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AN ANTHROPOMETRIC INVESTIGATION INTO THE PROBABLE CAUSE OF FORMATION OF 'CARRYING ANGLE': A SEX INDICATOR

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ABSTRACT

In the living the 'Carrying angle' measures around 173 degrees in males and 167 degrees in females. The cause of its formation is a long debated issue. The present study is an attempt to identify by anthropometric means the sexually dimorphic features in the bones of the elbow joint which makes the 'Carrying angle' a sex indicator. The distal end of the humerus and the proximal end of ulna playing major role in the formation of 'Carrying angle' have been examined for sex difference. The two measurements of the humerus (Trochlear angle and Inclination angle of Olecranon fossa) and three measurements of the ulna (Olecranon – coronoid angle, length and width of inferior medial trochlear notch) were devised for the study. Though the humeral angles failed to show any sex difference, the angle and dimensions of ulna exhibited statistically significant result. Could these parameters be the cause of sex differences the 'Carrying angle' exhibits at the elbow joint?

KEY WORDS: 'Carrying angle', sexual dimorphism, humerus, ulna

INTRODUCTION

When the forearm is completely extended and supinated, the long axis beyond the elbow joint is not in line with the upper arm but is deviated laterally. This is referred to as 'Carrying or Cubital angle' [Fig.1]. It measures around 173 degrees in males and 167 degrees in females [1]. The angle is neutralized when the forearm is flexed or pronated from extended supinated position.

The role of 'Carrying angle' in the sex determination and its cause of formation is a long debated issue in two 'A's, Anatomy and Anthropology. Surveying the available literature on the subject indicates that authors have expressed different views about its cause of formation. According to Mall [2], the axis of the elbow joint is set obliquely at nearly 84 degrees to both the humerus and ulna which is also agreed upon by Jones [3] after a lapse of nearly half a century. Langer [4] was of the opinion that the obliquity of the trochlea to the shaft of humerus is the cause. Even Decker [5] after more than a century gave the same reason pointing out that the inner lip of the trochlea of humerus is a ridge [groove] which is much deeper distally than anteriorly so that the ulna [with the forearm] is deflected in full extension by this ridge. Thinking on a similar line Kapandji [6] explained that the angle is formed as a result of the trochlear groove being vertical anteriorly but on the posterior aspect it runs obliquely, distally and laterally. This results in the formation of 'Carrying angle' in extension when the posterior aspect of the oblique groove makes contact with the trochlear notch of ulna and the angle is masked during flexion when the trochlear notch lies on the vertical groove in the anterior aspect.

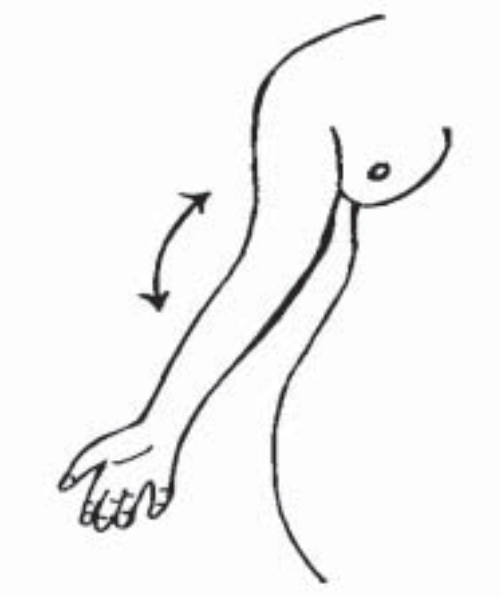


Fig. 1: 'Carrying angle' at the elbow joint

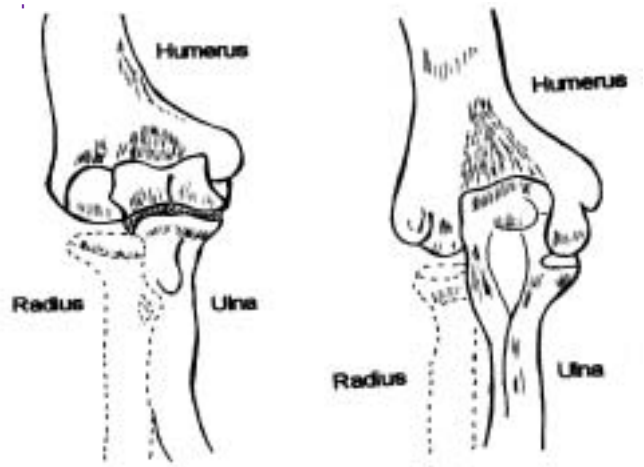
William et al. [7] considered the medial edge of the trochlea of humerus partly responsible as it projects nearly 6 mm below the lateral edge and the obliquity of the superior articular surface of the coronoid process which is not set at right angles

to the shaft of ulna. Last [8] suggested that in the ulna a curved ridge joins the prominences of the coronoid and olecranon processes which fits the groove in the trochlea of the humerus. The obliquity of the shaft of ulna to this ridge accounts for most of the 'Carrying angle' at the elbow.

Keeping the above views in mind, an attempt has been made in the present study to examine the sexual aspect of the 'Carrying angle' using some of the above suggested causes. Prior to devising measurements to fulfill the above objective it was felt necessary to understand the alignment of bones as it is when the arm is extended and supinated [i.e. when 'carrying angle' is formed]:

1. Distally, the medial lip of the trochlea of humerus rests on the inferior medial trochlear notch of ulna [Fig. 2a]
2. The ridge joining the prominences of olecranon and coronoid processes of ulna fits the groove in trochlea of humerus [Fig. 2a].
3. On the posterior aspect, the olecranon process of ulna fits into the olecranon fossa of the humerus [Fig. 2b].

New anthropometric measurements were devised to study the possible cause of sex difference.



(Anterior view) (Posterior view)

Fig. 2: The alignment of bones when the arm is extended and supinated

MATERIALS AND METHODS

The study was conducted at the Medico-Legal Institute at Bhopal in India. Twenty male and female bones were first exposed to the new methods of measurement to indicate the trend before enlarging the size of the sample. Data for this study are comprised of 40 humeri [20 males and 20 females] and 160 ulnae [100 male and 60 female]. The bones were dry and belonged to adult residents of central India.

The Medico-Legal institute at Bhopal is one of the premier institutions of India where the Police department and the legal authorities of central India refer all the medico-legal cases of the state for expert opinion. The second author [being the founder and former Director of the Institute] started with the collection and storage of skeletal material in 1973. The Institute has a collection of bones from medico-legal cases and unclaimed specimens. A majority of the sample were medico-legal specimens. Very few of the specimens were remains of unclaimed bodies, which were skeletonised in the department. Information regarding probable age at death, race, sex, and date of arrival in the institute, probable cause of death etc. was well documented in a register after examination. The bones were preserved in iron boxes coded with serial number. Abnormal or pathologically deformed bones were excluded from the study. Every care had been taken by the authors to include bones from a homogenous population.

In order to test for bilateral variation in the measurements, 20 sets of bones were subjected to a paired t-test. The difference was found to be insignificant at the 0.05 level, thus allowing the bones of both sides to be grouped together. However, only one bone, either left or right, has been included in the analysis.

Two measurements for humerus and three for ulna have been devised in this study based on the suggested cause of formation of 'Carrying angle'.

Measurements on Humerus

Trochlear angle: The humerus was placed with its posterior surface in contact with the osteometric board. A thread was adjusted to lie parallel to the distal most points on the lateral and medial projection of trochlea X and Y respectively. Care was taken to avoid the projecting capitulum [Fig. 3]. Another thread was adjusted to lie parallel to the long axis MN of the distal part of the shaft, where M and N were the midpoints of transverse diameters at the distal ends of upper four-sixth AB and upper five-sixth CD of the humeral length respectively. The angle was read between the threads MN and XY.

Inclination angle of olecranon fossa: The humerus was placed on the osteometric board with its anterior surface in contact. A thread was adjusted to lie parallel to the line joining the medial most extent A and lateral most extent B along the border of the olecranon fossa [Fig. 4]. The other thread was so adjusted that it lay parallel to the line joining the proximal most points on the articular border of trochlea, medially as C and laterally as D. The angle was read between the threads lying parallel to AB and CD on the osteometric board.

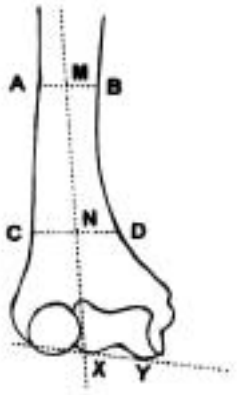


Fig. 3: Trochlear angle of humerus

AB and CD are the transverse diameters at the distal ends of upper four-sixth and five-sixth of the humeral length respectively. MN is the long axis of the distal portion of the humerus shaft whereas XY represents the tangent to the distal most points on the lateral and medial projections of trochlea

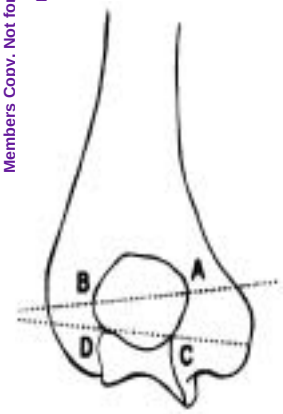


Fig. 4: Inclination angle of Olecranon fossa of humerus

AB, the line across the border of the olecranon fossa and CD along the proximal articular border of trochlea when joined and extended forms the angle

Measurements on Ulna

Olecranon - Coronoid Angle: The ulna was placed with its medial surface in contact with a board, especially designed for the purpose of measuring this angle [10]. The bone was placed in such a position on the board that the point projecting most posterior on the styloid process D touched the lateral wall of the board. The thread was adjusted to lie parallel to the line joining upper lip of the olecranon process A and the 'beak' of the coronoid process B. The angle was measured between the lateral wall of the board as a base and the thread joining the line AB [Fig. 5], extended to meet the base line. The angle was measured with a protractor.

Length and Width of Inferior Medial Trochlear Notch [IMTN]: The ulna was held facing anteriorly and the deepest constriction along the medial and lateral borders of the trochlear notch were labeled medially as P and laterally as Q [Fig. 6]. The highest point on the 'beak' of the coronoid process was labeled as B and the line along the ridge from the point B extending proximally to meet the line PQ at C dividing the coronoid articular surface into larger medial and smaller lateral part

The length of the inferior medial trochlear notch was measured with the help of Dial caliper between the point C and the highest point B on coronoid 'beak'. The width was measured at right angles to the length, between MN, N being the point projecting most medially on the border of trochlear notch on the 'Sublime Tubercle' and M was the line drawn laterally from point N meeting the line BC at right angles

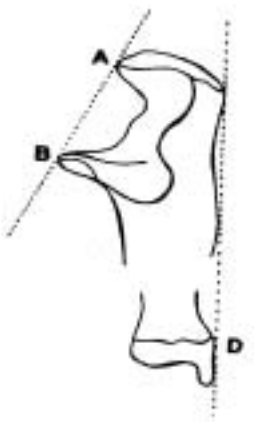


Fig. 5: Olecranon – Coronoid angle of ulna

The line AB joins the apex of projecting 'beak' of processes, Olecranon and Coronoid, marked A and B respectively. The bone is aligned with the Posterior most surface of the styloid process D touching the horizontal side Wall of the board

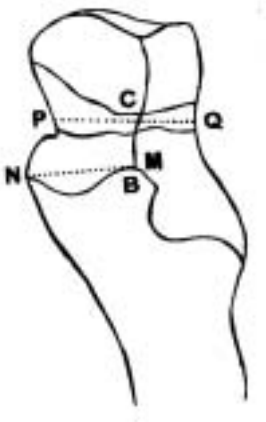


Fig. 6: Length BC and width MN of Inferior medial trochlear notch of ulna.

PQ is the deepest constriction at the junction of Olecranon and Coronoid Processes

The length and width of IMTN was further incorporated into an index using the formula:

Simple statistical analysis including mean, standard deviation and t-test was performed to study the sexual difference. Data on ulna were further subjected to discriminant function analysis using the SPSSX Subroutine software [9]. Except for the percentage of accuracy achieved by the three parameters of ulna the detailed analysis has been reported elsewhere [10].

RESULTS

The study on humerus used two variables, trochlear angle and Inclination angle of olecranon fossa. Table 1 shows the routine statistical analysis of their data. Both the angles exhibit similar mean value for males and females which is further confirmed by the statistically insignificant t-value. Hence the sample size was not enlarged beyond 20 males and 20 females.

Table 1 - Routine statistical analysis for Humerus angles

Angles	Males (20)		Females (20)		T- test
	Mean	SD	Mean	SD	
Trochlear Angle	104.23	2.42	104.53	1.76	P > 0.05
Inclination Angle of Olecranon fossa	4.88	1.60	5.43	2.15	P > 0.05

Table 2 presents the simple statistics for ulnar data. The male ulna exhibit greater value for angle and dimensions than the female. The sex difference measured by using t-test is also highly significant. The width-length IMTN index presents an insignificant sex difference. The direct variables when subjected to discriminant function analysis registered a fairly high accuracy especially for Olecranon – Coronoid angle (85%) in assigning sex.

DISCUSSION

An observation by Hooton [11] which became the basis of 'Carrying angle' theory is that the broad shoulders and narrow hips of male allow the arms to hang straight downwards, with long axis of the upper and lower segment approximately in the same straight line. Whereas in the female, the narrower shoulder and broader hips require a splaying out of the forearm axis in order that the hanging arms clear the hips. This may be true when palms are facing forwards as in anatomical position, but this argument will not stand in walking when the mid prone position is obtained with thumb directed forwards.

The present study had been undertaken with the sole purpose to identify by anthropometric means the sexually dimorphic features in the bones of the elbow joint which makes the 'Carrying angle' a sex indicator. For this the main players in the formation of 'Carrying angle', the distal end of humerus and the proximal end of ulna had been critically examined for sex difference.

Following the suggestion of Langer [4], Decker et al. [5] and William et al. [7] that the obliquity of the trochlea to the shaft of humerus and the projection of the medial flange of trochlea of humerus below the lateral edge is partly responsible for the 'Carrying angle' the present exercise of measuring the trochlear angle was undertaken expecting that the shaft obliquity and trochlear projection will be more in females. But as far as the sexual difference in the angle is concerned it has given an inconclusive result.

Steel and Tomlinson [12] have measured the trochlear angle of English humerus and obtained statistically insignificant sex difference [73.3 degrees for males and 74.5 degrees for females]. The lower value of the angle indicates that they have measured the inner angle instead of the outer on the medial side of humerus. According to Martin and Saller [13] the angle is always positive (probably

Table 2 - Statistical analysis for Ulnar measurements

Variables	Males (100)		Females (60)		T- test	Percentage accuracy
	Mean	SD	Mean	SD		using DFA a
Olecranon Coronoid angle	22.26	3.47	14.73	4.46	P < 0.001	85.0%
Length IMTN	16.01	1.40	14.39	0.98	P < 0.001	73.8%
Width IMTN	14.10	1.24	12.47	1.59	P < 0.001	70.6%
IMTN Width-Length Index	0.89	0.09	0.88	1.01	P > 0.05	-

a DFA = Discriminant function analysis

meaning thereby more than 90 degrees) implying that the tangent of the trochlea is inclined outward and upward. The method adopted in the present study for measuring the angle is different from them. But whatever is the method adopted their result also shows that trochlear angle cannot be used as a sex indicator.

In full extension on the posterior aspect the olecranon process of ulna fits in its corresponding fossa guided by the articular surface of trochlea of humerus. To check whether the inclination of the olecranon fossa with respect to the proximal trochlear articular border is same in both sexes, the measurement inclination angle of olecranon fossa had been devised. Instead of taking the long axis of the humerus as the base line, in this study line CD being the guiding hinge had been taken while line AB joining the medial and lateral most points on the border of the olecranon fossa represents the maximum width. Again the result was not productive for conclusion.

Shifting our attention to the adjacent bone and working on the suggestion given by Last [8] that the obliquity of the shaft of ulna to the line joining the prominences of olecranon and coronoid processes may be the cause of formation of 'Carrying angle', the measurement Olecranon – Coronoid angle was devised. The posterior surface of the ulna was put against a flat surface of the board devised with styloid process touching the board. This is virtually the position which is obtained in the fully extended supinated forearm.

As suggested by William et al. [7] and Last [8] it is a fact that upper end of ulna is at an angle with the long axis of the shaft and this comes to play its part only when the arm is extended and the olecranon process fits in the fossa. The sex difference exhibited by the angle has been proved by the highly significant t-value and also the high percentage accuracy achieved when subjected to discriminant function analysis.

In full extension, distally the medial lip of the trochlea of humerus rests on the IMTN of ulna [Fig. 2a]. On the presumption that if the relative size of female ulnar IMTN is smaller than male then in full extension the IMTN of ulna unable to contain the full projection of trochlea in its small area, will be pushed more laterally thereby reducing the 'Carrying angle'. Referring to Table 2, one finds that the mean length of IMTN among males [16.01mm] is significantly larger than that of females [14.1mm]. Similar is the trend for width of IMTN indicating a smaller articular surface available in females. But when the relative size of IMTN [Width – length Index] is compared between sexes, the result was inconclusive. Thus it indicated that though there is a difference in size in male and female IMTN, the difference is proportionate to the size of the bone.

In the present study the lower end of humerus does not show any sexual difference with relation to the measurements taken. But the adjacent bone ulna when studied for Olecranon-Coronoid angle showed clear cut sexual difference. We have no study to compare our result but the angulation and configuration we find at the upper end indicates that the forearm may show results of sexual dimorphism in the movement at the elbow joint particularly in the fully extended forearm.

CONCLUSIONS

1. Olecranon - Coronoid angle exhibiting high sexual dimorphism may be one of the cause of sexual difference observed in 'Carrying angle'.
2. The smaller Olecranon - Coronoid angle of female ulna suggests that the projection of olecranon process in female may be relatively larger than in male.
3. More investigations are required on this topic to resolve the issue of 'Carrying angle' being a sex dominant character.

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