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Evaluation of the carrying angle of the elbow joint in children's and adolescents and its correlation with various parameters

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Abstract
Background: The carrying angle is acute angle between median axis of the upper arm with fully extended and supinated forearm. 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.
Method: This cross-sectional study was conducted on120 children's in out-patient department at Mandya Institute of Medical Sciences, Mandya (Karnataka), India.
Results: For the purpose of analysis two set of age groups were made. The groups were 5-12 years and 13-18 years. Carrying angle was more in females and on right side. Positive correlation was found between carrying angle with various parameters measured.
Conclusion: The result of the study could be useful in the management of elbow displacement, fractures and surgical planning for elbow reconstruction.

Keywords: elbow, carrying angle, correlation.

Introduction
Apes and humans are distinguished from other primate species in possessing carrying angle at the elbow. The evolution of a carrying angle in apes is related to the need to bring the center of mass of the body beneath the supporting hand during suspensory locomotion as seen in lower limbs of humans in which the valgus knee brings the foot nearer the center of mass of the body during the single limb support phase of walking [1]. The role of carrying angle in the sex determination & its cause of formation is a long debated issue in Anatomy and Anthropology.
The carrying angle of the elbow is defined as the angle formed by the long axis of the arm and the long axis of the forearm in the frontal plane when the elbow is fully extended and the forearm is supinated [2]. In such a position, the forearm does not lie in one line with the arm, but it deviates lateral to the arm axis forming this angle [2]. It is generally said that carrying angle is greater in females than in males and the difference has been considered to be due to ligamentous laxity at the medial elbow or asymmetrical bone growth [2].
The angle is formed as a result of trochlear groove being vertical anteriorly but on the posterior aspect it runs obliquely distally and laterally. This results in formation of carrying angle in extension when posterior aspect of the oblique groove makes contact with the trochlear notch of ulna and the angle is marked during flexion when trochlear notch lies on the vertical groove in the anterior aspect [2]. However, some researchers reported no significant difference in carrying angle of males and females of any age group [3]. Studies have shown that there is a gradual increase in the carrying angle with skeletal maturation. It has been found that the carrying angle of the elbow changes from infancy to adulthood in a predictable manner [4]. The apparent difference in gender may be due to increased joint laxity in females permitting a greater degree of extension [2].
Variation in carrying angle among age groups, gender and race has been reported in literature. The average value of the carrying angle is 12.5 ±0.57 degrees in male and 15.26 ±0.45 degrees in females.

Females had higher values than males except in 3-5yrs age group in whom the carrying angle is greater in males [5, 6].

The evaluation of carrying angle value and its pathologic variations are important to identify the elbow deformities and in the diagnosis of diseases of the lateral and medial epicondyles [2, 3]. The rate of carrying angle increment for boys and girls is 0.42 and 0.60 per year, respectively [3]. Knowledge of measurement of carrying angle of the elbow and its variations is important when evaluating traumatic elbow injuries in childhood and in adolescence and other elbow disorders that require reconstruction arthroplasties [7]. The type of fracture a child sustains after fall on outstretched hand is also determined by the value of the carrying angle.

Hence, the present study aimed to determine the basal values of the clinical carrying angle in specific age groups and to study the difference in carrying angle between genders (i.e., Male and female) and to find out any correlation of carrying angle with different parameters like dominance, inter-epicondylar diameter, Body Mass Index, Height and length of forearm.

Material and Methods

This study was conducted in outpatient department of Orthopedics at Mandya Institute of Medical Sciences, Mandya, Karnataka for a period of 3 months from October 2016 to December 2016. The inclusion criteria were age group from 5 to 18 years of either sex. Individuals with history of fractures around the elbow and shoulder joint and with any congenital condition of elbow and shoulder were excluded from the study. For the purpose of analysis two set of age groups were made. The groups were 5-12 years and 13-18 years. Total 60 males and 60 females were included in the study after obtaining consent with 30 in each groups.

Method of data collection

- The carrying angle of both the limbs was measured while keeping the elbow completely extended. The angle was measured in three trials and then the average of the three trials was taken as the final carrying angle.

An improvised instrument Goniometer was used for measurement of carrying angle. The fixed arm of which could be placed on the median axis of the upper arm, the movable arm adjusted as to lie on the median axis of forearm & the angle read on the goniometer. Bicipital groove, biceps brachii tendon at its insertion and palmaris longus tendon at the wrist were palpated and marked as anatomical landmarks to demarcate the median axes of the arm and the forearm respectively. Measurement of carrying angle will be taken on the left side as well as on the right side to find out difference on both sides.

- Stature meter was used to measure the height. Height was measured in standing, erect, anatomical position from vertex to hill with bare foot.
- Weight of the patient was taken by the digital weighing machine.
- Inter-epicondylar diameter was measured using a caliper between prominent point of medial and lateral epicondyle.
- Length of the forearm was measured from lateral epicondyle to tip of radial styloid process using measuring tape.
- Body Mass Index(BMI) was measured using formula BMI=Weight(in Kg)/(Height in cm)^2

Results

Of the 120 children's included in the study mean age was 11.99+/-4.005, with mean BMI being 19.326+/-3.8088. Mean carrying angle on right side was 10.95+/-2.831 and on left side was 10.45+/-2.849. On comparing the carrying angle in females and males there was significant difference between them ($p<0.001$) with 12.18+/-2.99, 9.72+/-2.03 on right side and 11.45+/-3.27, 9.45+/-1.92 on left side respectively.

On comparing the carrying angle between two age groups(5-12 yrs and 13-18 yrs) there was significant difference ($p<0.001$) between them with carrying angle of 9.97+/-2.71, 11.93+/-2.62 on right side and 9.33+/-2.86, 11.57+/-2.38 on left side respectively.

In 5-12 yrs age group there was significant difference in the carrying angle between females and males with 11.47+/-2.82, 8.47+/-1.48 on right side and 10.60+/-3.34, 8.07/-1.48 on left side respectively. In 12-18yrs age group there was significant difference in the carrying angle between females and males with 12.90+/-3.03, 10.97+/-1.67 on right side and 12.30+/3.0, 10.83+/-0.015 on left side respectively.

Correlation of carrying angle with different parameters (age, height, BMI, length of forearm and inter-epicondylar diameter) of two age groups mentioned in table-1 and table-2

Table 1: Correlation of carrying angle and its P-value with age, height, BMI, length of the forearm and Inter-epicondylar diameter in 5-12 yrs age groups

Parameters	Carrying angle right	Carrying angle left
Age	0.399 (0.002)	0.498(<0.001)
Height	0.126(0.336)	0.249(0.055)
BMI	0.236(0.069)	0.216(0.098)
Length of forearm right	0.296(0.022)	0.392(0.002)
Length of forearm left	0.309(0.016)	0.411(0.001)
Inter-epicondylar diameter right	0.103(0.435)	0.157(0.232)
Inter-epicondylar diameter left	0.012(0.930)	0.138(0.294)

Table 2: Correlation of carrying angle and its P-value with age, height, BMI, length of the forearm and Inter-epicondylar diameter in 13-18 yrs age groups.

Parameters	Carrying angle right	Carrying angle left
Age	0.066(0.618)	0.083(0.529)
Height	0.040(0.762)	0.068(0.603)
BMI	0.139(0.290)	0.031(0.816)
Length of forearm right	0.070(0.596)	0.108(0.411)
Length of forearm left	0.002(0.985)	0.830(0.528)
Inter-epicondylar diameter right	0.120(0.363)	0.189(0.147)
Inter-epicondylar diameter left	0.082(0.536)	0.112(0.396)

Discussion

The carrying angle, which is found even in utero and is completely developed in a newborn is an outward angulation of the supinated forearm with the elbow extended [13] It exhibits considerable individual variation. Comparisons for the carrying angle should be made with the contralateral side rather than with any "normal standard [14]." The broad shoulders and narrow hips of the males, allow the arms to hang straight downwards with the long axis of the upper and lower segment approximately in the same straight line. Whereas in the females, the narrower shoulders and broader hips require a splaying out of the forearm axis in order that

the hanging arms clear the hips. This observation made by Hooton [15] became the basis for the theory of "carrying angle".

In the present study, of the 120 children's included mean carrying angle on right side was 10.95+/-2.831 and on left side was 10.45+/-2.849. The mean carrying angle in females and males was 12.18+/-2.99, 9.72+/-2.03 on right side and 11.45+/-3.27, 9.45+/-1.92 on left side respectively. The difference between males and females carrying angle was statistically significant ($p<0.05$).

Smith measured clinically the carrying angle of 80 girls and 70 boys [16]. Baughman *et al*. measured the carrying angle of 50 women and 50 men [17]. and Keat measured it in 25 women and men [18]. Beals found an average carrying angle of 17.8° in adults [19]. Keats found this angle to be 13° in women and 11 ° in men. Baughman *et al*. reported 15° in women and 11 ° in men. Steel and Tomlinson found a difference in the carrying angle of 0.9° [20]. Baughman *et al*. found the range of the carrying angle in men to be 2-21°, and in women 2-26°.

Paraskevas G *et al*., [8] studied carrying angle in 600 living individuals from Greece, aged 18–28 years. They measured supplementary angle using goniometer. In the age group of 19–28 years, carrying angle was significantly greater in females. Carrying angle was 12.23±0.30 in males and 15.77±0.410 in females. Steel FLD and Tomlinson JDW [20] investigated the left upper limb of 100 European adults using radiographs to measure carrying angle and obtained no statistically significant difference (males 19.280 and females 18.380). Beals RK [19] conducted study on various age groups including adult population in New Zealand, using radiographs. According to him, the mean carrying angle in adults was 17.80 and difference between males and females carrying angle was statistically not significant.

There are 2 hypotheses to explain why the carrying angle is more prominent in women than in men. The first hypothesis is related to the hormonal factor, which may influence the value of the CA in women [7, 8]. The second hypothesis is related to genetic factors. Many clinical observations reported that women with an XO genetic defect (Turner's syndrome) have greater CA than normal ones, whereas those with an abnormal increase in the number of X or Y chromosomes usually have lesser carrying angle [19].

Paraskevas G *et al*. [8] reported that carrying angle was significantly greater in the right upper limb than the left in both sexes, 12.20±3.80 in right and 11.46±3.20 in left upper limb in males and 16.52±4.230 in right and 15.36±3.230 in left upper limb in females. They also reported that in right-handed subjects angle was significantly greater in right upper limb in both sexes and in left-handed subjects, it was significantly greater in left upper limbs in both sexes. Shetty S [21] conducted study using radiographs on 52 subjects in South India and found that mean carrying angle in the left upper limb in males was 158.90 and in females 158.70 with the mean difference of 0.2. In right upper limb, mean angle in males was 160.50 and in females it was 160.20 with the mean difference of 0.3. Difference between the carrying angles of the right and left sides may suggest ligamentous laxity at the medial elbow or asymmetrical bone growth. Thirty percent of professional baseball pitchers have a valgus elbow deformity-an increased carrying in the dominant elbow (10-15 degrees), which can be taken as a bony remodeling to adapt to stress [2].

Similarly statistically significant results were found on comparing the carrying angle between males and females on both side in two age groups (5-12yrs and 13-18yrs) with higher carrying angle in adolescent groups.

Rajesh B *et al*., [12] conducted a study to evaluate the elbow carrying angle in normal adolescents of South India and also analyze the data statistically to find out any significant difference in the angle between the different groups of subjects within the study population. 60 adolescents with ages varying from 17 to 20 years were evaluated. The result of the study showed that the average carrying angle was 13.6 degrees for females and 6.7 degrees for males. The length of the forearm and the carrying angle showed significant negative relation. According to Khare GN *et al*., [5] the carrying angle does not help in keeping the forearm away from the side of pelvis during walking as during walk the forearm is pronated and carrying angle disappears in pronation of forearm. They found that carrying angle is inversely related to the height of a person, since the average height of females is lesser than the average height of males so average carrying angle is greater in females than males. Ruparelia S *et al*., [10] had done a study of carrying angle and it's correlation with various parameters. According to their study, height of the person was inversely related with the carrying angle. According to their study the height and 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, we found positive correlation between carrying angle and height, BMI and length of forearm in two age groups. One study by Paraskevas G *et al*., [8] inverse relationship of carrying angle and inter-epicondylar diameter, but in our study showed positive correlation of carrying angle and inter-epicondylar diameter.

Conclusions

This study demonstrated that age, sex, BMI and dominant side are important factors that affect the value of the carrying angle. We found positive correlation between length of forearm and inter-epicondylar diameter it carrying angle. Further studies required to look for the correlation of inter-epicondylar diameter to carrying angle.

Conflicts of interest: Nil

Source of funding: Nil

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