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RESEARCH ARTICLE

ANTHROPOMETRIC ANALYSIS OF THE HIP JOINT IN CENTRAL INDIA POPULATION USING COMPUTED TOMOGRAPHY

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Abstract

Background: The presently available hip prosthesis used in hip arthroplasty are designed based on the anthropometry of Western patients. These prosthesis do not replicate the exact anatomy of Indian patients, leading to postoperative complications and requiring revision surgery for correction. If the manufacturers keep in considering the anthropometric parameters of Indians while designing the prosthesis, this may lead to better clinical and functional outcome and higher patient satisfaction. So the present study was undertaken to understand the anthropometric variables of hip joint of Central Indian population and to compare these variables with the other Indian Ethnic groups and western population using computed tomographic images.

Materials And Methods: We had included 200 patients and both the left and right side hip joints were analysed. The anthropometric variables included were Neck-Shaft Angle (NSA), Head Diameter (HD), Neck Width (NW), Acetabular Angle of sharp(AA), Horizontal Offset (HO), Vertical Offset (VO), Medullary Canal Diameter at the level of Lesser Trochanter (MD_{LT}), and Acetabular Version (AV) were measured in all these individuals. Comparison of these parameters was done between the left and right side and among the males and females and compared with various populations and statistically analyzed

Result: The mean values were NSA 132.53°, NW 25.11 mm, HD 43.94 mm, AA of sharp 43.11°, HO 43.76 mm, VO 56.37 mm, MD_{LT} 23.00 mm, and AV 19.47°. We found a large variations in these parameters among the Indian ethnic groups and western population. Significant differences were seen between the males and females.

Conclusion: This study indicates that there are significant differences in anthropometric parameters of proximal femur among the Central India population compared with Western population. Even within the Indian population, the anthropometric parameters vary from region to region.

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Introduction:-

An excellent functional outcome in hip arthroplasty depends on how well the prosthesis is able to replicate the biomechanics of the original hip joint. Longevity has led to increase in the number of hip arthroplasties across the globe. Annually over 8 lac hip arthroplasties are performed.[1] Prosthetics are designed according to the anatomy of Western patients. The built of Indian patients is different from that of Western counterparts leading to mismatch between prosthesis and the original anatomy of the hip joint. This leads to complications such as aseptic loosening, uneven load distribution and discomfort after undergoing arthroplasty. A dimensional difference between femur bone and prosthetic components may lead to micromotion of the prosthetic stem during postoperative rehabilitation and hampers the trabecular bone in growth. A large implant size leads to femur fracture, and to prevent this the inclination is kept undersized. A small implant size leads to failure to hold the bone.[2] An appropriate size implant help overcome these problems. Prosthetics available in the market do not provide perfect fit to Indian patients, who are smaller in built in comparison to the western counterparts.[3]

Hence, the present study was undertaken to evaluate and compare the proximal femur dimensions of the central India population with population from other regions of India and western population. This will help the prosthetic manufacturers in designing region specific prosthesis.

Materials & Methods:-

The present prospective, comparative study was conducted on 200 individuals, aged between 20 to 70 years of either sex and having no hip abnormalities. Individuals having pre-existing hip pathologies like osteoarthritis, rheumatoid arthritis, tuberculosis of hip, old hip fractures, tumors of hip, lower limb deformity were excluded from the study.

All the individuals undergoing computed tomography of abdomen for reasons other than for hip pathologies. Were included in the study. These computed tomography images were used for evaluating the anthropometric parameters. In all the patients bilateral hip joints were evaluated. The Neck-Shaft Angle (NSA), Head Diameter (HD), Neck Width (NW), Acetabular Angle of sharp(AA), Horizontal Offset (HO), Vertical Offset (VO), Medullary Canal Diameter at the level of Lesser Trochanter (MD_{LT}), and Acetabular Version (AV) were measured in all these individuals. To use the computed tomography images for evaluating the anthropometric parameters, a voluntary written consent was obtained from these individuals. Individuals who were not willing, their computed tomography images were not included for analysis. Permission to conduct the study was obtained from the Ethics Committee of our institution. The statistical analysis was carried out using online statistical packages GraphPad and Epi Info. Comparison of left and right side of various anthropometric variables was done using Paired 't' test and comparison of anthropometric variables in relation to sex was done using Unpaired 't' test. The male and female comparison of anthropometric variables was done after calculating the average of right and left side. A p value of < 0.05 was taken as statistically significant.

Methodology:-

We had used the computed tomography images of all the individuals enrolled in the study and following parameters were analyzed

Neck Shaft Angle (NSA)

It is the angle that lies between the long-axis of shaft femur and long-axis of femur neck. Long-axis of shaft femur lies in the center of medullary canal and long-axis of femur neck is equidistant from the superior and inferior surface of femoral neck. (Fig. 1).

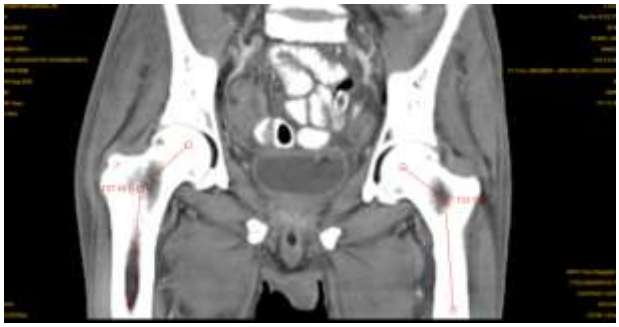

Fig. 1 :- Neck shaft angle measurement

Head Diameter (HD)
The diameter of the circle drawn over the spherical femoral head is equal to the head diameter. (Fig. 2)

Fig. 2:- Head diameter measurement.

Neck Width (NW)
The narrowest part of the femur neck is used for this measurement. It is measured by drawing a perpendicular line from top of the femur neck to the bottom of the femur neck. (Fig. 3)

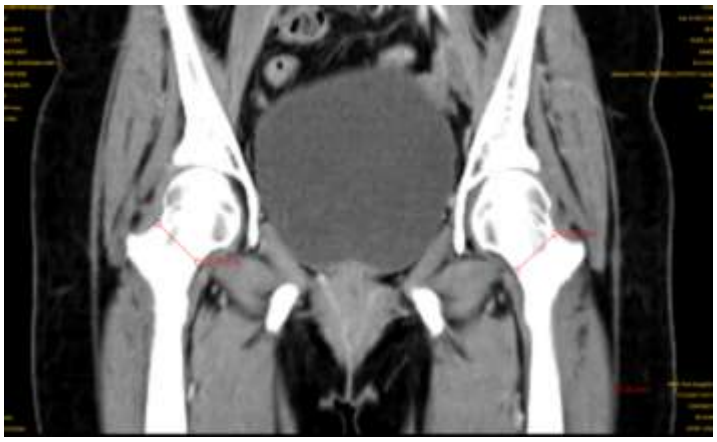

Fig. 3:- Neck width measurement.

Acetabular Angle of Sharp (AA)
It is a measure of an angle formed by drawing a horizontal line through the tear drop (coronal section) and by drawing another line from the tip of tear drop to anterior edge of acetabulum. (Fig. 4)

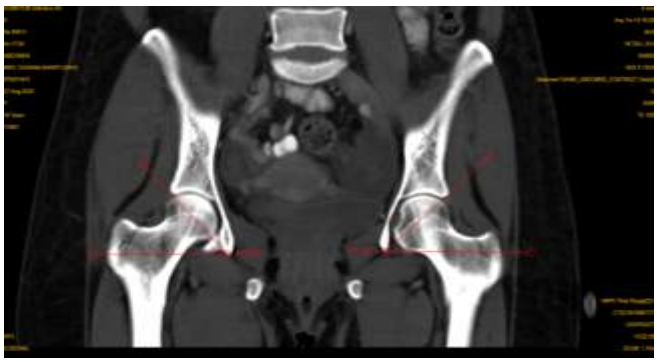

Fig. 4:- Acetabular angle of sharp measurement.

Horizontal Offset (HO)
It is the horizontal distance between the center of femoral head and the line bisecting the long-axis of shaft of femur. (Fig. 5)

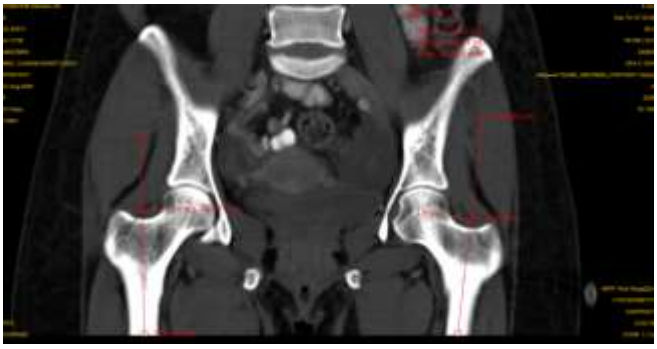

Fig. 5 :-Horizontal offset measurement.

Vertical Offset (VO):
It is the vertical distance between the center of femoral head and the tip of lesser trochanter. Also known as femoral head position. (Fig. 6)

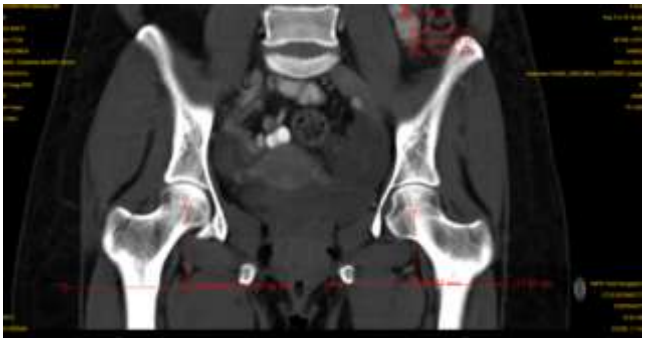

Fig. 6 :- Vertical offset measurement

Medullary Canal Diameter at Level of Lesser Trochanter (MD_{LT})
It is the length of mediolateral diameter of medullary canal measured at the level of middle of lesser trochanter. (Fig.7)

Fig. 7 :-Medullary Canal Diameter at Level of Lesser Trochanter measurement.

Acetabular Version (AV)
It is the angle formed between the line connecting both the posterior ischia and the line connecting the posterior lips of acetabulum. (Fig. 8)

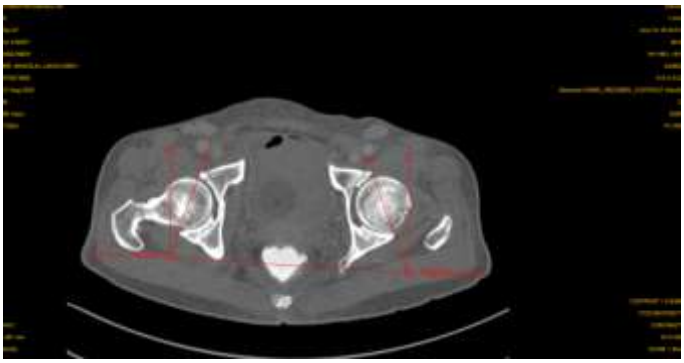

Fig. 8:- Acetabular version measurement.

All the data was captured in a customized proforma and then transferred to Microsoft Excel for analysis. Paired 't' test was applied to compare the means between right and left side. A p value of < 0.05 was taken as statistically significant.

Results:-

In the present study we had included 200 individuals with no hip abnormalities. Anthropometric measurements were done using the computed tomographic images. There were 94 (47%) females and 106 (53%) males. The mean age was 44.58 ± 19.68 years with a range from 20 to 70 years. All the anthropometric variables for left and right side were calculated separately.

Neck-shaft angle

The mean neck-shaft angle (NSA) was similar on the right side in comparison to left side (132.73 ± 6.12 vs. 132.33 ± 5.91, P=0.037) and was comparable between the males and females (133.41 ± 4.3 vs. 131.65 ± 4.46, P=0.227). The mean neck-shaft angle was 132.53 ± 4.37 degree with a range from 117 to 148 degrees.

Femoral head diameter

The mean femoral head diameter (HD) was similar on the right side in comparison to left side (43.39 ± 3.51 vs. 44.49 ± 3.46, P=0.001) and was comparable between the males and females (44.54 ± 2.53 vs. 43.34±2.37, P=0.641). The mean femoral head diameter was 43.94 ± 2.46 mm with a range from 38.0 to 51.2 mm.

Neck width

The mean neck width (NW) was similar between right side in comparison to left side (24.99 ± 3.28 vs. 25.23 ± 3.36, P=0.105) and was comparable between the males and females (25.16 ± 2.99 vs. 25.06 ± 3.00, P=0.579). The mean neck width was 25.11 ± 2.99 mm with a range from 15.50 to 33.50 mm.

Horizontal offset

The mean horizontal offset (HO) was similar on the both side in (43.97 ± 7.32 vs. 43.55 ± 7.82, P=0.018) and was comparable between the males and females (44.55 ± 5.29 vs. 42.97 ± 5.31, P=0.150). The mean horizontal offset was 43.76 ± 5.31 mm with a range from 25.31 to 57.0 mm.

Vertical offset

The mean vertical offset (VO) was similar on both side (56.33 ± 5.41 vs. 56.41 ± 5.00, P=0.002) and was comparable between the males and females (57.42 ± 3.82 vs. 55.32 ± 3.99, P=0.214). The mean vertical offset was 56.37 ± 3.89 mm with a range from 37.85 to 67.83 mm.

Acetabular angle of sharp

The mean acetabular angle of sharp (AA) was similar on the right side in comparison to left side (43.01 ± 2.02 vs. 43.21 ± 1.84, P=0.024) and was comparable between the males and females (43.21 ± 1.41 vs. 43.01 ± 1.25, P=0.468). The mean acetablar angle of sharp was 43.11 ± 1.35 degree with a range from 36.07 to 47.00 degree

Medullary canal diameter at lesser trochanter

The mean medullary canal diameter at lesser trochanter was similar on the right side in comparison to left side (22.55 ± 3.46 vs. 23.42 ± 2.62, P=0.001) and was comparable between the males and females (23.10 ± 2.61 vs. 22.85 ± 2.29, P=0.483). The mean medullary canal diameter at lesser trochanter was 23.00 ± 2.49 mm with a range from 19.00 to 40.2 mm.

Acetabular version

The mean acetabular version (AV) was similar on the right side in comparison to left side (19.54 ± 5.25 vs. 19.40 ± 5.68, P=0.001) and was comparable between the males and females (20.43 ± 3.85 vs. 18.54 ± 4.13, P=0.759). The mean acetabular version was 19.47 ± 3.96 degree with a range from 11.0 to 30.0 degree.

Table:- Comparison of anthropometric parameters among the males and females.

	Sex	**N**	**Mean**	**Std. Deviation**	**'t' value, df**	**P value**
Neck Shaft Angle (NSA)	F	94	133.41	4.30	1.212, df=198	0.227, NS
	M	106	131.65	4.46		
Femoral Head Diameter (HD)	F	94	43.34	2.37	0.468, df=198	0.641, NS
	M	106	44.54	2.53		
NeckWidth (NW)	F	94	25.06	3.00	0.555, df=198	0.579, NS
	M	106	25.16	2.99		
AcetabularAngle of Sharp (AA)	F	94	43.01	1.25	-0.728, df=198	0.468, NS
	M	106	43.21	1.41		
HorizontalOffset (O)	F	94	42.97	5.31	1.443, df=198	0.150, NS
	M	106	44.55	5.29		
VerticalOffset (VO)	F	94	55.32	3.99	1.246, df=198	0.214, NS
	M	106	57.42	3.82		
Medullary Canal Diameter at Lesser Trochanter (MD_{LT})	F	94	22.85	2.29	-0.703, df=198	0.483, NS
	M	106	23.10	2.61		
Acetabular Version (AV)	F	94	18.54	4.13	0.307, df=198	0.759, NS
	M	106	20.43	3.85		

Discussion:-

We had included 200 participants whose anthropometric analysis was carried out from the available CT scans done for other purposes. There is a male predominance in the study (53%) with a mean age was 44.58 ± 19.68 years with a range from 20 to 70 years.

Table:- Comparative analysis of the morphometry of the hip joint reported in different studies.

PARAMETERS	PRESENT STUDY	SENGODAN *et al*[8]	RAWAL *et al*[5]	Ravichandran et al[11]	Saikia et al[7]	Rubin et al[12]	Husman et al[6]	Mahaisavariya et al	Noble et al[9]	Agrawal et al[4]
FEMORAL HEAD DIAMETER	43.94	42.6	45.41±3.66	NOT RECORDED	NOT RECORDED	43.4±2.6	NOT RECORDED	43.98±3.47	45.9	41.0
NECK	25.11	27.5	NOT	30.99	NOT	NOT	NOT	NOT	NOT	28.5

WIDTH			RECORDED		RECORDED	RECORDED	RECORDED	RECORDED	RECORDED	9
NECK SHAFT ANGLE	132.53	135.4	124.42±5.49	126.55	139.5±7.5	122.9±7.6	129.2±7.8	128.04±6.14	125.4	132.62
HORIZONTAL OFFSET	43.76	37.6	40.23±4.85	NOT RECORDED	NOT RECORDED	47±7.2	40.5±7.5	NOT RECORDED	NOT RECORDED	39.34
VERTICAL OFFSET	56.37	46.9	52.33±7.19	NOT RECORDED	NOT RECORDED	56.1±8.2	57.3±8.1	48.94±4.95	NOT RECORDED	45.34
ACETABULAR ANGLE OF SHARP	43.11	20.2	NOT RECORDED	NOT RECORDED	39.2±4.9	NOT RECORDED	NOT RECORDED	NOT RECORDED	NOT RECORDED	22.58
MEDULLAR CANAL DIAMETER	23.00	35.5	NOT RECORDED	NOT RECORDED	18.2±5.6	27.9±3.6	NOT RECORDED	NOT RECORDED	NOT RECORDED	34.93
ACETABULAR VERSION	19.47	18.6	NOT RECORDED	NOT RECORDED	NOT RECORDED	NOT RECORDED	NOT RECORDED	NOT RECORDED	NOT RECORDED	20.60

The mean Neck-Shaft angle (NSA) was 132.53 ± 4.37 degrees (range: 117-148 degrees). This angle is comparable between the males and females. Segodan et al[4] found a higher neck-shaft angle in South Indian population, similarly Saikia et al[5] reported higher neck-shaft angle in North Eastern Indian population but Agarwala et al[6] reported similar neck-shaft angle in Southern Assamese population. While the studies done by Rubin et al[7] in Swiss population, Mahaisavariya et al[8] in Thai population and Noble et al[9] in Caucasian population found a lower neck-shaft angle in comparison to our study. A study done by Husmann et al[10] in French population found similar neck-shaft angle in their population. There is a large variation in the neck-shaft angle within India also, with higher angles seen in South Indians, North-East Indians and Southern Assamese. The available prosthesis in arthroplasty comes with a 131 degree neck-shaft angle, which is comparable to the Central Indian population, while it is smaller for other Indian Ethnic groups.

The mean femoral head diameter (HD) was 43.94 ± 2.46 mm (range: 38.0-51.2 mm). This diameter is comparable between the males and females. The femoral head diameter reported by Sengodan et al[4] (South India) and Agarwala et al[6] (Southern Assam) were slightly smaller; and that reported by Rawal et al[11] (North India) was larger than the present study. Noble et al[9] (Caucasian) also reported a higher femoral head diameter. Here also, the mean femoral head diameter varies from other Indian ethnic groups.

The mean neck width (NW) was 25.11 ± 2.99 mm (range: 15.50 to 33.50 mm), being comparable on the both the sides. The neck width is comparable between males and females. Sengodan et al[4] (South India), Ravichandran et al[12] (India) and Agarwala et al[6] (South Assam) reported a larger mean neck width in comparison to our study. For fixing fracture neck femur, usually 3 cancellous screws of size 6.5 mm are required, which becomes difficult. The thread diameter of DHS is 12.5 mm and that of barrel is 12.6 cm, for inserting the Richards screw rimming upto 11.5 mm and tapping upto 13.5 mm is required. This removes bone stock from neck and the implant occupies the available space in the neck, resulting in non-union and avascular necrosis, making it difficult to place the DHS.[12]

The mean horizontal offset (HO) was 43.76 ± 5.31 mm. The mean horizontal offset are comparable between the males and females. The mean horizontal offset reported by Sengodan et al[4] and Agarwala et al[6] was much smaller in comparison to our study results. Rawal et al[11] and Husmann et al[10] also reported smaller horizontal offset but were quite comparable to our study results. Rubin et al[7] (Swiss study) reported a larger horizontal offset in comparison to our study.

The mean vertical offset (VO) was 56.37 ± 3.89 mm. The mean vertical offset are comparable between the males and females. Sengodan et al[4], Rawal et al[11] and Agarwala et al[6] reported smaller vertical offset in their study. While the studies done by, Rubin et al[7], Husmann et al[10] reported a similar mean vertical offset in comparison to our study. The difference in size of femoral head offset leads to tension in the joint soft tissue and can cause post-surgery dislocation.[10,12] Maintaining the leg length (VO) and HO helps to preserve proper hip biomechanics and improves overall postsurgical patient satisfaction in total hip replacement. [13,14]

The mean acetabular angle of sharp (AA) was 43.11 ± 1.35 degree (range: 36.07 to 47.00 degrees). It is comparable between the males and females. Sengodan et al[4], Saikia et al[5] and Agarwala et al[6] found mean acetabular angle of sharp to be smaller in comparison to our study. There is a large variation among the Indian ethnic groups.

The mean medullary canal diameter (MD_{LT}) was 23.00 ± 2.49 mm (range: 19 to 40.2 mm). This was comparable between males and females. Sengoad et al[4] and Agarwala et al[6] reported a very large medullary canal diameter in comparison to present study. While studies done by Saikia et al[5] reported a much smaller canal diameter in their studies. This parameter also showed large variation among the Indian ethnic groups. The difference in the dimensions significantly impacts the performance of standard femoral stem size for cementless fixation.[15] Ducheyne et al reported that micromotion within the canal hinders bone in growth affecting the stability over a period of time and unequal load distribution leads to early failure and breakage of the stem.[16]

The mean acetabular version (AV) was 19.47 ± 3.96 degree (range: 11 to 30 degrees). This was comparable between the males and females. It was slightly lower in Sengodan et al[4] study and comparable with Agarwala et al[6] study. If the cup has been excessively anteverted, anterior dislocation can occur during hip extension, adduction, and external rotation. If the cup is retroverted, dislocation occurs posteriorly with flexion, adduction, and internal rotation. Excessive inclination of the cup can lead to superior dislocation with adduction, especially if there is a residual adduction contracture, or if the femur impinges on osteophytes left along the inferior margin of the acetabulum. Conversely, if the cup is inclined almost horizontally, impingement occurs in early flexion, and the hip dislocates posteriorly, this is accentuated if the cup also is in less anteversion.

Limitation Of the Study

The limitation of the study is that we have considered the data of other Indian Ethnic groups from the available literature, but no primary data collection was performed. A study with similar parameters on a larger population across India, would provide much more accurate data and will help in designing the prosthesis replicating the actual biomechanics of the hip bone. But definitely our study will provide baseline information for the manufacturers of prosthesis for designing the prosthesis and the surgeons for selecting appropriate prosthesis for their patients.

Conclusion:-

A prosthesis which replicates the actual hip joint biomechanics will give a better patient satisfaction and longevity to the prosthesis. In order to achieve that, while designing the prosthesis the ethnic differences should be kept in mind by the manufacturers. An incompatible prosthesis leads to many postoperative complications. Apart from geographical differences in the anthropometric parameters of Indians as compared to other countries, our study found that within India also, there are differences in these anthropometric parameters. Hence, we recommend that biomechanical engineers should develop implant designs to suit specific Indian population, which will improve the clinical and functional outcome, reduce the chances of revision surgery and ultimately saving the patients money.

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