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Original Research Article

Morphometric Parameters of The Humerus and Analysis of its Anatomical Variations

P. Mythili[1], P. Kanagavalli[2], S. Senthil Kumar[3], Aarav M. Shah[4], Niranjan A.[5]

[1]Assistant Professor, Department of Anatomy, Government medical college, Omandurar Government Estate, Chennai, Tamil Nadu, India

[2]Professor, Department of Anatomy, Government Medical College, Omandurar Government Estate, Chennai, Tamil Nadu, India

[3]Assistant Professor, Department of Internal Medicine, Government Medical College, Chengalpet, Tamil Nadu, India

[4]Third Year Undergraduate MBBS Student, Government Medical college, Omandurar Government Estate, Chennai, Tamil Nadu, India

[5]Prefinal Undergraduate MBBS Student, Government Medical College, Omandurar Government Estate, Chennai, Tamil Nadu, India

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Corresponding Author: Dr. Niranjan A.
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Abstract:

Background: The shoulder joint permits a wide range of motion but due to anatomical reasons the shoulder joint is more prone to dislocations and instability than other joints. Need for population specific measurements is emphasized, since most prostheses designs are available based on Caucasian samples.

Methods: Descriptive cross-sectional study on 47 dry adult humeri, both right (25) and left (22) were measured. Data was expressed as mean ± SD. An independent t test was used to compare parameters between right and left humerus.

Results: Statistically significant differences were observed in diameter of humeral head and surgical neck and also dimensions related to bicipital groove between the two sides. The value of indices differs from the west and between the sides though in few cases was statistically significant.

Conclusion: The morphometric study revealed a few important variations of the humerus in an Indian population. Thus, data regarding different measurements of humerus on population specific basis becomes important and would aid in precise surgery.

Keywords: Humerus, Morphometry, Bicipital Groove, Arthroplasty, Anatomical Variation.

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Introduction

The shoulder is a highly mobile joint, facilitating diverse upper limb motion, indispensable in day-to-day life. The highly mobile nature of this glenohumeral joint is owed to the articulation between the smooth and round humeral head and a comparatively shallow glenoid cavity. It is this arrangement that offers increased motion due to the very minimal surface area contact between the humeral head and glenoid at any one time, however decreasing the innate stability of this joint.[1] This balance between range of motion and stability can lead to instability, trauma or disease process of the joint, rendering the study of the anatomy of the proximal humerus paramount.

The morphometric data on the proximal humerus are particularly significant in clinical scenarios including bony defects like the Hill-Sachs lesion, as well as during reconstructions and replacements of the shoulder.[2] Prostheses used in shoulder arthroplasty procedures are often designed based on Western anatomical data, which may not adequately reflect the anatomical variations occurring in other population groups, resulting in size discrepancy in prostheses size which led to post operative pain, immobility and joint overstuffing. It is vital for data from different geographical groups to be established to improve size discrepancies in shoulder arthroplasty.

It is imperative that the anatomy be restored as far as possible to preserve the biomechanical functions of the shoulder. Accurate reconstruction of the anatomy will maintain the function of the deltoid and rotator cuff muscles along with their leverage arms and prevent joint instability. The geometric dimensions of the humeral head, in addition to its articular surfaces, must be precisely reproduced. Even small variations may shift joint kinematics and may impact final functional outcomes. Morphometric assessment is therefore crucial for optimal surgical results.

Hence this study was conducted to assess the morphometric parameters of the proximal humerus, analysing the anatomical variations and correlating them to their clinical relevance in the context of the glenohumeral joint for the design of suitable prostheses for shoulder related condition.[1]

Aim & Objectives

Aim: To study the morphometric parameters of the humerus and analyze its anatomical variations, with emphasis on its clinical significance in relation to the glenohumeral joint.

Objectives

1. To measure the morphometric parameters of the proximal humerus, including humeral head dimensions, anatomical neck, surgical neck, and bicipital groove.
2. To analyze anatomical variations of these parameters and correlate them with clinical conditions such as fractures, prosthesis design, and biceps tendon pathology.

Materials and Methods

Study Design: Descriptive cross-sectional study.

Study Setting: Department of Anatomy, GMC OGE.

Study Material: Dry adult human humeri (right and left sides).

Sample Size: The sample size required for the study is calculated using the parameters (mean and standard deviation) from the previous literature [2] with the prevalence 32% which showed the difference in the mean score at a 95% confidence interval using the formula.

$$n= \frac{Z^2 \times p(1-P)}{d^2}$$

N= 47

Sample size= 47

Parameters Studied

1. **General**
   - maximum length of humerus
   - side of humerus
2. **Proximal Humerus**
   - Vertical diameter (VD) of humeral head
   - Transverse diameter (TD) of humeral head
   - Circumference of humeral head
   - Diameter of surgical neck
3. **Bicipital Groove (BG)**
   - Length of Bicipital groove
   - Width of bicipital groove
4. **Ratio**
   - H/C ratio (Length of the Bicipital Groove divided by the Length of the Humerus)
   - Humeral Head Index (HHI)

Instruments Used

- Osteometric board → For measuring maximum length of humerus
- Vernier calliper → For measuring diameters and groove measurements
- Measuring tape → For measuring circumference of humeral head

Inclusion Criteria

- Fully ossified adult humerus
- Intact bones with clearly identifiable anatomical landmarks
- Both right and left humerus

Exclusion Criteria

- Broken or damaged humerus
- Bones with deformities or pathological changes
- Incompletely ossified (juvenile) bone

Procedure of Data Collection: A descriptive, cross-sectional study was performed on a sample of 47 dried adult human humerus (22 right and 25 left). All the specimens were procured from the Department of Anatomy GMC, OGE. All humerus that was completely ossified and devoid of any deformities and pathology were included in the study.

All the measurements were done using a digital vernier calliper (precision 0.01 mm). The length of the humerus was measured using the osteometric board. (Fig 3, 4)

The measurements taken were:

- **Humeral Head Height (HHH) –** which is a marker to determine the size of the prosthetic head.
- **Humeral Head Diameter (HHD) –** this is used to determine the appropriate size for the prosthetic head while attempting to maintain joint congruency.
- **Humeral Head Index (HHI) –** which describes the ratio between these dimensions and is a way to determine the proportion of the size of the humeral head.
- **Length of Bicipital Groove (BG Length) –** this refers to the stability and path of the long head of the biceps.

- **Width of Bicipital Groove (BG Width) –** determines whether there is subluxation of the tendon, or if the tendon gets entrapped.
- **The Maximum Length of the humerus (MLH)** is a measure used in forensic analysis and reconstruction of the stature.
- **H/C Ratio –** standardizes the length of the bicipital groove with reference to the length of the humerus.

Figure 1: Measurement of Transverse diameter of humerus

Statistical Analysis: Data were entered into Microsoft Excel and analysed using statistical software SPSS 22. Mean and standard deviation were calculated for all parameters. The 95% confidence interval was determined for each variable. Differences between right and left sides were analysed using the independent sample t-test, and a p-value < 0.05 was considered statistically significant.

Figure 2: Measurement of Vertical diameter of humerus

Results

This study included 47 humeri (Left-22, Right-25).

The results of the morphometric parameters measured are presented below (Table 1).

Table 1: Showing the Mean, SD and Range for various parameters.

Parameter	N	Mean ± SD	Range
Maximum length of humerus (cm)			
Both	47	29.99 ± 2.50	25.5 – 35.0
Left	22	29.89 ± 2.72	26.5 – 32.0
Right	25	30.07 ± 2.27	25.5 – 35.0
Vertical diameter of humeral head (mm)			
Both	47	40.55 ± 3.90	32.06 – 46.86
Left	22	40.4 ± 3.88	35.52 – 46.72
Right	25	40.7 ± 3.93	32.06 – 46.86
Transverse diameter of humeral head (mm)			
Both	47	37.50 ± 3.70	30.11 – 45.51
Left	22	37.69 ± 3.51	33.42 – 45.51
Right	25	37.34 ± 3.93	30.11 – 44.32
Circumference of humeral head (cm)			
Both	47	12.54 ± 1.21	10.5 – 14.5
Left	22	12.50 ± 1.18	11.0 – 14.5
Right	25	12.58 ± 1.25	10.5 – 14.5
Diameter of surgical neck (mm)			
Both	47	21.35 ± 2.70	16.16 – 26.89
Left	22	21.06 ± 2.13	17.72 – 25.45
Right	25	21.6 ± 3.17	16.16 – 26.89
Length of bicipital groove (cm)			
Both	47	5.89 ± 0.65	5.0 – 8.0
Left	22	5.8 ± 0.5	5.0 – 7.0
Right	25	5.97 ± 0.78	5.0 – 8.0
Width of bicipital groove (mm)			
Both	47	8.03 ± 1.25	6.11 – 11.3
Left	22	8.14 ± 1.34	6.11 – 11.3
Right	25	7.93 ± 1.15	5.82 – 10.35
H/C ratio			
Both	47	0.20 ± 0.02	0.15 – 0.27
Left	22	0.20 ± 0.02	0.17 – 0.22
Right	25	0.20 ± 0.02	0.17 – 0.27
Humeral Head Index (HHI)			
Both	47	0.925 ± 0.025	0.86 – 1.00
Left	22	0.93 ± 0.03	0.86 – 1.00
Right	25	0.92 ± 0.02	0.88 – 0.97

Maximum length of humerus (cm): The mean maximum length of humerus on the left side was 29.89 ± 2.72 cm, and on the right side was 30.07 ± 2.27 cm. Right side measurements were slightly higher than left side and the difference was found to be statistically significant ($p = 0.041$). (Fig 3)

On the left side, 95% confidence interval was 28.75 cm to 31.03 cm on the right side, 95% confidence interval was 29.18 cm to 30.96 cm.

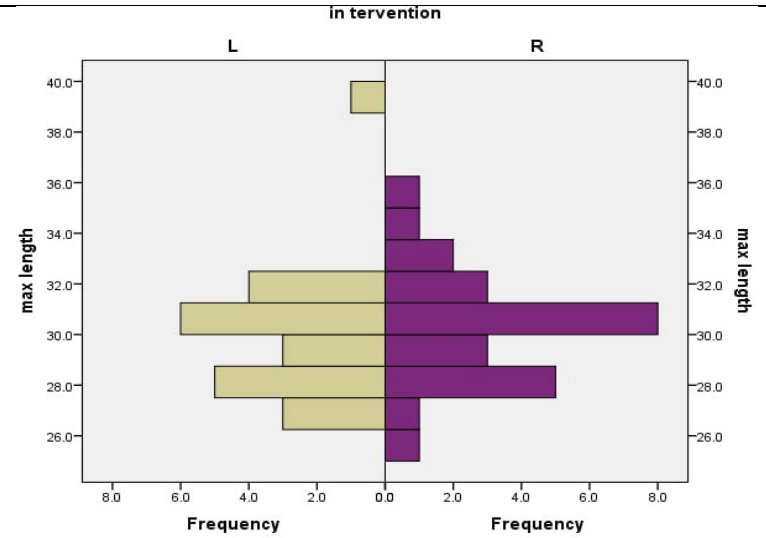

Figure 3: statistical analysis of VD of humerus

Vertical diameter of humeral head (VD) (mm): The mean vertical diameter on the left side was 40.4 ± 3.88 mm, and 40.7 ± 3.93 mm on the right side. The difference was statistically significant ($p = 0.043$) [Fig.4]

On the left side, 95% confidence interval was 38.78 mm to 42.02 mm on the right side, 95% confidence interval was 39.16 mm to 42.24 mm.

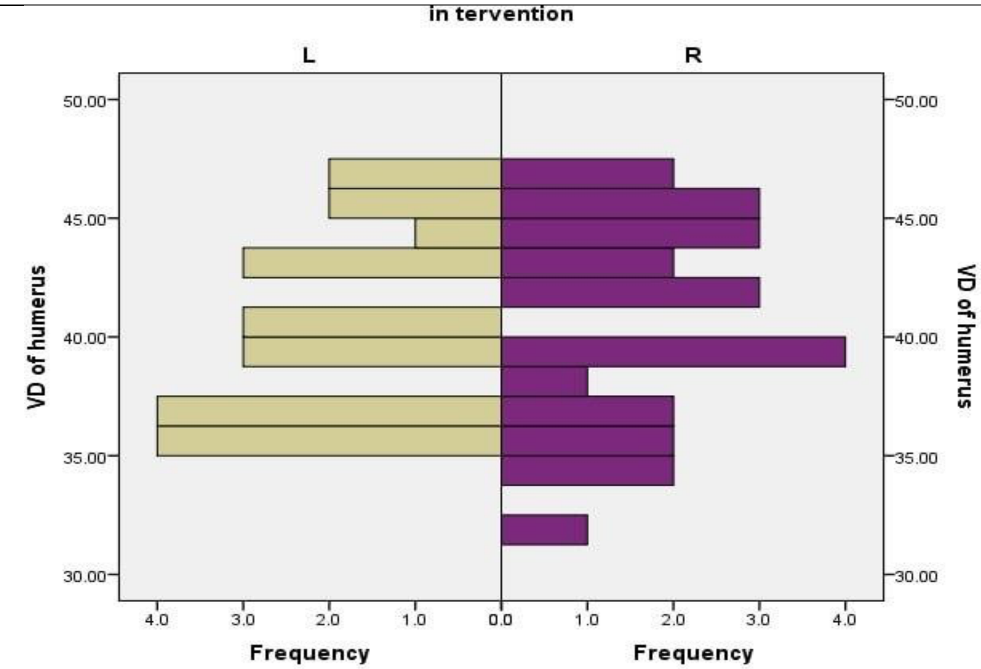

Figure 4: Statistical analysis of VD of humerus

Transverse diameter of humeral head (TD) (mm): The mean transverse diameter on the left side was 37.69 ± 3.51 mm, and 37.34 ± 3.93 mm on the right side. The difference was statistically significant (p = 0.034). [Fig.5]

On left side, 95% confidence interval was 36.22 mm to 39.16 mm, On the right side, 95% confidence interval was 35.80 mm to 38.88 mm.

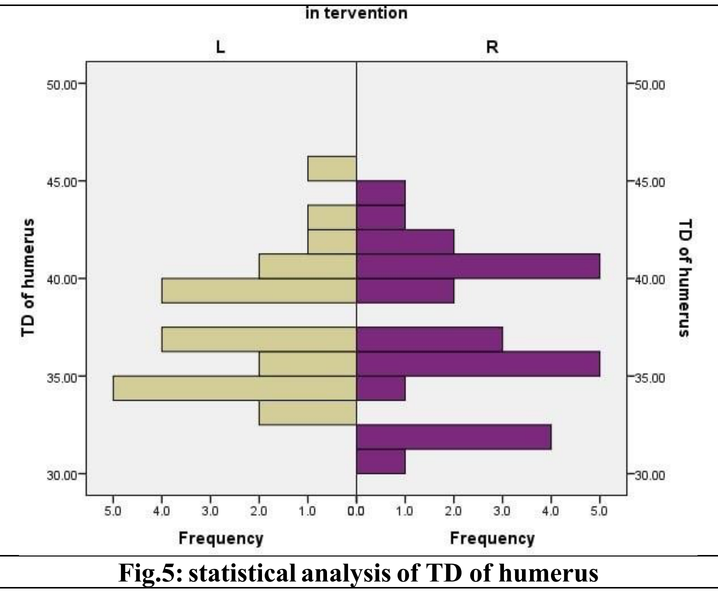

Fig.5: statistical analysis of TD of humerus

Circumference of humeral head (cm): The mean circumference on the left side was 12.50 ± 1.18 cm, and 12.58 ± 1.25 cm on the right side. The difference was found to be not statistically significant (p = 0.096). (Fig 6)

On left side, 95% confidence interval was 12.01 cm to 12.99 cm, On the right side, 95% confidence interval was 12.09 cm to 13.07 cm.

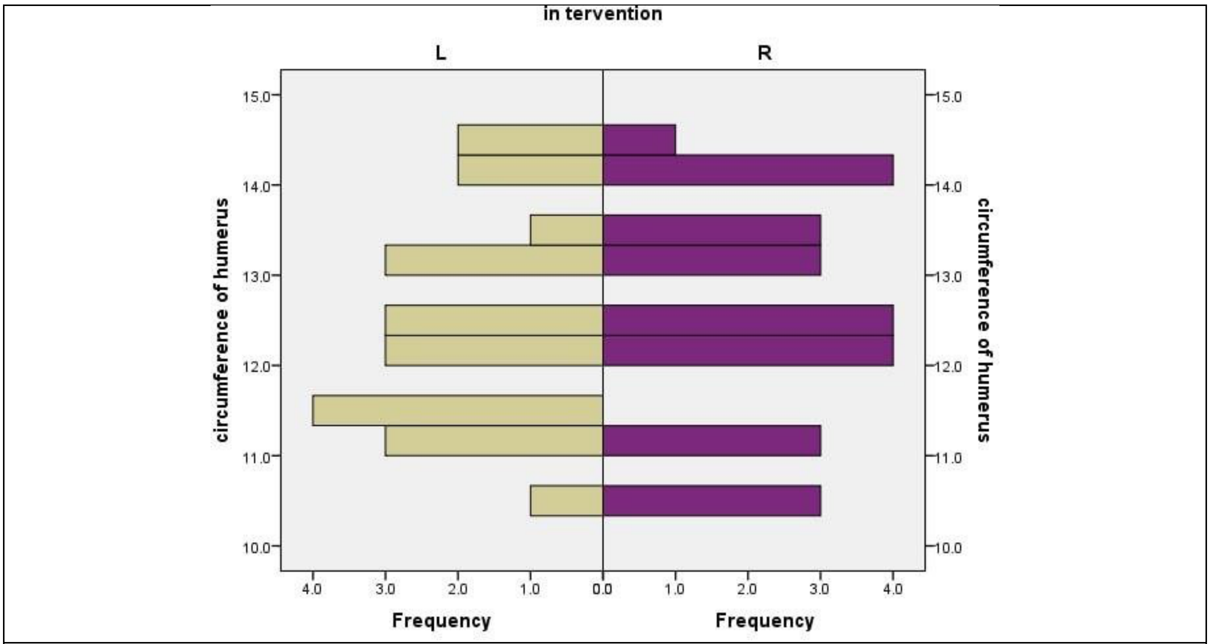

Figure 6: Statistical analysis of circumference of humerus head

Diameter of surgical neck (mm): The mean diameter of the surgical neck on the left side was 21.06 ± 2.13 mm, and 21.6 ± 3.17 mm on the right side. The difference was statistically significant (p = 0.019). (FIG 7)

On the left side, 95% confidence interval was 20.17 mm to 21.95 mm, On the right side, 95% confidence interval was 20.36 mm to 22.84 mm.

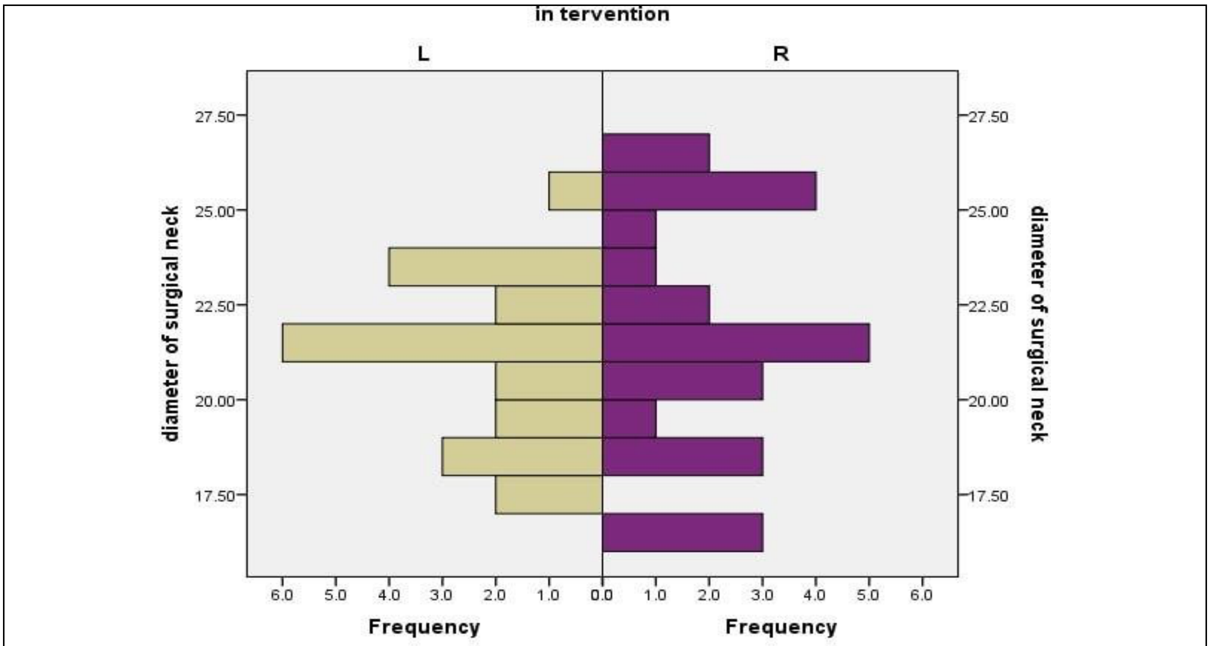

Figure 7: statistical analysis of diameter of surgical neck

Length of bicipital groove (cm): The mean length of the bicipital groove on the left side was 5.8 ± 0.5 cm, and 5.97 ± 0.78 cm on the right side. The difference was statistically significant (p = 0.012). [FIG.8]

On left side, 95% confidence interval was 5.59 cm to 6.01 cm, On the right side, 95% confidence interval was 5.66 cm to 6.28 cm.

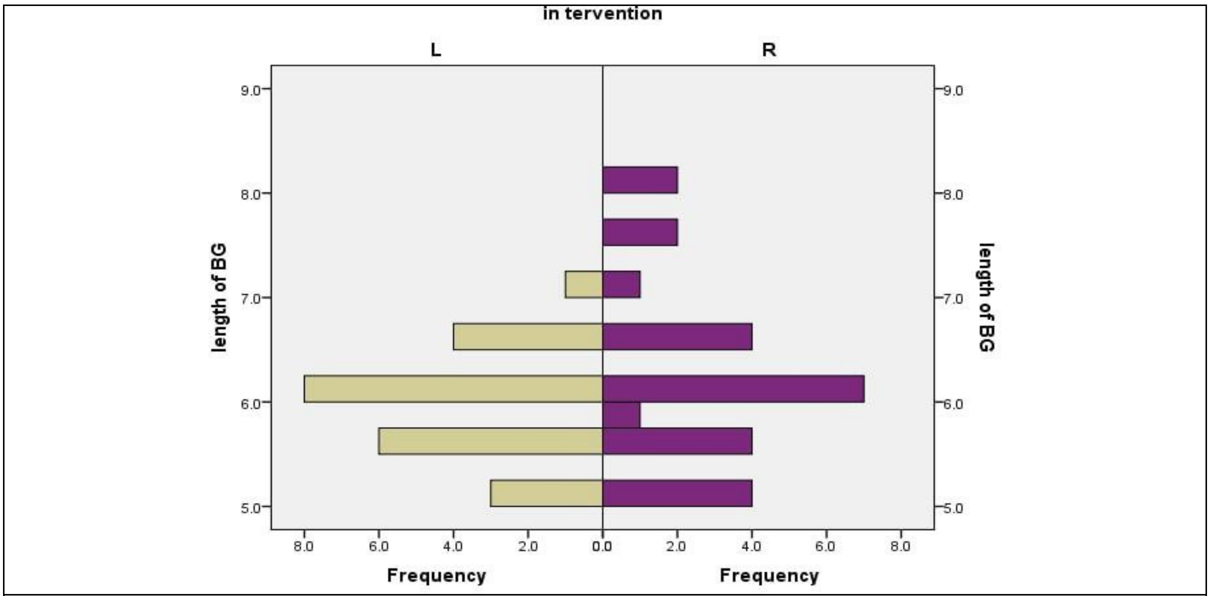

Figure 8: Statistical analysis of length of BG

Width of bicipital groove (mm): The mean width on the left side was 8.14 ± 1.34 mm, and 7.93 ± 1.15 mm on the right side. The difference was statistically significant (p = 0.03). [FIG.9]

On left side, 95% confidence interval was 7.58 mm to 8.70 mm, On the right side, 95% confidence interval was 7.48 mm to 8.38 mm.

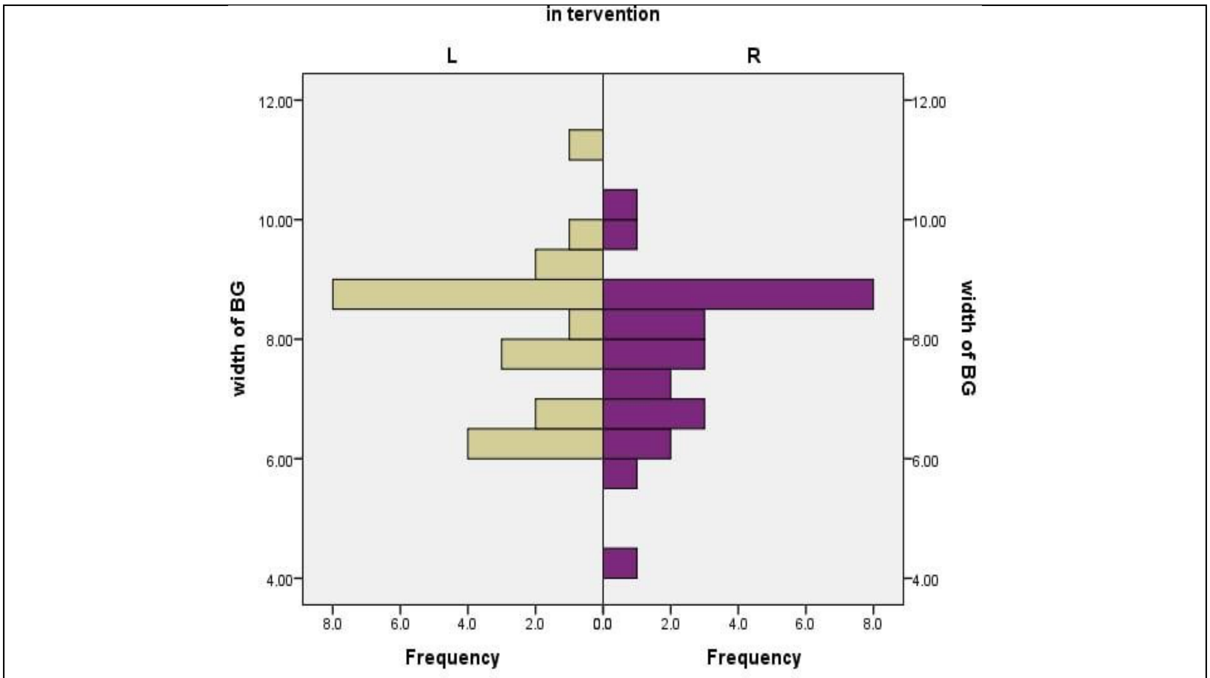

Figure 9: Statistical analysis of width of BG

H/C ratio: The mean H/C ratio on the left side was 0.20 ± 0.02, and 0.20 ± 0.02 on the right side. The difference was statistically significant (p = 0.036). [FIG.10]

On left side, 95% confidence interval was 0.191 to 0.209 on right side, 95% confidence interval was 0.192 to 0.208.

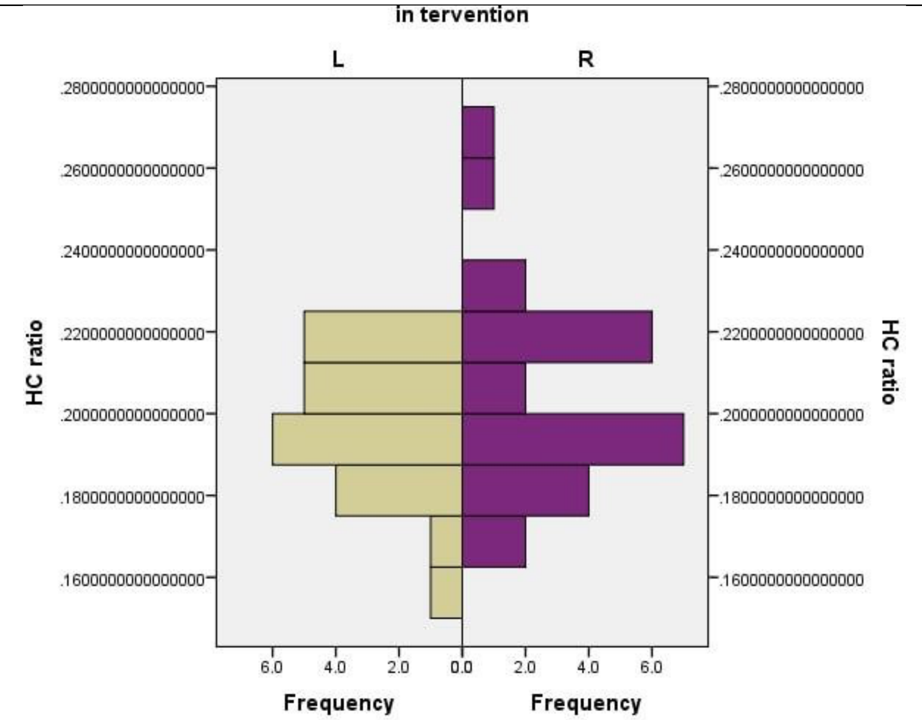

Figure 10: Statistical analysis of H/C ratio

Humeral Head Index (HHI): The mean HHI on the left side was 0.93 ± 0.03, and 0.92 ± 0.02 on the right side. The difference was found to be statistically significant (p = 0.025). [Fig.11]

On left side, 95% confidence interval was 0.917 to 0.943, On the right side, 95% confidence interval was 0.912 to 0.928.

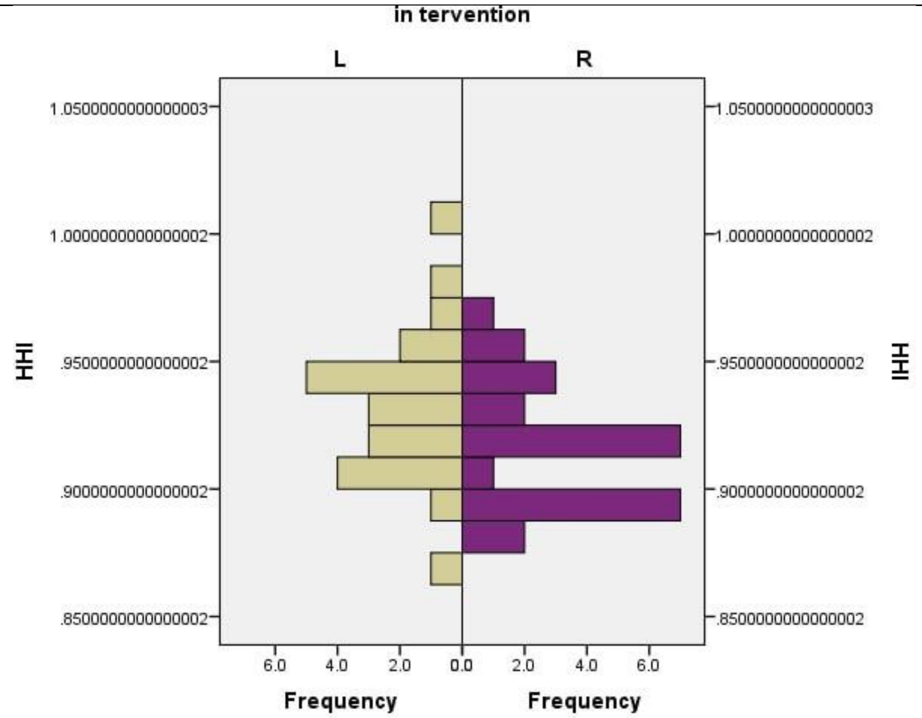

Figure 11: Statistical analysis of HHI

Discussion

The present study provides significant results on varied morphometric parameters in the proximal humerus compared to previously recorded studies, especially from Western countries. The variation demonstrates the need for region-specific anatomical data in orthopaedic surgery and prosthesis design.

In the present study, both right and left humeral heads have a comparable value of the vertical and transverse diameters though they show a statistically significant difference. The mean vertical diameter in this study was 40.7 ± 3.93 mm (right) and 40.4 ± 3.88 mm (left), while the transverse diameter measured 37.34 ± 3.93 mm (right) and 37.69 ± 3.51 mm (left). These values are relatively lower when compared to the findings of Hertel, who reported mean diameters of 44.5 ± 4 mm in the frontal plane and 42 ± 3.8 mm in the sagittal plane. Variations may be explained on the basis of anatomical differences of various ethnic groups in different regions.[3]

No significant side differences were found for circumference of the humeral head. There are statistically significant differences between right and left for the diameters of the surgical neck and the bicipital groove morphology.

Restoration of the original size of the humeral head is important in shoulder replacement surgery.[3] However, the prosthetic components come in fixed size and do not replicate the original anatomy, especially in populations with smaller morphometric values. Studies have confirmed that perfect restoration of anatomy is the key to successful surgical outcome; it restores normal biomechanics, tension of soft tissues, and normal center of rotation of the glenohumeral joint, to achieve the normal movement, and avoid further eccentricity, wear of joint, implant loosening.

Harryman have stated that the use of non-anatomical components with fixed size severely restricts shoulder motion, which includes flexion, rotation, elevation and even a reduction in thickness can limit the articulation between the humeral head and glenoid, leading to poor outcome.[1]

The mean value of width and length of the bicipital groove also have statistically significant side differences. Abnormalities of the morphology of the bicipital groove are clinically significant as it is essential in maintaining stability of the tendon of long head of biceps; its abnormal size or configuration is thought to result in subluxation or dislocation of tendon and can lead to inflammation like bicipital tendinitis.[4]

The values for H/C ratio and Humeral head index (HHI) in the present study do not show statistically significant side differences though they reveal a somewhat lower range compared to the previous reports, except the significantly observed differences. The H/C ratio and humeral head index are important indices to understand the proportional size of the humeral head.

In shoulder instability the size and configuration of the humeral head are important, defects such as the Hill-Sachs lesion and glenoid bone loss reduce the stability of the shoulder [2]. Failure to appreciate these bony abnormalities are the main causes of recurrence after soft tissue procedure for instability. It have suggested a new term "glenoid track" that illustrates the relationship between glenoid and humeral dimensions to achieve recurrent stability.[5]

In regard to shoulder instability, the morphometric values can affect the Bankart repair and the Latarjet procedure, to achieve anatomical restoration. Previous reports emphasized the importance of anatomical size of the humerus.[6]

Conclusion

This study supports the findings in studies which state that there are variations in dimensions of the proximal humerus between Western populations and this studied population. This population study reveals parameters with certain lesser dimensions that might not be incorporated adequately in present prostheses. The sizes are mostly derived from Western populations and do not cater to the population study where some values are smaller. Hence, population specific morphometric data is essential for prosthetic selection and design of humeral prostheses for replacement arthroplasty.[7]

Many prosthetic devices are designed on the basis of the values found in western literature and therefore the differences in dimension have not been accounted for, thereby leading to poor fitting of prosthesis in many cases in this population as these smaller sizes are less incorporated.

Statistically significant differences were seen between right and left sides in many parameters that are important. Various other parameters such as dimension of the bicipital groove and calculated parameters such as ratio of H/C and index of humerus reveal variations that play a crucial role in clinical conditions such as tendon instability and joint mechanics.

Declaration

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Conflict of Interest: Nil

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