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Radiographic Evaluation of the Normal Elbow Carrying Angle in Adults

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In this study, the angle was examined radiologically in an attempt to determine its measurements in adults using a simple method. Antero-posterior plain X-ray views of the normal elbow region were taken in the Radio-Diagnostic Department of Al-Majma'ah, King Khalid Hospital, KSA. The study included 90 cases (45 males and 45 females). Measurement of the carrying angle was done to be confined to the lower third of the humerus and the upper third of the forearm to exclude any interference due to extensions of shaft of the long bones of the elbow in the actual values of the angle. The study demonstrated that the carrying angle is significantly greater in females than in males. In males, it ranged from 5° to 17° with a mean of 9.29±2.98°, while in females it ranged from 10° to 27° with a mean of 18.47±4.12°. The revealed differences between the carrying angles in males and females can be considered as a secondary sex character. The recorded measurements also might be helpful in the management of disorders of the elbow and in its reconstruction after fractures. Furthermore, the proposed method in this study is simple, easy and more or less accurate as it measures the actual angulations at the elbow.

Key words: Carrying angle, normal elbow, sex differences, radiology

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INTRODUCTION

Potter (1895) was the first to carry out a quantitative investigation on the carrying angle in man i.e., the angle of obliquity between the upper arm and the fully extended and supinated forearm. The obliquity of the forearm is more pronounced in women than in men. However, the line of the upper arm and forearm becomes straightened out when the forearm is in the usual working position of almost full pronation (McMinn, 1994). The carrying angle permits the forearms to clear the hips in swinging movements during walking and important when carrying objects (Chen, 2007). Snell (2004) recorded angle measurements of 170° and 167° for males and females, respectively. The difference in the carrying angle between male and female and considering it as a secondary sex character as well as its role in the sex determination are long debated issues in anatomy and anthropology researches (Khare *et al*., 1999; Purkait and Chandra, 2004). The main reasons for this controversy are differences in the definition of the angle and the variations in the measuring methods (Zampagni *et al*., 2008a).

This study is aimed to assess the carrying angle in an attempt to determine its values in both sexes, proposing a simple and reliable method for measuring it. Furthermore, estimation of the carrying angle could be useful in managements of elbow disorders, such as fractures or epicondylar diseases and evaluation of elbow reconstruction (Zampagni *et al*., 2008b).

MATERIALS AND METHODS

Elbow radiographs of patients evaluated for clinical suspicion of orthopedic disorders were studied. Cases with fractures, tumours or surgery were excluded. Normal anteroposterior radiographic views with the elbow fully extended and the forearm fully supinated were examined. Those with obliquity or rotation of view were excluded. No rotation was evidenced by visualizing the two humeral epicondyles and slight superimposition of the radial head, neck and tuberosity over the proximal ulna (Ahmad, 2002). The investigation included 90 elbow radiographs of adults (45 males and 45 females). Their ages ranged from 18 to 76 years, mean age 35 years. Image of one elbow for each patient was available. They were explored in the radio-diagnostic department of Al-Majma'ah, King Khalid Hospital, K.S.A. between December 2008 and November 2009. The selected radiographs were photographed.

Carrying angle was investigated in each radiograph. It was measured between a line passing through the mid-axis of the lower third of humerus and a line along the mid-axis of the upper third of forearm between radius and ulna on the anteroposterior view. The two lines were extended to meet at the mid-point of Trans-Epicondylar Distance (TECD). The line of mid-axis of forearm was taken to pass from the point midway between the radius and ulna in the upper third of forearm to the mid-point of trans-epicondylar distance, passing through the superior radio-ulnar joint (Fig. 1). The angle was measured with a manual goniometer. Each author carried out the measurements independently. Inter-examiner reliability was determined by a comparison of the obtained results by each researcher.

Fig. 1: Anteroposterior radiographic view of right elbow of an adult female. It shows the carrying angle (*). It is the supplementary angle between the mid-axis of humerus (HA) and the mid-axis of forearm (FA). The two lines (HA and FA) meet at the mid-point of Trans-Epicondylar Distance (TECD)

Simple statistical analysis (Faragher, 2005) of the collected measurements including mean, Standard Deviation (SD) and t-test was done to assess any gender differences existed. To account for multiple comparisons, the level of significance was defined as p-value of less than 0.0001.

RESULTS

In the anatomical position, the bones of forearm appear to diverge laterally forming with the humerus a carrying angle (Fig. 1). The outward tilt of bones of forearm appears to be associated with more projection of the medial trochlear edge of the humerus than the lateral one. The tilt is more obvious in the region of the upper third of forearm, as the line of ulna changes its direction below that level (Fig. 2). Then, the carrying angle is defined as the supplementary angle lying between the median longitudinal axis of the humerus and that of the upper third of bones of forearm. Measurements of the carrying angle revealed that it ranges from 5° to 27°. Statistically, there are no significant differences in the mean inter-examiner reliability. The results of measurements are outlined in Table 1. The angle is significantly greater in females than in males. In males, it ranges from 5° to 17° with a mean of 9.29±2.98°, while in females it ranges from 10° to 27° with a mean of 18.47±4.12°. The mean values in both males and females, their standard deviations, standard errors of difference and confidence interval are shown in Table 2.

Fig. 2: Anteroposterior radiographic view of left elbow of an adult male. It shows the angulation (black *) of the shaft of ulna. The line of direction (D) of the shaft is marked. The radial head (RH), neck (RN) and tuberosity (RT) are seen to be slightly superimposed over the proximal ulna. The outward tilt of the radius and ulna appears to be associated with more projection of the medial edge (white *) of the trochlea than the lateral one (LT). The view also shows capitulum (C), shadow of olecranon (TO) superimposed on the trochlea, medial epicondyle (MEC), lateral epicondyle (LEC), olecranon fossa (O), coronoid process (CP) and superior radio-ulnar joint (SRU)

Table 1: Results of measurements of carrying angle in both females and males

	Females		Males	
Serial No.	Side	Carrying angle (°)	Side	Carrying angle (°)
1	R	16	L	11
2	R	16	L	12
3	R	15	L	6
4	R	18	R	13
5	R	21	R	10
6	R	17	R	16
7	L	17	L	8
8	R	16	R	7
9	R	17	R	10
10	L	17	L	8
11	R	21	R	9
12	R	15	R	15
13	L	12	R	7
14	L	16	L	9
15	R	13	R	11
16	R	17	R	12
17	L	18	L	8
18	R	15	L	5
19	R	19	R	10
20	L	20	L	10
21	L	10	L	11
22	R	26	R	7
23	L	18	R	9
24	R	14	R	11
25	R	22	L	12
26	R	26	R	8
27	R	20	R	7
28	L	21	L	9
29	L	23	R	11
30	R	16	R	11
31	L	20	R	16
32	R	10	R	8
33	L	26	L	5
34	R	18	L	6
35	R	14	R	9
36	R	22	R	5
37	R	26	L	10
38	L	20	R	17
39	L	21	R	8
40	R	27	R	6
41	R	19	R	8
42	L	17	R	9
43	L	23	R	6
44	R	16	R	8
45	L	20	R	5

R: Right elbow; L: Left elbow

Table 2: Statistical analysis of the carrying angle measurements

	Carrying angle (°)	
Sex	Mean±SD	Range
Males (N = 45)	9.29°±2.98°	5°-17°
Females (N = 45)	18.47°±4.12°	10°-27°
Statistical values		
SE = 0.746		
95% CI = -10.68 to -7.67		
p-value = <0.0001		

N: Number of cases, SD: Standard deviation, SE: Standard error of difference, CI: Confidence interval

DISCUSSION

In spite of significant advances in imaging of the elbow (multiplanar capabilities of MRI, volumetric CT imaging), conventional radiographs remain the first line in imaging technique for evaluation of elbow disorders. Plain radiographs allow accurate diagnosis (Sans and Railhac, 2008). The present study investigated the radiological measurements of carrying angle at the normal elbow joint.

Carrying angle is defined as the outward angulation of the supinated forearm with the elbow extended. It is found even in-utero and remains remarkably constant throughout the childhood and adult life (King and Secor, 1951). Du Plessis (1975) attributed its formation to the trochlea of the lower end of the humerus. The researcher, stated that the inner lip of the trochlea is a ridge which is much deeper distally than anteriorly, so that the ulna with the forearm is deflected laterally in full extension by this ridge. This deflection disappears in flexion as the ridge becomes less distinct. McMinn (1994) added that the upper end of the ulna shares in the angle formation. He reported that there is a curved ridge in the deep trochlear notch at the upper end of the ulna. This ridge joins the prominences of the coronoid process and olecranon and fits the groove in the trochlea of the humerus. The obliquity of the shaft of the ulna to this ridge accounts for most of the carrying angle at the elbow. Du Plessis (1975) said that the angle may be disturbed by fractures of the lower end of the humerus or by rupture of the collateral ligaments, which act as stays to the bones. If the carrying angle is increased the condition of cubitus valgus results. If it is obliterated the condition of cubitus varus ensues. The current study revealed that the angle is significantly greater in females than in males. This finding is in a general agreement with that of other studies that considered it as a secondary sex character (Potter, 1895; Khare and Rai, 1998; Van Roy *et al*., 2005; Yilmaz *et al*., 2005; Chang *et al*., 2008). A contrasting finding showing no differences in carrying angle between males and females was observed by Khare *et al*. (1999). They stated that the angle is greater in shorter persons compared to taller ones. Also, Beals (1976) denied any real difference in the angle between both sexes. However, the researcher, attributed the apparent differences to the increased joint laxity in females, allowing a greater degree of extension. The carrying angle of the dominant arm was found to be significantly greater than that of the non-dominant arm in both sexes (Yilmaz *et al*., 2005). In the Present study, image of only one elbow for each patient was available. A mean carrying angle of 18.47±4.12° was found in females, while in males it was 9.29±2.98°. These results showed a greater gender difference in the carrying angle than in the other results, such as that of Van Roy *et al*. (2005) which was 16.7±2.6° in the female and 11.6±3.2°in the male subjects. Most controversy in the reported carrying angle values is the result of differences in methodology and definition (Zampagni *et al*., 2008a). The angle is usually assessed in full elbow extension, with a protractor goniometer, or derived from X-ray images (Van Roy *et al*., 2005). The intersection of the line along the mid-axis of the upper arm and the line along the mid-axis of the forearm defines this angle (Yilmaz *et al*., 2005). Chang *et al*. (2008) defined the axis of the arm distally at the midpoint between the medial and lateral epicondyles of the humerus and proximally at the lateral border of the cranial surface of the acromion. They added that the axis of the forearm is defined distally at the midpoint between the distal radial and ulnar styloid processes and proximally at the midpoint between the medial and lateral epicondyles of the humerus. On the other hand, Steel and Tomlinson (1958) defined it as the acute angle lying between the tangent to the medial side of the head of the humerus produced through the tip of the medial epicondyle and a line joining the tip of the epicondyle with the medial side of the lower end of the ulna. However, Snell (2004) stated that it represents the obtuse angle between the long axis of the extended forearm and that of the arm. In the present study, it was measured as the supplementary angle between the mid-axis of the lower third of humerus and that of the upper third of forearm. The measurement was confined to the region of the elbow. This might eliminate the possible effects of deviations of shaft of ulna, such as varus angulation stated by Windisch *et al*. (2007), in the measurements of the angle. Moreover, the use of radiographic images in the current study helps to reduce the differences in measurements due to variations of the soft tissues in the upper limbs of each individual.

The use of simple method to measure the carrying angle taken from plain X-rays in this study leads us to propose it to be used in the actual future researches and clinical practice. In addition, the values reported in this study might be useful in the management of elbow disorders. Also, the great difference in the angle values

between females and males might be used in forensic medicine as a base for sex discrimination from the bones forming it.

CONCLUSION

In conclusion, this study demonstrated that the carrying angle is significantly greater in females than in males, so it can be considered as a secondary sex character. The recorded measurements might be helpful in management of disorders of the elbow and its reconstruction after fractures. Moreover, the proposed method in this study is simple, easy and accurate as it alleviates the effect of any deviation of long bones of the arm and forearm in the measurements. Therefore, it measures the actual angulations at the elbow.

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