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Indian Journal of Orthopaedics Surgery

Journal homepage: www.ijos.co.in

Original Research Article

Anthropometric analysis of normal hip joint using computed tomography scan in central Indian population

Sparsh Jain[1*], Pradeep Choudhari[1], Sourabh Khande[1]

[1]Dept. of Orthopaedics, Sri Aurobindo Medical College and PG Institute, Indore, Madhya Pradesh, India

Abstract

Background: Hip prostheses currently available for arthroplasty are primarily modelled on the anatomical characteristics of Western populations. As a result, these implants often fail to accurately match the anatomical dimensions of Indian patients, which may lead to postoperative complications and, in some cases, necessitate revision surgeries. Incorporating region-specific anthropometric data, particularly from the Indian population, into prosthesis design could potentially improve clinical outcomes and enhance patient satisfaction. Therefore, this study was carried out to examine the hip joint morphology in the Central Indian population and compare it with other Indian ethnic groups and Western data.

Aim and Objective: To assess the anthropometric parameters of the hip joint using CT scans in individuals with anatomically normal hip joints.

Materials and Methods: This study included 200 individuals, analysing both left and right hip joints. The measured variables were Neck-Shaft Angle (NSA), Head Diameter (HD), Neck Width (NW), Sharp's Acetabular Angle (AA), Horizontal Offset (HO), Vertical Offset (VO), Canal Diameter (CD), and Acetabular Version (AV). Comparisons were made between right and left sides and across genders. The collected data were also compared with findings from other populations and subjected to statistical analysis.

Results: The average values recorded were: NSA – 133.41°, NW – 3.04 cm, HD – 3.98 cm, AA – 38.9°, HO – 3.7 cm, VO – 4.65 cm, CD – 2.25 cm, and AV – 21.38°.

Conclusion: The findings highlight distinct differences in proximal femur anatomy between the Central Indian and Western populations. Even within India, regional variations in hip morphology exist, underscoring the need for population-specific prosthesis designs.

Keywords: Anthropometry, Hip joint, Neck shaft angle, CT Scan, Acetabular version, Head diameter, Vertical offset, Horizontal offset, Canal diameter, Acetabular angle of sharp, Neck width.

Received: 31-03-2025; **Accepted:** 26-05-2025; **Available Online**: 11-07-2025

1. Introduction

The hip prostheses currently utilized in arthroplasty procedures are primarily designed based on anatomical data from Western populations. However, these implants often do not align well with the size and structural orientation of hips in the Indian population, leading to postoperative complications and, in some cases, the need for revision surgeries to correct implant mismatch.[1] Noticeable anthropometric differences exist between Western and Indian hips, which this study aims to explore in terms of size and spatial configuration.

Numerous researchers have observed racial disparities in skeletal dimensions and attempted to link these anatomical variations to an increased incidence of conditions such as hip osteoarthritis, femoral neck fractures, and slipped capital femoral epiphysis.[2,3] Wiberg highlighted the role of acetabular dysplasia in the early onset of osteoarthritis.

The proximal femur consists of the femoral head, neck, and the greater and lesser trochanters. The hip joint is formed through the articulation of the femoral head with the acetabulum. The femoral neck, a narrow section of bone, connects the femoral head to the shaft. Anthropometric measurements of the femur can provide valuable insights into

*Corresponding author: Sparsh Jain
Email: sparsh94jain@gmail.com

https://doi.org/10.18231/j.ijos.2025.025

height estimation, sex determination, and population-specific skeletal traits.

Due to variations in ossification and environmental or genetic influences, the morphology of the hip joint and proximal femur differs across global populations. In bipedal posture, the proximal femur undergoes functional adaptations. Orthopedic literature frequently discusses the anatomical features of the proximal femur, especially the relationship between the proximal portion and the femoral shaft. Factors such as genetics, age, gender, race, and lifestyle contribute to differences in femoral geometry.[4-6] These structural variations underline the importance of region-specific data in pre-surgical planning and in understanding hip joint biomechanics. A comprehensive morphometric study of the proximal femur is particularly useful for managing disorders such as hip osteoarthritis, femoral neck fractures, and intertrochanteric fractures.

In a population-based study, Nurzenski et al. reported that lifestyle choices can influence the structural strength of the proximal femur.[3] Siwach et al. compared Indian femoral parameters with those of Western and Hong Kong Chinese populations, noting that Western implants often proved too large or were poorly aligned, resulting in complications such as bone splintering and fractures.[4] Reddy et al. pointed out that an improper match between the femoral stem and native bone can result in micromotions that ultimately lead to osteolysis, aseptic loosening, and persistent thigh pain.[7]

These mismatches in prosthetic sizing can interfere with bone ingrowth during recovery and rehabilitation. Oversized implants risk inducing fractures, while undersized components may fail to provide adequate fixation. Correctly sized implants can help mitigate such issues. Given that Indian patients tend to have smaller statures than Western individuals, current prosthetic designs may not offer an ideal anatomical fit.

2. Material and Methods

This was a hospital-based observational study conducted at the Department of Orthopaedics, Sri Aurobindo Institute of Medical Sciences (SAIMS). Individuals with clinically normal hip joints, either visiting the outpatient or inpatient departments and who either provided informed consent or had undergone abdominal and pelvic CT scans for unrelated reasons, were enrolled after obtaining approval from the institutional ethics committee.

A total of 200 participants of varying ages and both sexes were included. Key anatomical measurements of the hip joint were recorded, including neck-shaft angle (NSA), head diameter (HD), neck width (NW), acetabular angle (AA), horizontal offset (HO), vertical offset (VO), canal diameter (CD), and acetabular version (AV).

Data collection was performed using a Philips 128-slice CT scanner. These parameters were measured bilaterally (right and left sides) and analysed in relation to age and sex. The findings were also compared with values from other population-based studies, and statistical analysis was conducted accordingly.

2.1. Neck shaft angle

The angle formed by the intersection of the femur's long axis and its neck's long axis. The femoral shaft axis is a line that is traced through two locations that are equally spaced from the femoral shaft's mediolateral surface in the medullary canal's centre. The two points that are equally spaced from the superior and inferior surfaces of the femoral neck are joined to form the neck axis.

2.2. Head diameter

The ideal spherical femoral head is covered with a perfect circle, and the diameter of the circle is measured.

*2.3. Neck width (**Figure 1**)*

At the narrowest point of the femoral neck, a line perpendicular to the neck axis is measured.

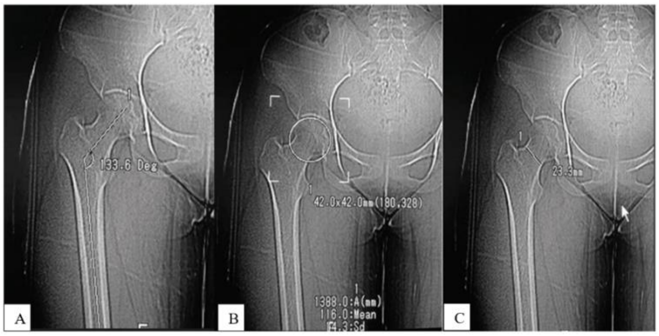

Figure 1: **A):** Neck shaft angle; **B):** Head diameter; **C):** Neck width

*2.4. Acetabular angle (**Figure 2**)*

The line border of the acetabulum and the pelvic teardrop intersected at this angle. Two lines are drawn through the teardrop and from the tip of the teardrop to the anterior edge of the acetabulum in the coronal regions of the CT scan pictures. The definition of the angle created by these two lines is the acetabular angle of sharp.

2.5. Horizontal offset

The horizontal distance between the femoral head's centre of rotation and a line that cuts the long axis of the femur shaft is known as the horizontal offset, or simply femoral offset. The centre of the femoral head and the centre of the femoral medullary canal were both marked with lines. The measured distance between the two lines gives the HO.

2.6. Vertical offset

The vertical distance from the centre of the femoral head to the tip of the lesser trochanter is known as the vertical offset or femoral head position.

2.7. Canal diameter

Measured at the midpoint of the lesser trochanter, the medullary canal's mediolateral diameter.

*2.8. Acetabular version (**Figure 3**)*

It is the angle measured between a line that joins the posterior lips of the acetabulum to the posterior ischia.

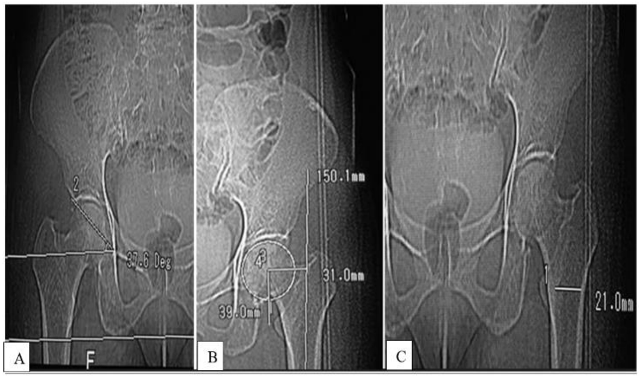

Figure 2: Acetabular angle; **B)**: Horizontal & vertical offset; **C):** Canal diameter

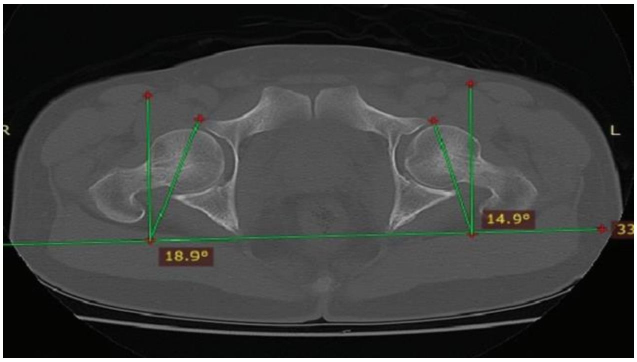

Figure 3: Acetabular version

3. Observations and Results

34 (17%) patients were in the age group of 20 years or less; 53 (26.5%) were in the age group of 21-40 years; 62 (31%) were in the age group of 41-60 years; and 51 (25.5%) were in the age of more than 60 years.

Most of the patients were in the age group 41-60 years, followed by 21-40 years.

The mean age of the patients was 44.64 ± 17.66 years (range: 15 to 72 years). (**Figure 4**)

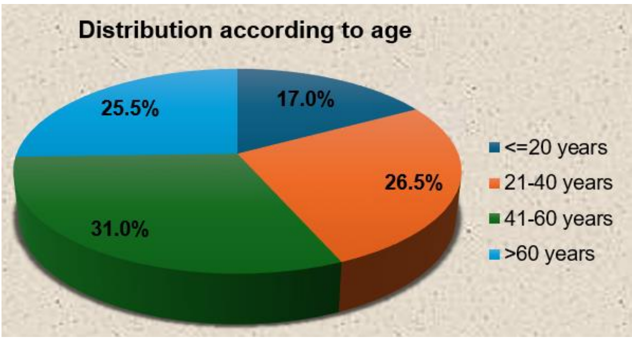

Figure 4: A pie diagram shows the distribution of patients according to age

There were 98 (49%) females and 102 (51%) males in the present study. There was nearly comparable proportion of males and females in the study. (**Figure 5**)

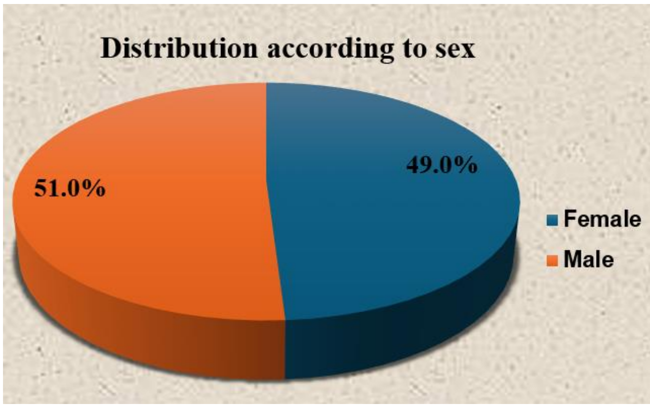

Figure 5: A pie diagram shows the distribution of patients according to sex

Table 1: Comparison of right and left neck shaft angle and neck width in relation to the sex (N=200)

Parameter	**Female [Mean ± SD]**	**Male [Mean ± SD]**	**Unpaired 't' value, df**	**P value**
Neck shaft angle (Right)	132.00 ± 29.49	135.79 ± 6.44	-2.936, df=198	0.004*
Neck shaft angle (Left)	133.14 ± 6.19	137.45 ± 5.27	-5.307, df=198	0.001*
Neck width (Right)	2.81 ± 0.40	3.38 ± 4.12	1.407, df=198	0.161, NS
Neck width (Left)	2.89 ± 0.36	3.11 ± 2.78	0.781, df=198	0.436, NS
Parameter	**Right [Mean ± SD]**	**Left [Mean ± SD]**	**Paired 't' value, df**	**P value**
Neck shaft angle	131.48 ± 21.55	135.34 ± 6.12	-2.514, df=199	0.013*
Neck width	2.99 ± 1.96	3.09 ± 2.91	1.321, df=199	0.188, NS

Unpaired 't' test and Paired 't' test applied. P value <0.05 was considered as statistically significant

Table 1 shows the comparison of right left neck shaft angle in relation to the sex.

Neck shaft angle (Right): The mean neck shaft angle in females was 127.00 ± 29.49 degrees; and in males, it was 135.79 ± 6.44 degrees. The difference was found to be statistically significant (P=0.004). The mean neck shaft angle (right) was significantly more in males compared to the females.

Neck shaft angle (Left): The mean neck shaft angle in females was 133.14 ± 6.19 degrees; and in males, it was 137.45 ± 5.27 degrees. The difference was found to be statistically significant (P=0.001). The mean neck shaft angle (left) was significantly more in males compared to the females.

Neck shaft angle: The mean neck shaft angle of right side was 131.48 ± 21.55 degrees, and that of left side was 135.34 ± 6.12 degrees. The difference was found to be statistically significant (P=0.013). The mean neck shaft angle of left side was significantly more compared to the right side.

Neck width (Right): The mean neck width in females was 2.81 ± 0.40 cm; and in males, it was 3.38 ± 4.12 cm. The difference was found to be statistically not significant (P=0.161). The mean neck width (right) was comparable between the males and females.

Neck width (Left): The mean neck width in females was 3.11 ± 2.78 cm; and in males, it was 2.89 ± 0.36 cm. The difference was found to be statistically not significant (P=0.436). The mean neck width (left) was comparable between the males and females.

Neck width: The mean neck width of right side was 3.09 ± 2.91 cm, and that of left side was 2.99 ± 1.96 cm. The difference was found to be statistically not significant (P=0.188). The mean neck width was comparable between the right and left side.

Table 2: Comparison of right and left head diameter in relation to the sex (N=200)

Parameter	**Female [Mean ± SD]**	**Male [Mean ± SD]**	**Unpaired ‘t’ value, df**	**P value**
Head diameter (Right)	3.68 ± 0.42	4.15 ± 0.42	-7.888, df=198	0.001*
Head diameter (Left)	3.79 ± 0.42	4.29 ± 0.34	-9.303, df=198	0.001*
Parameter	**Right [Mean ± SD]**	**Left [Mean ± SD]**	**Paired ‘t’ value, df**	**P value**
Head diameter	3.92 ± 0.48	4.05 ± 0.46	-6.236, df=199	0.001*

Unpaired ‘t’ test and Paired ‘t’ test applied. P value <0.05 was considered as statistically significant

Table 3: Comparison of right and left acetabular angle in relation to the sex (N=200)

Parameter	**Female [Mean ± SD]**	**Male [Mean ± SD]**	**Unpaired ‘t’ value, df**	**P value**
Acetabular angle (Right)	40.51 ± 8.56	38.31 ± 4.67	-0.819, df=198	0.414, NS
Acetabular angle (Left)	40.86 ± 8.69	38.89 ± 5.26	-0.033, df=198	0.974, NS
Parameter	**Right [Mean ± SD]**	**Left [Mean ± SD]**	**Paired ‘t’ value, df**	**P value**
Acetabular angle	39.41 ± 6.85	39.875 ± 7.13	0.095, df=199	0.924, NS

Unpaired ‘t’ test and Paired ‘t’ test applied. P value <0.05 was considered as statistically significant

Table 4: Comparison of right and left horizontal and vertical offset in relation to the sex (N=200)

Parameter	**Female [Mean ± SD]**	**Male [Mean ± SD]**	**Unpaired ‘t’ value, df**	**P value**
Horizontal offset (Right)	3.49 ± 0.64	4.11 ± 0.93	-5.442, df=198	0.001*
Horizontal offset (Left)	3.43 ± 0.70	3.74 ± 0.57	-3.357, df=198	0.001*
Vertical offset (Right)	4.37 ± 0.41	4.61 ± 0.66	-2.989, df=198	0.003*
Vertical offset (Left)	4.61 ± 0.55	5.02 ± 0.70	-4.574, df=198	0.001*
Parameter	**Right [Mean ± SD]**	**Left [Mean ± SD]**	**Paired ‘t’ value, df**	**P value**
Horizontal offset	3.81 ± 0.86	3.59 ± 0.65	5.394, df=199	0.001*
Vertical offset	4.49 ± 0.56	4.82 ± 0.66	-9.606, df=199	0.001*

Unpaired ‘t’ test and Paired ‘t’ test applied. P value <0.05 was considered as statistically significant

Head diameter (Right): The mean head diameter in females was 3.68 ± 0.42 cm; and in males, it was 4.15 ± 0.42 cm. The difference was found to be statistically significant (P=0.001). The mean head diameter (right) was significantly larger in males compared to the females.(**Table 2**)

Head diameter (Left): The mean head diameter in females was 3.79 ± 0.42 cm; and in males, it was 4.29 ± 0.34 cm. The difference was found to be statistically significant (P=0.001). The mean head diameter (left) was significantly larger in males compared to the females.

Head diameter: The mean head diameter of right side was 3.92 ± 0.48 cm, and that of left side was 4.05 ± 0.46 cm. The difference was found to be statistically significant (P=0.001). The mean head diameter of left side was significantly larger compared to the right side.

The **Table 3** shows the comparison of right left acetabular angle in relation to the sex.

Acetabular angle (Right): The mean acetabular angle in females was 40.51 ± 8.56 degrees; and in males, it was 38.31 ± 4.67 degrees. The difference was found to be statistically not significant (P=0.414). The mean acetabular angle (right) was comparable between the males and females.

Acetabular angle (Left): The mean acetabular angle in females was 40.86 ± 8.69 degrees; and in males, it was 38.89 ± 5.26 degrees. The difference was found to be statistically not significant (P=0.974). The mean acetabular angle (left) was comparable between the males and females.

Acetabular angle: The mean acetabular angle of right side was 39.41 ± 6.85 degrees, and that of left side was 39.8 ± 7.13 degrees. The difference was found to be statistically not significant (P=0.924). The mean acetabular angle was comparable between the right and left side.

The **Table 4** shows the comparison of right left horizontal offset in relation to the sex.

Horizontal offset (Right): The mean horizontal offset in females was 3.49 ± 0.64 mm; and in males, it was 4.11 ± 0.93 mm. The difference was found to be statistically significant (P=0.001). The mean horizontal offset (right) was significantly larger in males compared to the females.

Horizontal offset (Left): The mean horizontal offset in females was 3.43 ± 0.70 mm; and in males, it was 3.74 ± 0.57 mm. The difference was found to be statistically significant (P=0.001). The mean horizontal offset (left) was significantly larger in males compared to the females.

Horizontal offset: The mean horizontal offset of right side was 3.81 ± 0.86 mm, and that of left side was 3.59 ± 0.65 mm. The difference was found to be statistically significant (P=0.001). The mean horizontal offset of left side was significantly smaller compared to the right side.

Vertical offset (Right): The mean vertical offset in females was 4.37 ± 0.41 mm; and in males, it was 4.61 ± 0.66 mm. The difference was found to be statistically significant (P=0.001). The mean vertical offset (right) was significantly larger in males compared to the females.

Vertical offset (Left): The mean vertical offset in females was 4.61 ± 0.55 mm; and in males, it was 5.02 ± 0.70 mm. The difference was found to be statistically significant (P=0.001). The mean vertical offset (left) was significantly larger in males compared to the females.

Vertical offset: The mean vertical offset of right side was 4.49 ± 0.56 mm, and that of left side was 4.82 ± 0.66 mm. The difference was found to be statistically significant (P=0.001). The mean vertical offset of left side was significantly larger compared to the right side.

The **Table 5** shows the comparison of right left canal diameter in relation to the sex.

Canal diameter (Right): The mean canal diameter in females was 4.37 ± 0.41 mm; and in males, it was 4.61 ± 0.66 mm. The difference was found to be statistically significant (P=0.001). The mean canal diameter (right) was significantly larger in males compared to the females.

Canal diameter (Left): The mean canal diameter in females was 4.61 ± 0.55 mm; and in males, it was 5.02 ± 0.70 mm. The difference was found to be statistically significant (P=0.001). The mean canal diameter (left) was significantly larger in males compared to the females.

Canal diameter: The mean canal diameter of right side was 2.38 ± 0.40 mm, and that of left side was 2.12 ± 0.35 mm. The difference was found to be statistically significant (P=0.001). The mean canal diameter of left side was significantly smaller compared to the right side.

Table 5: Comparison of right and left canal diameter in relation to the sex (N=200)

Parameter	Female [Mean ± SD]	Male [Mean ± SD]	Unpaired ‘t’ value, df	P value
Canal diameter (Right)	2.29 ± 0.33	2.46 ± 0.44	-3.141, df=198	0.002*
Canal diameter (Left)	2.07 ± 0.29	2.18 ± 0.38	-2.352, df=198	0.020*
Parameter	**Right [Mean ± SD]**	**Left [Mean ± SD]**	**Paired ‘t’ value, df**	**P value**
Canal diameter	2.38 ± 0.40	2.12 ± 0.35	13.455, df=199	0.001*

Unpaired ‘t’ test and Paired ‘t’ test applied. P value <0.05 was considered as statistically significant

Table 6: Comparison of right and left acetabular version in relation to the sex (N=200)

Parameter	Female [Mean ± SD]	Male [Mean ± SD]	Unpaired 't' value, df	P value
Acetabular version (Right)	23.95 ± 6.71	19.11 ± 3.81	6.308, df=198	0.001*
Acetabular version (Left)	22.29 ± 5.74	20.31 ± 5.81	2.423, df=198	0.016*
Parameter	**Right [Mean ± SD]**	**Left [Mean ± SD]**	**Paired 't' value, df**	**P value**
Acetabular version	21.48 ± 5.93	21.28 ± 5.85	0.517, df=199	0.606, NS

Unpaired 't' test and Paired 't' test applied. P value <0.05 was considered as statistically significant

The **Table 6** shows the comparison of right left acetabular version in relation to the sex.

Acetabular version (Right): The mean acetabular version in females was 23.95 ± 6.71 degrees; and in males, it was 19.11 ± 3.81 degrees. The difference was found to be statistically significant (P=0.001). The mean acetabular version (right) was significantly smaller in males compared to the females.

Acetabular version (Left): The mean acetabular version in females was 22.29 ± 5.74 degrees; and in males, it was 20.31 ± 5.81 degrees. The difference was found to be statistically significant (P=0.016). The mean acetabular version (left) was significantly smaller in males compared to the females.

Acetabular version: The mean acetabular version of right side was 21.48 ± 5.93 degrees, and that of left side was 21.28 ± 5.85 degrees. The difference was found to be statistically not significant (P=0.606). The mean acetabular version was comparable between right and left side.

4. Discussion

Anthropometric studies can offer details on different bone and joint conditions, traits and how they differ amongst various collectives.

Assessing the anatomic state, bone density, and bone structure is made easier with the help of CT scan technology.[8]

The morphometric characteristics differ depending on the patient's race, ethnic background, and country of origin. There are a vast variety of physical, genetic, cultural, and linguistic traits found throughout the Indian subcontinent.[9,10]

Neck-Shaft angle (NSA) ranged from 117-148 degrees, with a mean of 132.53 ± 4.37 degrees. Between males and females, this angle is similar. Agarwala et al.[11] recorded a similar neck-shaft angle in the Southern Assamese population, whereas Sengodan et al.[12] discovered a higher neck-shaft angle in the South Indian population. Similarly, Saikia et al.[13] reported a higher neck-shaft angle in the North Eastern Indian population. In contrast to our findings, the studies conducted by Rubin et al. [14] in the Swiss population and Mahaisavariya et al.[15] in the Thai population found a lower neck-shaft angle.

All measurements were conducted by a single independent examiner to eliminate inter-observer variability. The data were analysed both collectively for the entire population and by subgroupings, including right vs. left side and male vs. female. In our findings, the medullary canal diameter at the level of the lesser trochanter did not differ significantly between genders. However, other parameters—such as the neck-shaft angle (NSA), head diameter (HD), neck width (NW), Sharp's acetabular angle (AA), horizontal offset (HO), vertical offset (VO), and acetabular version (AV)—exhibited statistically significant differences between males and females. When comparing the right and left sides, only the femoral head diameter and Sharp's acetabular angle showed significant variation. No other parameters demonstrated statistically significant differences in our study.

Table 7: Comparison of data among sex

Parameters	Population mean	Male		Female	
		Right	Left	Right	Left
Femoral head diameter	3.98	4.15 ± 0.42	4.29 ± 0.34	3.68 ± 0.42	3.79 ± 0.42
Neck Width	3.04	3.38 ± 4.12	3.11 ± 2.78	2.81 ± 0.40	2.89 ± 0.36
Neck Shaft Angle	133.4	135.79 ± 6.44	137.45 ± 5.27	132.00 ± 29.49	133.14 ± 6.19
Horizontal offset	3.70	4.11 ± 0.93	3.74 ± 0.57	3.49 ± 0.64	3.43 ± 0.70
Vertical offset	4.65	4.61 ± 0.66	5.02 ± 0.70	4.37 ± 0.41	4.61 ± 0.55
Canal Diameter	2.25	2.46 ± 0.44	2.18 ± 0.38	2.29 ± 0.33	2.07 ± 0.29
Acetabular Angle	39.64	38.31 ± 4.67	38.89 ± 5.26	40.51 ± 8.56	40.86 ± 8.69
Acetabular version	21.38	19.11 ± 3.81	20.31 ± 5.81	23.95 ± 6.71	22.29 ± 5.74

Table 8: Comparative analysis with other studies

Parameters	Present study (India, Indore, SAIMS)	Sengodan et al.	Agarwala et al. (Indian	Pradeep et al. (Indian)	Elaheh et al. (Iran)	Rubin et al. (Swiss)	Mahasavariya et al. (Indian)
Femoral head diameter	3.98	4.26	4.10	4.39	4.77	4.34	4.39
Neck Width	3.04	2.75	2.85	2.51	2.89	Not reported	Not reported
Neck Shaft Angle	133.41	135.4	132.62	132.53	142.4	122.9	128.04
Horizontal offset	3.7	3.76	3.93	4.37	Not reported	4.7	Not reported
Vertical offset	4.65	4.69	4.53	5.63	Not reported	5.6	4.89
Canal Diameter	2.25	2.02	2.25	3.55	Not reported	Not reported	Not reported
Acetabular Angle	39.64	35.5	34.9	43.11	Not 4.34reported	27.9	Not reported
Acetabular version	21.38	18.6	20.60	19.47	Not reported	Not reported	Not reported

5. Conclusion

The results of this study demonstrate that there are notable differences in hip joint anthropometry between Indian and Western populations. Due to the considerable diversity in skeletal structure across global ethnicities, individuals from smaller-framed groups—such as the Indian population—often face challenges during total hip arthroplasty (THA). These challenges stem from the limited availability of prosthetic implants that match their anatomical dimensions. The insights gained from this research could contribute to the development of hip prostheses tailored specifically for the Indian demographic. However, to strengthen and generalize these findings, a large-scale, multicenter study across various regions in India is recommended.

6. Limitations

To improve the accuracy and applicability of the findings, a larger, multicentric study encompassing diverse Indian populations is recommended. Such data would be invaluable in the development of hip prostheses that more closely replicate the native biomechanics of the Indian hip joint.

7. Source of Funding

None.

8. Conflict of Interest

None declared.

9. Ethical No.

Ethical No.: ECR/748/Inst/MP2015/RR-22.

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Cite this article: Jain S, Choudhari P, Khande S. Anthropometric analysis of normal hip joint using computed tomography scan in central Indian population. *Indian J Orthop Surg*. 2025;11(2):130–137.