiliac ligament and the iliolumbar ligament, while opposing forward rotation of the sacral promontory are the sacrotuberous and sacrospinous ligaments. The sacroiliac ligaments soften towards the later months of pregnancy and permit some slight rotation of the sacrum during parturition (Sinnatamby, 2011).

The sacrococcygeal joint is a symphysis between the apex of the sacrum and the base of the coccyx, with an intervening disc of fibrocartilage. A short anterior sacrococcygeal ligament unites the bones at the front. Behind, there are two posterior sacrococcygeal ligaments is a short deep one uniting the adjacent bones and a superficial which closes over the sacral hiatus at the lower end of the sacral canal. At each side there is a lateral sacrococcygeal ligament running from the transverse process of the coccyx to the inferolateral angle of the sacrum, completing a foramen for the anterior ramus of the fifth sacral nerve. This ligament may become ossified. Slight flexion and extension are possible at this joint (Sinnatamby, 2011).

The pubic symphysis as its name implies, is a secondary cartilaginous joint. The body surfaces of the pubes are each covered with a thin plate of hyaline cartilage and the two sides are connected by fibrocartilage forming an interpubic disc. Centrally a tissue-fluid space may develop, but it is never lined with synovial membrane. Ligamentous fibres forming the superior pubic ligament reinforce the symphysis above, and below it is strengthened by the arcuate pubic ligament. No perceptible movement occurs at the symphysis; some separation of the pubes may occur during parturition.

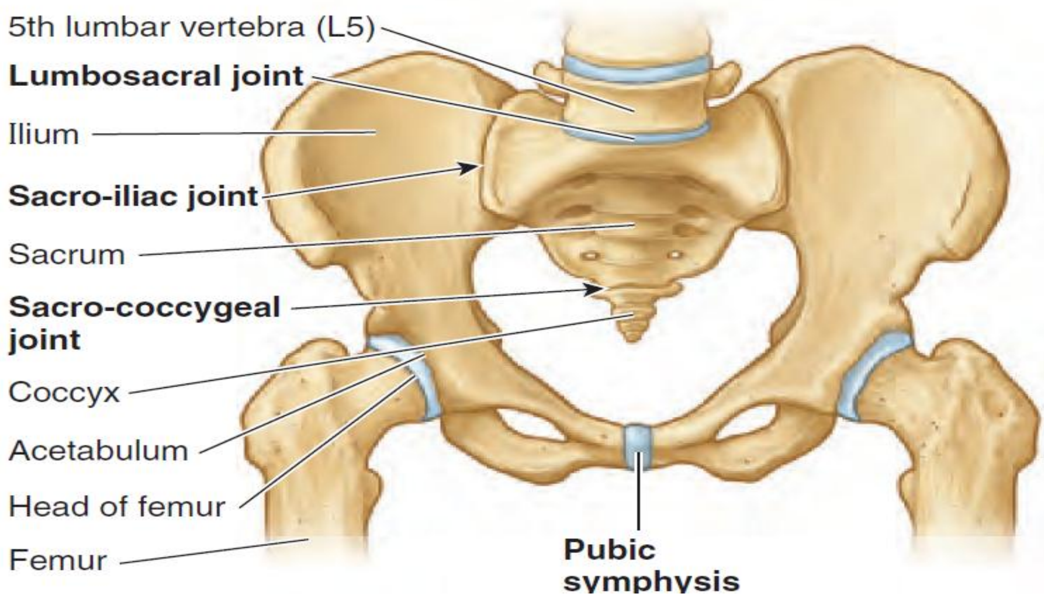

Plate II: The Anterior View of the Bony Pelvis Showing the Joints
(Source: Moore *et al.,* 2014).

The sacrotuberous ligament is a flat band of great strength. It is blended with the posterior sacroiliac ligament and is attached to the posterior border of the ilium and the posterior superior and posterior inferior iliac spines, to the transverse tubercles of the sacrum below the auricular surface, and to the upper part of the coccyx. From this wide area the ligament slopes down to the medial surface of the ischial tuberosity. The lower edge of the ischial attachment is prolonged forwards and attached to a curved ridge of bone. This prolongation is the falciform process; it lies just below the pudendal canal. The sacrotuberous ligament is narrower in the middle than at either end. Its gluteal surface gives origin to gluteus maximus. The ligament is said to be the phylogenetically degenerated tendon of origin of the long head of biceps femoris. It is pierced by the perforating cutaneous nerve and branches of the inferior gluteal vessels and coccygeal nerves (Sinnatamby, 2011).

The sacrospinous ligament lies on the pelvic aspect of the sacrotuberous ligament. It has a broad base which is attached to the side of the lower part of the sacrum and the upper part of the coccyx. It narrows as it passes laterally, where its apex is attached to the spine of the ischium. The coccygeus muscle lies on the pelvic surface of the ligament. The ligament is the phylogenetically degenerated posterior surface of the coccygeus muscle. The sacrotuberous and sacrospinous ligaments, with the lesser sciatic notch of the ischium, enclose the lesser sciatic foramen, whose lateral part is occupied by the emerging obturator internus muscle and whose medial part leads forwards into the pudendal canal above the falciform process of the sacrotuberous ligament (Sinnatamby, 2011).

The iliolumbar ligament is shaped like a “V” lying sideways, the apex of the V being attached to the transverse process of L5 vertebra, from which upper and lower bands fan outwards. The upper band passes to the iliac crest, giving partial origin to quadratus lumborum and becoming continuous with the anterior layer of the lumbar fascia. The lower band runs laterally and downwards to blend with the front of the anterior sacroiliac ligament (Sinnatamby, 2011).

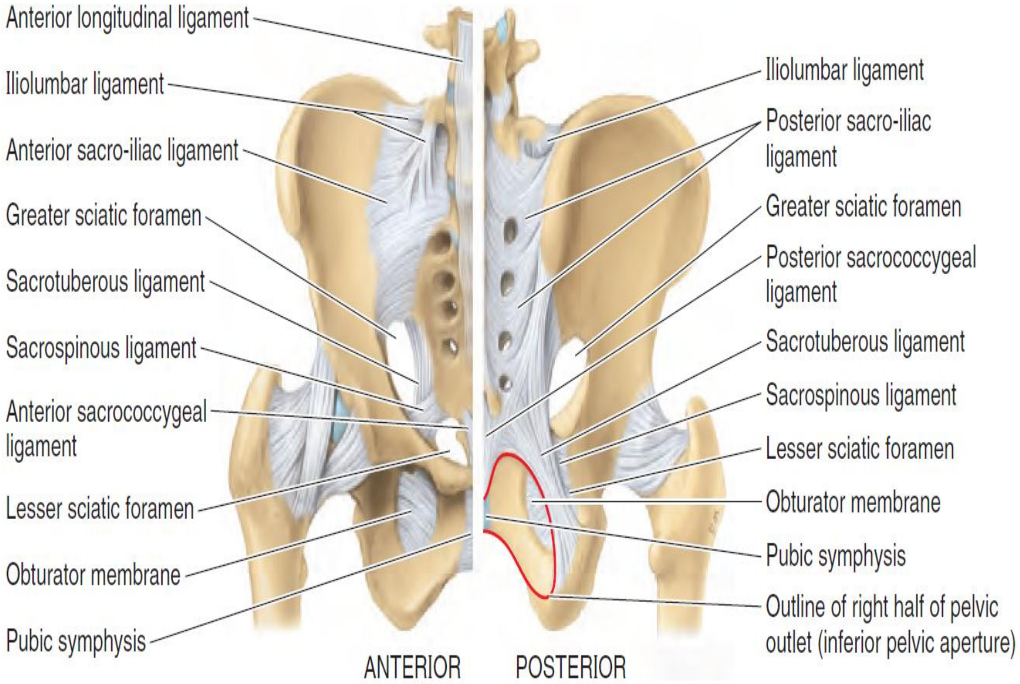

Plate III: Ligaments of Pelvic Girdle (Source: Moore *et al.*, 2014).

The funnel-shaped pelvic cavity—the space bounded peripherally by the bony, ligamentous, muscular pelvic walls and floor which is the inferoposterior part of the abdominopelvic cavity. The pelvic cavity is continuous with the abdominal cavity at the pelvic inlet but angulated posteriorly from it. Although continuous, the abdominal and pelvic cavities are described separately for descriptive purposes, facilitating the regional approach. The pelvic cavity contains the terminal parts of the ureters, the urinary bladder, rectum, pelvic genital organs, blood vessels, lymphatics, and nerves. In addition to these distinctly pelvic viscera, it also contains what might be considered an overflow of abdominal viscera: loops of small intestine (mainly ileum) and, frequently, large intestine (appendix and transverse and/or sigmoid colon). The pelvic cavity is limited inferiorly by the musculofascial pelvic diaphragm, which is suspended above (but descends centrally to the level of) the pelvic outlet, forming a bowl-like pelvic floor. The pelvic cavity is bounded posteriorly by the coccyx and inferior most sacrum, with the superior part of the sacrum forming a roof over the posterior half of the cavity. The bodies of the pubic bones, and the pubic symphysis uniting them, form an antero-inferior wall that is much shallower (shorter) than the posterosuperior wall and ceiling formed by sacrum and coccyx. Consequently, the axis of the pelvis (a line in the median plane defined by the center point of the pelvic cavity at every level) is curved, pivoting around the pubic symphysis. The curving form of the axis and the disparity in depth between the anterior and posterior walls of the cavity are important factors in the mechanism of fetal passage through the pelvic canal (Moore *et al.*, 2014).

Modern humans are to a large extent characterized by bipedal locomotion and large brains. Because the pelvis is vital to both locomotion and childbirth, natural selection has been confronted by two conflicting demands: a wide birth canal and locomotion efficiency, a conflict referred to as the "obstetrical dilemma". The female pelvis, or gynecoid pelvis, has evolved to its maximum width for childbirth — a wider pelvis would make women unable to walk. In contrast, human male pelvises are not constrained by the need to give birth and therefore are more optimized for bipedal locomotion (Merry, 2005; Schuenke *et al*., 2006).

There are four types of pelvic and which are: Gynaecoid, Anthropoid, Android and Platypelloid.

- The gynecoid is the most suitable female pelvic shape. This allows normal child birth with ease. It has round pelvic inlet and shallow pelvic cavity with short ischial spines. All these feature allow rapid birth of the baby. So Gynaecoid Pelvis is the most suitable pelvic shape for childbirth.
- Anthropoid pelvis has oval shaped inlet with large anterio-posterior diameter and comparatively smaller transverse diameter. It has larger outlet. The problem in this pelvis is the inlet. The diameter of inlet favors the engagement of fetal head in occiput-posterior position that may slow down the progress of labor. If head engages in anterior position then labor progress normally in most of the cases.
- Android shaped pelvis has triangular or heart-shaped inlet and is narrower from the front. It has prominent ischial spines and also has narrower transverse outlet diameter. African-Caribbean women are more at risk of having an android shaped pelvis. Child birth is difficult and more complicated in android shaped pelvis than gynaecoid pelvis. Women have to push harder, walk more often and chances of instrumental vaginal delivery are high. It may prolong the labor.

- Platypelloid pelvis is has narrow antero-posterior diameter of pelvic inlet. The pelvic inlet is specifically kidney shaped. The pelvic cavity is usually shallow and diameters of outlet are favorable for the process of labor. But platypelloid pelvis doesn't allow the head to engage with ease. But if the head manage to engage then rest of the process of labor may occur normally but in most of the cases it is longer as compared to progress of labor in case of gynaecoid pelvis (Merry, 2005).

2.6 EMBRYOLOGY OF THE PELVIS

Formation of the vertebral column from the 44 mesodermal somatomeres occurs in conjunction with primary neurulation down to the 30th somite, which correspond to the S1-2 junction (Estin & Cohen, 1995). The S-2 segment down to the coccyx is derived from somites 31 to 44 and arises from the caudal eminence (tail bud) during secondary neurulation and the retrogressive differentiation that follows. Initially in the newborn, the five sacral vertebrae resemble their lumbar counterparts until ossification of the sacral ala begins late in the 1st year of life (Esses *et al*., 1991). Each sacral vertebra has five ossification centers: a primary center, one in each epiphysial plate, and two for the two vertebral arches. The lateral parts of the sacrum form from 10 additional ossification centers. The initial six sites derive symmetrically from the first three vertebrae, which represent the costal elements. An additional four sites are derived from the two epiphysial plates on each lateral surface, along with one for the auricular surface and another for the remaining thin lateral edge of the bone. Fusion of the sacral vertebra starts at puberty, beginning with the costal elements. The VBs begin fusing when the individual reaches 18 years of age; this continues during the next two decades in a caudal to cranial fashion. Complete fusion of the sacrum has been reported to occur between Years 25 and 33 of life and is related to the loadbearing aspects of this region (Agur, 1999; Esses & Botsford, 1997). In support of the Woolf law regarding bone remodeling, children with paraplegia or those who do not bear weight across the sacral region do not form the singular osseous sacral mass from fusion of the independent vertebrae.

The hip bone is ossified from eight centers: three primary, one each for the ilium, ischium, and pubis; and five secondary, one each for the crest of the ilium, the anterior inferior spine (said to occur more frequently in the male than in the female), the tuberosity of the ischium, the pubic symphysis (more frequent in the female than in the male), and one or more for the Y-shaped piece at the bottom of the acetabulum. The centers appear in the following order: in the lower part of the ilium, immediately above the greater sciatic notch, about the eighth or ninth week of fetal life; in the superior ramus of the ischium, about the third month; in the superior ramus of the pubis, between the fourth and fifth months. At birth, the three primary centers are quite separate, the crest, the bottom of the acetabulum, the ischial tuberosity, and the inferior rami of the ischium and pubis being still cartilaginous. By the seventh or eighth year, the inferior rami of the pubis and ischium are almost completely united by bone. About the thirteenth or fourteenth year, the three primary centers have extended their growth into the bottom of the acetabulum, and are there separated from each other by a Y-shaped portion of cartilage, which now presents traces of ossification, often by two or more centers. One of these, the os acetabuli, appears about the age of twelve, between the ilium and pubis, and fuses with them about the age of eighteen; it forms the pubic part of the acetabulum. The ilium and ischium then become joined, and lastly the pubis and ischium, through the intervention of this Y-shaped portion. At about the age of puberty, ossification takes place in each of the remaining portions, and they join with the rest of the bone between the twentieth and twenty-fifth years. Separate centers are frequently found for the pubic tubercle and the ischial spine, and for the crest and angle of the pubis (Gray, 1918).

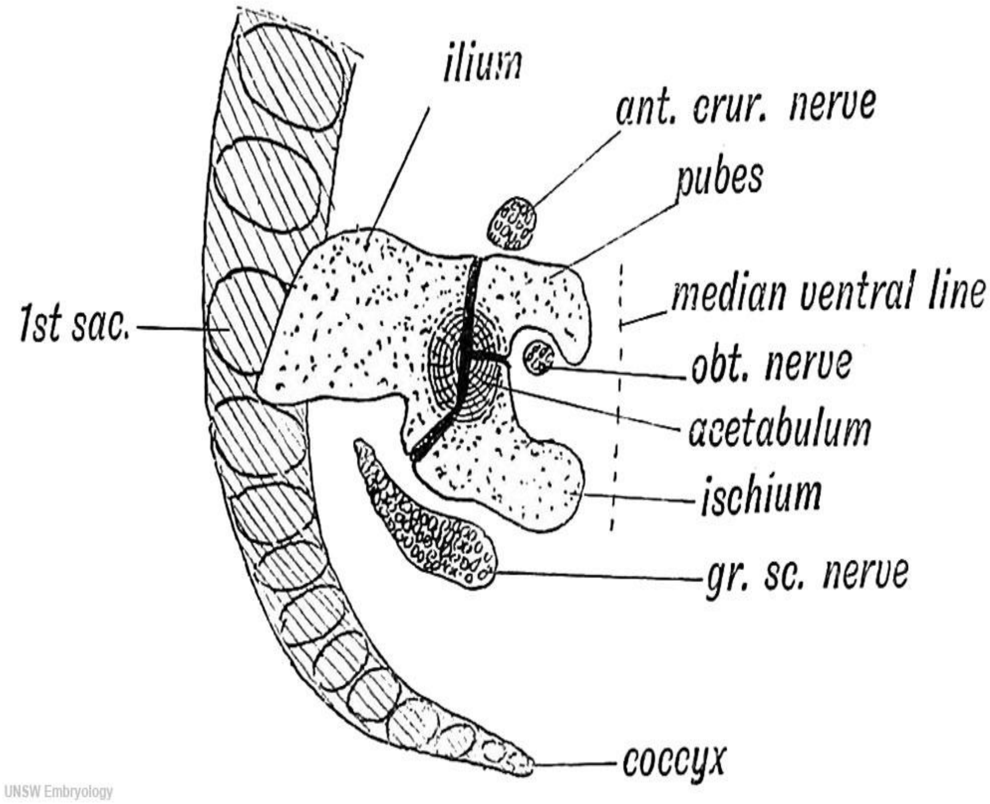

Plate IV: Pelvic Girdle of a Human Foetus at the Fifth Week of Development (Source: Keith, 1918).

2.7 BLOOD SUPPLY OF THE PELVIS

The common iliac arteries are branches of the abdominal aorta. The left common iliac artery is shorter than the contralateral vessel owing to the fact that the abdominal aorta is displaced to the left by the inferior vena cava. The longer right common iliac artery travels in an inferolateral direction anterior to the fourth and fifth lumbar vertebrae, the junction of the common iliac vein and inferior vena cava, as well as the ipsilateral sympathetic trunk, iliolumbar artery and lumbosacral trunk. The right common iliac vein and the right psoas major muscle lie superior and inferior (respectively) to the artery. The left common iliac vein forms the medial boundary of the right common iliac artery, while the inferior vena cava forms its lateral boundary (Standring, 2008).

The common iliac arteries bifurcate at the sacroiliac joint to give off an internal and a larger external iliac artery. The external iliac artery is the main blood supply to the lower limb, while the internal iliac artery perfuses the pelvic viscera, perineal and gluteal regions. The common iliac arteries may also give off vasa nervorum (small arteries that supply nerves), branches to the ureter, as well as direct branches to the peritoneum (Standring, 2008).

The external iliac artery becomes the femoral artery (at the mid inguinal point), it gives off two branches that support the contents of the pelvis. These are the inferior epigastric artery and the deep circumflex iliac artery. The inferior epigastric artery is an artery of the anterior abdominal wall that leaves the external iliac artery opposite to the origin of the deep circumflex iliac artery. It takes a superomedial course adjacent to the medial wall of the deep inguinal ring before continuing through the substance of rectus abdominis, where it anastomoses with the superior epigastric artery. The deep circumflex iliac artery emerges from the lateral surface of the external iliac artery and takes a superolateral course towards the anterior superior iliac spine. It forms several anastomoses directly with the lateral circumflex femoral, superior gluteal and iliolumbar arteries, and indirectly with the inferior epigastric and lumbar arteries (Standring, 2008).

The smaller branch of the common iliac artery is the internal iliac artery. It commences anterior to the lumbosacral and sacroiliac joints. At the roof of the greater sciatic foramen, the internal iliac artery divides to give off an anterior and a posterior trunk. The posterior trunk courses through the greater sciatic foramen to enter the gluteal region, while the anterior trunk continues in line with its parent branch (Standring, 2008). The anterior trunk of the internal iliac artery has several branches supplying the pelvic viscera. These include the superior vesical, inferior vesical, middle rectal, vaginal (in females), obturator, uterine, internal pudendal and inferior gluteal arteries.

The superior vesical artery is a large vessel that takes an anteroinferior course, caudal to the pelvic brim along the lateral wall of the pelvis. In males, it perfuses the proximal vas deferens and seminal vesicles; and in both genders, it brings arterial blood to the distal ureter and bladder. The inferior vesical and middle rectal arteries may share origins as they branch from the anterior internal iliac artery. The inferior vesical artery supplies the bladder, and in males it also supplies the prostate, vasa deferentia, and seminal vesicles. In females, the artery may be replaced by the vaginal artery, which otherwise would arise from the uterine artery (a large artery running inferomedial to the uterine broad ligament). There may be multiple branches of the middle rectal artery. It courses the lateral border of the mesentery of the rectum (mesorectum). The obturator artery is limited superiorly by its eponymous nerve and inferiorly by its vein. It is posterior to the ureter and vas deferens (in males). It gives off an iliac branch to the iliac fossa (supplying the bone and associated muscle), a vesical branch to the bladder and a pubic branch that forms an anastomosis with the pubic branch of the inferior epigastric artery and the contralateral pubic artery. The internal pudendal artery arises caudal to the origin of the obturator artery and travels inferolaterally towards the lower margin of the greater sciatic foramen. It enters the perineum – after leaving between ischiococcygeus and piriformis – via the lesser sciatic foramen. It gives off branches to the muscles and nerves in the pelvic and gluteal regions. Finally, the inferior gluteal artery provides arterial supply to piriformis, iliococcygeus and ischiococcygeus muscles. It may also support the middle rectal arterial network. This artery is a large terminal vessel that takes a posteroinferior route between piriformis and the sacral plexus, posterior to the internal pudendal artery. It enters the gluteal region after passing through the greater sciatic foramen, where it runs beneath gluteus maximus. The posterior trunk of the internal iliac artery gives off the superior gluteal, lateral sacral and iliolumbar arteries (Standring, 2008).

The largest branch of the internal iliac artery is the superior gluteal artery. It travels postero-inferiorly between the sacral rami before leaving the pelvis via the greater sciatic foramen, cranial to the piriformis muscle. It then bifurcates to give off a superficial branch, which supplies gluteus maximus and sacral skin as well as a deep branch, which supplies gluteus medius and gluteus minimus. The lateral sacral arteries may emerge from the posterior trunk either as a paired artery or as a single branch. If the vessel arises as a single branch, it subsequently divides to give off an inferior and a superior branch. The anterior sacral foramina provide conduits for the superior vessels to enter the sacral canal and supply the canal and its contents. They subsequently leave the canal via the dorsal sacral foramina to supply the musculature and skin of the dorsal sacrum. The inferior branches anastomose with the median sacral artery and its contralateral counterpart on the ventral surface of the coccyx. The subsequent branches utilize the same route as the superior lateral sacral artery to gain access to the sacral canal and the dorsal sacrum. Thirdly, the iliolumbar artery is the first to emerge from the posterior trunk of the internal iliac artery. It travels superolateral toward the sacroiliac joint behind the obturator nerve on its way toward the medial aspect of psoas major. Here it divides into an iliac and a lumbar branch. The iliac branch brings arterial supply to iliacus muscle before anastomosing with the iliac branches of the obturator artery (Standring, 2008).

2.8 VENOUS DRAINAGE OF THE PELVIS

The pelvic venous system is responsible for taking blood from the pelvic walls and viscera back to the main circulation. Like the arterial analogues, the external iliac vein primarily drains the lower limbs, while the internal iliac vein drains the pelvic viscera, walls, gluteal region and perineum. In most instances, the major veins are mirror images of their arterial counterparts. However, the smaller vessels can vary from one individual to another. The lymphatic system, however, is relatively simple and follows the major vessels of the pelvis (Standring, 2008).

The inferior epigastric, deep circumflex iliac and pubic veins are all pelvic tributaries of the external iliac vein. The external iliac vein is a cranial continuation of the femoral vein. The nomenclature of the vessel changes at the mid inguinal point, posterior to the inguinal ligament. The deep circumflex iliac vein is a product of the venae comitantes of the eponymous artery. It crosses the anterior surface of the external iliac artery before entering the external iliac vein. Inferior to the entry point of the deep circumflex iliac vein, the inferior epigastric vein enters the external iliac vein cranial to the inguinal ligament. The pubic vein forms a bridge between the obturator vein and the external iliac vein. On the left hand side, the external iliac vein is always medial to its corresponding artery. However, on the right, it starts out in a medial position and gradually becomes posterior as it gets closer to the point of fusion (Standring, 2008).

The internal iliac vein receives the middle rectal, obturator, lateral sacral, inferior gluteal and superior gluteal veins as tributaries. The obturator vein enters the pelvis by way of the obturator foramen, where it takes a posterosuperior route along the lateral pelvic wall, deep to its artery. In some instances, the vessel is replaced by an enlarged pubic vein, which then terminates in the external iliac vein. The superior and inferior gluteal veins are venae comitantes of their corresponding arteries. The tributaries of the superior gluteal veins are named after the branches of the corresponding artery. They pass above piriformis and enter the pelvis via the greater sciatic foramen before terminating in the internal iliac vein as a single branch. The inferior gluteal veins form anastomoses with the first perforating vein and medial circumflex femoral vein before entering the pelvis via the greater sciatic foramen. The middle rectal vein is a product of the rectal venous plexus that drains the mesorectum and the rectum. It also receives tributaries from the bladder, as well as gender specific tributaries from the prostate and seminal vesicle or the posterior wall of the vagina. It terminates in the internal iliac vein after travelling along the pelvic part of levator ani. Finally, the lateral sacral veins travel with their arteries before entering the internal iliac vein (Standring, 2008). The internal and external iliac veins unite at the sacroiliac joint, on the right hand side of the fifth lumbar vertebra, to form the common iliac vein. The right common iliac vein is almost vertical and shorter than the left common iliac vein, which takes a more oblique course. The right obturator nerve crosses the right common iliac vein posteriorly, while the sigmoid mesocolon and superior rectal vessels cross the left common iliac vein anteriorly. The internal pudendal vein drains to the internal iliac vein, while the median sacral veins drain into the common iliac vessels directly. The median sacral veins unite into a single vessel before entering the left common iliac vein. The internal pudendal veins (venae comitantes of their corresponding artery) receive inferior rectal veins and either clitoral and labial or penile bulb and scrotal veins before joining the common iliac vein (Standring, 2008).

2.9 LYMPHATIC DRAINAGE OF THE PELVIS

The pelvic lymph nodes are named after the vessels they aggregate around. The three general groups that drain the pelvis and its contents are the internal, external and common iliac nodes. The internal iliac nodes drain the majority of the contents of the pelvic viscera, with the exception of the gonads and most of the rectum. They are arranged around the branches of the internal iliac vessels and also drain the deep perineum, gluteal region and muscles of the posterior thigh. The external iliac nodes are arranged into medial, anterior and lateral clusters. The major drainage channel is via the medial subgroup of nodes. It receives lymph from the inguinal nodes (and by extension, the lower limb), adductor regions, fundus of the bladder and membranous urethra. It also drains the clitoris or glans penis, membranous urethra, upper vagina and uterine cervix and prostate. Both the internal and external iliac nodes drain to the common iliac nodes. These are also subdivided into anterior, medial and lateral groups (Standring, 2008).

2.10 NERVES SUPPLY OF THE PELVIS

The lumbosacral trunk (L4, L5, S1, S2 and S3), sacral plexus and coccygeal plexus all pass through the pelvic cavity. Fibers of the pelvic splanchnic (parasympathetic), sacral splanchnic (sympathetic) and the inferior hypogastric plexuses also have fibers supplying the viscera of the pelvis. The left and right paravertebral sympathetic ganglion chains terminate in the pelvis, by fusing anterior to the pelvic surface of the coccyx to form the ganglion impar. The sacral ventral rami provide visceral and muscular innervation to the contents of the pelvis. More specifically, the second to fourth ventral rami innervate the viscera, while the fourth ventral ramus and its branches supplies levator ani, ischiococcygeus, iliococcygeus, the external anal sphincter and the skin between the coccyx and anus (Standring, 2008).

2.11 APPLIED ANATOMY OF THE BONY PELVIS

The size of the lesser pelvis is particularly important in obstetrics because it is the bony canal through which the fetus passes during normal child birth. To determine the capacity of the female pelvis for childbearing, the diameters of the lesser pelvis are noted radiographically or manually during a pelvic examination. The minimum anteroposterior (AP) diameter of the lesser pelvis, the true (obstetrical) conjugate from the middle of the sacral promontory to the posterosuperior margin (closest point) of the pubic symphysis, is the narrowest fixed distance through which the baby’s head must pass in a vaginal delivery. This distance, however, cannot be measured directly during a pelvic examination because of the presence of the bladder. Consequently, the diagonal conjugate is measured by palpating the sacral promontory with the tip of the middle finger, using the other hand to mark the level of the inferior margin of the pubic symphysis on the examining hand. After the examining hand is withdrawn, the distance between the tip of the index finger (1.5 cm shorter than the middle finger) and the marked level of the pubic symphysis is measured to estimate the true conjugate, which should be 11.0 cm or greater. In all pelvic girdles, the ischial spines extend toward each other, and the interspinous distance between them is normally the narrowest part of the (the passageway through the pelvic inlet, lesser pelvis, and pelvic outlet) through which a baby's head must pass at birth, but it is not a fixed distance. During a pelvic examination, if the ischial tuberosities are far enough apart to permit three fingers to enter the vagina side by side, the subpubic angle is considered sufficiently wide to permit passage of an average fetal head at full term (Moore *et al.,* 2014).

Anteroposterior compression of the pelvis occurs during crush accidents (as when a heavy object falls on the pelvis). This type of trauma commonly produces fractures of the pubic rami. When the pelvis is compressed laterally, the acetabula and ilia are squeezed toward each other and may be broken. Fractures of the bony pelvic ring are almost always multiple fractures or a fracture combined with a joint dislocation. To illustrate this, try breaking a pretzel ring at just one point. Some pelvic fractures result from the tearing away of bone by the strong ligaments associated with the sacro-iliac joints. Pelvic fractures can result from direct trauma to the pelvic bones, such as occurs during an automobile accident, or be caused by forces transmitted to these bones from the lower limbs during falls on the feet. Weak areas of the pelvis, where fractures often occur, are the pubic rami, the acetabula (or the area immediately surrounding them), the region of the sacro-iliac joints, and the alae of the ilium. Pelvic fractures may cause injury to pelvic soft tissues, blood vessels, nerves, and organs. Fractures in the puboobturator area are relatively common and are often complicated because of their relationship to the urinary bladder and urethra, which may be ruptured or torn. Falls on the feet or buttocks from a high ladder may drive the head of the femur through the acetabulum into the pelvic cavity, injuring pelvic viscera, nerves, and vessels. In individuals younger than 17 years of age, the acetabulum may fracture through the triradiate cartilage into its three developmental parts or the bony acetabular margins may be torn away (Moore *et al*., 2014).

The larger cavity of the inter-pubic disc in females increases in size during pregnancy. This change increases the circumference of the lesser pelvis and contributes to increased flexibility of the pubic symphysis. Increased levels of sex hormones and the presence of the hormone relaxin cause the pelvic ligaments to relax during the latter half of pregnancy, allowing increased movement at the pelvic joints. Relaxation of the sacro-iliac joints and pubic symphysis permits as much as a 10–15% increase in diameters (mostly transverse, including the interspinous distance), facilitating passage of the fetus through the pelvic canal. The coccyx is also able to move posteriorly. The one diameter that remains unaffected is the true (obstetrical) diameter between the sacral promontory and the posterosuperior aspect of the pubic symphysis. Relaxation of sacro-iliac ligaments causes the interlocking mechanism of the sacro-iliac joint to become less effective, permitting greater rotation of the pelvis and contributing to the lordotic (“swayback”) posture often assumed during pregnancy with the change in the center of gravity. Relaxation of ligaments is not limited to the pelvis and the possibility of joint dislocation increases during late pregnancy (Moore *et al.*, 2014).

Spondylolysis is a defect allowing part of a vertebral arch (the posterior projection from the vertebral body that surrounds the spinal canal and bears the articular, transverse, and spinal processes) to be separated from its body. Spondylolysis of vertebra L5 results in the separation of the vertebral body from the part of its vertebral arch bearing the inferior articular processes. The inferior articular processes of L5 normally interlock with the articular processes of the sacrum. When the defect is bilateral, the body of the L5 vertebrae may slide anteriorly on the sacrum (spondylolisthesis) so that it overlaps the sacral promontory. The intrusion of the L5 body into the pelvic inlet reduces the AP diameter of the pelvic inlet, which may interfere with parturition (child-birth). It may also compress spinal nerves, causing low back or lower limb pain. Obstetricians test for spondylolisthesis by running their fingers along the lumbar spinous processes. An abnormally prominent L5 process indicates that the anterior part of L5 vertebra and the vertebral column superior to it may have moved anteriorly relative to the sacrum and the vertebral arch of L5. Medical images, such as sagittal magnetic resonance imaging (MRI), are taken to confirm the diagnosis and to measure the AP diameter of the pelvic inlet (Moore *et al.,* 2014).

During childbirth, the pelvic floor supports the fetal head while the cervix of the uterus is dilating to permit delivery of the fetus. The perineum, levator ani, and ligaments of the pelvic fascia may be injured during child birth. The pubococcygeus and puborectalis, the main and most medial parts of the levator ani, are the muscles torn most often. These parts of the muscle are important because they encircle and support the urethra, vagina, and anal canal. Weakening of the levator ani and pelvic fascia (e.g., tearing of the paracolpium) from stretching or tearing during childbirth, may decrease support for the vagina, bladder, uterus, or rectum, or alter the position of the neck of the bladder and the urethra. These changes may cause urinary stress incontinence, characterized by dribbling of urine when intra-abdominal pressure is raised during coughing and lifting, for instance, or lead to the prolapse of one or more pelvic organs (Moore *et al*., 2014).

CHAPTER THREE

MATERIALS AND METHODS

3.1 RESEARCH DESIGN

A retrospective and cross sectional study design was adopted for the study.

3.2 STUDY AREA

This study was carried out in the department of Radiology, Murtala Muhammad Specialist Hospital Kano, Nigeria. It is a hospital with health facility as number one (1) Kano state hospital which is located in the Kano municipal, and the research was also conducted in National Orthopaedic hospital Dala, Kano which was established in 1959. Kano is located on a latitude of 12^0 $37^/$ North, 9^0 $33^/$ South and 7^0 $43^/$ West and is bordered on the East by Bauchi and Jigawa States, to the South by Kaduna state and to the West and North by Katsina State. The specialist hospital is the largest hospital in the State and serving the most populous individuals in the state while the services rendered by the National Orthopaedic Hospital extend to all the Northern States and to neighbouring countries like Niger and Chad. The resources available in this Hospital are therefore stretched because of this wide coverage. The total land area of Kano state is 20,760sq kilometers with population of 9,383,682 based on the official 2006 National Population Census with a distribution of males (51%) to females (49%), (NPC, 2006).

The Radiology department of both hospitals has intensively contribution to the population of the state and neighboring states which are equipped with various types of imaging facilities including modern state of the art equipment with both diagnostic and interventional procedures/services offered routinely.

3.3 STUDY SAMPLE

A total of five hundreds (500) pelvic radiographs comprising two hundred and fifty (250) males and two hundred and fifty (250) females were used. The age range was 18 – 60 years that were referred to Radiology departments of both hospitals mentioned above. Only pelvic radiographs of seven (7) years back were included in the study (from 2010 to 2017), and any radiographs of pelvic with normal showed no underlying bone diseases which could have affected the intact pelvic bone, free from bone fractures and osteoporosis.

3.4 STUDY POPULATION

A total of five hundreds pelvic radiographs were used. The radiographs contained only the indigenes from all States in Nigeria that were referred to Department of Radiology, Murtala Muhammad Specialist Hospital Kano, and National Orthopaedic Hospital Dala, Kano.

3.5 SAMPLE SIZE

A total of 500 radiographs which satisfied all the inclusion criteria were fully recruited for the study. This includes all the normal pelvic X-ray films that have been reported within 2010 - 2017. The radiographs were assessed reported and reviewed by a Consultant Radiologist.

3.6 SAMPLE SIZE DETERMINATION

Sample size was determined using the formula developed by Lwanga & Lemeshow (1991); which stated that;

$n = Z^2Pq/d^2$

Where;

n = minimum sample size

Z = Statistic for the level of confidence of 95%, which is conventional, 1.96).

P = Proportion in the target population 50% (0.5)

q = 1-P, 1-0.5 = 0.5

d = sampling error which is 5% (0.05)

Therefore, $n = (1.96)^2(0.5)(0.5)/(0.05)^2 = 384.16$

Approximately, a total of 500 radiographs records of patients consisting of both sexes that attended the Radiology Department in Murtala Mohammad Specialist hospital Kano and National Orthopedic Hospital Dala, Kano, X-ray films were studied.

3.7 SAMPLING TECHNIQUE

This is a retrospective study in which the anteroposterior pelvic radiographs of 18 – 60 years old people that were reported normal were non-random selected from Radiologist which was purposive or judgmental technique because the radiographs were picked by radiologist from Department of Murtala Mohammad Specialist hospital, Kano and National Orthopaedic hospital Dala, Kano.

3.8 ETHICAL APPROVAL

Letters from the Department of Anatomy, Bayero University, Kano, was given to ethics and research committee under the Kano State Ministry of Health for the approval of ethical permit and also ethical permit of National Orthopedic Hospital Dala, Kano. The ethical approvals were obtained from both Kano State Ministry of Health and also from the National Orthopedic Hospital Dala, Kano.

3.9 MATERIALS

The materials used in this study included:

i. Digital vernier caliper; NEIKO 6 –INCH
ii. Illuminator box (viewing box).
iii. 500 normal pelvic X-ray films from Murtala Mohammad Specialist Hospital, Kano and National Orthopedic Hospital Dala, Kano.
iv. Protractor, Ruler.
v. Temporary markers.

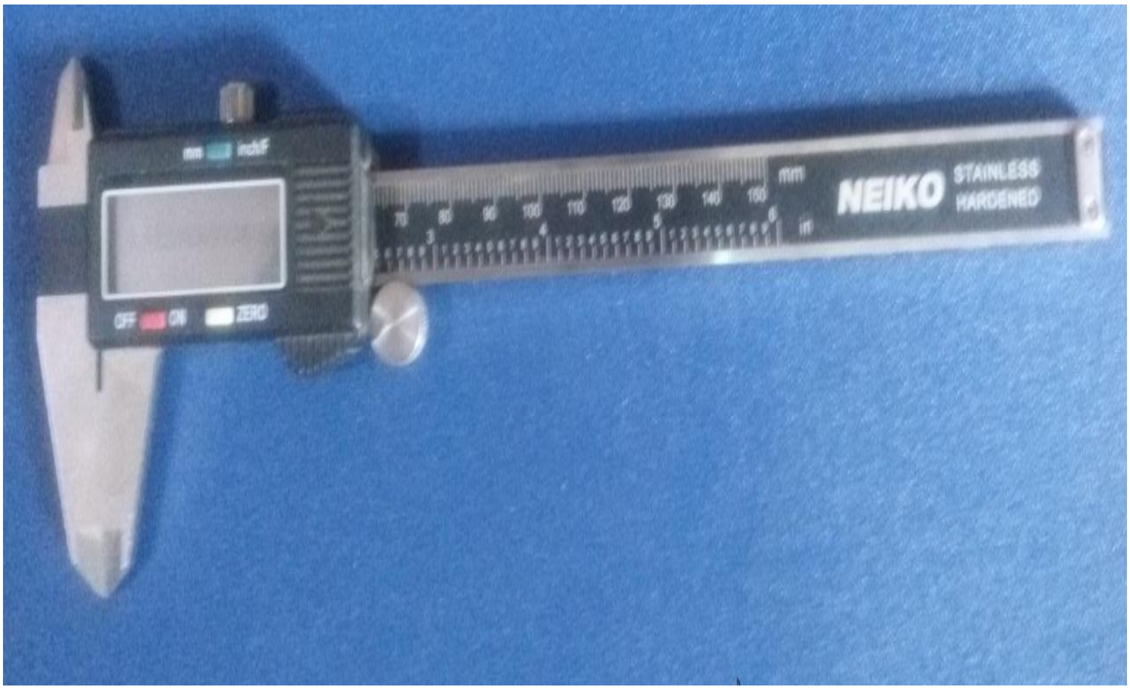

Plate V: Shows NEIKO 6 – INCH Stainless Steel Digital Caliper with Fractional and Decimal Display.

Plate VI: Shows EWEM – Janus, D – 8380 Landau/Isar, Viewing Box, Made in U.S.A. 1989.

Plate VII: Shows LARIES Double Color Whiteboard Marker. NEW///HL-006 Made in China.

3.10 SELECTION CRITERIA

3.10.1 Inclusion Criteria

i. Normal antero-posterior pelvic radiographs of adult Nigerians were selected
ii. Only pelvic radiographs of adult Nigerians were included.
iii. Age range of pelvic radiographs of adult Nigerians from 18 to 60 years.
iv. Pelvic radiographs of adult Nigerians within the record of seven years from (2010 to 2017).

3.10.2 Exclusion Criteria

i. Abnormal pelvic radiographs with damages, deformity, fractures and pelvic floor diseases.
ii. Pelvic radiographs of non-adult Nigerians.
iii. Pelvic radiographs outside the age range of 18-60 years.
iv. Pelvic radiographs of adult Nigerians outside the record of seven years from 2010 to 2017.

3.11 METHODS

The methods used in this study were adopted base on techniques suited for the measurement of the distances and landmarks.

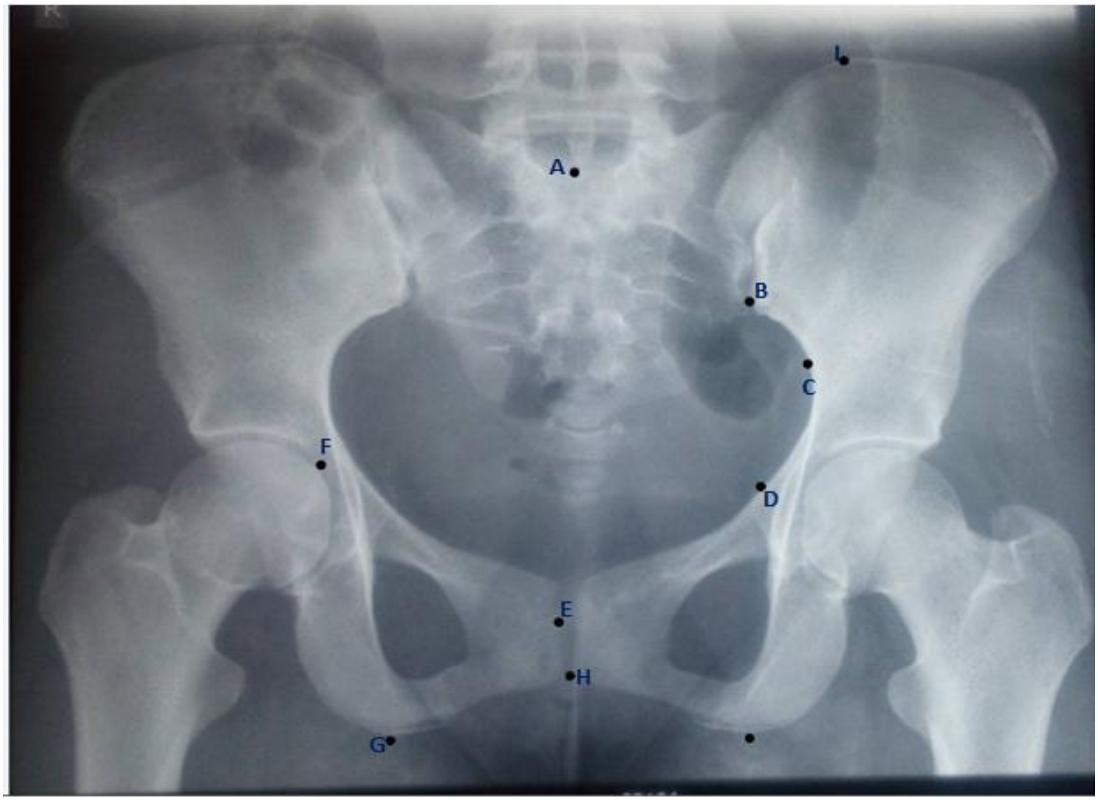

Plate VIII: Shows the Landmarks of Normal Antero-posterior Pelvic Radiograph in Adult Nigerians.

KEYS:

A. Sacral promontory.

B. Scacroiliac joint.

C. Illiopectinal line.

D. Illiopectine eminence.

E. Superior one-third of pubic symphysis

F. Center of acetabulum junction.

H. Inferior margin of pubic symphysis

G. Inferior ramus of ischium

I. Tip of iliac crest

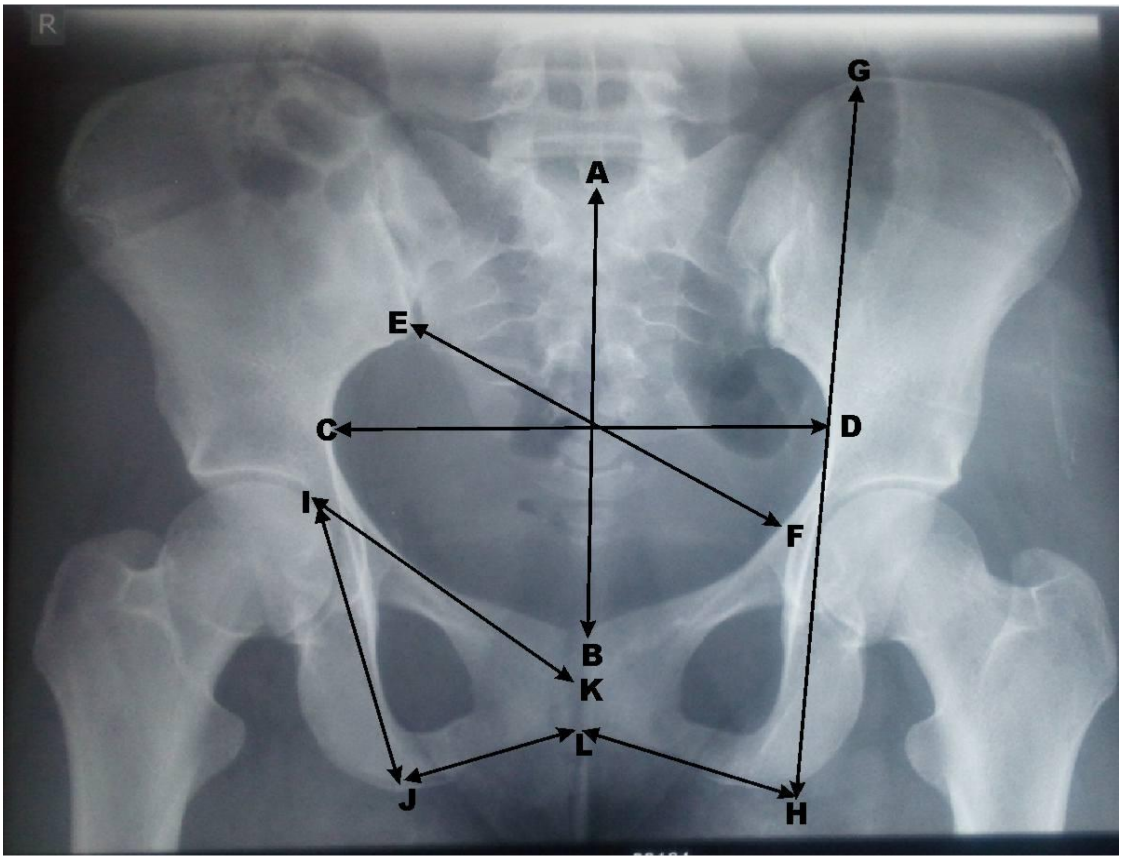

Plate IX: Shows the Illustration of Distances in Pelvic Dimensions in Adult Nigerians.

KEYS:

A-B is the anteroposterior diameter of pelvic inlet.

C-D is the transverse diameter of pelvic inlet.

E-F is the oblique diameter of pelvic inlet.

G-H is the pelvic height.

I-J is the ischium length.

I-K is the pubic length.

H-L-J is the subpubic angle.

3.11.1 Measurement of Anteroposterior of Pelvic Inlet

The anteroposterior of pelvic inlet was measured in millimeter (mm) from sacral promontory to superior margin of pubic symphysis using digital vernier caliper as described by Kolesova and Vetra, 2012.

3.11.2 Measurement of Transverse Diameter of Pelvic Inlet

The transverse diameter of pelvic inlet was measured in millimeter (mm) using digital vernier caliper, which is the widest distance between curviest part of iliopectineal lines as described by Kurki and Decrausaz, 2015.

3.11.3 Measurement of Oblique Diameter of Pelvic Inlet

The distance from the lower part of sacro-iliac joint of one side to the opposite side of ilio-pubic eminence was also in millimeter (mm) using digital vernier as described by Kurki and Decrausaz, 2015.

3.11.4 Measurement of Pelvic Height

The pelvic height was measured in millimeter using digital vernier caliper from the most superior point of iliac crest to the most inferior point on the ischial tuberosity as described by Smrke and Biscevic, 2007.

3.11.5 Measurement of Ischium Length

The ischium length was measured using digital vernier caliper in millimeter (mm) is the distance from the center of acetabulum junction to the most inferior point on the ischial tuberosity as described by Ekanem *et al*., 2009.

3.11.6 Measurement of Pubis Length

The distance from the center acetabulum junction to the superior one-third of the pubic symphysis was measured using digital vernier caliper in millimeter as described by Ekanem *et al*., 2009.

3.11.7 Measurement of Subpubic Angle

The subpubic angle was measured in degree using protractor and ruler, which is formed at pubic arch by the convergence of distances from the inferior rami of the ischium and pubis on the either side as described by Karakas *et al*., 2013.

3.12 DATA ANALYSES

The data were expressed as mean ± standard deviation, frequencies and percentage. Mann-Whitney test was used to determine the sexual dimorphism. Stepwise binary logistic regression was used for generate an equation for sex discrimination. Two sample t-test was employed to determine sex differences in asymmetry of pelvic height. Analyses were carried out using SPSS version 21.0 statistical packages. $P < 0.05$ was considered significant.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 DESCRIPTIVE STATISTICS OF PELVIC DIMENSIONS OF ADULT NIGERIANS

Table 4.1, shows the descriptive statistics of pelvic diameters, lengths, height and angle. The mean for anteroposterior diameter of pelvic inlet was 133.76mm ± 11.38mm, and the mean of oblique diameter was 118.77mm ±9.49mm, whereas for transverse diameter of pelvic inlet a mean of 133.42mm ± 10.97mm was observed. The mean for pubic length was 79.65mm±7.51 while the ischial length mean was 81.39mm ±5.99mm. The mean of sub-pubic angle was 99.44^0. The left and right pelvic height had means of 221.65mm ±13.7mm and 221.74mm ± 13.15mm respectively.

Table 4.1: Descriptive Statistics for Pelvic Dimensions of Adult Nigerians

Variables	Mean	SD	Range	Minimum	Maximum	Variance
Antero-posterior diameter of pelvic inlet (mm)	133.76	11.38	60.00	100.30	160.30	129.46
Pubic length (mm)	79.65	7.51	41.70	58.30	100.00	56.43
Ischium length (mm)	81.39	5.99	37.40	59.30	96.70	35.84
Oblique diameter (mm)	118.77	9.49	53.90	92.80	146.70	90.05
Transverse diameter of pelvic inlet (mm)	133.42	10.97	53.20	110.00	163.20	120.32
Sub-pubic angle (^{0})	99.44	17.13	65.00	65.00	130.00	293.60
Left pelvic height (mm)	221.65	13.07	85.00	180.00	265.00	170.92
Right pelvic height (mm)	221.74	13.15	87.00	180.00	267.00	173.00

4.2 SEX DIFFERENCES OF PELVIC DIMENSIONS OF ADULT NIGERIANS

From Table 4.2, it was observed that females have significantly higher mean values of all the diameters. Similarly, higher mean values in females were also observed in pubic length; however, males tend to have significantly higher mean values in ischial length than the females and also pelvic height. In the sub-pubic angle females have greater significantly mean values then the males.

Table 4.2: Sex Differences of Pelvic Dimensions of Adult Nigerians

Variables	Sex	Mean ± SD	Min - Max	Z	P-Value
Antero-posterior diameter of pelvic inlet (mm)	Male	127.78 ± 9.06	100.30 - 152.80	-12.007	<0.001
	Female	139.75 ± 10.27	107.50 - 160.30		
Pubic length (mm)	Male	74.37 ±5.59	58.30 - 89.60	-16.359	<0.001
	Female	84.93 ± 5.08	68.30 - 100.00		
Ischium length (mm)	Male	83.02 ±5.53	67.20 - 96.70	-6.399	<0.001
	Female	79.76 ± 5.99	59.30 - 96.60		
Oblique diameter (mm)	Male	112.83 ±6.52	93.10 - 130.20	-14.639	<0.001
	Female	124.71 ± 8.19	92.80 - 146.70		
Transverse diameter of pelvic inlet (mm)	Male	126.55 ±7.37	110.00 - 147.20	-14.366	<0.001
	Female	140.29 ± 9.60	116.50 - 163.20		
Sub-pubic angle (^{0})	Male	83.93 ±7.47	65.00 - 100.00	-19.332	<0.001
	Female	114.96 ± 7.03	93.00 - 130.00		
Left pelvic height (mm)	Male	226.68 ±12.04	198.00 - 265.00	-8.679	<0.001
	Female	216.62 ± 12.11	180.00 - 250.00		
Right pelvic height (mm)	Male	226.83 ±12.14	198.00 - 267.00	-8.752	<0.001
	Female	216.66 ± 12.14	180.00 - 250.00		

4.3 FREQUENCY DISTRIBUTION OF FEMALE PELVIS TYPES OF ADULT NIGERIANS

Table 4.3 shows the frequency distribution of female pelvis types. The anthropoid had the highest percentage of 49.20%, follow by the gynaecoid with 31.60% and the least was platypelloid with 1.20%.

Table 4.3 Frequency Distribution of Female Pelvis Types of Adult Nigerians

Classification	Frequency	Percentage
Anthropoid	123	49.20%
Gynaecoid	79	31.60%
Android	45	18.00%
Platypelloid	3	1.20%
Total	250	100.00%

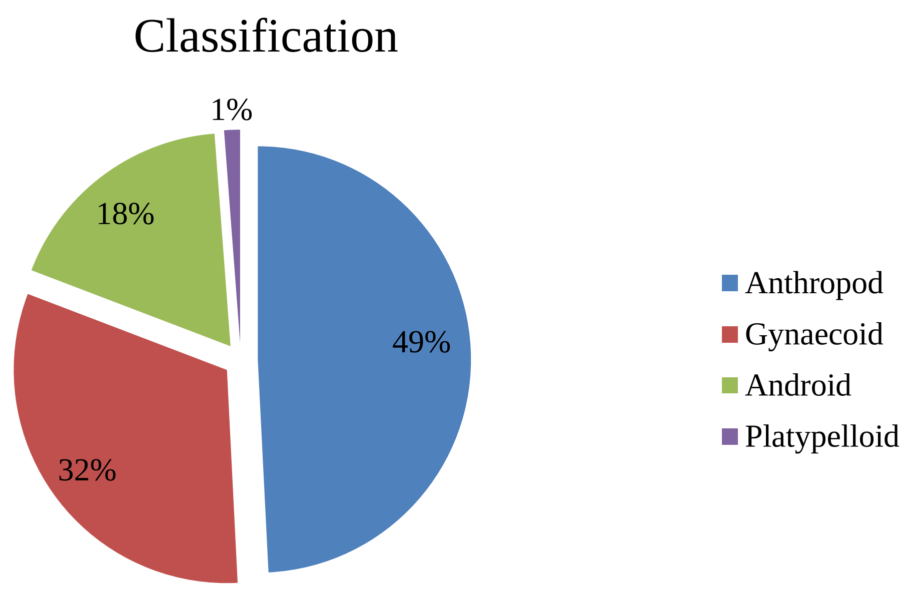

Figure 4.1: Shows the Frequency of Female Pelvis Types (n=250).

4.4 GENERATED EQUATIONS FOR SEX DISCRIMINATION USING PELVIC DIMENSIONS AND ANGLE

All the equations obtained discriminated the sex more than by chance (v2 =658.311–693.147, P<0.05). With regards to sex discrimination, sub-pubic angle was the single best predictor of sex with an accuracy of 98.4% and 73–98% contribution to the prediction, with higher level of misclassification (-2 Log likelihood= 34.837) compared to rest of the equations. However, the percentage accuracy increased to 100% when four variables (sub-pubic angle, pubic length, left pelvic height and ischial length) were included in the equation and percentages contribution of 75–100% was achieved. It was also observed that misclassification level reduced by about 100% (-2Loglikelihood=0.00).

Table 4.4: Generated Equations for Sex Discrimination Using Pelvic Dimensions of Adult Nigerians

Steps	Equations (y = mx + c)	Accuracy (%)	-2 Log likelihood	Cox & Snell R^2	Nagelkerke R^2	Chi - square
1	Sex = 0.634(subpubic angle)+(-61.959)	98.4	34.837	0.73	0.98	658.311
2	Sex = 0.649(subpubic angle)+ 0.255 (Pubic length) + (-83.64)	99.2	26.543	0.74	0.98	666.604
3	Sex = 0.82(subpubic angle)+ 0.602 (Pubic length) + (-0.337) (Left pelvic height) + (-52.78)	99.4	10.907	0.74	0.99	682.24
4	Sex = 2.493(subpubic angle)+ 5.551 (Pubic length) + (-1.963) (Left pelvic height) +(-3.593)(ischial length) + (47.149)	100	0.00	0.75	1.00	693.147

If the predicted value is equal to or more than 0.5 it is considered female and if it is less than 0.5 (or negative value) it is considered to be male,*P<0.05.

4.5 SEXUAL DIMORPHISM IN SIGN AND ABSOLUTE ASYMMETRY OF PELVIC HEIGHT

In figure 4.2: below, there was sex difference in both sign and absolute asymmetry, however, the left height showed leftward asymmetry in both sexes. Using one sample t-test, the mean of sign asymmetry was not greater than zero indicating fluctuating type of asymmetry.

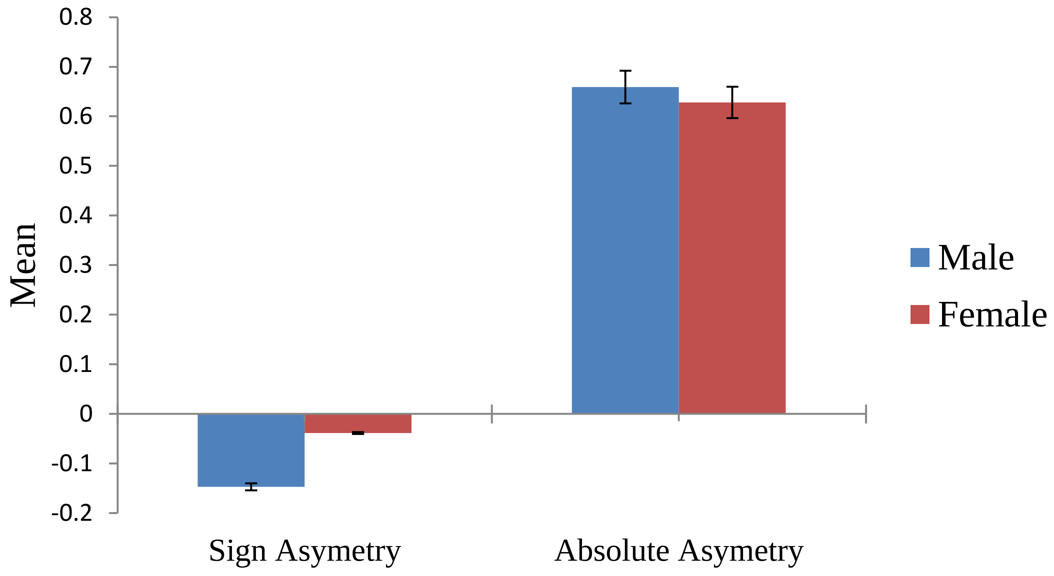

Figure 4.2: Sexual Dimorphism in Signed and Absolute Asymmetry of Pelvic Height.

4.6 DISCUSSION

The distinctive morphology of the human pelvic (innominate) bone and its clear sexual dimorphism makes it of interest from anatomical, anthropological, and forensic point of view.

The male pelvis is heavier and thicker than the female pelvis and usually has more prominent bony markings. The female pelvis is wider, shallower and has a larger pelvic inlet and outlet. Anatomical differences in the human pelvis are more pronounced during pubertal age especially in females. It is believed that sex hormones have a part to play in this variation. In females, the secretion of these hormones increases with age and reaches its peak during adolescence, while in males it was found out that the shape of the innominate bone is transformed to the male type under the influence of androgen (Iguchi *et al*., 1989). Though the primary function of the pelvis in males and females are for locomotion, it is specially adapted for childbirth in the females (Hanna & Washburn, 1953). This may explain the significantly higher sex differences in pelvic dimensions observed in females in all races when compared with that of the males.

In the present study, the mean value of pubic length of males were recorded as 74.37mm, while that of the females were 84.93mm which was similar to figures obtained by Oladipo *et al*. (2009) in eastern Nigeria. The ischial length for males was recorded as 83.02mm and that of the females was 79.76mm, which agreed with the findings of Oladipo *et al*. (2009) on males' ischial length of eastern Nigerians with a mean of 84.4mm for males and it was higher in females with a value 83.0mm, which was almost the same with the present study. Ekamen *et al*. (2009) who reported that the mean pubic length was significantly longer in females than males, whereas the mean ischial length was significantly higher in males than females in Cross River people of Nigeria and almost the same with results they obtained from Lagos state population by Ekanem *et al*. (2014) but both their findings in Cross River and Lagos were lower in mean value than the present study. It was also observed that, the findings of mean value from this study were higher than those findings from these researchers Oladipo *et al*. (2010; 2012) in South-south Nigerians and Ikwerre ethnic group, Washburn (1948) of American Negro and Davivong (1963) of Australian Aborigines. The findings differ from this study which might be due to difference techniques, sample size, physical activities and genetic factor. However, the mean value in the present study is lower than the findings of these researchers Attah *et al*. (2015) on pubic length and ischial length of Borno state population with a mean of 81.0mm and 91.7mm for males respectively while in females it was 92.7mm and 87.3 mm respectively and Oladipo *et al*. (2015) reported the findings of Urhobos and Itsekiris ethnic groups were also higher than the mean value of the present study. The mean value of antero-posterior diameter of pelvic inlet of the present study in both sexes were higher than these authors' findings (Correria *et al*., 2005; Karakas *et al*., 2013) and the mean value of transverse diameter of pelvic inlet of the findings of above authors were lower than the present study but the above findings and the present study were higher in females than males. It was observed that sexual dimorphism in body size is a critical factor in influencing pelvic dimorphism. They observed that the pubic length for both sexes particularly that of the females showed accelerated changes depending on the body size. Body size is known to be influenced by environmental, nutritional and genetic factors. The present study with the previous studies showed that there were differences in sexual dimorphism in both sexes, with the female variables being higher than those of males except the ischial length.

The size and shape of their pelvis reflects a complex history of heredity and environmental interactions. However, it has been noted that in the temperate, and industrialized population, that women of greater socio- economic means are generally healthier, taller, have roomier pelvis and better reproductive history than those who are less fortunate (Thoms, 1956). It cannot be assumed however that the same holds true for women living under different bicultural condition (Tonnis, 1976). More studies done on the characterization of the normal female pelvis globally shows that 50% women had the Gynaecoid pelvis, 22.4% had android, 22.7% had anthropoid pelvis and 4.4% had the platypelloid (Savona, 2007).

It was observed that the finding in this research was different from the global results, the result showed that there were four (4) types of pelvis present in this study and these are the Gynecoid consisting 31.60% of the study population, having an average antero-posterior diameter of 139.63mm and transverse diameter of 144.22mm respectively. The android, with an outcome of 18% having an antero-posterior diameter of 128.63mm and transverse diameter of 145.13mm, respectively. The platypelloid had 1.20%, having an average anteroposterior diameter of 123.30mm and transverse diameter 157.13mm of the study while anthropoid type had the highest percentage of 49.20% with an average of antero-posterior of 144.29 and transverse diameter of 135.57mm. It was observed that the present study result was different from other studies within the country, Akpaniwo *et al*. (2016) observed only three types of pelvic types of 588 films to determine the rate of gynaecoid, android, platypelloid and anthropoid, and the percentages were 8%, 39%, 53% and 0% respectively while research was also conducted by (Bukar *et al*., 2013) on pelvic types of 400 films and the percentages of gynaecoid, android, platypeloid and anthropoid which were 90.3%, 9%, 0% and 0.8% respectively. This present study showed that anthropoid type had the highest percentage of 49.20% which was different from a research in Jos by Akpaniwo *et al*. (2016) with highest of platypelloid 53% and that of Borno state by Bukar *et al*. (2013) with highest of 90.3% gynaecoid. Fatima *et al*., (2013), conducted a research on Sudanese female pelvis and their results showed that there were two mains pelvis types in the Sudan, out of four known types in the world, the two types were: The anthropoid pelvis (oval birth canal) and the gynaeocoid pelvis (rounded birth canal). The two types presented as: In north of Sudan 68% of cases were anthropoid while 32% of cases were gyneacoid. In South of Sudan, 30% of cases were anthropoid and 70% of cases were gyneacoid. In west of Sudan 49.3% of cases were anthropoid and 50.7% of cases were gyneacoid. In East of Sudan, 22% of cases were anthropoid and 78% of cases are gyneacoid and their findings were contrary to the present study which had the four (4) female pelvic but anthropoid and gynaecoid were the real dominant of the study. According to Caldwell and moloy classification on pelvis types, black women are common with anthropoid type about 50% which was related with the present study and it may be due to nutritional background from the childhood, genetic variation, physical activities and hormonal secretion. Women who have such a pelvis shape tend to have “larger rear ends” and may carry a lot of adipose tissue/weight in the buttocks as well as in the abdomen. These women can have a flat abdomen with some real effort “they may have to drop body fat levels down a bit lower than women with the other two aforementioned pelvis types, but it’s doable” (Fatima *et al*., 2013).

According to Washburn (1948), the pubic bone is the pelvis part which is most responsive to the action of female hormones and the sub-pubic angle increases during the growth in females. Traditionally, a sub-pubic angle less than 90^o indicates a male phenotype, whereas an angle more than 90^o indicates a female phenotype

(Rosing *et al*., 2007). However, this cut-off value is very crude and has significant overlap around it. These factors complicate sex determination, and necessitate the definition of more refined and population-specific cut-off values. However, the literature data on subpubic angles in males and/or in females are surprisingly few in number and the ones that report both sexes independently in contemporary populations are usually for Blacks (Tague, 1992; Ridgeway *et al*., 2008). As population differences are known to affect the expression of sexual dimorphism, new studies on different populations must be conducted to find population-specific discriminatory values (Krogman & Iscan, 1986).

The mean of sub-pubic angle in the present study for both sexes were 83.93^{o} in males while 114.96^{o} in females. Igbigbi and Nanono-Igbigbi (2003) conducted research on African black race in Uganda and Malawi and the findings turned out to be higher values or mean compared to the present study but the females sub-pubic angle of Uganda was similar to this present study, which is an indication of regional variation of the sub-pubic angle among black subjects. The presence of sexual, regional, and racial variability of the sub-pubic angle could possibly be explained on genetic, dietary, and environmental factors. However, it was higher than those findings of Handa *et al*. (2003) of American white in USA, Ridgeway *et al*. (2008) of both American white and American black in USA, Tague (1992) of American white, American black and Amerindian. There may be possible effect of age on the sub-pubic angle or level of sex hormone on the pubic bone. Incongruence between the studies should be explained by use of different statistical methods and use of different techniques by different researchers. Technical variations may create unrealistic data as one may encounter when using projection film radiography, and may make a full comparison of the sub-pubic angle between races and populations impossible. The findings from these researchers Oladipo *et al*. (2009) of Igbo and Ijaws, Oladipo *et al*. (2010) of Ikwerre and Kalabaris ethnic groups, Isaac *et al*. (2014) of Calabar peoples in Cross River state, were all higher than the present study but the mean of females' sub-pubic angle in the present study was higher than that of Igbo ethnic group conducted by Oladipo. Analysis of the sex differences in the sub-pubic angle showed that it was statistically significant ($p<0.01$) agreeing with the results of above authors.

The left and right male pelvic height in this study were higher than that of female and this was similar to the findings, by Afrianty *et al*., (2013), Gupta and Arora (2013), Wescott *et al*., (2008). The above findings were all lower than the present study which may be due to geographical areas or genetic variations. The present study showed the sex difference in both sign and absolute asymmetry. However, the left height showed leftward asymmetry in both sexes and the mean of sign asymmetry was not greater than zero indicating fluctuating type of asymmetry. Asymmetry of the bony pelvis has been clinically examined, typically in reference to lower back pain (Al-Eisa *et al*., 2006; Badii *et al*., 2003; Levangie, 1999).

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 SUMMARY

The present study revealed sex differences between males and females from measurements of normal pelvic radiographs, the differences may be due to hormonal secretion during maturity and exposure to the physical activities. Although it was supported by various workers in the past, the difference between their parameters and present parameter indicates racial difference.

It has been shown that the antero-posterior diameter of pelvic inlet differs with females having higher mean value than males. Oblique diameter of pelvis in females was significantly higher than the males. It was also found that the transverse diameter of pelvic inlet in females were significantly higher than males, which could be due to hormonal secretion or exposure to physical activities. This study also identified that the ischial length revealed difference with males having higher mean value than females due to body size, while pubic length also showed the differences with females having higher values than the males which may be due to hormonal secretions which increased the pubic bone length for the purpose of pelvic outlet or childbirth. The subpubic angle of the females was significantly higher than the males. The variables in females showed higher sexual dimorphism than the males' counterpart.

The findings in the present study showed that the anteroposterior diameter of pelvic inlet differs sexually, with females having higher mean value than males. Oblique diameter of pelvis in females was sexually different and higher than the males. It was also found that the transverse diameter of pelvic inlet in females was sexually different to that of males, which could be due to hormonal secretion or exposure to physical activities. And the present study, showed the highest percentage of sexual difference in all the variables measured in the research with 98.4% for sexual discrimination.

The female pelvis types of adult Nigerians have shown that the anthropoid has the highest percentage of 49.2% which was followed by gynaecoid with 31.6% and they were the dominant among the pelvis types in this locality.

There was sex difference in both sign and absolute asymmetry; however, the left height showed leftward asymmetry in both sexes and the mean of sign asymmetry was not greater than zero indicating fluctuating type of asymmetry.

All these differences are due to hormonal activities, genetic variation, and body complexity, nutritional background from childhood and exposure to the physical activities by females than males.

5.2 CONCLUSION

The present study has confirmed the accuracy of sex determination using measurements of different structures in the pelvic radiographs of adult Nigerians. The findings of the study indicated that pelvic dimensions are sexually dimorphic as seen that females have higher values than males except in pelvic height and ischial length.

Sub-pubic angle was the single best predictor of sex in pelvic dimensions among adult Nigerians. The study has revealed that the anthropoid of female pelvis type has the highest percentage, followed by gynaecoid of female pelvis type of adult Nigerians. There was sex difference in pelvic height asymmetry and the males were higher than the females.

It was shown that all the variables were greater in females than males. This statement is in line with the established literature and that pelvic region undergoes changes during maturation, with the females mostly having larger and lighter pelvic region than males, which may be due to hormonal secretion, exposure to physical activities.

5.3 RECOMMENDATIONS

i. There is need for further research for sex determination using normal pelvic radiographs for the other parts of the country in order to identify the variations in sex determination and ethnicity, since geographic areas differ, genetic variation, hormonal activities and exposure to physical activities affect the bone size, as the study was done using normal pelvic radiographs from Murtala Mohammad Specialist Hospital, kano and National Orthopaedic Hospital Dala, Kano.

ii. There is need to create database, which may help in identification of individuals, during bio- archaeological and forensic investigations.

iii. There is need for further research using other techniques or methods, like MRI and CT scan for better measurements and accuracy.

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Appendix

KANO STATE OF NIGERIA

MINISTRY OF HEALTH

MOH/Off/797/T.I/341 14th March 2017

Adam Nma Jibril
Department of Human Anatomy,
Faculty of Basic Medical Sciences,
College of Health Sciences,
Bayero University,
Kano.

RE: REQUEST FOR ETHICAL APPROVAL

Reference to your letter dated 27th February, 2017 on the above request addressed to the Chairman Ethical Sub-Committee Operational Research Advisory Committee Unit of the Ministry, requesting for ethical approval to conduct a research at Murtala Muhammad Specialist Hospital, Kano.

2. The research titled *"Sex Determination from Pelvic Dimensions Using Radiograph Among Adults Hausa Ethnic Group in Kano State"* is for the award of Master of Science Degree in Anatomy (MSc Anatomy).

3. In view of the foregoing, I wish to convey the Ministry's approval for you to conduct the research at the above mentioned hospital in Kano.

4. You are also requested to share your findings with the Ministry of Health, Kano.

5. Best Regards.

Hamza Ahmad
DPRS
Secretary (ORAC),
For: Honourable Commissioner.

2nd & 3rd Floor, Post Office Road, P.M.B. 3066, Kano
Tel: 064-634233, 634426, 635640, 633482, 632535, 647922, 634983, 635616
Cables or Telegram: COMMHEALTH KANO

NATIONAL ORTHOPAEDIC HOSPITAL, DALA - KANO

NOHD/RET/ETHIC/43

29th March, 2017

Adam Nma Jibril,
Dept. of Anatomy,
Faculty of Basic Medical Sciences,
Bayero University, Kano,
P.M.B. 3011 - Kano.

ETHICAL CLEARANCE

RE: *"Sex Determination from Pelvic Dimensions Using Radiograph Among Adults Hausa Ethnic Group in Kano."*

Following receipt and consideration of your Research Proposal by the **HOSPITAL RESEARCH ETHICS COMMITTEE**, I am directed to inform you that Ethical Clearance is hereby granted to you for the conduct of the above titled study.

I am further directed to advise you to adhere strictly to the approved methodology and to kindly make available a copy of the final approved research to the Hospital, please.

Best wishes.

KABIR ABDULSALAM
For: MEDICAL DIRECTOR

DATA SHEET FOR RESEARCH ON ASSESSEMENT OF PELVIC DIMENSIONS USING RADIOGRAPH OF ADULT NIGERIANS.

Hospital………….. Tribe……………………. Date…………………….

S/N	AGE	SEX	APDPI (mm)	OD (mm)	TDPI (mm)	SA (mm)	PL (mm)	IL (mm)	RPH (mm)	LPH (mm)

APDPI = Anteroposterior diameter of pelvic inlet, OD = Oblique diameter, TDPI = Transverse diameter of pelvic inlet, PL = Pubic length, IL = Ischial length, SA = subpubic angle RPH = Right pelvic height, LPH = Left pelvic height.