

Original article:

Carrying angle of the Elbow: It's Changes From Childhood to Adulthood : Morphometric Study in Eastern India.

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Abstract:

Introduction: It is important to know the carrying angles of both elbows in the evaluation of deformities around the joint which may guide the management protocol. This study was performed to determine the basal values of the clinical carrying angle in specific age groups and sexual variation in the eastern part of India and compare it with other studies.

Methods: The study was conducted in R.G.Kar Medical College and a few schools in north Kolkata. We evaluated 360 persons with ages varying from 3 to 19 years distributed in groups. Carrying angle was measured by goniometer.

Results: The average value of the carrying angle was 12.5 ± 0.57 degrees in male and 15.26 ± 0.45 degrees in females. Carrying angle increases with age and was more on the dominant side(right) in both sexes. Females had higher values than males except in 3-5yrs age group where carrying angle was greater in males.

Conclusion: In the present study we have found that in early and late adolescent age group the mean of carrying angle are always higher in female than in male and more on the dominant side.

Key Words: Carrying angle, elbow

Introduction:

The lower part of the humerus and the upper part of the radius and ulna comes in the formation of the elbow joint. The elbow joint includes two articulations - humeroulnar- between trochlea of humerus and the ulnar trochlear notch and humeroradial -between the capitulum of humerus and the radial head. Hence it is a compound synovial joint. The trochlea is not a simple pulley as its medial flange exceeds its lateral, thus projecting to a lower level so that the plane of the joint is 2cm distal to interepicondylar line. In humans, however, the arm and the forearm are not positioned in a straight line. The level of the elbow joint is situated 2cm below the line joining the two epicondyles of the humerus. The

deviation of the forearm from the long axis of the arm is measured by the carrying angle.

Anatomists consider the external angle between the humerus and the ulna as the carrying angle when the forearm is fully extended and supinated. This diverges laterally making the angle obtuse in nature about 163° ¹. This angle is greater in males than in females. Clinicians however commonly consider the smaller internal angle of deviation of the ulna from the long axis of the humerus to be the carrying angle of the elbow. This is an acute angle (approximately 14° in males [range $2^\circ - 26^\circ$] and 16° in females [range $2^\circ - 22^\circ$]). The carrying angle in this case is greater in females than in males^{2,3}. In the present

study, we shall follow the clinician's point of view. Normal carrying angle is such that it increases the range of motion of the forearm and hand. Increased carrying angle causes a valgus deformity of the elbow. The knowledge of its variations is essential, especially for the handling and monitoring of traumatic lesions that affect the pediatric elbow⁴. In physiological conditions this parameter varies according to age⁵, gender^{4,6}, hyperextension of the elbow⁷, dominant upper limb⁸, anthropometric characteristics such as height² and intertrochanteric distance⁹ and can be measured by simple clinical and radiographic technique⁴. The present study attempts to determine the carrying angle of the elbow in subjects of different ages and sexes and to compare with other studies. This information will be of help in studying the biomechanics of the elbow joint. As fewer studies are available in India, it will throw some light on the morphological variations of the carrying angle from eastern part of India.

Materials And Methods :

The study was conducted over a period of two years in the Department of Anatomy and Orthopedics, R.G. Kar Medical College, G.S.M.S. for boys (Taki House), North Calcutta K.G. school and Victoria Institution, Kolkata.

For the purpose of the study, three sets of age groups were taken. The groups were-3 to 5 years, 11 to 13 years and 17 to 19 years. This correlates well with the period of growth of long bones, the appearance of secondary centers of ossification and the final union, modeling and maturity of bones. Total 180 males and 180 females were selected.

The carrying angle was measured on both the elbows by a goniometer with forearm in extended and supinated position (Fig 1). Subjects with trauma or pathologies around the elbow were excluded from the

study. In all the selected cases, right upper limb was the dominant side. The subject was made to stand in anatomical position, in erect posture with the feet together, arms by the sides, and the palm facing forward. The arm was in extended supine position. A line was drawn joining the lateral extremity of the anterior axillary fold and maximum width over the deltoid. Midpoint (A) of the line was marked. Midpoint (B) of the interepicondylar line was marked. The point A and B was joined by skin pencil which represents the axis of the arm and this line extended up to point C. Midpoint (D) of the interstyloid process was marked by skin pencil. The point B and D was joined which represents the axis of forearm. The angle (CBD) was measured with a goniometer which represents the carrying angle¹⁰ (Fig 1 and 2). Every measurement was taken twice by same examiner in a well illuminated room and the average value was recorded. All linear measurements was made using a Freeman 5 meter steel tape, Kristeel (Shinwa) 6 inch engineering scale, 2m flexible canvas or plastic tape and a pair of Vernier calipers. Angular measurements was taken with a goniometer. Skin pencil was used as marker. The measurements were photographed and analyzed with Photoshop CS2. The obtained data were subjected to extensive statistical analysis using MS excel software and statistical formula. The average value of each parameter was calculated separately for males and females.

Observations and Results :

The study population included 180 males and 180 female students. They were divided into 3 age groups- 3-5 yrs, 11-13 yrs and 17-19 yrs. It was observed that the carrying angle was highest in 17-19 yrs and lowest in 3-5 yrs (Table I & Table 2). The difference was statistically significant ($p < 0.0001$). So,

carrying angle increases with age. The maximum value of the carrying angle measured was 16 degree in females and 14 degree in males. The minimum value recorded was zero degree in 3-5 yrs age group where the angle was yet to develop.

In 3-5 yrs age group, carrying angle varied between 0-2 degrees in either sexes in right as well as left sides. The difference was statistically insignificant for right and left arm ($p>0.05$). But when gender was considered, carrying angle was greater in male than female (in both sides) and the difference was statistically significant (Table 3).

At 11-13 years of age for male the mean angle measured for dominant arm (right) was significantly greater than those of the contra lateral side ($p<0.001$) but in case of female this difference was statistically insignificant ($p>0.05$) as shown in Table 3.

At 17-19 years of age, for male the mean angle measured for dominant arm (right) was significantly greater than those of the contra lateral side ($p<0.0001$) but in case of female this difference was statistically insignificant ($p>0.05$) where both upper limbs showed a mean carrying angle of 15.27 ± 0.45 degrees. The height was also measured for each subject but no significant correlation was found with the carrying angle in respective age group.

Discussion :

The long axis of the arm and forearm are not in alignment due to obliquity of the elbow joint. This deviation is measured as carrying angle- an acute angle made by the median axis of the fully extended and supinated forearm thus measuring the lateral obliquity of the forearm². The carrying angle is caused partly by projection of the medial trochlear edge about 6mm beyond its lateral edge and partly by obliquity of the coronoid's superior articular surface, which is not orthogonal to the ulna's shaft¹.

The shaft of the ulna is angled slightly laterally from the line of the trochlear notch to form the carrying angle¹¹.

Decker¹² gave a similar reason pointing out that, in the inner lip of trochlea of humerus is a ridge (groove) which is much deeper distally anteriorly so that ulna (with the forearm) is deflected in full extension by this ridge. Kapandji³ explained that the angle is formed as a result of trochlear groove being vertical anteriorly but on the posterior aspect it runs obliquely distally & laterally. This results in formation of carrying angle in extension when posterior aspect of oblique groove makes contact with the trochlear notch of ulna and the angle is masked during flexion when trochlear notch lies on vertical groove in the anterior aspect.

It has been found that the carrying angle of the elbow changes from infancy⁷ to adulthood in a predictable manner. Our study also revealed increase of carrying angle with age (Table I & 2). The angle increases up to the age of 15 years (approx.). Thereafter it remains constant for the lifetime of the individual. The angle is greater in the dominant limb than the non-dominant limb of both sexes, suggesting that natural forces acting on the elbow modify the carrying angle. In the present study the dominant upper limb (right) depicted higher carrying angle in male as well as females except in 3-5 yrs age group where both right and left upper limb had similar values. Developmental, ageing and possibly racial influences add further to the variability of this parameter¹³.

The carrying angle can influence how objects are held by individuals - those with a more extreme carrying angle may be more likely to pronate the forearm when holding objects in the hand to keep the elbow closer to the body.

Paraskevas et al in 2004⁹ studied the carrying angle at the elbow in a population of students. They found that the mean carrying angle was 12.88 degrees in men and 15.07 degrees in women. The values are close to our study which shows the mean carrying angle as 12.5 and 15.26 degrees in male and female respectively. The carrying angle changed with skeletal growth and maturity. The angle was always greater on the side of the dominant hand. They also confirmed the inverse relationship of carrying angle and intertrochanteric diameter.

Yilmaz E et al in 2005¹³ had studied carrying angle using a manual goniometer in 1275 healthy volunteers with a mean age 22.87 ± 15.99 years. They found that the carrying angle of dominant arm was found to be significantly higher than the non-dominant arm in both sexes. Our study also reflected a similar picture.

Tükenmez et al in 2004⁸ studied carrying angle of the elbow in 2000 children at the ages of six and fourteen years. They came to conclusion that the mean angle from dominant arm was significantly greater than those of the contra lateral side in both sexes and age group. The mean angle of both elbows were greater in girls than those of the corresponding elbow in boys at six years of ages while vice versa was the case at fourteen years of age, however difference did not reach significance ($p > 0.05$). In the present study the results differ in 3-5 yrs age group where carrying angle in boys were higher (1.15 ± 0.95 degrees) as compared to girls (0.20 ± 0.55 degrees) and the difference was statistically significant ($p < 0.0001$).

In the present study we have found that in early and late adolescent age group the mean of carrying angle are always higher in female than in male, which corroborates with studies by Balasubramanian P⁴. Golden DW et al⁷ concluded that increased elbow

extension may contribute to the increased carrying angle seen in females compared with males. Table 4 shows a comparison of the carrying angles in different studies. However, no gender differences had been found in a study by Zampigini M.L.⁶

Purkait R et al in 2004¹⁶ had done a study on carrying angle over dry bone. They had attempt to identify by anthropometric means the sexually dimorphic features in the bone of elbow joint which makes the carrying angle a sex indicator. The distal end of the humerus & the proximal end of ulna are playing major role in the formation of carrying angle. They had proved that the lower end of humerus does not show any sexual difference but the adjacent bone ulna for olecranon – coronoid angle showed clear cut sexual difference. Terra BB et al¹⁷ concluded in their study that there was no significant statistical difference between the clinical and radiographic measurements of carrying angle.

Khare GN et al² studied the carrying angle of the elbow in children. They came to the conclusion that the carrying angle develops in response to pronation of the forearm and is dependent on length of the forearm bones. Lesser the length of forearm bones greater is the carrying angle. So the carrying angle is more in shorter persons as compared to taller persons. Ruparelia S et al¹⁸, had done a study of carrying angle and it's co-relation with various parameters. According to their study, height of the person was inversely related with the carrying angle. There was significant difference between male & female carrying angle, in female it was 11.8 degree and in male it was 6.9 degree. Greater carrying angle in female was considered as secondary sex characteristic. According to their study the height & length of the forearm were directly related to each other. Length of the forearm in female was 22.7 cm

on right side and 22.6 cm on left side where as in male this value was 24.9 cm on both sides which was inversely related to the carrying angle. In the present study, the correlation between carrying angle and height found was not statistically significant. Length of the forearm bones were not measured in our study. Chang Hung Chu et al¹⁹, concluded that an increased carrying angle of the elbow appeared to be an independent risk factor of non trauma-related ulnar neuropathy. Knowledge of measurement of carrying angle of the elbow and its variations is important when evaluating traumatic elbow injuries in childhood and in adolescence⁴ and other elbow disorders that require reconstruction²⁰ or arthroplasties (surface and semiconstrained)²¹. The type of fracture a child sustains after fall on

outstretched hand is also determined by the value of the carrying angle. A new type of fracture hitherto undescribed in the literature, T-Y fracture of the distal humeral epiphysis is also reported².

Conclusion :

In the present study we have found that in early and late adolescent age group the mean of carrying angle are always higher in female than in male and more on the dominant side. Comparison with other studies shows wide regional variations, implying environmental and genetic factors during growth and development. Morphological variations of the carrying angle helps in evaluation of injuries around the elbow and the type of fracture sustained with fall on outstretched hand.

Table 1: Comparison of Carrying Angle of Right side in different age groups

Age Group(yrs)	Carrying Angle(Degree)		P Value
	Mean±SD		
	Male	Female	
3-5	1.15±0.95	0.2±0.55	<0.0001
11-13	6.83±0.64	7.98±0.68	<0.0001
17-19	13.02±0.34	15.27±0.45	<0.0001

Table 2- Comparison of Carrying Angle of Left side in different age groups

Age Group(yrs)	Carrying Angle(Degree)		P Value
	Mean±SD		
	Male	Female	
3-5	1.15±0.95	0.2±0.55	<0.0001
11-13	6.47±0.60	8.02±0.68	<0.0001
17-19	12.25±0.57	15.27±0.45	<0.0001

Table 3- Comparison of Carrying Angle between Males and Females of different age groups

Age Group(yrs)	Carrying Angle(Degree)		P Value
	Mean±SD		
	Right	Left	
3-5			
Male	1.15±0.95	1.15±0.95	>0.05
Female	0.2±0.55	0.2±0.55	>0.05
11-13			
Male	6.83±0.64	6.47±0.60	<0.0001
Female	7.98±0.68	8.02±0.68	>0.05
17-19			
Male	13.02±0.34	12.25±0.57	<0.0001
Female	15.27±0.45	15.27±0.45	>0.05

Table 4- Comparison of Carrying Angle in different Studies

Study	Mean carrying angle in male (degree)	Mean carrying angle in female (degree)
Rai J et al ¹⁴	13.26	17.91
Khare GN ²	13.56	16.92
Keats et al ¹⁵	11.00	13.00
Paraskevas et al ⁹	12.88	15.07
Present study	12.50	15.26

Fig 1: Shows measurement of carrying angle with goniometer. A is the midpoint of the line joining anterior axillary fold and maximum width over deltoid, B denotes midpoint of the interepicondylar line, C is a point where line joining AB is extended, D is the midpoint of the interstyloid process.

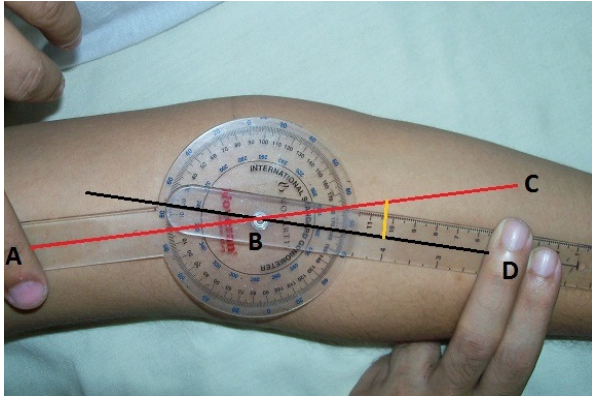
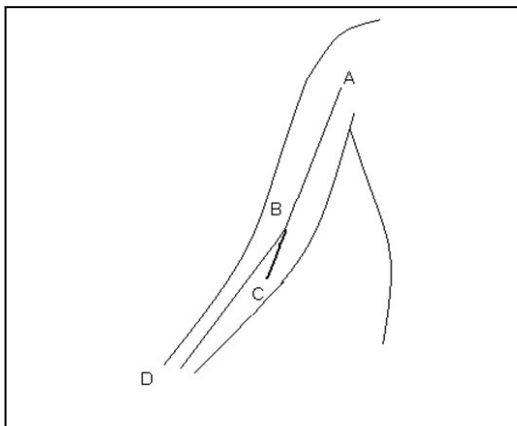


Fig 2 : Shows the angle marked CBD denotes the carrying angle as measured in the present study.



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