
**“ANATOMICAL PARAMETERS OF HIP JOINT IN
ADULT HUMAN CADAVERS OF NORTH KARNATAKA
– A CROSS SECTIONAL STUDY”**

by

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**Under the Guidance of
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MAY 2012

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LIST OF ABBREVIATIONS USED

AP-	Anteroposterior
PA-	Posteroanterior
cm-	Centimeter
mm-	Millimeter
OA-	Osteoarthritis
J. -	Journal of
Avg-	Average
AD-	Acetabular dysplasia
Jt-	Joint
SD -	Standard deviation
SEE -	Standard Error of Estimate
NS-	Nothing Significant
S-	Significant
M-	Male
F-	Female

ABSTRACT**BACKGROUND AND OBJECTIVES**

Most of the studies described anatomical parameters on X-ray. Here the measurements were carried out on adult human cadavers. This study will essentially help orthopedicians to make suitable hip joint prosthesis, also help forensic expert in disputed sex and help to understand biomechanics of hip joint. These parameters help us to understand etiopathogenesis of disease like osteo-arthritis of hip joint.

METHEDODOLOGY

A total 60 hip joints were studied in 20 male and 10 female cadavers. Various measurements taken with soft tissue in situ like vertical diameter of head of femur, diameter of acetabulum and depth of acetabulum. These measurements were taken using vernier caliper and a steel scale. Mean values of three parameters were recorded and compared between males and females. The mean values also compared with right and left side for males and females. The mean diameter of acetabulum compared with mean vertical diameter of head of femur for both the sexes.

RESULTS

- (a) The mean vertical diameter of head of femur was found to be 43.75 mm in males and 40.30 mm in females.
- (b) The mean diameter of acetabulum was found to be 45.15 mm in males and 41.50 mm in females.

- (c) The mean depth of acetabulum was found to be 31.78 mm in males and 29.70 mm in females.
- (d) The mean values of three parameters were found to be greater in males than in females.
- (e) The mean values of three parameters was found to be greater on right side in both males and females.
- (f) In both sexes the mean diameter of acetabulum was found to be greater than the mean vertical diameter of head of femur.

INTERPRETATION AND CONCLUSIONS

The mean values of vertical diameter of head of femur, depth and diameter of acetabulum were found to be significantly greater in males than in females. The parameters of hip joint are immense importance to orthopaedicians, radiologists, and prosthetists. These values are useful to identify the fragment of bone for sex determination sent to forensic expert.

It was found that the diameter of acetabulum was significantly more than that of vertical diameter of head of femur. This explains why osteoarthritis is rare in Indians as compared to the Western world.

The acetabulum was relatively deeper in this study compared to other similar study. This explains why congenital subluxation is rare in Indians. These parameters will help the orthopaedicians, prosthetist to design suitable hip prosthesis.

KEY WORDS: Acetabulum, Femoral head, Diameter, Vernier caliper, Adult cadaver

CONTENTS

SL. NO	TOPIC	PAGE NO.
1	INTRODUCTION	1
2	OBJECTIVES	5
3	REVIEW OF LITERATURE	6
4	METHODOLOGY	33
5	RESULTS	40
6	DISCUSSION	55
7	CONCLUSION	79
8	SUMMARY	81
9	BIBLIOGRAPHY	83
10	ANNEXURE I – MASTER CHART	90
11	ANNEXURE II – PHOTOGRAPHS	92

LIST OF TABLES

TABLE NO.	DESCRIPTION	PAGE NO.
1	Measurements taken in male cadavers	42
2	Measurements taken in female cadavers	44
3	Mean vertical diameter of head of femur	45
4	Mean diameter of acetabulum	46
5	Mean depth of acetabulum	47
6	Average values of three parameters	48
7	Comparison of right side parameters with left side in males	49
8	Comparison of right side parameters with left side in females	50
9	Comparison of parameters between males and females	51
10	Comparison of vertical diameter of head of femur with diameter of acetabulum in males and females	52
11	Comparative study of vertical diameter of head of femur	73
12	Right and left side analysis of mean vertical diameter of head of femur	74
13	Comparative study of diameter of acetabulum	75

14	Comparative study of depth of acetabulum in males and females	76
15	Comparative study of depth of acetabulum on right side and left side	77
16	Comparison of vertical diameter of head of femur North Karnataka and South Karnataka	77
17	Comparison of diameter of acetabulum between south Karnataka and north Karnataka	78
18	Comparison of depth of acetabulum between South Karnataka and North Karnataka	78

LIST OF GRAPHS

GRAPH NO.	DESCRIPTION	PAGE NO.
1	Mean vertical diameter of head of femur	45
2	Mean diameter of acetabulum	46
3	Mean depth of acetabulum	47
4	Average values of three parameters	48
5	Comparison of right side parameters with left side in males	49
6	Comparison of right side parameters with left side in females	50
7	Comparison of parameters between males and females	51
8	Comparison of vertical diameter of head of femur with diameter of acetabulum in males and females	52

LIST OF FIGURES

FIGURE NO.	DESCRIPTION	PAGE NO.
1	Material used for the study	37
2	Method used for measuring vertical diameter of head of femur	38
3	Method used for measuring diameter of acetabulum	38
4	Method used for measuring depth of acetabulum	39
5	Thirty specimen studied	92

INTRODUCTION

The anatomical parameters of hip joint will be of immense importance to orthopaedicians, radiologists and prosthetists. These parameters help in designing patient specific implants and can be utilized to understand etiopathogenesis of osteoarthritis.

The study of dimensions of femoral head and acetabulum has been carried out by several anatomists and anthropologists. They concluded that the dimension of femoral head is variable and it varies according to sex, race, heredity, climate and other geographical factors. Therefore population specific data is required to identify the sex of a person¹.

Determination of individual sex from the available skeleton is of great importance in the identification of a person. In medico-legal cases, determination of stature, sex and age from skeletal remains of deceased person is often referred to anatomists and anthropologists. Therefore most of the long bones either individually or in combination have been subjected to statistical and morphological analysis.

To understand hip joint mechanics, knowledge of anatomy of proximal femur is a pre-requisite. Knowledge of the bony component of hip joint will not only help the radiologists but will also be of immense importance to orthopaedicians and prosthetists².

Race, climate, heredity, and geographical areas also have strong influence over anthropometric parameters of bone. Therefore, the present study was undertaken to know

the average vertical diameter of head of femur, diameter and depth of acetabulum in cadavers of North Karnataka Region.

Although various dimensions of acetabulum and femoral head have been measured by several studies and all such studies were conducted either on dry specimens or on X-rays. This study is unique because we are measuring hip joint parameters with soft tissues in situ.

Availability of such data can help in constructing best possible prosthesis for patients of total hip replacements in North Karnataka Region. Any deviation from the obtained parameters has a strong correlation with development of various kinds of hip joint diseases, such as primary osteoarthritis of hip, acetabular dysplasia etc.

Assessment of these parameters to detect the sex by radiograph, CT scan, MRI would include magnification errors and may not be cost effective for the developing countries like India. Awareness of average dimensions of hip joint in both sexes helps in determination of sex by forensic experts. As this is a cadaveric study, various parameters are almost near normal situations, as those encountered on operation table.

Anatomy of proximal femur and acetabulum are very important in total hip replacement surgery. The distance from the lesser trochanter to the centre of femoral head from contralateral hip during pre-operative templating is a useful means of predicted anatomy of proximal femur on the hip to be operated. When the anatomy is distorted and direct measurements are not possible, the ratio between vertical diameter of head of femur and the distance from lesser trochanter to centre of femoral head can be used as a

guide to determine geometry of proximal femur. This is how the study can contribute to total hip replacement surgery in North Karnataka Region³.

The implant devices and prosthesis designed for skeleton of western population are large in size, angles, orientation and thread lengths also mismatch the femora. This variable size implant will produce mismatch in prosthesis and give rise to many complications. Implants that are designed keeping in mind the anthropometric and biomechanics data will help in designing patient specific implants this will minimize the complications⁴.

Acetabulum is hemispherical cavity, central on the lateral aspect of the hip bone facing anteroinferiorly. It is valuable to know diameter and depth of acetabulum for surgical treatment of acetabular fractures. Anterior acetabular ridge morphology is important in total hip arthroplasty⁵.

Acetabular parameters also help in the detection of disputed sex. Acetabular depth is a very important parameter in diagnosis of the frequency of acetabular dysplasia and normal hip joint morphometry in adults.

The measurements of normal parameter of acetabulum are very important in North Karnataka people to give population specific data for acetabular parameters.

Knowledge of the anatomical parameters of bony components of hip joint is very essential as it will open new horizons into better understanding of etiopathogenesis of

diseases like primary osteoarthritis of hip joint. An abnormal joint is more prone to develop degenerative changes than a joint having normal anatomy.

Sixty hip joints were dissected in department of anatomy, KLE's J.N. Medical College, Belgaum. All the measurements were taken with vernier calipers and data obtained was analysed and interpreted.

AIMS AND OBJECTIVES

AIMS

- (a) To know the various parameters of hip joint in adult human cadavers of North Karnataka, this will be helpful to orthopedic surgeon and prosthetist to make best possible prosthesis for hip joint.
- (b) These parameters also help the forensic expert to detect the sex of given fragment of bone.
- (c) These parameters help us to understand the etio-pathogenesis of primary osteoarthritis.

OBJECTIVES

- (1) To measure following parameters in adult human cadavers of North Karnataka.
 - Vertical diameter of head of femur
 - Diameter of acetabulum
 - Depth of acetabulum
- (2) Compare and contrast the parameter of male and female cadavers.
- (3) Compare and contrast the right and left hip joint in males.
- (4) Compare and contrast the right and left hip joint in females.
- (5) To correlate average diameter of acetabulum with the average vertical diameter of head of femur in both males and females.

REVIEW OF LITERATURE FOR HIP JOINT

GROSS ANATOMY OF HIP JOINT

The hip joint is a multiaxial, synovial ball and socket (spherical, condyloid) type of joint. The femoral head articulates with cup shaped acetabulum, its centre lying little below the middle third of inguinal ligament. The articular surfaces are reciprocally curved but neither co-extensive nor completely congruent.

The femoral head is covered by articular cartilage, except for a rough pit for the ligament of teres. Femoral head is closely fitted to acetabulum in an area of almost half of a sphere. The acetabular articular surface is an incomplete ring. The lunate surface is broadest above where the pressure of body weight falls in erect posture and narrowest in pubic region. It is deficient at the acetabular notch.

Acetabular articular surface is covered by hyaline cartilage. The acetabular fossa within acetabulum is devoid of cartilage and fitted with fibro-fatty tissue, covered by synovial membrane. Acetabular depth is increased by acetabular labrum and the notch is bridged by transverse acetabular ligament.

Ligaments of joint are - capsular ligament with synovial membrane, acetabular labrum, transverse acetabular ligament, ligament of head of femur, iliofemoral ligament, pubofemoral ligament and ischiofemoral ligament. The joint is strengthened anteriorly by pubofemoral ligament, iliofemoral and posteriorly by ischiofemoral ligament.

Iliofemoral ligament- The iliofemoral ligament is inverted Y shaped ligament, which lies anteriorly and intimately blended with capsule. Its apex is attached between

the anterior inferior iliac spine and acetabular rim, its base to the intertrochanteric line. Ligament is usually pierced by ascending branch of lateral circumflex femoral artery. In erect posture line of gravity passes slightly behind the centre of both femoral heads. In order to prevent the natural tendency of backward tilting of the pelvis at the hip joint, the anterior part of the capsule is made strong by intervention of the strong iliofemoral ligament. The tension of the ligament prevents hyperextension of the hip joint. Intact iliofemoral ligament in dislocated hip joint act as a fulcrum to set the femoral head in acetabular socket.

Pubofemoral ligament- The pubofemoral ligament is a triangular ligament with base above and apex below. It lies inferomedially and supports the joint on this aspect. Its base is attached to iliopubic eminence, superior pubic ramus and obturator crest. Inferiorly it blends with anteroinferior part of capsule and medial band of iliofemoral ligament.

Ischiofemoral ligament- It is relatively weak and supports the capsule posteriorly. Above it is attached to ischium posteroinferior to the acetabulum. From ischium its fibres spiral behind the femoral neck to be attached into greater trochanter deep to the iliofemoral ligament.

Ligament of the head of femur- This ligament is also called round ligament or ligamentous teres of head of femur. It is triangular ligament with apex attached to fovea of the head and its base to the transverse acetabular ligament. It is ensheathed by a conical reflection of the synovial membrane. It does not increase the stability of joint. It carries arteries to the head of femur derived from acetabular branch of the obturator and

medial circumflex femoral arteries. In fracture of femoral neck these arteries may be torn which gives higher incidence of necrosis of femoral head.

Movements at this joint include- flexion, extension, adduction, abduction, circumduction, medial rotation and lateral rotation.

Flexion of hip with extended knee is limited to about 90 to 100 degree due to tension of hamstring muscle but the range of flexion is increased to about 120 degree when the knee is flexed. Passive flexion of hip until it meets the abdomen is associated with some degree of flexion of vertebral column. Flexion makes the joint loose pack and the capsule is relaxed. Range of extension beyond vertical line about 10-20 degree and is arrested by the tension of iliofemoral ligament. All ligaments are maximally taut in extension and head occupies the depth of acetabular socket with maximum congruence in extension. So extension makes joint close packed in position.

Adduction and abduction takes place in anteroposterior axis, which passes through centre of head of femur. Adduction is limited by apposition of opposite thigh and by tension of the lateral band of iliofemoral ligament and ligamentum teres femoris. Medial and lateral rotation occurs around a vertical axis, upper end of which passes through centre of head of femur. The lower end of the axial line passes through medial condyle of femur when the foot is on the ground.

Arterial supply of head and neck of femur is clinically very important. It is derived from acetabular branch of obturator artery and medial circumflex femoral artery. These arteries reach the head through round ligament of head. Retinacular vessels arise from

medial circumflex femoral artery, run along the neck of the femur through capsule. Nutrient artery of femur gives few branches to the neck and head of femur⁶.

Hip joint is an example of ball and socket type. The range of movement provided by the hip joint is less than that of shoulder joint but hip joint provides much more strength and stability than shoulder joint. These features of hip joint arise from:-

- (1) The depth of acetabulum increased by acetabular labrum
- (2) Strength of the ligaments and the surrounding muscles

The long narrow neck of femur increases the range of movement but produces weak zone which is liable to fracture especially in the aged persons⁷.

Chauhan R, Paul S, Dhaon B K (2002) from department of anatomy in MAMC - Delhi studied fifty four hip joints in North Indian cadavers. The study was done on cadavers with soft tissue in situ. This gives average values of various parameters to near normal situation.

Their study revealed that the average vertical diameter of head of femur in males was 45.44 mm and 45.84 mm on right and left side respectively. In females the values were 43.87 mm and 44.67 mm on right and left side respectively. They observed the average vertical diameter of head of femur was 45.64 mm in males and 44.27 mm in females. They reported the vertical diameter of head of femur was 44.55 mm on right side and 45.25 mm on left side. Average diameter of acetabulum was found to be 47.10 mm in males and 44.38 mm in females on right side. The corresponding measurement was 47.48 mm in males and 46.00 mm in females on left side. They reported its value in males was 47.29 mm and in females its value was 45.19 mm. The average depth of

REVIEW OF LITERATURE

acetabulum was found to be 27.49 mm in males and 24.68 mm in females on right side. The corresponding measurement on left side was 28.18 mm in males and 27.70 mm in females. They found that the depth of acetabulum was 27.83 mm and 25.19 mm in males and in females respectively

Their study showed that all three parameters were greater in males than in females. Mean values for all the three parameters were greater on left side than on right side. The mean values of the acetabular diameter were greater than the vertical diameter of head of femur, which accounts for the rarity of occurrence of primary osteoarthritis in Indians².

Christos Papaloucas et al. (2007) studied 100 male and 100 female right pelvic and femoral bones in Greece. They measured distance from pubic tubercle to anterior rim of acetabulum, vertical diameter of femoral head, and depth of acetabulum on hip joint bones. They found that average distance from pubic tubercle to acetabulum anterior margin is 50.80 mm in males and 53.60 mm in females. Average diameter of acetabulum in males is 55.70 mm and 49.10 mm in females. Average depth of acetabulum in males was 24.20 mm and in females it was 20.40 mm. Average vertical diameters of head of femur in males was 48.50 mm and 41.60 mm in females.

They have concluded that all measured values were greater in males than the females. The distance from pubic tubercle to anterior rim of acetabulum was smaller than diameter of the acetabulum in males. The ratio of this distance over diameter of acetabulum was larger in females. They have also concluded that ratio of vertical femoral head diameter over acetabular diameter is reduced in females. This ratio favours the

REVIEW OF LITERATURE

higher incidence of congenital hip dislocation, most probably due to the loose fitting of the femoral head in acetabulum. It was also observed that women have significantly smaller femoral head radius and proportionally larger distance between the acetabulum rims than men. Both these features lead to an increase of contact stress in the hip joint articular surfaces. This factors in combination with other factors such as age, estrogen deficiency, after menopause results in higher incidence of osteoarthritis in females⁸.

Chhibber and Singh (1970) studied the weight of right and left lower limb in 10 cadavers and reported that the left lower limb was heavier in 7 cadavers and right lower limb was heavier in 3 cadavers. This difference in weight is believed to be a result of functional dominance of one limb over the other. So the parameters of left lower limb bone should be more than the right lower limb bones⁹.

Singh (1970) made observations on 94 right handed healthy medical students from Rohtak Medical College and 25 left handed non-medical persons from that area. He observed that while walking there is tendency to put left foot forwards in both right and left handed persons. This means wear and tear is more in left limb than the right limb. Almost all left handed and majority of right handed person put greater strain on left lower limb than on right lower limb. Thus dimension of bone forming the hip joint of left side should be more, so as to bear greater loading force on femur¹⁰.

Krogman WM et al. (1946) showed that not more than 95 % accuracy can be achieved even when all bones of the human body are present for identification of an individual. This makes identification of sex from single bone very difficult. Male bones

are however, generally longer, thicker and heavier, with prominent muscle attachments¹¹.

Kurrat et al. (1978) studied 10 hip joints from embalmed cadavers in Germany. He has done the study to measure thickness of articular cartilage and simultaneously measured vertical diameters of head of femur and diameter acetabulum. He found that the vertical diameter of head of femur for males ranges from 49 to 52 mm and for females it was from 39 to 43 mm. The diameter of acetabulum for male cadavers was 49-53 mm and for female cadavers it was from 43 to 45 mm¹².

Yasar Iscan and Ding Shihai (1995) studied 87 Chinese adult skeletons and concluded that distal epiphyseal breadth is most dimorphic part of Chinese femur. This was in contrast with earlier findings on American white and black population in which vertical diameter of head of femur was most dimorphic. This and other significant differences underscore the necessity of obtaining population specific values for metric analysis of sex. Finally they have concluded that maximum dimorphism was found at major weight bearing joints suggesting that, the size difference between Chinese males and females may be in large part functional in nature, perhaps arising from sex-specific physical activities. They also reported that the vertical diameter of head of femur in males was 46.16mm and in females it was 41.13¹³.

A study by RC Siwach and S Dahiya (2003) from PGIMS Rohtak India studied 150 cadaveric femurs morphologically and radiologically using standardized technique to obtain anthropometric parameters like vertical diameter of head of femur, femoral head position, and femoral neck ante-version and neck-shaft angle. These measurements were

used to calculate the femoral head volume and cross sectional area of femoral neck. Percentage of neck occupied by various implants was calculated. These values were compared with values in Hong Kong, Caucasian, Chinese and Westerns. It was concluded that implant designed for Western populations should be used judiciously and future implants designed were to be customized to suit Indian bones. The incidence of intra-operative complication like splintering and fractures are due to oversized implants which were manufactured keeping in mind Western parameters of femurs¹⁴.

K.R. Nagesh et al. (2006) studied adult hip bone of 36 males and 31 females belonging to South Indian population. They concluded that sex of a person can be identified by acetabulum - pubic index. By acetabulum - pubic index they found that index below 77.50 identified as females, the accuracy is 81.00 %. If the index is above 77.50, they were identified as males with 83.00 % accuracy¹⁵.

B.Genser -strobl et al. (2004) in Austria studied forty two hip joint by p40 plastination procedure. Hip joint were cut into slices 3 mm thick, for exact distance measuring, the sections were scanned into the computer. Following mean measurements for hip joint were obtained. They found that the average vertical diameter of head of femur was 48.94mm. Diameter of acetabulum was 48.94 mm and depth of acetabulum was 16.43 mm in Austrian hip joints. Femoral head radius was 22.68 mm. The aim of study was to introduce an unconventional and new method for morphometric hip data by using plastination¹⁶.

KC Saikia et al. (2008) studied 104 individuals out of which 63 were males and 41 were females in Guwahati Medical College, Assam, India. They found that acetabular

depth was 2.5 cm in males and 2.5 cm in females. They also found that vertical diameter of head of femur was 43.05 mm in males and 40.75 mm in females. They concluded that anatomical parameters of hip joint, is very essential as it would help better understanding of etio-pathogenesis of disease like primary osteoarthritis of hip joint. Awareness of average diameter of acetabulum and femoral head would assist prosthetist in designing suitable prosthesis according to need of a particular individual. The parameter and its values show difference when compared to other Western literature¹⁷.

S Das De et al. (1985) studied sixty hip joints from fresh cadavers, obtained from national university of Singapore and general hospital, Singapore. This included 52 male and 8 female hip joints. They found that 57 out of 60 hips showed no progressive type of degenerative changes. The progressive type of change was seen in only three hips. Two of these hips showed changes in superior posterior zone of the acetabulum and corresponding mirror areas from femoral head. These two specimens had ununited fracture neck of femur and it seems possible that some biomechanical alteration of joint loading had followed injury to these two joints. Thus only one specimen showed unexplained progressive degenerative changes. From this finding it has been concluded that age related degenerative changes are not uncommon in Asian hips but progressive degenerative changes leading to osteoarthritis are rare¹⁸.

Young – Hoo Kim (1989) in Korea studied acetabulum in 172 fetus and 665 adults. He found that fetal acetabulae and femoral heads are spherical and that proportion of the head contained in acetabulum remains constant and congruous throughout the fetal

and adult life. No evidence was found that the congruity of hip joint was a cause of osteoarthritis. Stable hip joint at birth have low incidence of congenital dislocation of hip. The spherical femoral head and acetabulum seem to be contributing factor for low incidence of primary osteoarthritis of hip in Koreans¹⁹.

Review of literature for vertical diameter of head of femur

Ruma Purkait and Heeresh Chandra (2002) studied 280 dry adult femora from 200 males and 80 females from resident of Central India. In their study the mean vertical diameter of head of femur was found to be 44.28 mm in males and 38.39 mm in females. They concluded that sexual dimorphism was maximum at the ends of femur. The ends of a bone are the areas where a number of muscles make their insertion and subjected to more pull than at the point of origin. If sex of a person has to be detected, then vertical diameter of head of femur is the single best determinant with an accuracy of 91.1 % and epicondylar width with 89.6% accuracy²⁰.

Michael Sean Patton et al. (2006) studied relationship between proximal femoral geometry and fracture of hip joint in England. For this he studied radiographs of 50 patients with intracapsular and 50 patients with extracapsular fractures of hip. The parameters studied on this radiograph are neck width, vertical head diameter, trochanter diameter, neck length. He found the vertical diameter of head of femur in males 60.20 mm and 53.93 mm in females. This shows that vertical diameter of head of femur is more in males than in females. They also concluded that increase in femoral neck length is the cause of increased proximal femoral fractures in elderly people. It has been suggested that variations in proximal femoral geometry also play important role in hip fracture²¹.

REVIEW OF LITERATURE

Masood Umer et al. (2010) in Pakistan studied pelvic radiographs of 116 male and 20 female healthy volunteers. The purpose of the study is to measure the morphology of the proximal femur in Pakistan. They studied 12 parameters of proximal femur, among them one parameter was vertical diameter of head of femur. The mean vertical diameter of head of femur in Pakistani population was 50.10 mm. They also concluded that morphology of proximal femur in studied population differed significantly from those of western population indicating the regional variation. So these parameters can be utilized to construct population specific prosthesis in Pakistan²².

Thomas K Black (1978) studied 114 skeletons from Ohio USA, which included 63 males and 51 female skeletons. He measured femoral head circumference and femoral length for the determination of sex from fragment of femur. They recorded that individuals with femur circumference greater than 81mm were classified as males, those with circumference less than 81mm classified as females. Of the 107 individuals who were assigned sex by femoral head circumference, 85% were correctly classified. From this they concluded that femoral head circumference can be a useful tool in determination of sex, especially where skeletal remains are fragmentary or poorly preserved. For skeletal collections in good condition, femoral head circumference can serve as rapid and reliable method of sexual assessment²³

Javadekar BS (1961) studied 108 femora from 86 adult male and 22 adult female cadavers in India. Measurements were taken from femora with articular cartilage in situ. In his study the average vertical diameter of head of femur in males was 45.26 mm and in females 40.37 mm. He studied that femur showing a diameter of less than 40 mm can be identified as female and one having diameter more than 45 mm should be considered as

male. He also found that the maximum difference between right and left femoral diameter is 2 mm in a same individual²⁴.

Prasad R, et al. (1996) studied 171 adult femurs from south India, grouped into males and females. All bones belonged to subjects from Tamilnadu in South India. From these 171 adult femora they had taken many dimensions, among them one was vertical diameter of head of femur. In their study average vertical diameter of head of femur was 43 mm in males and 39.10 mm in females. They reported that vertical diameter of head of femur was 41.05 mm on right side and 41.05 on left side. They also observed that there was significant difference in mean vertical diameter of head of femur between males and females. No significant differences in values were observed between right and left side. They also suggested that bone fragments such as head of femur can be used to determine the length of femur²⁵.

Akhtari Afroze, M Durrul Huda (2005) studied the vertical diameter of head of femur in Bangladeshi people. They studied 123 paired human femora (radiological view) of which 52 were males and 71 were females. In this study they have measured both vertical and transverse diameter of head of femur. They found that there was no significant difference between the values on right and left side of vertical diameter of femoral head. In males identification point for vertical diameter of head of femur were 53 mm on right side and 52 mm on left side. In females it was 43 mm on right side and 42 mm on left side. They concluded that the values for vertical diameter of head of femur were more for Bangladeshi males than the females. They reported the value for vertical diameter of head of femur was 51.55 mm in males and 45.65 mm in females. They also

found that the vertical diameter of head of femur was 48.65 mm on right side and 48.55 mm on left side¹.

Thomas Dwight (1905) studied 200 male and 200 female femora obtained from Harvard Medical College, America. He took measurements with the cartilage intact. The average measurement of vertical diameter of head of femur in males was 49.68 mm and in females it was 43.84 mm. All measurements were on bones of both sides. He concluded that head of femur was larger in males as compared with females²⁶.

Felt WTL (1959) believed that gross shape of long bones was caused by intrinsic factors, while specific details were determined by the adaptation to functional environment. It is therefore likely that heredity is major factor in formation of long bones due to its different function in different race. They concluded that average vertical diameter of head of femur was different in different races²⁷.

Parson F G (1914) studied three hundred English femora, they showed that if vertical diameter of head of femur was greater than 47.00 mm, the bone belongs to a male and when below 45.00 mm, it is a female bone. The vertical diameter of head of male femur was 49 mm and 43.4 mm in female. They also found that the width of lower end of femur forms a valuable clue to the sex, in those cases in which the vertical diameter of head of femur was impossible to obtain. A breadth of lower end of femur below 71 mm was identified as bone of a female and above 72 mm as bone of a male²⁸.

Hasimoto M (1938) studied the Chinese femurs, found that vertical diameter of head of femur for males were 46.80 mm. He concluded that if vertical diameter of head of femur is more than 47mm then the bone belongs to the male²⁹.

REVIEW OF LITERATURE

According to Khan (1959), on Indian subjects in Bombay, vertical diameter of head of femur was 48.00 mm in males and 41.00 mm in females³⁰.

A study on Australian Aborigine by V. Davivongs (1963) showed that the vertical diameter of femoral head in males was 43.05 mm and in females 38.16mm. He examined 75 males and 75 females dry femur bone and found these values. In his study there was very great difference in the values of male and female for vertical diameter of femoral head³¹.

A study was done by L. Lofgren (1956) on adult male and female femora in Finland. He measured the vertical diameter of head of femur by measuring it from highest and lowest point on head of femur. He found that average vertical diameter of head of femur in males was 48 mm and it was 44 mm in females. He had not compared left and right side parameters of femur. He concluded that value for vertical diameter of head of femur was greater in males than in females³².

A study done by Gonzalo J Trancho et al. (1997) on 132 femora, which include 60 male and 72 female femora from Spanish population. They found that vertical diameter of head of femur was 47.15 mm in males and 41.13 mm in females. There was a significant difference between male and female vertical diameter of head of femur. They concluded that these differences are mainly due to differences in body size and muscular activity in both the sexes. They concluded that in 90 % of cases we can determine sex of a person by proximal end of femur³³.

B. Isaac et al. (1996) studied 171 adult South Indian femora devoid of any gross pathology. They measured parameters like neck-shaft angle, length of neck, maximum

vertical diameter of head of femur. Regression equations for neck-shaft angle correlated with other parameters. From this correlation, following conclusions were derived:-

- (a) Neck-shaft angle can be estimated from proximal femoral fragment.
- (b) Required size of the length of neck can be determined to design prosthesis for restoration of normal neck-shaft angle.

They also found that vertical diameter of head of femur correlates positively with maximum femoral length suggesting short stature to have smaller vertical diameter of head of femur³⁴.

S.A. Asala et al. (1998) studied the vertical diameters of head of femur of 504 human femurs, which included 257 males and 247 females from Nigeria. The identification and demarking points were determined. The mean vertical diameter of head of femur in males was significantly greater than females. The vertical diameter of head of femur in males was 54.23 mm and 54.08mm on right and left femora respectively. In females it was 47.14mm and 46.83 mm on right and left side respectively. They found that the vertical diameter of head of femur was 54.16 mm in males and 47.00 mm in females. They concluded that vertical diameter of femoral head as well as the identification and demarking points that are derived from them are of use in sex and regional identification of femora³⁵.

B.R. Kate (1964) studied 1000 femora from 15 cities in different regions of India. He found that the average vertical diameter of head of femur in North Indians was 42.00 mm and in South Indians it was 40.30 mm. The average for Indians was 41.20 mm from his study. It was also found that the males and females femur of selected place showed

REVIEW OF LITERATURE

that the average vertical diameter of head of femur was greater on right side in females. In places where measurements were taken on both right and left sides it was observed that the average vertical diameter of head of femur was more on right side. He also stated that vertical diameter of head of femur reaches at its maximum at the time of epiphyseal fusion. The average thickness of articular cartilage was found to be 2.8 mm with range of 1-4 mm. He also found that average vertical diameter of head of femur in Indian males was 41.50 mm and in Indian females was 39.00 mm³⁶.

S.A. Asala (2001) studied that the mean vertical diameter in 520 femora of South African white population of European origin and African blacks from South Africa. He found that mean vertical diameter of head of femur was 48.40 mm in males and 42.32 mm in females of South African whites of European origin. In African blacks it was 44.51 mm in males and 39.81 mm in females. They observed the vertical diameter of head of femur was 45.36 mm on right side and 45.36 mm on left side. There was no significant difference in values of right and left sides. In both races it was noted that vertical diameter of head of femur was significantly greater in males than in females. In both the sexes the values for vertical diameter of head of femur were greater in South African whites than black South Africans. This study shows the existence of racial difference in the vertical diameter of head of femur³⁷.

Leelavathy et al. (2001) did a study on 200 adult femora in St. John medical College Bangalore, India. It included 70 male and 90 female femurs. They have studied 10 parameters from the femur and the best parameter to determine sex was found out. The parameters are maximum length, A-P diaphyseal curvature index, trochanteric length, upper end length etc. These parameters were analyzed statistically and three step

analysis was made. Among the 10 parameters applied, length was found to be the best index in sex determination of femur. Male femur can be sexed with high degree accuracy while there is ambiguity in sexing the female femora. It has found that maximum femoral length is 2 cm more than trochantric length. It was also been observed that female femur was shorter than male femur. In the male left femur was longer than right femur³⁸.

Taner Ziylan et al. (2002) studied 72 femurs which included 36 right and 36 left side from University of Selek Turkey. All skeletal remains brought from different parts of Turkey. Total 11 parameters related to femur were taken. The statistical analysis of all measured parameters showed no significant difference between right and left femora except for the vertical diameter of right femoral head, which was significantly greater than those corresponding on left femur. Vertical diameter of head of right femur was 45.20 mm and that of left femur was 43.40 mm. Femoral anthropology from two different time periods revealed great amount of variations that are likely to be results of variable factors such as nature of work, mode of life, continuous modification of lifestyle. That may affect the characteristics of man as well as the effects of civilization on composition of human body in both positive and negative ways³⁹.

P.S. Igbigbi et al. (2000) studied 496 pelvic radiographs, from Queen Elizabeth Central Hospital, Malawi. They measured both vertical and transverse diameter of head of femur. Identification and demarking points were determined for vertical diameter of head of femur. Male identification points derived from vertical diameter of head of femur were 53.00 mm on right side and 56.00 mm on left side. In females identification point's values were 37.00 mm on right side and 42.00 mm on left side. Demarking points for vertical diameter of head of femur was 54.93 mm on right side and 54.76 mm on left side.

For females it was 37.77 mm on right side and 38.95 mm on left side. They found that the vertical diameter of head of femur was 48.30 mm in males and 44.56 mm in females. They observed the vertical diameter of head of femur was 46.45 mm on right side and 46.40 mm on left side. This study showed that both methods exhibited sexual dimorphism. They were less sophisticated and require fewer measurement of femoral head diameter than current method employed for sex determination. Use of demarking points for sex determination gave high level of accuracy. They concluded finally that cases where more sophisticated methods of sex determination from bone were lacking, identification points and demarking point's method should be used⁴⁰.

Aasis Unnanuntana et al. (2010) studied 200 cadaveric femora by digital photography. The determination of limb length during total hip arthroplasty requires consideration of both position of the acetabulum and the anatomy of proximal femur. They concluded that measurement of distance from lesser trochanter to centre of femoral head from contralateral hip during pre-operative period used for predicting anatomy of proximal femur on hip to be operated. When anatomy is distorted and direct measurement is not available for determination of geometry of proximal femur then the ratio between vertical diameter of head of femur and distance from lesser trochanter to centre of femoral head can be used to know the geometry of proximal femur. Hence vertical diameter of head of femur from available data helps in total hip replacement surgery. They reported that vertical diameter of head of femur in males was 55.46mm and in females was 48.73mm. They reported the vertical diameter of head of femur was 52.12 mm on right side and 52.06 mm on left side³.

REVIEW OF LITERATURE

AK Mishra et al. (2009) studied 25 adult cadaveric femora, morphologically and radiologically from Nepal Medical College Kathmandu Nepal. They concluded that implant device and prosthesis for Western skeleton were large in size, their angles, orientation and thread angle also mismatch the femora. To get rid of this problem was to fit the prosthesis on implants by removing more bone which decreased bone stock, increased the risk of intra-operative fractures and post-operative complication. Hence they concluded implants that were designed by taking into account of anthropometric and biomechanic data of specific population helped in designing patient specific implants, thereby minimized the complications. The average vertical diameter of head of femur morphologically was 42.90 mm and radiologically 44.26 mm in Nepali population⁴.

Gita Malla et al. (2002) studied 170 femora which include 100 male and 70 females from a German population. This study provided measurements of femoral dimensions in contemporary German population and analyzed sexual dimorphism by discriminant analysis. They found that the vertical diameter of head of femur was 49.0 mm in males and 44.0 mm in females, transverse head diameter was 49.00 mm in males and 43.00 mm in females. The stepwise procedure with all head measurement showed that the results for transverse diameter could not be improved. Both vertical and transverse diameter has almost same values. Above said parameters were greater in males than in females. This was due to the fact that male bones are longest, prominent muscular markers and they are heavy⁴¹.

Review of literature for parameters of acetabulum

B.Mukhopadhaya and B. Barooah (1967) studied anatomical parameter of head of femur and the acetabulum in 100 hip joints of 50 adult human cadavers. The cadavers were obtained from Patna Medical College. They concluded that the common habit among Indians of sitting on the floor or squatting keeps the hip joints in flexion thereby protecting joints from continuous weight bearing stress. This is a possible explanation for rarity of osteoarthritis among Indians. He found that the radius of femoral head is always less than the depth acetabulum, showing that head of femur will be perfectly fitted into acetabular cavity. It was also found that depth of acetabulum will be always more than the radius of head of femur. These findings shows that head will be perfectly fitted into acetabular cavity and no mechanical fault. Due to this osteoarthritis of hip joint is rare in Indians as compared with Western Population⁴².

Antun salamon et al. (2004) studied morphological characteristics of the acetabulum in 30 macerated pelvic bones in Croatia. They found that depth of acetabulum was in the range of 21mm to 38mm with mean value of 30mm. Values of limbus acetabuli curvature radius in the range of 21.80 to 30.50 mm with mean values of 25.80 mm. The mean diameter of acetabulum was 51.60mm. From these values they have concluded that the choice of prosthesis has to be in accordance with dimensions and shape of acetabulum, with properly designed mechanical elements. This is important for load transmission and mobility of prosthesis in hip joint replacement. This will prevent the endoprosthesis failure and development of complications⁴³.

Kordelle et al. (2006) studied the development of the acetabulum in patients of slipped capital femoral epiphysis, at Harvard medical school, Boston, USA. They found that mean diameter of acetabulum was 53.00 mm and mean depth of acetabulum was 23.00 mm. They also concluded that patients with slipped capital femoral epiphysis generally do well if the slip is mild because good congruity between femoral head and the acetabulum remains. Moderate to severe slip may cause some abnormality of acetabulum and eventually lead to degenerative joint disease such as osteoarthritis⁴⁴.

Namchai varodompun et al. (2002) studied in Bangkok, Thailand 152 dry pelvic bones, which includes 118 male bones and 34 female bones. Study had been done to determine the relation between acetabular diameter and thickness. They had measured the diameter and thickness in all 152 pelvic bones. The average diameter of acetabulum was found to be 51.82 mm for all acetabulums. The mean diameter for male bone was 52.38 mm and female bone was 49.54 mm. This shows values are greater in males than females for diameter of acetabulum. They have concluded that thickness of the posterior superior and posterior inferior parts of acetabulum were 85% and 72% of the acetabular diameters. They also showed that acetabulum can accommodate more than 37 mm and less than 44 mm of screw length in total hip replacement surgeries⁴⁵.

Walmsley T (1927) demonstrated that the femoral head was adjusted in acetabular cavity accurately and the movements of head of femur were limited. Joints in which bone surfaces are closely adapted in this way are particularly liable to strain injury and they are undoubted factors in production of osteoarthritis. So the study concluded that hip joint was more prone to develop osteoarthritis⁴⁶.

REVIEW OF LITERATURE

Lloyd Roberts GC (1955) did a study at Royal national Orthopedic Hospital London on cause of osteoarthritis. He observed that minor anatomical variation in between the articular surface of femoral head and acetabulum was the cause of osteoarthritis. He also noted that in more than fifty percent cases the etiology was unknown, among the idiopathic cases shallow acetabulum was the most common cause of osteoarthritis⁴⁷.

Radiological surveys by E.A. Nicoll and N.T. Holden (1961) in 350 hip joints in England found that very deep and very shallow acetabulum predisposed the person to osteoarthritis of hip joint. In his survey out of 350 cases 195 cases were of arthritis of hip joint. These people had the abnormal values of acetabular diameter. He found that abnormalities of acetabulum were more in females and hence females were more prone to develop osteoarthritis of hip joint⁴⁸.

Study by R. O. Murray (1965) in London examined pelvic radiographs of 200 patients. In this 100 hip joints had normal acetabular anatomy and rest of the hip had some kind of pathology. He concluded that osteoarthritis in the presence of normal anatomy was seen in 35 % with female to male preponderance of 4:1 approximately. Osteoarthritis in abnormal anatomy of acetabulum was observed in 65 % cases with female to male preponderance of 4:1. He also concluded that the onset of symptoms was 57.7 years in the presence of normal anatomy of acetabulum. The age of onset of symptoms was 51.5 years in the presence of abnormal anatomy of acetabulum. It suggested that onset of osteoarthritis symptoms were earlier when the anatomy of acetabulum was distorted. They also showed that, average depth of acetabulum in males and in females were 13.00 mm and 12.00 mm respectively⁴⁹.

John Emmett (1967) studied 148 acetabulum in adult human cadavers of age group 30-50 years, in New York University's Medical School. He found that diameter of acetabulum was 50.80 mm in males and 47.62 mm in females. Average depth of acetabulum was 25.40 mm in males and 23.81 mm in females. He concluded that the parameters were more in males than females⁵⁰.

A study in France by M.P. Moon et al. (1998) took measurement in 79 males and 76 females hemi pelvis. They found that average diameter of acetabulum was 51.92 mm in males and 47.17 mm in females. Depth of acetabulum was 26.91 mm in males and 24.77 mm in females. They concluded that both the parameters were more in males than females⁵¹.

A study was done by Macaluso PJ Jr (2009) on digital photographs of acetabulum from skeleton in France. The skeleton sample consists of 46 males and 36 females. The measurements were then subjected to both discriminate function and logistic regression analysis in order to develop osteometric standards for sex assessment. He concluded from his study that metric analysis of acetabular size provides a highly accurate and easily replicable, method of discriminating sex. He also concluded that addition of area and perimeter data of acetabulum derived from digital image may provide more effective method of sex assessment than that offered by traditional linear measurement alone⁵².

Macaluso PJ Jr (2010) analyzed a study by Styen and Patriquin who demonstrated that accuracies for a combined sample of South African blacks, whites, Greeks, differed very little from those obtained separately for three groups. They derived a formula for determining the sex of person from acetabular diameters. They were of the opinion that

formulae derived by their study for sex determination could apply to variety of populations. This study assessed the accuracy of discriminate function equation for acetabular diameter published by above said authors. Present study concluded that sex determination by population specific parameters and by grouped pool formulae did not differ appreciably. This study suggested that pelvic and non-pelvic data from disparate population, to develop additional osteometric standards for discriminating sex with high accuracy across human groups⁵³.

Murphy (2000) published a series of papers describing sexual dimorphism among New Zealand Polynesian skeletal remains. He studied 21 male and 35 female hip bones. He demonstrated that a single measurement of maximum diameter of acetabulum could be used to identify sex with approximately 85.2 % - 86.2% of the study sample correctly. Patriquen et al. (2005) noted that acetabular diameter was most diagnostic pelvic dimension among black South Africans yielding 84 % accuracy in identifying sex of a person⁵⁴.

Study by Aimee C. Perreira BS et al. (2011) on 50 pelvic CT scan from University of California, USA. They measured acetabular version using 3-d models thus eliminating positional factors. Acetabular retroversion is characterized by abnormal depth, acetabular bony coverage and orientation. They concluded that retroversion involves the acetabulum at all levels and include the entire pelvic segment containing the acetabulum and ischial spine. Acetabular retroversion was one of the causes of osteoarthritis of hip joint. Recognizing acetabular deformities and restoring normal anatomy may prevent the development of osteoarthritis⁵⁵.

S. Benazzi et al. (2008) studied 83 adult os coxae of known age. His study describes the diagnostic value of acetabulum in detection of sex, based on its planar image and related metric data. Digital photographs of acetabulum were taken, dimension related to acetabulum were derived using software. These measured dimensions were subjects to statistical programme for social sciences (SPSS) discriminant and classification of function analysis. These available values show significant difference between sexes, and 96.40 % of cases were correctly classified as male and female⁵⁶.

Werner Kohnlein MD et al. (2009) studied sixty six bony acetabulae from Institute of Anthropology Research, Switzerland. They found that the average diameter of acetabulum was 47.50 mm in females and 54.00 mm in males. The study also showed the difference in the depth of articular surface of acetabulum in males and females. Depth was less in females and more in males. So females were more prone to develop osteoarthritis than males due shallow acetabulum compared to males⁵⁷.

A study on Serbian population by D. Jeremic et al. (2011) evaluated morphology of human acetabulum for sex dimorphism. They evaluated 370 hip joint radiographs, which included 222 males and 148 females. They measured acetabular angle of sharp, centre edge angle of Weisberg, acetabular depth, acetabular obliquity. They found that average acetabular angle was 38.00 degree, average angle of Weisberg was 33.50 degree. The average acetabular depth was 11.9 mm, in males it was 12.5 mm, in females it was 11.20 mm. Mean acetabular roof obliquity was 7.6. If acetabular depth is less than 9 mm, this was considered to be acetabular dysplasia. Mean acetabular depth in Chinese population was 11.8 mm and in English population it was 14.40 mm. It was concluded from this study that the value of acetabular depth decreased with increase in age, the

value in females was less than that for males. This sex related differences in acetabular morphology were the cause for more dysplastic females acetabulae compared with males. This data suggest that prevalence of acetabular dysplasia was lower in Serbian population than Western population⁵⁸.

A radiographic study by Chang-Dong Han et al. (1998) on 591 Korean hip joints over 20 years old, which include 319 males and 276 females. Radiographs were used to measure the parameter of acetabulum. The parameters studied are centre edge angle, acetabular angle, acetabular depth, acetabular roof obliquity and roof angle. The mean acetabular depth was 10.90 mm. it was 11.50 mm in males and 10.20 mm in females. The values of acetabular depth decreased with increase in age, and value was less in females than males. This shallow acetabulum predisposes the females to osteoarthritis. In this study they had found that the prevalence of acetabular dysplasia was higher in Asia compared to western countries. The prevalence in England was 1.00% and in Korea it was 1.80%⁵⁹.

Jeong – Min Park et al. (2011) studied 428 radiographs which include 186 males and 242 females in Korea. They had studied centre edge angle, acetabular depth, acetabular angle, head-neck ratio, neck-shaft angle. Hip dysplasia is defined as centre edge angle < 25 degree, acetabular depth < 9 mm, acetabular angle <42 degree. These parameters were used to predict development of osteoarthritis. Average acetabular depth was 11.60 mm, in males it was 11.80 mm and in females it was 11.40 mm. They concluded that radiological parameters of hip dysplasia were strongly, if not perfectly, inter-correlated. Age and gender had significant association with radiological parameter

of hip dysplasia or proximal femoral deformity. Old age and female sexes were predisposing factors for acetabular dysplasia and osteoarthritis⁶⁰.

Funda Tastekin Aksu et al. (2006) studied 154 hip bones in Inciratti, Turkey. They measured depth of acetabulum, diameter of acetabulum and acetabular ridge morphology. The mean value for acetabular depth and diameter were 29.49 mm and 54.29 mm respectively. They found positive and significant correlation between depth and the diameter of acetabulum. They concluded that depth of acetabulum correlates with diameter of acetabulum. Most common acetabular shape was curved. This information may be helpful for early diagnosis of acetabular dysplasia, during arthroplasty, treatment of hip joint fractures and in diagnosing congenital hip dysplasia⁵.

METHODOLOGY

A total 60 hip joints were studied in 20 male and 10 female cadavers. The measurements were taken with soft tissue in situ, which includes vertical diameter of head of femur, diameter and depth of acetabulum. These measurements were taken using vernier caliper and a steel scale. Mean values of three parameters were recorded and compared between males and females. The mean values were compared with right and left side for males and females. The mean diameter of acetabulum was compared with mean vertical diameter of head of femur for both the sexes.

Material

The material for study will be 30 adult human cadavers obtained during routine dissection from department of anatomy, J .N. Medical College, Belgaum. The study was carried on 30 cadavers, which included 20 male and 10 female cadavers of age group 18 to 85 years.

Study Design

This is cross-sectional study.

Duration of study: One and half years

Sample size:

The study will be conducted on 30 adult cadavers that is on 60 hip joints. Sample size is based on probable number of cadavers that will be dissected during the study period.

Inclusion Criteria

All cadavers in the age group 18 to 85 years available during study period.

Exclusion Criteria

Cadavers with deformed or traumatized hip joint, pelvis and lower limb.

Method of collection of data

Permission was obtained from the head of department of anatomy and principle J.N.Medical College, Belgaum to conduct the study. The project was submitted to Independent Ethics Committee of J.N.Medical College, Belgaum. After getting approval letter from Independent Ethics Committee of J.N.Medical College Belgaum, the study commenced.

The followings steps were carried out to dissect hip joint on both sides as given in the Cunningham's Manual:

1. Femoral vessels and nerve were cut immediately inferior to inguinal ligament.
2. Sartorius and rectus femoris muscles were cut about 5 cm from their origins and turned downwards. Iliopsoas muscle was cut near its insertion and the two parts were turned upwards and downwards exposing the psoas bursa and capsule of hip joint. The bursa was removed and margins of thick iliofemoral ligament were identified.
3. Articular capsule was incised along the borders of iliofemoral ligament and all parts of capsule were removed.

4. Open the hip joint to disconnect the round ligament of femur or cutting the round ligament with scalpel⁷.

The dissected hip joints were considered normal if:--

a. The acetabulum was spherical and cartilage lining was smooth and horse shoe shaped and ended abruptly at the inner margin forming the acetabulum as unbroken line.

b. The articular cartilage of femoral head was smooth and uniform with no evidence of marginal ossification.

c. Outer edge of cartilage and labrum of acetabulum blended without any distinct demarcation.

d. Acetabular fossa was filled with fibro fatty tissue and it had smooth surface.

e. Head of femur should form two third of the sphere, with round ligament attached in its centre. Deformed or any congenital deformity of head of femur was excluded from the study.

With soft tissue in situ, using vernier caliper and metallic scale, various parameters of head of femur and acetabulum have been calculated as follows :-

(a) Vertical diameter of head of femur:-

Vernier caliper was used to measure vertical diameter of femoral head. It was taken at right angle to long axis of neck of femur, which meant the straight distance between the most superior to most inferior points of the femoral head. The transverse

diameter was not taken because there was not any significant difference between vertical and transverse diameter of head of femur.

(b)Diameter of acetabulum:-

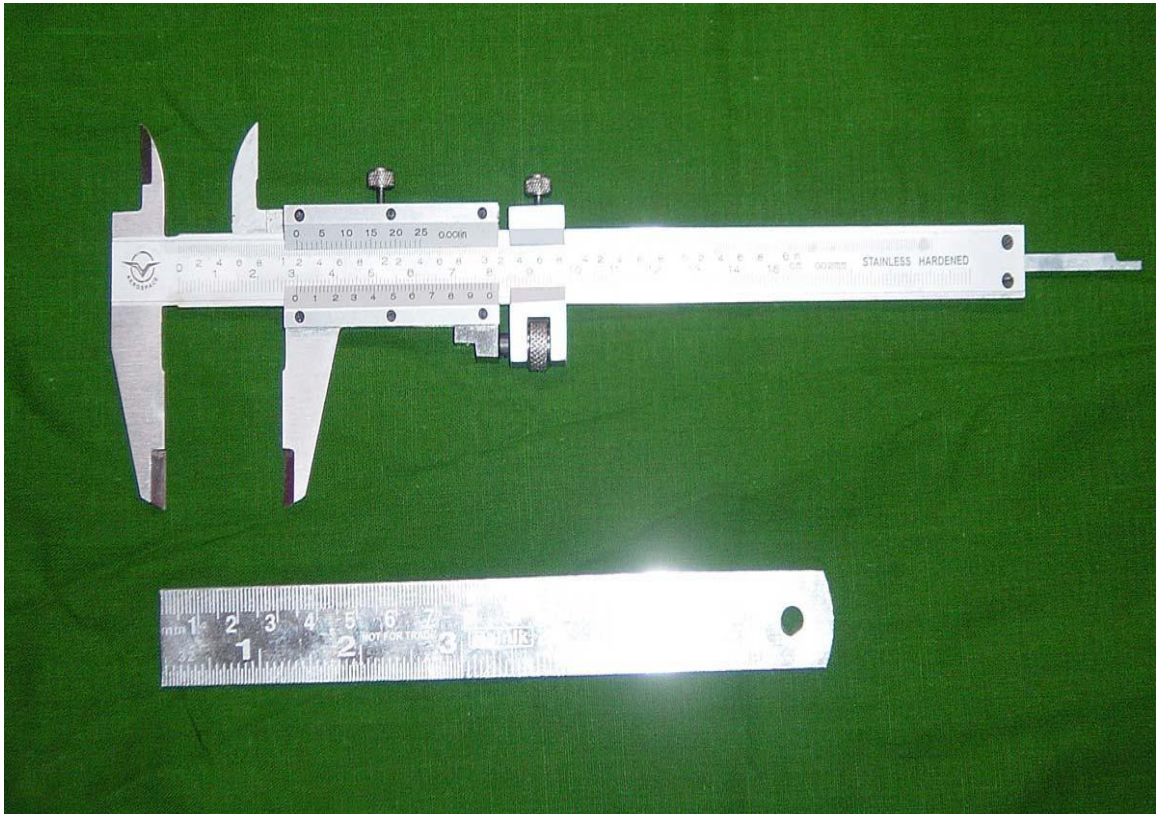
Maximum diameter of the acetabulum was measured across the edges of acetabulum using vernier caliper.

(c)Depth of acetabulum:-

A thin metallic scale was placed across diameter of the acetabulum. Depth of acetabulum was measured by using vernier caliper from centre of the acetabulum to metallic scale. Measurement was made more accurate as $1/10^{\text{th}}$ of a millimeter by vernier caliper.

Intraobserver variation was avoided by measuring each parameter three times by each of the three investigators and mean of the three readings were taken as final value and recorded.

FIG 1: MATERIALS USED FOR STUDY



INSTRUMENTS USED: VERNIER CALIPER AND METALLIC SCALE

FIG 2: METHOD USED FOR MEASURING VERTICAL DIAMETER OF HEAD OF FEMUR

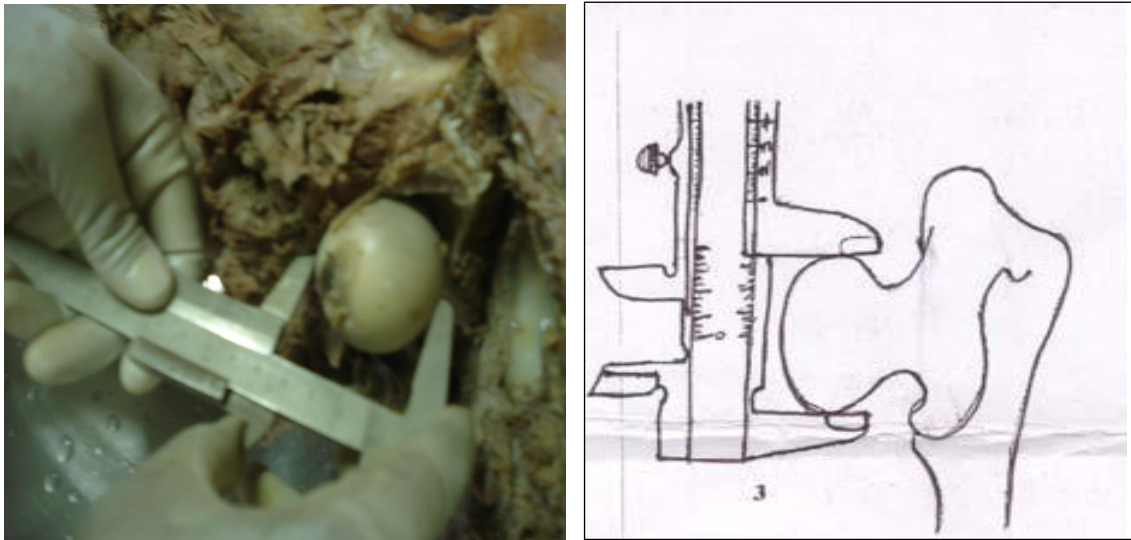


FIG 3: METHOD USED TO MEASURE DIAMETER OF ACETABULUM

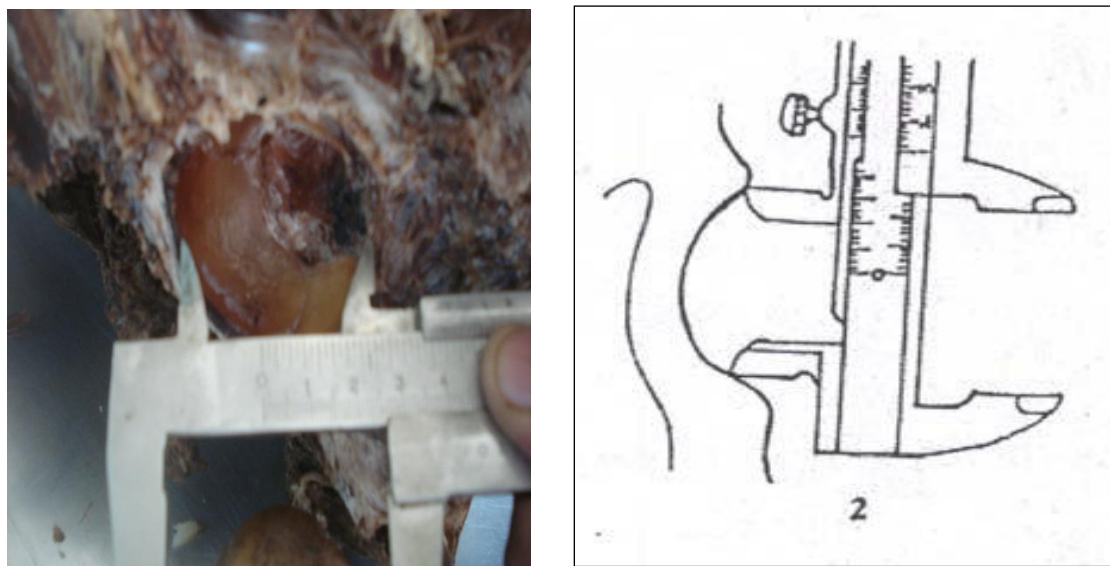


FIG 4: METHOD USED TO MEASURE DEPTH OF ACETABULUM



RESULTS

In this study parameters of sixty hip joints were measured using vernier caliper. In 30 human cadavers of age group 18-85 years belonging to 20 male cadavers and 10 female cadavers with soft tissue in situ.

The following parameters were taken:-

- Vertical diameter of head of femur
- Diameter of acetabulum
- Depth of acetabulum

All measurements were taken three times by three separate investigators. The mean of the three readings were considered as the final reading and recorded.

The data thus collected was analyzed and tabulated as follows:-

Measurements taken in sixty hip joints are given in table 1 and 2. This gives the mean values for vertical diameter of head of femur, diameter of acetabulum and depth of acetabulum of 40 males and 20 females hip joints.

In table 3, mean vertical diameter of head of femur for 20 right and 20 left hip joints in males and 10 right and 10 left side hip joints in females are given.

In table 4, mean diameter of acetabulum for 20 right and 20 left hip joints in males and 10 right and 10 left side hip joints in females are given.

In table 5, mean depth of acetabulum for 20 right and 20 left hip joints in males and 10 right and 10 left side hip joints in females are given.

From the mean values given in table 3, 4, 5, the mean values for all three parameters was calculated for 40 male hip joints and 20 female hip joints, which include hip joints of both sides. These values are given in table 6.

In males, the mean values of three parameters on right side were compared with corresponding left side values. (Table 7)

In females the mean values of three parameters on right side were compared with corresponding left side values. (Table 8)

The mean values of three parameters on right side in males were compared with corresponding values on right side in females. (Table 9)

The mean values of three parameters on left side in males were compared with corresponding values on left side in females. (Table 9)

In males and females right side mean values for diameter of acetabulum were correlated with right side mean value for vertical diameter of head of femur. (Table 10)

In males and females left side mean value for diameter of acetabulum were correlated with left side mean value for vertical diameter of head of femur. (Table 10)

Measurement taken in male cadavers (in mm) Table – 1

Serial no	Cadaver no	Vertical diameter of head of femur		Diameter of acetabulum		Depth of acetabulum	
		Right	Left	Right	Left	Right	left
1	1	43	42	46	45	32	33
2	3	46	46	47	46	30	32
3	4	46	45	46	47	25	26
4	6	45	46	46	46	33	31
5	7	44	42	44	44	30	30
6	9	45	44	45	45	36	34
7	10	43	41	44	43	34	32
8	12	44	44	45	45	33	32
9	14	45	45	46	46	32	31
10	16	42	43	44	43	30	31

Measurements taken in male cadavers (in mm) Table - 1

Serial no	Cadaver no	Vertical diameter of head of femur		Diameter of acetabulum		Depth of acetabulum	
		Right	Left	Right	Left	Right	Left
11	17	44	44	42	41	31	32
12	19	38	37	39	40	30	30
13	20	45	47	46	48	36	36
14	21	44	44	46	46	34	33
15	22	44	44	46	46	32	31
16	23	47	45	48	47	35	34
17	25	37	36	42	40	30	31
18	26	46	44	48	48	30	31
19	28	45	45	47	48	32	31
20	29	47	46	48	47	33	32

Measurements taken in female cadavers (in mm) Table – 2

Serial no	Cadaver no	Vertical diameter of head of femur		Diameter of acetabulum		Depth of acetabulum	
		Right	Left	Right	Left	Right	Left
1	2	41	42	42	43	32	31
2	5	40	40	42	42	30	28
3	8	37	36	38	40	30	29
4	11	40	36	41	40	28	27
5	13	44	43	45	44	28	27
6	15	43	42	44	43	33	32
7	18	40	39	41	40	30	29
8	24	42	41	43	42	31	30
9	27	39	38	40	38	30	28
10	30	42	41	42	40	31	30

Table. 3: Mean vertical diameter of head of femur (in mm)

	Male(n=20)		Female(n=20)	
	Right (20)	Left (20)	Right (10)	Left (10)
Minimum value	37	36	37	36
Maximum value	47	47	44	43
Mean	44.00	43.50	40.80	39.80
Standard deviation	2.57	2.81	2.04	2.48

Graph 1: showing mean vertical diameter of head of femur from table 3 (in mm)

Series1-Minimum value, Series2-Maximum value, Series3-Mean value

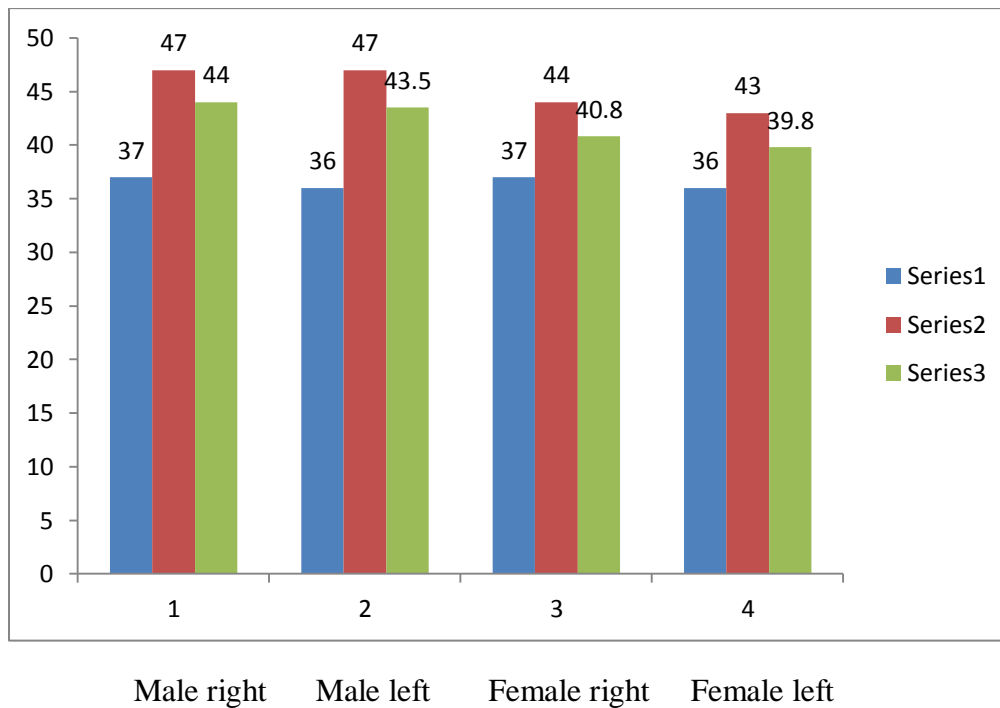


Table. 4: Mean diameter of acetabulum (in mm)

	Male (n = 40)		Female (n=20)	
	Right (20)	Left (20)	Right (10)	Left (10)
Minimum value	39	40	38	38
Maximum value	48	48	45	44
Mean	45.25	45.05	41.80	41.20
Standard deviation	2.26	2.50	1.98	1.87

Graph 2: showing mean diameter of acetabulum from table 4 (in mm)

Series1-Minimum value, Series2-Maximum value, Series3-Mean value

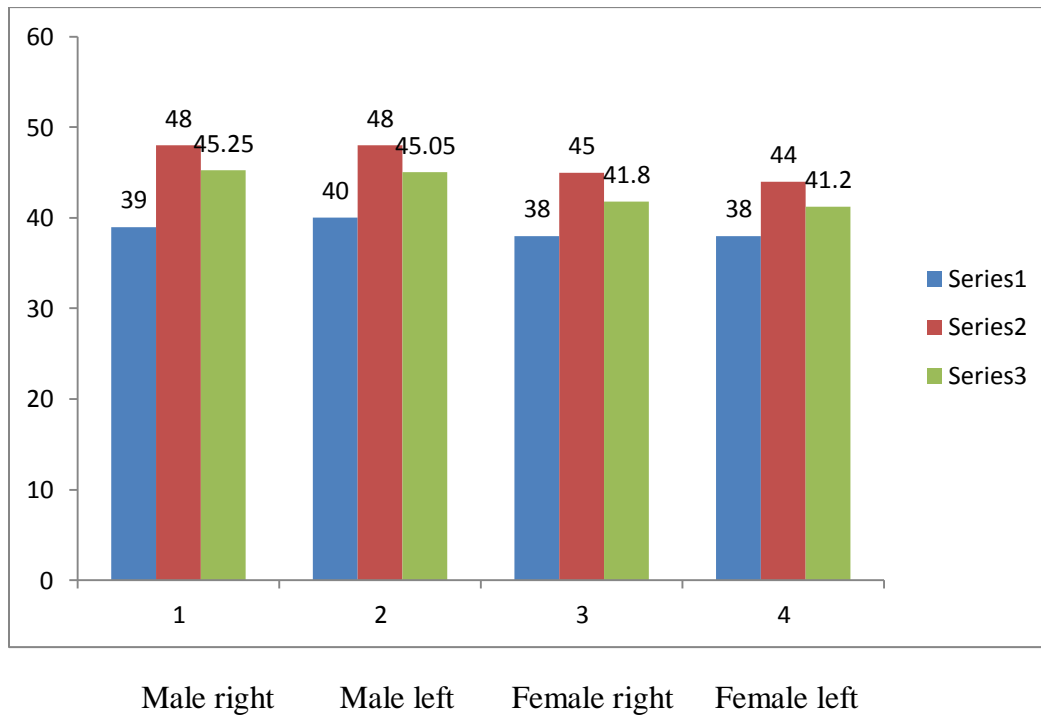


Table. 5: Mean depth of acetabulum (in mm)

	Male (n = 40)		Female (n=20)	
	Right (20)	Left (20)	Right (10)	Left (10)
Minimum value	25	26	28	27
Maximum value	36	36	33	32
Mean	31.90	31.65	30.30	29.10
Standard deviation	2.57	1.98	1.55	1.66

Graph 3: showing mean depth of acetabulum from table 5 (in mm)

Series1-Minimum value, Series2-Maximum value, Series3-Mean value

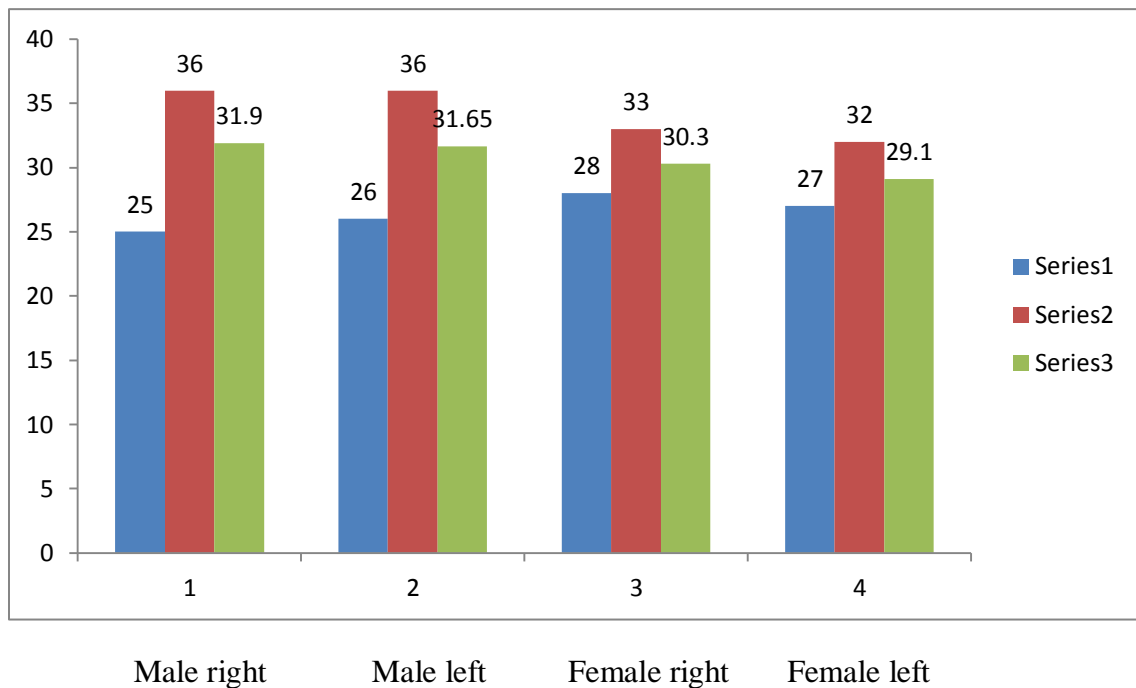


Table.6: Average values of three parameters (in mm)

Gender		Mean vertical diameter of head of femur	Mean diameter of acetabulum	Depth of acetabulum
Males	n = 40	43.75	45.15	31.78
Females	n = 20	40.30	41.50	29.70
Mean		42.02	43.32	30.74

Graph 4: showing average values of all three parameters from table - 6 (in mm)

Series 1- Males and Series 2- Females

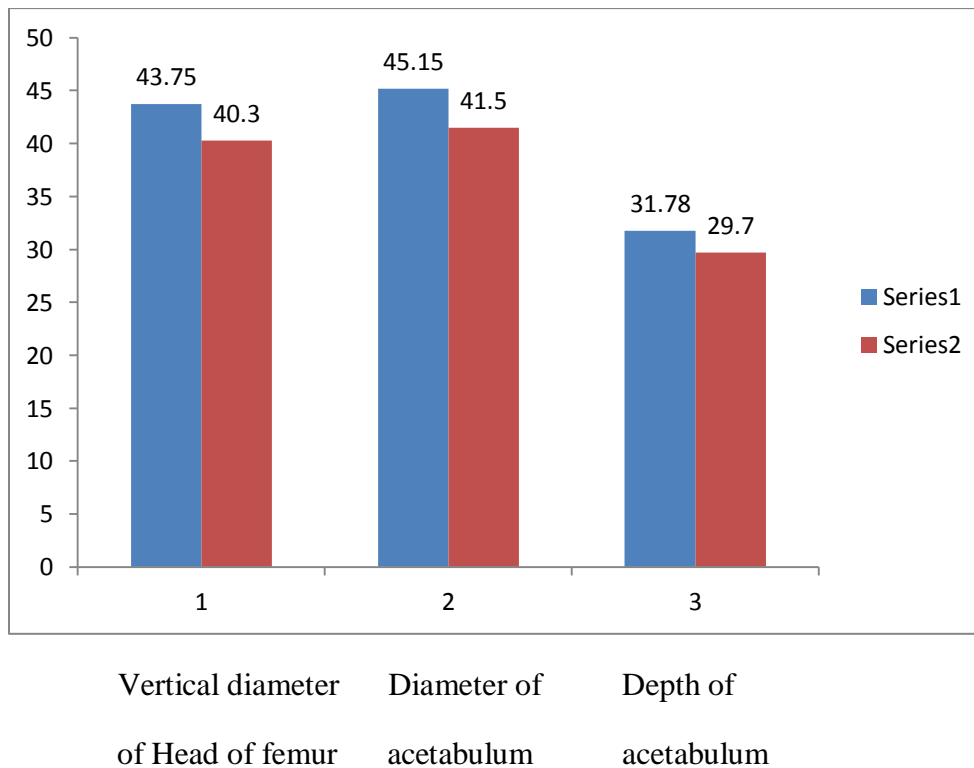


Table.7: Comparison of right side parameters with left side in males (in mm)

Parameters	Right			Left			P value
	n	Mean	SD	n	Mean	SD	
Vertical diameter of head of femur	20	44.00	2.57	20	43.50	2.81	0.056 S
Diameter of acetabulum	20	45.25	2.26	20	45.05	2.50	0.358 NS
Depth of acetabulum	20	31.90	2.57	20	31.65	1.98	0.366 NS

Graph 5: showing comparison average of right side parameters (in mm) with left side in males from table - 7

Series 1- right side, series 2- left side

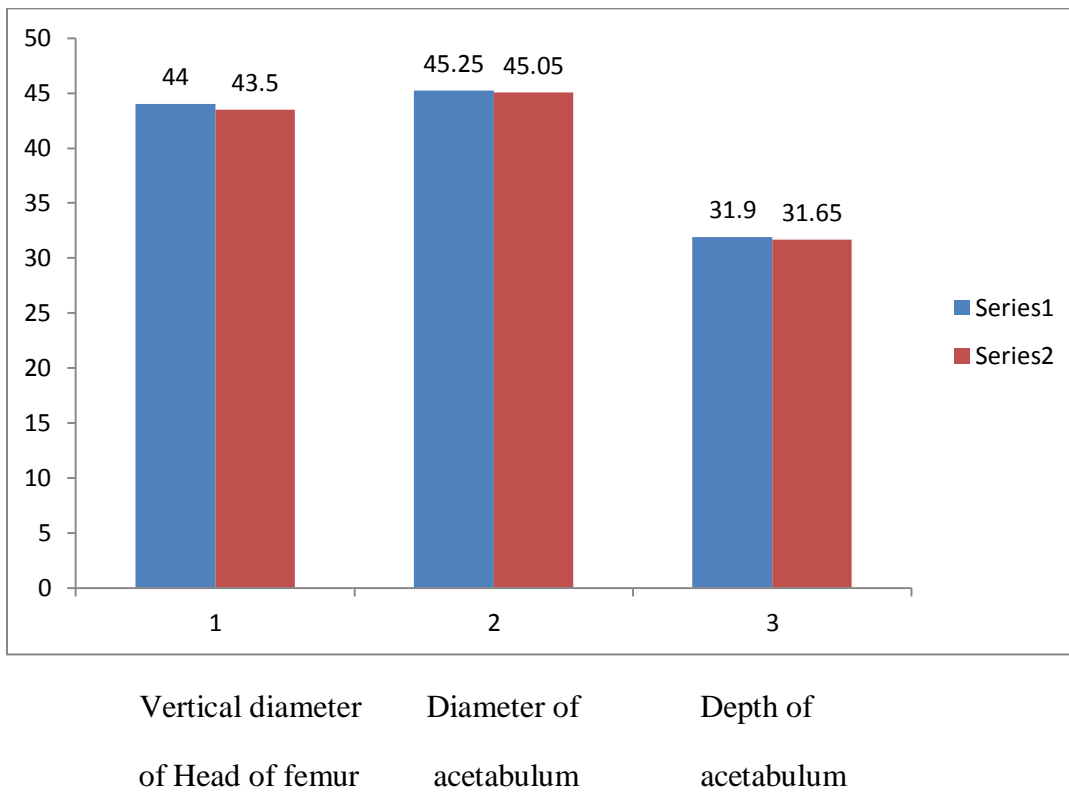
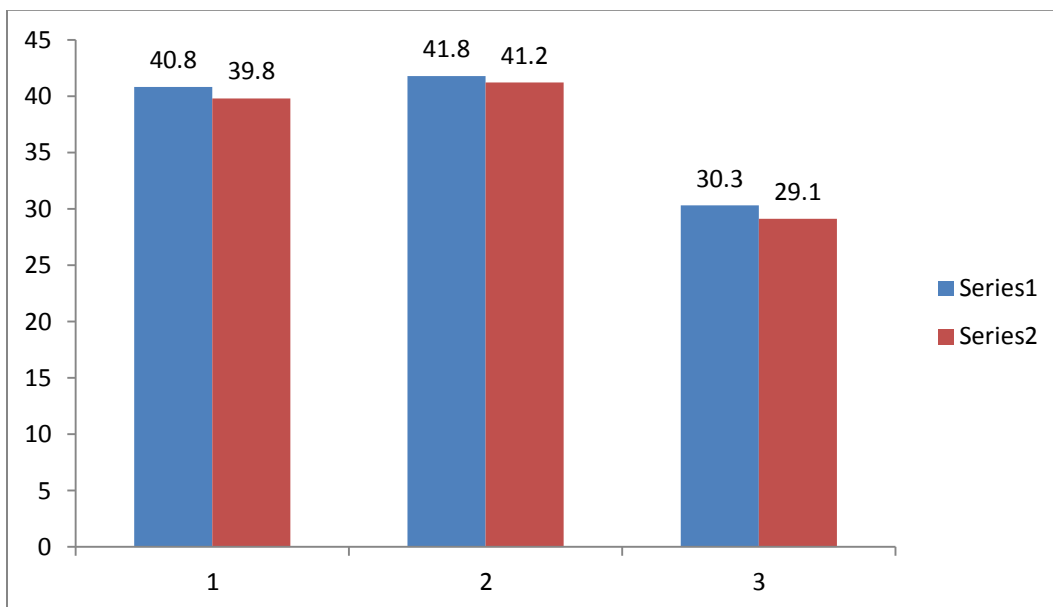


Table – 8: Comparison of right side parameters with left side in females (in mm)

Parameters	Right			Left			P value
	n	Mean	SD	n	Mean	SD	
Vertical diameter of head of femur	10	40.80	2.04	10	39.80	2.98	0.0319 S
Diameter of acetabulum	10	41.80	1.98	10	41.20	1.87	0.1678 NS
Depth of acetabulum	10	30.30	1.56	10	29.10	1.66	0.000008 S

Graph 6: showing Comparison of right side parameter with left side in females (in mm) from table 8

Series 1- right side and Series 2 – left side



Vertical diameter
of Head of femur

Diameter of
acetabulum

Depth of
acetabulum

Table – 9: Comparison of parameters (in mm) between males and females

Parameters	Side	Male			Female			P Value
		n	Mean	S.D.	n	Mean	S.D.	
Vertical diameter of head of femur	Right	20	44.00	2.57	10	40.80	2.04	0.002 S
	Left	20	43.50	2.81	10	39.80	2.98	0.0015 S
Diameter of acetabulum	Right	20	45.25	2.26	10	41.80	1.98	0.0003 S
	Left	20	45.05	2.50	10	41.20	1.87	0.00019 S
Depth of acetabulum	Right	20	31.90	2.57	10	30.30	1.56	0.0830 NS
	Left	20	31.65	1.98	10	29.10	1.66	0.0016 S

Graph 7: showing Comparison of parameters (in mm) between males and females from table 9

Series 1 –Male parameters, Series 2 – Female parameters

1and 2-Vertical diameter of head of femur, 3 and 4- Diameter of acetabulum, 5 and 6- Depth of acetabulum

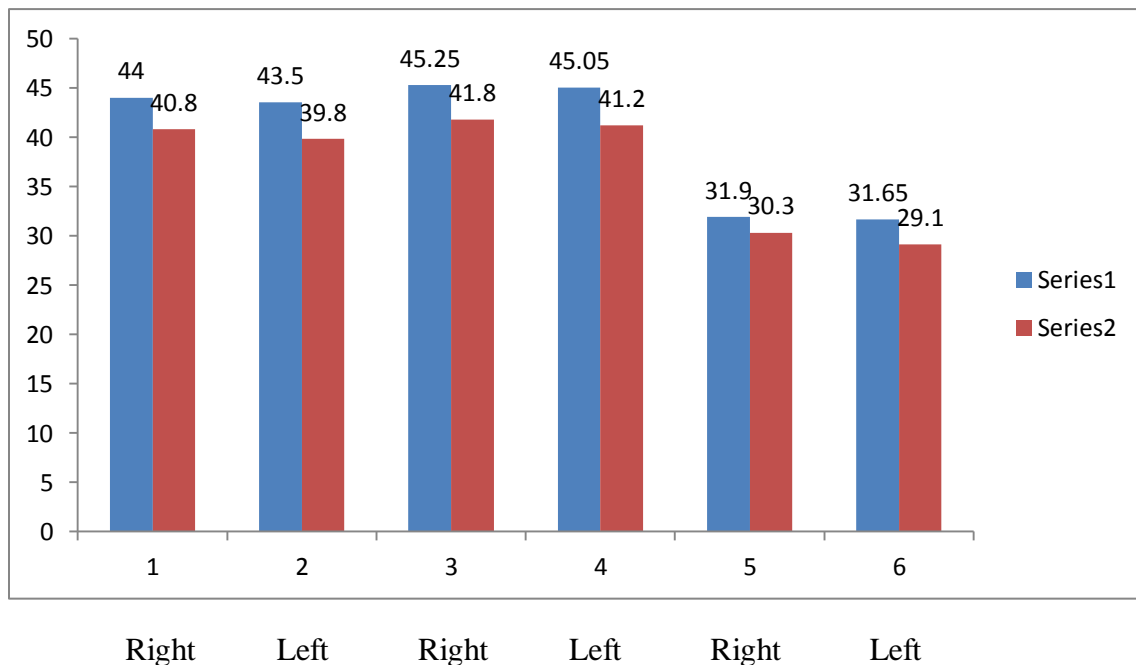
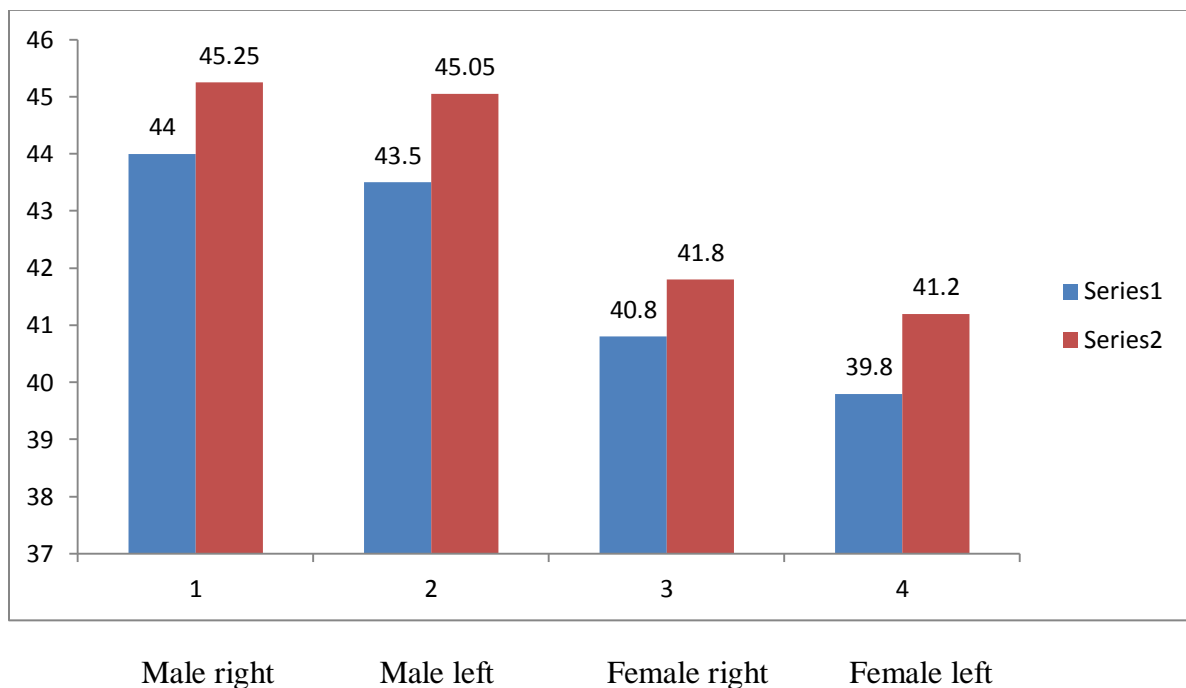


Table. 10: Comparison of vertical diameter of head of femur with diameter of acetabulum (in mm) in males and females

Gender	Side	n	Vertical diameter of head of femur	S.D.	Mean diameter of acetabulum	S.D.	P Value
Males	Right	20	44.00	2.57	45.25	2.26	<0.00001 S
	Left	20	43.50	2.81	45.05	2.50	<0.00001 S
Females	Right	10	40.80	2.04	41.80	1.98	<0.00001 S
	Left	10	39.80	2.98	41.20	1.87	<0.00001 S

Graph 8: showing comparison of vertical diameter of head of femur with diameter of acetabulum (in mm) from table - 10

Series 1- Vertical diameter of head of femur, Series 2 – Diameter of acetabulum



OBSERVATION**Males**

- (a) The mean vertical diameter of head of femur on right side was 44.00 mm and left side was 43.50 mm with range of 37 mm to 47 mm on right and 36 mm to 47 mm on left side.(Table 3)
- (b) The mean diameter of acetabulum was 45.25 mm on right side and 45.05 mm on left side with values range from 39 mm to 48 mm on right side and 40 mm to 48 mm on left side. (Table 4)
- (c) The mean depth of acetabulum was 31.90 mm on right side and 31.65 mm on left side. Minimum value for right side is 25 mm and maximum value for right side is 36 mm. On left side minimum value is 26 mm and maximum value was 36 mm. (Table 5)

From above observation it was concluded that all the parameter are more on right side than left side. This is because most of the people are right sided and they use right limbs most of the time.

Females

- (a)The mean vertical diameter of head of femur was 40.80 mm and 39.80 mm on right and left side respectively. The minimum value is 37 mm and 36 mm on right and left side respectively. . The maximum value for right side is 44 mm and for left side it is 43 mm. (Table 3)

(b)The mean diameter of acetabulum on right side is 41.80 mm and left side is 41.20 mm. The minimum value for right is 38 mm and left side is 38 mm. The maximum value for right side is 45 mm and left side is 44.00 mm.

(c)Mean depth of acetabulum on right side is 30.30 mm and 29.10 mm in left side. The minimum value for right side depth of acetabulum is 28 mm and left side it is 27 mm. The maximum value for right side is 33 mm and for left side it is 32 mm. (Table5)

From the above observations it was noted that the values are higher on right hip joint than on left hip joint parameters in females. (Table 8)

In all 10 cadavers studied in females the vertical diameter of head of femur, diameter of acetabulum and depth of acetabulum are greater on right side than on left side. It was also noted that no cadaver had the values greater than 2 mm difference on right and left side. (Table 2)

From above data comparison was made for male and female hip joint parameters. It was noted that the three parameters are more in males than females. The difference of values between males and females are statistically significant. The difference was significant for all the three parameters that is vertical diameter of head of femur, diameter of acetabulum and depth of acetabulum. (Table 9)

It was also observed from above parameters that diameter of acetabulum is always greater than the head of femur in both males and females. (Table 10)

DISCUSSION

Hip joint is one of the major joint of the body. It is a multiaxial, synovial ball and socket (spherical, cotyloid) type of joint. Menschik (1997) described it as rotational conchoids.

Dimension of the acetabulum and head of femur help in the reconstruction of hip joint i.e. help in manufacturing of best suitable prosthesis for the given population. Normal dimensions of the hip joint also help in the treatment of the acetabular fracture, and total hip replacement. Anatomical parameters of hip joint by radiographic techniques may produce magnification errors. So parameters obtained by present study are with soft tissues in situ. So these parameters are near to normal situation for a given population.

Knowledge of anatomical parameters of the bony components of hip joint is very essential because it will help in early detection of disputed sex of a person. We can also identify the race of a person by these parameters. Awareness of the normal parameter of hip joint can also help in diagnosis of acetabular dysplasia. In turn it opens a new horizon into understandings of etio-pathogenesis of diseases like primary osteoarthritis. An abnormal joint is more prone to develop osteoarthritis rather than joint with normal parameters.

Most of the workers studied the head of femur and acetabulum parameters separately. Most of the previous studies have been done just to identify sex, race, stature and the segment of bone or skeleton. The present study has been done keeping in mind the hip joint prosthesis and to know the etio-pathogenesis of primary osteoarthritis.

ANALYSIS OF VERTICAL DIAMETER OF HEAD OF FEMUR

The normal values for vertical diameter of head of femur in males and females are given in Table No. 11 for different set of populations

(A)VERTICAL DIAMETER OF HEAD OF FEMUR IN AFRICA AND WESTERN WORLD

Gita Malla et al. (2000) studied the vertical diameter of head of femur in Munich, on German population. They concluded that the vertical diameter of head of femur was 49.00 mm in males and 44.00 mm in females⁴¹.

P.S. Igbigi et al. (2000) studied femora in Blantyre, on Malawian population. They found that the vertical diameter of head of femur was 48.30 mm in males and 44.56 mm in females⁴⁰.

Asala SA et al. (1998) studied in Maiduguri, on Nigerian population and found that the vertical diameter of head of femur was 54.16 mm in males and 47.00 mm in females³⁵.

Again the study done by Singh et al. (1986) in Calabar cross river state, Nigeria observed the value of vertical diameter of head of femur was 52.02 mm in males and 46.80 mm in females¹⁰.

Clark et al. (1987) in Washington, USA reported that vertical diameter of head of femur was 51.30 mm in males and 46.80 mm in females⁶¹.

Thomas Dwight (1905) studied femur head in Ann Arbor, Michigan, USA. He reported that the vertical diameter of head of femur was 49.68 mm in males and 43.84 mm in females²⁶.

V.Davivongs (1963) studied femora of Australian Aborigines in Adelaide Australia. They showed mean vertical diameter of head of femur was 43.05 mm in males and 38.16 mm in females³¹.

Gonzalo et al. (1997) in Madrid, Spain observed the vertical diameter of head of femur was 47.15 mm in males and 41.13 mm in females³³.

Aasis Unnanuntana et al. (2002) studied vertical diameter of head of femur in Ohio, USA. They reported that vertical diameter of head of femur in males was 55.46 and in females was 48.73mm³.

From above said values the vertical diameter of head of femur for both males and females in Africa and Western world was greater than the present study. But the values of present study are very near to the study done by V.Davivong on femora of Australian Aborigine population.

(B) ANALYSIS FOR VERTICAL DIAMETER OF HEAD OF FEMUR IN ASIA:-

A study by Akhatari Afroze et al. (2005) in Rajshahi, Bangladesh reported the value for vertical diameter of head of femur was 51.55 mm in males and 45.65 mm in females¹.

A study by Yasar Iscan (1995) et al. in Etas-unis, China reported the vertical diameter of head of femur was 46.16 mm in males and 41.13 mm in females¹³.

These values of vertical diameter of head of femur are very close to the present study. But the values for vertical diameter of head of femur in Bangladesh are very close to the value to the Western world, which is greater than the present study.

(C) ANALYSIS FOR VERTICAL DIAMETER OF HEAD OF FEMUR IN INDIA:-

A study by Ruma Purkait et al. (2002) in Bhopal, Madhya Pradesh, Central Indian population found that the value of vertical diameter of head of femur was 44.28 mm in males and 38.39 mm in females²⁰.

Khan (1959) conducted a study on dry femur in Bombay, India found that the vertical diameter of head of femur was 48.00 mm in males and 41.00 mm in females³⁰.

Javadekar BS (1961) studied vertical diameter of head of femur in Ahmedabad, Gujarat. They found that the vertical diameter of head of femur was 45.26 mm in males and 40.37 mm in females²⁴.

B.R. Kate (1964) studied the femora from 15 cities from India. He found the average vertical diameter of head of femur in North Indians was 42.00 mm and in South India it was 40.03 mm and in Central India it was 40.90 mm. Average vertical diameter of head of femur was 41.20 mm for whole India. He reported that the average values for vertical diameter of head of femur in India, in males it was 41.50mm and in females it was 39.00 mm³⁶.

Rajendra Prasad et al. (1996) worked on dry femora in Vellore, Tamil Nadu, South India. They found the average vertical diameter of head of femur was 43.00 mm in males and 39.10 mm in females²⁵.

Chauhan R et al. (2002) did a cadaveric study in New Delhi, India. They observed the average vertical diameter of head of femur was 45.64 mm in males and 44.27 mm in females².

In present study the vertical diameter of head of femur was 43.75 mm in males and 40.30 mm in females. These values are very nearer to the studies done in South India. But the studies done in North India, Central India and in Gujarat the values are little higher than the present studies. It indicates that the values are different in different regions of India. This shows the regional variation of vertical diameter of head of femur in India.

From above studies it was also concluded that the vertical diameter of head of femur was more in males than in females. This sex difference in vertical diameter of head of femur was based on the fact that the males skeleton was longer and more robust than skeleton of an average females.

ANALYSIS OF VERTICAL DIAMETER OF HEAD OF FEMUR IN RIGHT AND LEFT SIDES (TABLE 12)

Aasic Unnanuntuna et al. (2010) studied the femora in Cleveland, Ohio, USA. They reported the vertical diameter of head of femur was 52.12 mm on right side and 52.06 mm on left side³.

P.S.Igbigbi et al. (2000) did a study in Blantyre, on Malawian population for head of femur. They observed the vertical diameter of head of femur was 46.45 mm on right side and 46.40 mm on left side⁴⁰.

Taner Ziylan et al. (2002) studied in Konya, Turkey and found that the vertical diameter of head of femur was 45.20 mm on right side and 43.40 mm on left side³⁹.

Akhtari Afroze et al. (2005) studied the femur in Rajshahi, Bangladesh and found that the vertical diameter of head of femur was 48.65 mm on right side and 48.55 mm on left side¹.

Rajendra Prasad et al. (1996) studied the femur in Vellore, Tamil Nadu, India. They reported that vertical diameter of head of femur was 41.05 mm on right side and 41.05 on left side²⁵.

Asala SA (2001) studied the femur in Johannesburg, South Africa and observed the vertical diameter of head of femur was 45.36 mm on right side and 45.36 mm on left side³⁷.

Chauhan R et al. (2002) in New Delhi, India studied the femur and reported the vertical diameter of head of femur was 44.55 mm on right side and 45.25 mm on left side².

The measurements of vertical diameter of head of femur vary from region to region. But there was very less difference between the vertical diameter of head of femur on right and left sides observed. In present study the vertical diameter of head of femur in males was 44.00 mm on right side and 43.50 mm on left side. In females it was 40.80mm on right side and 39.80mm on left side. Average value on right side was 42.40mm and on left side it was 41.65mm.

Javadekar BS (1961) from his study on femora observed the vertical diameter of head of femur on right and left side femora from same individual may have maximum difference of 2.00 mm.

In present study the vertical diameter of head of femur was more on right side than left side. But according to Chauhan et al. the mean vertical diameter of head of femur was greater on left side in both males and in females.

Rajendra Prasad et al., Asala SA (2001) concluded that there was no significant difference between right and left side in the vertical diameter of head of femur, which was same as that of the present study.

Singh et al. (1970) concluded that all the left handed and majority of right handed person put greater strain on left lower limb than right lower limb. Thus dimensions of bone forming left lower limb was more so as to bear greater loading force. But the present study shows the dimension of bone forming right lower limb is more.

A study by A.K.Mishra et al. (2009) in Khatmandu, Nepal reported the average value for vertical diameter of head of femur was 42.90 mm. This value was near to our study⁴.

Masood Umer et al. (2010) in Karachi, Pakistan by radiographic study found that mean value for vertical diameter of head of femur was 50.10mm²².

B.Gensor-Stroble et al. (2004) in Vienna Austria found that the average vertical diameter of head of femur was 48.94mm, which was greater than the present study¹⁶.

In present study the mean vertical diameter of head of femur was 42.02mm which is very close to study done by AK Mishra in Nepal. There was significant difference in mean values of studies done by B.Gensor Stroble and Masood Umer with present study. This was because Europeans have larger vertical diameter of head of femur than the Indians.

From the above study it can be concluded that if vertical diameter of head of femur was more than 44.00 mm the given bone belongs to a male. If the value of the vertical diameter of head of femur was less than 41mm, it can be concluded that the bone belongs to a female. This is how the present study helps in determining the sex of the person in North Karnataka.

A study by Issac et al. concluded that short statured persons have smaller vertical diameter of head of femur as compared to taller individuals. But in present study we have not measured the height of the cadavers and compared with the vertical diameter of head of femur. So this finding cannot be concluded from present study³⁴.

We also found that the vertical and transverse diameter of head of femur does not differ much. So we have measured the vertical diameter of head of femur. This finding was similar as that of Gita Malla et al. where they have concluded that the vertical and transverse diameter of head of femur does not differ much.

In the present study it was found that mean vertical diameter of head of femur was 43.75 mm in males and 40.30 in females. From this it can be concluded that the vertical diameter of head of femur in North Karnataka ranges from 40mm to 44mm. If vertical diameter of head of femur in given bone ranges between these values then it may be

concluded that the bone belongs to north Karnataka region. This is how present study will help in the identification of a person.

A study by AK Mishra concluded that the vertical diameter of head of femur can be utilized to design patient specific implant for hip replacement. So the vertical diameter of head of femur from present study can be utilized to design implant specific to North Karnataka population.

Taner Ziyalan et al. concluded that femoral head diameter from two different time period revealed great amount of variation. This variation was due to modification of life style and mode of work. As we observed values from table 11 from Indian studies it shows that the value from present study does not show much variation.

ACETABULUM

ANALYSIS OF DIAMETER OF ACETABULUM

Analysis of diameter of acetabulum presented in table 13

Study by Shino et al. (1950) in Basel, Switzerland, found that diameter of acetabulum was 54.00 mm in males and 49.20 mm in females⁶².

Study by Stein et al. in San Francisco, USA, reported the diameter of acetabulum was 55.70 mm in males and 48.50 mm in females⁶³.

Thompson et al. (2000) in London, UK, observed diameter of acetabulum was 52.90 mm in males and 45.10 mm in females⁶⁴.

Chauhan R et al. (2002) in New Delhi, India, studied in North Indian population the average diameter of acetabulum. They reported its value in males was 47.29 mm and in females its value was 45.19 mm. These values are very near to the values of present study².

John Emmett et al. (1967) carried a study on hip bone in New York, USA and found that the average diameter of acetabulum in males and in females was 50.80 mm and 47.62 mm respectively⁵⁶.

M.P.Moon et al. (1998) in Paris, France studied the diameter of acetabulum. He reported the diameter of acetabulum in males and in females was 51.92 mm and 47.17 mm respectively⁵¹.

Werner Kohnlein MD et al. (2009) in Geneva, Switzerland studied dry hip bone. They found that the diameter of acetabulum in males was 54.00mm and in females was 47.50mm⁵⁷.

Namchai Varodompun et al. (2002) in Bangkok, Thailand studied dry pelvic bone. They reported that diameter of acetabulum in males was 52.38mm and in females was 49.54mm⁴⁵.

Christos Papaloucas et al. (2007) in Hellas, Greece studied pelvic bones. They found that the diameter of acetabulum in males was 55.70mm and in females was 49.10mm⁸.

In present study we found diameter of acetabulum was 45.15 mm in males and 41.50 mm in females. This shows that the mean diameter of acetabulum was more in

males and less in females. Greater diameter in males attribute to the robust and longer bones in males as compared to females. Hence this parameter helps in determination of sex.

From above said studies it can be concluded that the values of diameter of acetabulum was more in the western world and Africa as compared with the present study. But the values are very near to the study done by Chauhan R et al. in India. This shows the regional variation of the values for diameter of the acetabulum.

B. Genser Stroble et al. (2004) studied diameter of acetabulum in Vienna, Austria. They found that the average diameter of acetabulum was 48.94 mm in Austrian population¹⁶.

Funda Tastekin Aksu et al. (2006) in Inciralti, Turkey, studied acetabulum morphology and observed the average diameter of acetabulum to be 54.29 mm⁵.

Antum Salamon et al. (2004) in Zagreb, Croatia studied the pelvic bone. They found that the average diameter of acetabulum was 51.60 mm⁴³.

Kordelle J et al. (2006) in Harvard medical school, Boston, USA studied acetabulum. They reported that the average diameter of acetabulum was 53.00 mm⁴⁴.

Namchai Varodompon et al. (2002) in Bangkok, Thailand studied dry pelvic bone. He reported that the average diameter of acetabulum was 51.82 mm⁴⁵.

In present study it was found that the average diameter of acetabulum was 43.32 mm. This value was very less as compared to above said studies. This may be due to

diameter of the acetabulum was greater in Western world as compared with the Indian values.

Chauhan R et al. (2002) concluded that the diameter of acetabulum was always greater than the vertical diameter of head of femur and this would decrease the risk of osteoarthritis in Indians as compared to Western population. The present study also correlates with findings of Chauhan R et al. study on each and every cadaver shows that the diameter of acetabulum was greater than the vertical diameter of head of femur in the present study.

The mean diameter of acetabulum was 45.15 mm in males and 41.50 mm in females. The mean diameter of head of femur was 43.75 mm in males and 40.30 mm in females which was less than the diameter of acetabulum in both sexes. This shows that the head of femur perfectly fits in acetabulum. This perfect mechanical fitness will prevent the strain and stress on hip joint. This explains the rarity of osteoarthritis in India as compared to Western world.

The diameter of acetabulum was more on right side than on the left side in present study. But the difference in the diameter was not so significant. The maximum difference between right and left side was not more than 2.00 mm.

Congenital hip dislocation incidence may be less in Indians. This was because, the parameters from present study shows that the head of femur fits perfectly into acetabulum. Loose fitting of head of femur into acetabulum was the cause of congenital hip dislocation. We can conclude from present study that congenital hip dislocation was less common in North Karnataka and in India as compared to western world.

From the present study it can be concluded that if diameter of acetabulum was less than 42 mm then the given bone belongs to the female. If diameter of acetabulum was more than 46 mm then the bone belongs to the male. These values will help in the identification of sex in North Karnataka population. It can be also concluded that if values of diameter of acetabulum ranges from 42mm to 46mm then the bone belongs to North Karnataka region. This will help in the identification of person in North Karnataka.

ANALYSIS OF DEPTH OF ACETABULUM

Analysis of depth of acetabulum is presented in Table 14 and 15.

Jeong Min Park et al. (2011) in Goyang, Korean population reported that the depth of acetabulum was 11.80 mm in males and 11.40 mm in females⁶⁰.

D. Jeremic et al. (2011) studied the depth of acetabulum in Kragujevac, Serbia. They found that depth of acetabulum was 12.50 mm in males and 11.20 mm in females⁵⁸.

Murry RO (1965) in London, UK, showed the average depth of acetabulum in males and in females were 13.00 mm and 12.00 mm respectively⁴⁹.

John Emmett (1967) studied on hip bones in New York, USA observed depth of acetabulum in males 25.40 mm and in females 23.81 mm⁵⁰.

M.P. Moon et al. (1998) on cadaveric study in Paris, France reported that the depth of acetabulum was 26.91mm in males and 24.77 mm in females⁵¹.

Chauhan R et al. (2002) in New Delhi, India, studied on North Indian population, found that the depth of acetabulum was 27.83 mm and 25.19 mm in males and in females respectively².

The present study showed the average depth of acetabulum was 31.78 mm in males and 29.70 mm in females. These values are nearer to the studies done by M.P. Moon et al. (1998), John Emmet et al. (1967), and Chauhan R et al. (2002).

The present study shows the depth of acetabulum was more than the studies done by Funda Tastekin Aksu et al. (2006), John Emmet et al. (1967), M.P. Moon et al. (1998), and K.C. Saikia et al (2008). This is because in present study the acetabular labrum is intact while measuring the depth of acetabulum. On contrary John Emmet et al. (1967), Funda Tastekin Aksu et al. (2006) and Moon et al. (1998) had measured on dry hip bones.

The values for depth of acetabulum in the present study are more than the studies done by Jeong Min Park et al, Chong Dong Han (1998), D. Jeremic et al., Murry RO (1965). This is because all the above said studies are radiological studies and present study has been done on cadavers keeping the acetabular labrum intact in situ which increases the depth of acetabulum.

If the mean acetabular depth was less than 9 mm, the persons are very prone to develop osteoarthritis. Shallow acetabulum was one of the causes for osteoarthritis. In the present study it was shown that acetabulum in Indian population has got adequate depth. So the incidence of osteoarthritis is less in Indian population as compared to Western population.

From the various studies and present study it was found that the depth of acetabulum was more in males than in females. In present study the depth of acetabulum was 31.78 mm in males and 29.70 mm in females which are very significant. From above values it reveals that the females have shallow acetabulum due to which they are more prone to develop osteoarthritis of hip joints.

The difference in values for the depth of acetabulum for right side and left side is not so significant. Both the sides have got similar values.

As we are unaware of the age of these cadavers we could not determine the age changes in parameters of acetabulum. Study by Jeong Min park et al., D.Jeremic, Murray RO, concluded that old age was one of the causes of osteoarthritis. This was because as age advances depth of acetabulum decreases. This finding could not confirmed by present study.

Funda Tastekin Aksu et al. (2006) in Inciralti, Turkey, observed that the average depth of acetabulum was 29.49 mm. This value was less than that of present study because they studied on dry hip bones⁵.

B. Genser Stroble (2005) studied radiographs in Vienna, Austria found that the average depth of acetabulum was 16.43 mm¹⁶.

D.Jeremic (2011) in Kragujevac, Serbia found that the mean depth of acetabulum was 11.9mm. This value was very less than the present study because study done by D.Jeremics was a radiological study⁵⁸.

In present study the mean value of depth of acetabulum was 30.74mm. Above said studies have got very less values as compared to present study. It was because above said studies are either radiological studies or carried on dry bones.

The depth and diameter from present study can be utilized for determining abnormal acetabulum. Abnormal acetabulum was one of the major causes of osteoarthritis. Any deviation from normal parameters of acetabulum can cause osteoarthritis. These parameters of acetabulum help in early diagnosis of osteoarthritis in North Karnataka population.

Abnormal anatomy of hip joint was the cause of osteoarthritis and acetabular dysplasia. To prevent further complication we need to restore the normal anatomy of hip joint. The parameters from present study can be utilized to restore normal anatomy in North Karnataka population. This will prevent the complications such as hip pain and disability in patients of this region.

We cannot compare the values obtained by above said studies for regional variations. This was because most of the studies either were done on the dry bones or they were radiological studies. So the values were very less as compared with present study. No other study was similar as this except the study done by Chauhan R et al. in North India. The values obtained by Chauhan R et al. are very near to present study.

Comparison of value for the vertical diameter of head of femur, depth of acetabulum, diameter of acetabulum in North Karnataka cadavers and South Karnataka cadavers have shown in Table 16, 17 and 18.

In comparison with study done by Lavanya Varma (2006) in Bangalore, South Karnataka cadavers, it was observed that vertical diameter of head of femur was greater in South Karnataka cadavers than North Karnataka cadavers in males. It was 44.31 mm in South Karnataka and 44.00mm in North Karnataka on right side. On left side values in South Karnataka was 44.76mm and North Karnataka it was 43.50mm. But in females vertical diameter of head of femur was more in North Karnataka cadavers than South Karnataka cadavers. Vertical diameter of head of femur in a female North Karnataka cadaver was 40.80mm and South Karnataka cadaver was 39.74 on right side and on left side in North Karnataka it was 39.80mm and South Karnataka it was 39.42mm.

Diameter of acetabulum was more in North Karnataka cadavers than South Karnataka cadavers in both sexes on right side. Diameter of acetabulum in male North Karnataka cadavers was 45.25mm and South Karnataka it was 45.22mm on right side. In females right side it was 41.80mm in North Karnataka and 40.65mm in South Karnataka. Values were more on left side in South Karnataka cadavers in males and less in females. In male on left side it was 45.05 mm in North Karnataka and 45.39mm in South Karnataka. In females on left side in North Karnataka cadaver was 41.20mm and South Karnataka cadaver was 40.21mm

The acetabular depth was greater in North Karnataka cadavers than South Karnataka cadavers on both the sexes in both the sides. Depth of acetabulum in North

Karnataka male cadavers was 31.90mm on right side and in South Karnataka it was 28.00mm, on left side in North Karnataka it was 31.65mm and South Karnataka it was 28.52mm. On right side in female North Karnataka cadavers depth was 30.30 and South Karnataka it was 27.09mm. In female cadavers in North Karnataka values on left side were 29.10mm and 26.73mm in South Karnataka cadavers.

It has been also observed from above comparison that for North Karnataka cadavers most of the values for right side were greater than left side in both sexes. But in South Karnataka most of the values were greater in left side as compared to the right side in both sexes.

From above comparison it was found that most of values are different for North Karnataka cadavers and South Karnataka cadavers. This shows the regional difference of parameters within Karnataka. The data from above said studies can be used to design population specific prosthesis. It can be used to identify the fragment of bone belonging to North Karnataka region.

The depth of acetabulum was more in North Karnataka cadavers than South Karnataka cadavers. From this it can be also concluded that population in South Karnataka is more prone to develop osteoarthritis than North Karnataka population.

Table 11: Comparative study of vertical diameter of head of femur

Serial no	Authors	Male	Female
1	Gita malla et al. (2006) in Germany	49.00 mm	44.00 mm
2	Aasis Unnanuntana(2002) in USA	55.46 mm	48.73 mm
3	P S Igbigbi et al. (2000) in Malawi	48.30 mm	44.56 mm
4	Asala SA et al. (1998) in Nigeria	54.16 mm	47.00 mm
5	Singh et al. (1986) in Nigeria	52.02 mm	46.80 mm
6	Clarke et al. (1987) in England	51.30 mm	45.10 mm
7	Akhtari Afroze et al. (2005) Bangladesh	51.55 mm	45.65 mm
8	Ruma Purkait et al. (2005) in India	44.28 mm	38.39 mm
9	Thomas Dwight (1905) in USA	49.68 mm	43.84 mm
10	Khan (1959) in India	48.00 mm	41.00 mm
11	Javadekar BS (1961) in India	45.26 mm	40.37 mm
12	V.Davivongs(1963) in Australia	43.05 mm	38.16 mm
13	B.R.Kate (1964) in India	41.50 mm	39.00 mm
14	Yasar Iscan M et al. (1995) in China	46.16 mm	41.13 mm
15	Rajendra Prasad et al. (1996) in India	43.00 mm	39.10 mm
16	Gonazalo et al. (1997) in Spain	47.15 mm	41.13 mm
17	Chauhan R et al.(2002) in India	45.64 mm	44.27 mm
18	Present Study in North Karnataka	43.75 mm	40.30 mm

Table- 12: Right and Left side analysis of vertical diameter of head of femur (in mm)

	Authors	Right	Left
1	Aasis Unnanuntana et al. (2010) in USA	52.12 mm	52.06 mm
2	P.S. Igbigbi et al. (2000) in Malawi	46.45 mm	46.40 mm
3	Taner Ziylan et al. (2002) in Turkey	45.20 mm	43.40 mm
4	Akhtari Afroze et al. (2005) in Bangladesh	48.65 mm	48.55 mm
5	Rajendra Prasad et al. (1996) in India	41.05 mm	41.05 mm
6	Asala SA (2001) in South Africa	45.36 mm	45.36 mm
7	Chauhan R et al. (2002) in India	44.55 mm	45.25 mm
8	Present study	42.40mm	41.65mm

Table-13: Comparative study of diameter of acetabulum (in mm)

	Authors	Diameter of acetabulum	
		Male	Female
1	Shino et al.(1950) inSwitzerland	54.00 mm	49.20m
2	Stein et al. (1982) in USA	55.70 mm	48.50 mm
3	Thompson et al. (2000) in UK	52.90 mm	49.00 mm
4	Vandenbussche et al. (2008) in France	51.90 mm	45.10 mm
5	B. Genser Stroble et al. (2004) in Austria	48.94 mm	48.94mm
6	Funda Tastekin aksu et al. (2006) in Turkey	54.29 mm	54.29mm
7	Chauhan R et al. (2002) in India	47.29 mm	45.19 mm
8	John Emmett (1967) in USA	58.80 mm	47.62 mm
9	M.P. Moon et al. (1998) in France	51.92 m	47.17 m
10	Werner Kohnlein MD et al(2009) Switzerland	45.15 mm	41.50 mm
11	Namchai Varodompun et al(2002) Thailand	52.38mm	49.54mm
12	Present study	45.15mm	41.50mm

Table- 14: Comparative study of depth of acetabulum (in mm)

	Authors	Depth of acetabulum	
		Male	Female
1	Funda Tastekin aksu et al. (2006) in Turkey	29.49mm	29.49mm
2	Jeong Min Park et al.(2011) in Korea	11.80 mm	11.40 mm
3	Chang-Dong Han et al. (1998) in Korea	11.50 mm	10.20 mm
4	D. Jeremic et al. (2011) in Serbia	12.50 mm	11.20 mm
5	K.C. Saikia et al. (2005) in India	25.00 mm	25.00 mm
6	B. Genser Stroble et al. (2005) in USA	16.43 mm	16.43mm
7	Murray RO (1965) in USA	13.00 mm	12.00 mm
8	John Emmett (1967) in USA	25.40 mm	23.81 mm
9	M. P. Moon et al. (1998) in France	26.91 mm	24.77 mm
10	Chauhan R et al. (2002) in India	27.83 mm	25.19 mm
11	Present study	31.78 mm	29.70 mm

Table- 15: Comparative study of depth of acetabulum (in mm)

	Authors	Right	Left
1	K.C. Saikia et al. (2008) in India	25.00 mm	25.00 mm
2	D.Jeremic et al. (2011) in Serbia	11.90 mm	11.90 mm
3	Chang Dong Han et al. (1998) in Korea	10.90 mm	10.90 mm
4	Jeong Ming park et al. (2011) in Korea	11.60 mm	11.60 mm
5	Mukhopadhaya and Barooah (1967) in India	24.65 mm	24.51 mm
6	Present study	31.10mm	30.37mm

Table- 16: Comparison of vertical diameter of head of femur North Karnataka and South Karnataka (in mm)

Authors		Male		Female	
		Right	Left	Right	Left
South Karnataka Lavanya varma (2006)	Mean	44.31 mm	44.76 mm	39.74 mm	39.42 mm
	SD	2.75 mm	2.67 mm	1.52 mm	1.34 mm
Present study	Mean	44.00 mm	43.50 mm	40.80 mm	39.80 mm
	S.D.	2.57 mm	2.81 mm	2.04 mm	2.48 mm

Table-17: Comparison of diameter of acetabulum between South Karnataka and North Karnataka (in mm)

Authors		Male		Female	
		Right	Left	Right	Left
South Karnataka Lavanya varma (2006)	Mean	45.22 mm	45.39 mm	40.65 mm	40.21 mm
	S.D.	3.07 mm	2.72 mm	1.65 mm	1.74 mm
Present study	Mean	45.25 mm	45.05 mm	41.80 mm	41.20 mm
	S.D.	2.26 mm	2.50 mm	1.98 mm	1.87 mm

Table-18: Comparison of depth of acetabulum between South Karnataka and North Karnataka (in mm)

		Male		Female	
		Right	Left	Right	Left
South Karnataka Lavanya et al (2006)	Mean	28.00 mm	28.52 mm	27.09 mm	26.73 mm
	S. D.	2.17 mm	2.22 mm	2.22 mm	2.26 mm
Present study	Mean	31.90 mm	31.65 mm	30.30 mm	29.10 mm
	S. D.	2.57 mm	1.98 mm	1.56 mm	1.66 mm

CONCLUSION

The anatomical parameters of hip joint help the prosthetists and biomechanical engineers to design the best possible, population specific prosthesis for the hip replacement surgery in North Karnataka. This will prevent the complications arising from the mismatch of the prosthesis in total hip replacement surgeries in North Karnataka. It was found that most of the prosthetists will design the prosthesis keeping in mind the parameters available from the western countries. This study will give parameters which are very specific to North Karnataka population by which prosthetists can design more perfect prosthesis.

Present study provides valuable parameters which will help the forensic expert in early detection of disputed sex, race, and stature of a person. In this study it was found that the parameters vary from males to females and parameters also vary from right and left side.

These parameters also help in early diagnosis of acetabular dysplasia which in turn helps in the prevention of osteoarthritis. The knowledge of anatomical parameters of hip joint helps in better understanding of etio-pathogenesis of primary osteoarthritis. Mean diameter of acetabulum was 43.32mm, in males it was 45.15 mm and in females it was 41.50 mm. Average vertical diameter of head of femur was 42.02mm, in males it was 43.75 mm and in females it was 40.30 mm. This shows that head of femur perfectly fitted into acetabulum, hence there was no strain and stress on hip joint. This shows that North Karnataka population was less prone to develop osteoarthritis of hip joint.

From above studies it was also concluded that the regional variation in parameters measured do exist when the data of two different continents and countries was considered. But within the country parameters of hip joint were not much variable. The values from North and South India do not vary much. It was found that for all the three parameters the values from present study do not differ more than 10 mm from the parameters of North Indian cadavers.

The values are more in the males than in the females. It was due to longer and robust bones in males than in the females. This above said fact was also proved by the present study. In the sixty hip joints we have studied it was found that the values are more for male cadavers than the female cadavers. It was also observed in this study that values are little more on the right side than on the left side for all hip joint parameters. This finding was stastically insignificant. This was against the study done in North India by Chauhan R et al. They found that the values for all the three parameters are more on left side. They have explained this by quoting that, most of the persons use their left lower limb more frequently than the right. So the left lower limb bears more load and thus have higher values for all the three parameters. The present study was done on the cadavers with soft tissue in situ. This gives the average values of various parameters to near normal situation as encountered on the operation table.

The limitation of the present study was its small sample size. Further studies on larger population will redefine its results and various parameters values. Parameters of hip joint are specific to age, sex and race. Hence the present parameters can be applied only to the sex and race from which the sample has been drawn.

SUMMARY

In this study we have measured vertical diameter of head of femur, diameter of acetabulum and depth of acetabulum in 30 adult cadavers (20 males and 10 females) in North Karnataka.

It was observed in the study that average vertical diameter of head of femur was 42.02mm, in males it was 43.75 mm and in females it was 40.30 mm. From these observations it can be concluded that if vertical diameter of head of femur was more than 44 mm, then the given bone belongs to the male. If vertical diameter of head of femur was less than 40 mm, it can be said that the given bone belongs to the female in North Karnataka cadavers.

Mean diameter of acetabulum was 43.32 mm, in males it was 45.15 mm and in females it was 41.50 mm. In the present study, it can be concluded that diameter of head of femur was found to be smaller than average diameter of acetabulum. This shows that femoral head is perfectly fitted into the acetabulum which is one of the main reason for less incidence of osteoarthritis of hip in North Karnataka as compared to the Western countries.

The mean depth of acetabulum was 31.78 mm in males and 29.70mm in females in the present study. Here, it was observed that depth of acetabulum was more in North Karnataka compared with cadavers in Western Countries. This explains the less incidence of osteoarthritis in North Karnataka. Shallow acetabulum has more incidences of acetabular dysplasia and osteoarthritis. The deeper acetabulum noted in North Karnataka cadavers also prove that congenital subluxation of hip is less in North Karnataka.

Present study provides valuable parameters which will help the forensic expert in early detection of disputed sex, race, and stature of a person. These parameters also help the prosthetist to design the best possible population specific prosthesis for the hip replacement surgery in North Karnataka. These parameters also help in early diagnosis of acetabular dysplasia which in turn helps in the prevention of osteoarthritis. The knowledge of anatomical parameters of hip joint helps in better understanding of etio-pathogenesis of primary osteoarthritis.

From above studies it was also observed that the regional variation in parameters measured do exist when the data of two different continents and countries was considered. But within the country not much variation was observed. The values are more in the males than in the females. It was due to longer and robust bones in males than in the females. It was also observed in this study that values are little more on the right side than on the left side for all hip joint parameters. This difference was statistically insignificant. The present study was done on the cadavers with soft tissue in situ. This gives the average values of various parameters to near normal situation.

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MASTER CHART

Serial no	Cadaver no	Sex	Vertical diameter of head of femur		Diameter of acetabulum		Depth of acetabulum	
			Right	Left	Right	Left	Right	Left
1	1	M	43	42	46	45	32	33
2	3	M	46	46	47	46	30	32
3	4	M	46	45	46	47	25	26
4	6	M	45	46	46	46	33	31
5	7	M	44	42	44	44	30	30
6	9	M	45	44	45	45	36	34
7	10	M	43	41	44	43	34	32
8	12	M	44	44	45	45	33	32
9	14	M	45	45	46	46	32	31
10	16	M	42	43	44	43	30	31
11	17	M	44	44	42	41	31	32
12	19	M	38	37	39	40	30	30
13	20	M	45	47	46	48	36	36
14	21	M	44	44	46	46	34	33
15	22	M	44	44	46	46	32	31
16	23	M	47	45	48	47	35	34
17	25	M	37	36	42	40	30	31
18	26	M	46	44	48	48	30	31
19	28	M	45	45	47	48	32	31
20	29	M	47	46	48	47	33	32

MASTER CHART

Serial no	Cadaver no	Sex	Vertical diameter of head of femur		Diameter of acetabulum		Depth of acetabulum	
			Right	Left	Right	Left	Right	Left
21	2	F	41	42	42	43	32	31
22	5	F	40	40	42	42	30	28
23	8	F	37	36	38	40	30	29
24	11	F	40	36	41	40	28	27
25	13	F	44	43	45	44	28	27
26	15	F	43	42	44	43	33	32
27	18	F	40	39	41	40	30	29
28	24	F	42	41	43	42	31	30
29	27	F	39	38	40	38	30	28
30	30	F	42	41	42	40	31	30

FIG 5: Material studied: Odd numbers- right side and even- left side specimens,



RIGHT

LEFT

RIGHT

LEFT



RIGHT

LEFT

RIGHT

LEFT

