



ISSN:

2542-2758 (Print) 2542-2804 (Online)

ARTICLE INFO:

Received date: September 23, 2025

Accepted date: December 5, 2025

Published date: December 31, 2025

KEYWORDS:

Anaerobic bacteria, Bacteroides fragilis, Drug Resistance, Microbial, Drug Sensitivity Tests, Surgical Wound Infection

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Access the article online



DOI: 10.62065/bjhs751

CITATION:

Yadav SK, Yadav R. Anthropometric Study of the Humeral Torsion Angle and Its Sex- and Side-Related Variations. 2025; 10 (3): 104-108.

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Anthropometric Study of the Humeral Torsion Angle and Its Sex- and Side-Related Variations

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ABSTRACT

Introduction: The humerus plays a critical role in the evolution of the human upper limb, characterized by an angle between the transverse axis of the humeral head and the transcondylar (epicondylar) axis of the distal humerus, known as the Angle of Humeral Torsion (AHT). Abnormal humeral torsion leads to brachial plexus birth palsy or rotational deformities and increased torsion leads to an adaptive change, protecting the shoulder from injury during high-velocity throwing.

Objectives: The present study aims to measure the Angle of Humeral Torsion (AHT) in healthy young adults using a validated manual palpation technique, and to compare the AHT between males and females as well as two sides.

Methodology: This cross-sectional study included 104 healthy medical students (62 males and 42 females, aged 18–24 years) from Nobel Medical College and Teaching hospital, Nepal. The Angle of Humeral Torsion (AHT) was measured on both sides using a validated manual palpation technique. Sex differences and right–left variations in AHT were evaluated using independent-samples and paired t-tests, respectively with a significance level set at $p < 0.05$.

Results: Results showed a significantly higher ($p < 0.001$) mean AHT in males (35.44 ± 1.78 , right side 62 and left side 62, $N=124$) compared to females (32.61 ± 1.25 , right side 42 and left side 42, $N=84$), with significant gender difference. Comparing right (34.66 ± 2.19) and left (33.95 ± 2.04) angle of torsion showed significant difference ($p=0.001$), reported bilaterally asymmetrical humeral torsion.

Conclusions: Estimation of angle of humeral torsion (AHT) in healthy young adult male reported higher angle compared to females and higher angle in right side reporting significant difference. The findings provide important anthropometric data relevant to Orthopaedic and rehabilitative practices in the Nepalese population.

Introduction

Humeral torsion determines how the humeral head aligns within the glenoid fossa and directly influences the internal and external rotational ranges. Higher torsion leads to increased external rotation and reduced internal rotation, whereas lower torsion results in increased internal rotation and reduced external rotation. Increased humeral torsion in the dominant arm is commonly seen as an adaptive response to repetitive high-velocity throwing. The upper limb in humans evolves to form complex appendicular structures, among which the humerus plays a central role. A key anatomical feature of the humerus is the torsional twist of its head in relation to its shaft (medial and lateral epicondyle of humerus). This is referred to as humeral torsion.¹ The Angle of Humeral Torsion (AHT) is quantified by the intersection of two axes: one that bisects the articular surface of the humeral head proximally, and the other being the trans-epicondylar line at the distal end of the bone.² The humeral torsion angle represents the degree of twist

of the humerus along its longitudinal axis and is quantified as the acute angle formed medially and posteriorly between the transcondylar axis (distal humerus) and the line bisecting the humeral head (proximal humerus).³

Research shows that humeral torsion varies with how the upper limb is used, especially among people who participate in different sports. Individuals with high levels of physical activity generally exhibit lower torsion angles, whereas those who are less active tend to display higher torsional values.^{4,5}

The topic of humeral torsion has been extensively examined by researchers worldwide. Current evidence indicates that torsion can be classified into two forms: primary torsion, which is determined embryologically and varies by species, and secondary torsion, which develops postnatally as muscular forces act on the bone. The muscles responsible for internal and external rotation of the shoulder and arm play a major role in shaping secondary torsion by exerting force on the humeral shaft. Notably, studies of professional baseball pitchers have shown increased shaft thickness and modified humeral torsion, illustrating the bone's adaptation to repeated biomechanical stress. Humeral torsion has also been extensively studied in patients with Recurrent Anterior Dislocation of the Shoulder (RADS). It has been found that a higher torsion angle correlates with an increased incidence of shoulder dislocation. In such cases, even minor trauma may result in dislocation compared to individuals with normal AHT values.⁶⁻⁸

Therefore, mid-shaft circumference, along with the angle and length of the humerus, is a relevant anatomical consideration in such assessments. The clinical implications of studying humeral torsion are significant, with notable applications in orthopaedic surgery, where precise anatomical understanding can improve surgical outcomes.⁹

Since, technically humeral head and neck can't be palpated easily, bicipital-forearm angle (BFA) measurement is widely used to quantify humeral torsion (HT).³ Because the ulna is essentially perpendicular to the epicondylar axis (line connecting medial and lateral epicondyle of humerus) when the elbow is flexed to 90°, the angle between the ulna and vertical is BFA and can be used to assess HT which was addressed by Ito et al (1995).¹⁰ Thus, present study measures humeral torsion angle based on BFA measurement as Dashottar conducted a study in Ohio state University to validate the measurement demonstrating that using palpation to orient the bicipital tuberosities is a valid method of measuring BFA and assessing HT. The mean BFA measured with ultrasound and palpation were 31.5° (SD 7.5°) and 30.5° (SD 7.9°) respectively, which were not statistically different ($F = 0.0$; $p = 0.99$).³ The linear relationship between humeral head retroversion and the bicipital groove angle (α) can be expressed as $\alpha = 0.7125 \times \text{retroversion} (\beta) + 24.8128$. The average angle α and β was 40.08° ($\pm 11.15^\circ$) and 42.19° ($\pm 12.64^\circ$).¹¹

To date, there is limited documentation on the comparative analysis of humeral torsion angle within the Nepalese population. This study aims to fill that gap through an anthropometric analysis by palpation method, which may have clinical relevance for orthopaedic and rehabilitative interventions. The present

study offers a descriptive analysis of the humeral torsion angle in young adult individuals, with the goal of evaluating its differences among male vs. female side related variations.

Methodology

A cross-sectional study was conducted at Nobel Medical College and Teaching Hospital, Biratnagar, Nepal, between June 2021 and May 2022. Purposive sampling was used to recruit basic science medical students who were healthy and had no history of fractures or other orthopaedic pathologies.

The study population comprised 104 students (62 adult males, 42 adult females) enrolled in MBBS, BDS, and Bsc. Nursing programs at the aforementioned institution. Written informed consent was obtained from all participants prior to data collection. Ethical approval for this study was obtained from the Institutional Review Committee of Nobel Medical College and Teaching Hospital (Ref No. NMCTH 429/2021).

The participants' age and sex were documented. The angle of humeral torsion was assessed bilaterally (both right and left arms) using a non-imaging, manual palpation-based method.³ The method requires two examiners at a time. Volunteers were positioned supine, with arms at the side, elbow flexed to 90°, the forearm midway between supination and pronation with palm facing the subject. The clearance of the forearm in internal rotation (IR) was increased by placing a pillow under the distal humerus. First examiner began the trial by palpating the lateral tip of the acromion with his thumb, then glided the thumb inferiorly between the anterior and middle fibres of deltoid to the head of humerus. At times, it was helpful to ask the subject to isometrically contract the deltoid in order to detect the interval between the anterior and middle fibres. Next, Examiner palpated the greater and lesser tuberosities of the humerus. At this point, the orientation of the palpating thumb was changed from the tip of the thumb facing inferior to the tip facing medial. The subject's humerus was then rotated medially and laterally, and the humerus was considered in its desired orientation when the greater and lesser tuberosities were both felt under the thumb. If the lesser tuberosity was not felt under the thumb, as happened occasionally, the most prominent part of the greater tuberosity was used to orient the humerus. To reduce measurement error, each assessment was repeated, and the mean value was used for analysis. Scale was placed between two tuberosities which was parallel to the floor at this position. A second scale was dropped down perpendicular to this tuberosity axis (Fig 1). The third scale was placed parallel to the ulnar border of the forearm (Fig 2 A, B). The intersecting point between perpendicular scale and the scale parallel to the ulnar border was measured with protractor (inclinator) and the angle was recorded (Fig 3). The procedure was repeated three times and the mean value was used for analysis to improve the accuracy and reliability.

This hands-on, landmark-based method is a validated non-radiological approach for estimating humeral torsion, and has been shown to be a reliable technique for identifying side-to-side differences in torsion alignment.³

Statistical data analysis

SPSS version 24 was used in this study. Age, sex of the participants was documented including mean and standard deviation (SD) of the angle of humeral torsion for all 62 adult males and 42 adult females. The independent sample t-test was used to check for significant differences between male and female. Angle of humeral torsion (AHT) for both right and left sides were compared using paired t test.

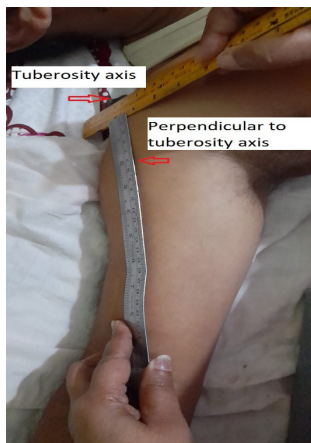


Figure 1: Finding tuberosity axis and a perpendicular line dropped from this axis.

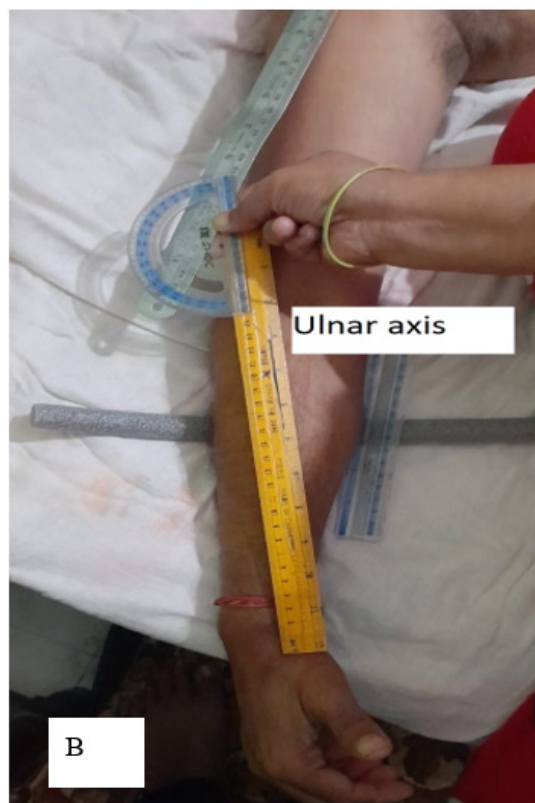


Figure 2(A,B): Angle measured between ulnar axis and perpendicular axis.

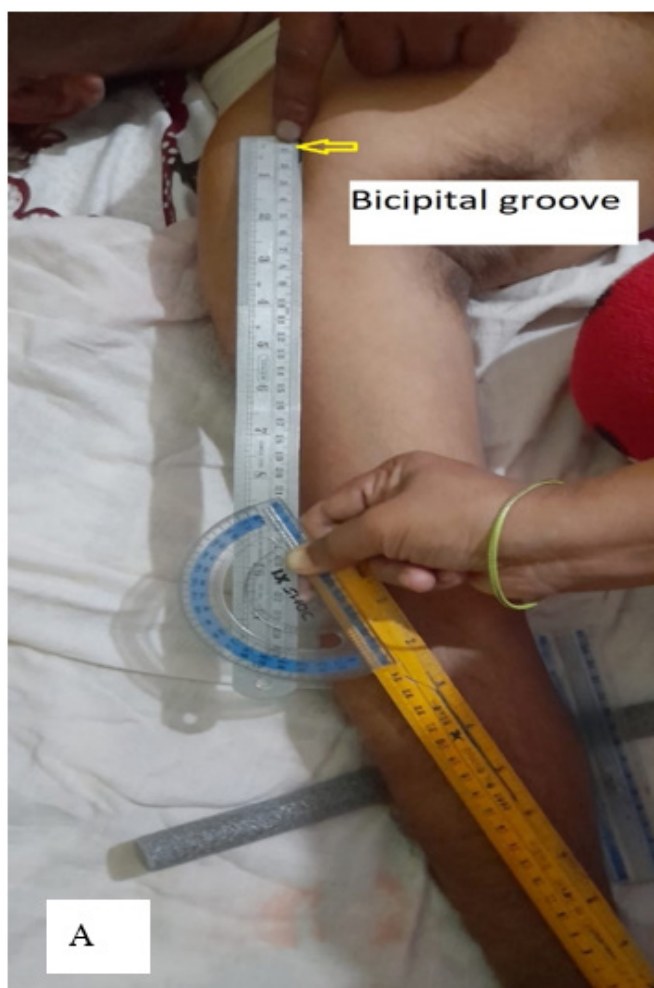


Figure 3: Angle measured BFA ≈ Humeral torsion angle³

Results

The present study aimed to estimate the normal angle of humeral torsion in young healthy adults; mean age of male (M=62) was 21.69±1.07 years and female (F=42) was 20.29±0.78 years. The mean angle of torsion for male (62 x 2 sides= 124) was 35.44± 1.78 degree and for female (42 x 2 sides= 84) was 32.61 ± 1.25

degree. Comparing angle of torsion between male and female, the differences was highly significant ($p < 0.001$) as displayed in table 1.

Table 1: Comparative analysis of angle of torsion between male and female (N=208).

Gender	Sample (N=208)	Age Mean \pm SD, (yrs.)	(AHT) Mean \pm SD ($^{\circ}$)	SEM	Sig.(P)
M	124	21.69 \pm 1.07	35.44 \pm 1.78	0.16	<0.001
F	84	20.29 \pm 0.78	32.61 \pm 1.25	0.14	

M=Male, F=Female, AHT=Angle of Humeral Torsion ($^{\circ}$) degrees), yrs. =years

Table 2. shows comparison using paired t test between right and left sided angle of torsion in male and female (N=208) combined together. The report shows difference in right and left angle of torsion which was highly significant ($P < 0.001$).

Table 2: Comparison between right and left sided angle of torsion (N=208).

Variables (AHT, N=208)	AHT Mean \pm SD ($^{\circ}$)	SEM	Sig.(P)
Rt. (N=104)	34.66 \pm 2.19	0.22	<0.001
Lt. (N=104)	33.95 \pm 2.04	0.04	

Rt. =right, Lt=left, AHT=Left Angle of Humeral Torsion, ($^{\circ}$) = degree

Discussion

The present study estimates the normal humeral angle of torsion in human body with standard validated palpation method of measurement.³ Demographic variables of the subjects were documented along with angle of humeral torsion (AHT) from both right and left side for each male and female subjects.

Present study shows higher humeral torsion angle (M=35.44 \pm 1.78 $^{\circ}$, F= 32.61 \pm 1.25 $^{\circ}$, $p < 0.001$) for male (N=62) compared to female (N= 42). Several studies showed similar trend where the angle of torsion for male was comparatively higher (Rt= 56.24 $^{\circ}$, Lt= 60.42 $^{\circ}$ Rwanda population), (Rt=54.00 $^{\circ}$, Lt=57.59 $^{\circ}$ Burundi population), (Rt= 52.67 $^{\circ}$, Lt=54.33 $^{\circ}$ Kenya population) and (Rt=53.30 $^{\circ}$, Lt= 58.34 $^{\circ}$ Uganda population) compared to female (Rt=57.00 $^{\circ}$, Lt=55.40 $^{\circ}$ Rwanda population), (Rt=51.50 $^{\circ}$, Lt=57.50 $^{\circ}$ Burundi population), (Rt=55.00 $^{\circ}$, Lt=59.00 $^{\circ}$ Kenya population) and (Rt=55.70 $^{\circ}$, Lt=58.20 $^{\circ}$ Uganda population).¹²

Moreover, to find out the difference between right AHT (34.64 \pm 2.20 $^{\circ}$) and left (33.95 \pm 1.97 $^{\circ}$), the mean angle was analysed which was significantly higher ($p < 0.001$) for right compared to left in present study. Similar finding was observed in a study conducted in India in 150 dry bones; the mean angle of torsion was 34.90 \pm 0.946 $^{\circ}$ for rt. side, 31.04 \pm 0.796 $^{\circ}$ for lt. side.¹³ Palpation method documented the dominant shoulder having significantly larger humoral torsion (HT) angle compared to the non-dominant shoulder (32 $^{\circ}$ \pm 6 vs. 27 $^{\circ}$ \pm 4, $p = 0.0004$).¹⁴ Assessment via United

States also found dominant shoulder HT greater than HT of non-dominant shoulder (29 $^{\circ}$ \pm 12 vs 20 $^{\circ}$ \pm 10, $p = 0.0007$, respectively).¹⁵ Research suggests that the AHT is largely influenced by biological activity as Mehta and Chaturvedi¹⁶ reported higher average AHT on the right side. The HT angle reported in the present study was measured exclusively in dominant right-handed individuals, and the findings are consistent with those of several studies conducted in Asian populations.

A study by SS Dare et al., the angle of torsion was recorded 54.54 \pm 0.69 $^{\circ}$ and 58.71 \pm 0.66 $^{\circ}$ for right and left side, respectively, in male humeri. Similarly, 55.47 \pm 1.59 $^{\circ}$ and 57.56 \pm 1.96 $^{\circ}$ were recorded on the right and left female humeri respectively.⁹ Angle of humeral torsion documented in present study was less (Rt= 34.64 \pm 2.20 $^{\circ}$, Lt= 31.04 \pm 0.796 $^{\circ}$) compared to those of above findings which may be due to geographical variations or the activities performed by different individuals. Shah RK has noted the angle of torsion for left side to be ranging from -5 to 60 and on the right side it was 12 to 130 degrees among workers in different races.⁶ The range of HT was reported to be -5 $^{\circ}$ to 50 $^{\circ}$ (Boileau et al, 2008; Robertson et al, 2000).^{17, 18} The HT angle documented in present study are less but it is within the range as mentioned by Shah RK,⁶ Boileau et al¹⁷, Robertson et al.¹⁸

Thus, this measurement represents a new reference point for our geographical area and adds valuable region-specific data to the available documentation. Humeral torsion is a dynamic anatomical parameter that can be altered by geography, habitual activities as well as by various surgical procedures.

Conclusion

Estimating the angle of humeral torsion (AHT) in healthy young adult's male showed significantly higher value compared to females. Comparing humeral torsion of right and left delineate significant difference, indicating bilateral asymmetry in AHT within individuals. These findings establish baseline values for humeral torsion in this population and highlight sex and side baseanatomical variation, which may have clinical and biomechanical implications.

Recommendations

Clinicians and anatomists should consider the humeral torsion angle (HTA) values specific to the studied population when assessing shoulder pathology or planning orthopaedic procedures (e.g., humeral head replacement, fracture fixation)

Limitation of the Study

Present study was carried out among particular group of students with average sample size which may not reflect the large general population. Study doesn't document the anthropometric variables like; height, weight, BMI, ethnic group, and socioeconomic status which also limits the study. Without imaging confirmation, the calculated values rely solely on clinical measurements, which may introduce measurement variability.

Acknowledgement

I would like to express my sincere gratitude to everyone who

assisted me, especially the medical students, all the faculty and staff of the anatomy department, and the statistician who performed the data analysis.

Conflict of Interest: None

Financial Disclosure

The authors state that they have no financial interests connected to this study. The work was fully supported by the researchers themselves, with no outside funding or sponsorship involved in its design, implementation, or publication. All costs were personally covered by the authors, ensuring that the study was carried out independently and without external influence.

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