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Original Article

Radiographic evaluation of the carrying angle and its correlation with various skeletal elements of the elbow joint in Iranian people

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Abstract

Background and aims: Evaluating the carrying angle and other anthropological features is important in determining elbow deformities. This study evaluated the carrying angle and various skeletal elements in normal Iranian adults.

Methods: The present study includes the elbow radiographs of 253 adolescents (87 women and 166 men). The carrying angle, articular surface angle, radial neck-shaft angle, and inter-epicondylar diameter have been measured. Then, a statistical analysis was conducted by gender and side for each measure. Spearman's or Pearson's correlations were used to detect the correlation between means.

Results: The mean carrying angle, radial neck-shaft angle, articular surface angle, and inter-epicondylar diameter were 19.72 ± 7.68°, 11.21 ± 4.45°, 85.19 ± 7.62°, and 85.80 ± 66.47 (mm) respectively. Statistically significant differences were not found between the left and right sides in all parameters for both males and females. However, significant differences were found between genders in inter-epicondylar diameter ($P = 0.0001$). Further, a significant negative correlation was found between the carrying and articular surface angles in males ($r = -0.29$) and females ($r = -0.33$). However, there was no significant correlation between the carrying angle and radial neck-shaft angle or inter-epicondylar diameter.

Conclusion: The present study showed the mean value of carrying angle, radial neck-shaft angle, articular surface angle, and inter-epicondylar diameter in Iranian people. The result of this study might be useful in the management of elbow disorders such as fractures and displacement as well as elbow reconstruction surgery procedures.

Keywords: Elbow, Radius, Carrying angle

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Introduction

The elbow joint is a complex hinge joint that plays an important role as the mechanical link between the shoulder and wrist in the upper extremity. The carrying angle of the elbow is described as the angle between the long axes of the humerus and the axis of the supinated and extended ulna in the coronal plane (1). The angle is formed as a result of the more distal position of the trochlea compared with the capitulum in the distal end of the humerus coupled with the slight valgus angulation of the trochlear notch of the ulna concerning its shaft (2,3). This anatomy is important in functional and diagnosing abnormalities such as medial apophysitis, osteonecrosis of the capitellum, and complication of supracondylar fracture (4,5). Moreover, the evaluation of pathologic variations of carrying angle identifies elbow deformities such as cubitus valgus or varus (6,7). The basal scale of the carrying angle has been documented in many reports. Although some studies have reported that the angle differs noticeably between genders and is greater in females than in males (4,8), some studies revealed no significant difference in carrying angle based on gender (9,10).

It has been documented that some elbow joint-related parameters measured by radiographic techniques such as carrying angle, radial neck-shaft angle, articular surface angle, and inter-epicondylar distance are considerably reliable (4,11, 12).

This study examined carrying angle, radial neck-shaft angle, articular surface angle, and inter-epicondylar distance on radiographs of the elbow region, its gender, and side differences in the Iranian adult population.

Materials and Methods

From April 2019 to October 2021, radiographs of the uninjured elbow were taken from 253 skeletally healthy adults, comprising 87 women and 166 men with a mean age of 39.3 years (range 21–48) for the study. They were recruited at the Orthopedic Department of Be'sat hospital. All participants were right-handed. Radiographs with a history of elbow pathologies were excluded.

Radiographic Evaluation

The measurements were repeated twice for each radiograph. The parameters were evaluated on anteroposterior radiographs as follows:

The carrying angle is defined as the angle between the long axes of the humerus and ulnar shafts (4,13). The axis of the ulnar body was dragged as a line between the midpoints of two proximal and distal transverse lines. The proximal line was passed at the base of the olecranon process, and the distal line was at the level of the radial tuberosity (Figure 1).

The methods used to measure radial neck-shaft angle and articular surface angle were based on Goldfarb and colleagues' study (4), and inter-epicondylar diameter was measured according to Shiva Prakash and colleagues' study (14). The radial neck-shaft angle, as shown in Figure 1, is the angle between a longitudinal line perpendicular to the articular surface of the radial neck and a longitudinal line along the radial shaft.

The articular surface angle is between the longitudinal axis of the humerus shaft, and a transverse line along the most distal aspect of the bony trochlea and the capitellum (Figure 1).

The inter-epicondylar diameter was measured between the prominent points of medial and lateral epicondyles (Figure 1).

Statistical Analysis

The statistical analysis was performed using SPSS 16.0 (IBM, USA), and the data were presented as mean ± standard deviation. To compare parameters in left and right and in males and females, we first performed the Kolmogorov-Smirnov test to assess the normality of data distribution. *P* values were found to be higher than 0.05 for the carrying angle, confirming the normality of the distribution of this parameter. However, radial neck-shaft angle, articular surface angle, and inter-epicondylar diameter were not normally distributed as their *P* values were less than 0.05. An independent t-test was also used for normally distributed data (carrying angle), and the Mann-Whitney test was employed as a nonparametric test for the comparative examination of data.

The correlation between the carrying angle and the other variables (i.e., radial neck-shaft angle, articular surface angle, and inter-epicondylar diameter) was evaluated by Spearman's rank correlation coefficient or Pearson's correlation coefficient depending upon the normality of the data. In the case of normally distributed parameters, Pearson correlation was used, whereas Spearman's correlation was used for the other parameters.

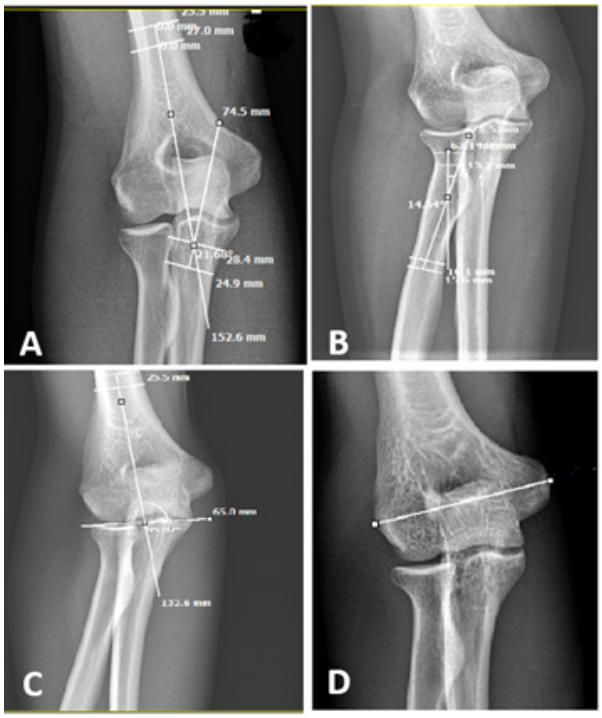

Figure 1. Measurement of carrying angle (A), radial neck-shaft angle (B), articular surface angle (C), inter-epicondylar diameter (D)

Results

A total of 166 males (48%) and 87 females (52%) were enrolled, and they were all right-handed. The mean values of each radiographic measurement, categorized by side and gender, are presented in Tables 1 and 2. Table 3 compares the mean carrying angle, radial neck-shaft angle, and articular surface angle between the two sides in males and females.

The results demonstrated no statistically significant differences between the left and right sides in all parameters for males and females ($P > 0.05$). Significant differences were, however, found between genders in inter-epicondylar diameter ($P < 0.001$), as depicted in Table 2.

There was a positive correlation between the inter-epicondylar diameter and carrying angle in men (r = 0.07, $P = 0.35$) and women (r = 0.09, $P = 0.41$), although it was not significant (Table 4). Additionally, a positive

Table 1. Radiographic measurements by laterality

Measurements	Side		*P* value
	Left (n = 122)	Right (n = 131)	
	Mean (SD)	Mean (SD)	
Carrying angle (°)	19.72 (7.67)	19.88 (6.81)	0.85
Radial neck-shaft angle (°)	11.21 (4.45)	11.00 (3.52)	0.81
Articular surface angle (°)	85.19 (7.62)	86.69 (8.28)	0.34
Inter-epicondylar diameter (mm)	66.47 (6.11)	66.79 (6.06)	0.87

Note. SD: Standard deviation.

Table 2. Radiographic measurements by gender

Measurements	Gender		*P* value
	Male (n = 166)	Female (n = 87)	
	Mean (SD)	Mean (SD)	
Carrying angle (°)	19.91(7.18)	19.58(7.35)	0.730
Radial neck-shaft angle (°)	10.82(4.11)	11.64(3.71)	0.054
Articular surface angle (°)	85.43(8.11)	86.99(7.71)	0.098
Inter-epicondylar diameter (mm)	69.53(4.21)	61.11(5.21)	0.001

Note. SD: Standard deviation.

Table 3. Comparison of mean carrying angle, radial neck-shaft angle, and articular surface angle between two sides in male and female

Measurements (Male)	Side		*P* value
	Left (n = 82)	Right (n = 84)	
	Mean (SD)	Mean (SD)	
Carrying angle (°)	20.28 (7.69)	19.56 (6.67)	0.52
Radial neck-shaft angle (°)	11.08 (4.61)	10.57 (3.57)	0.83
Articular surface angle (°)	84.52 (7.60)	86.32 (8.52)	0.24
Inter-epicondylar diameter (mm)	69.50 (4.39)	69.57 (4.04)	0.91
Measurements (Female)	**Left (n = 40)**	**Right (n = 47)**	***P* value**
Carrying angle (°)	18.55 (7.61)	20.46 (7.09)	0.23
Radial neck-shaft angle (°)	11.49 (4.14)	11.77 (3.33)	0.72
Articular surface angle (°)	86.55 (7.59)	87.36 (8.87)	0.86
Inter-epicondylar diameter (mm)	60.27 (4.14)	61.83 (5.92)	0.19

Note. SD: Standard deviation.

Table 4. Correlation coefficient relating carrying angle and radiographic measurements in male and female

	Correlation Coefficient (r)	*P* value
Measurements (Male)		
Radial neck-shaft angle	0.09	0.210
Articular surface angle	-0.29	0.001
Inter-epicondylar diameter	0.07	0.350
Measurements (Female)		
Radial neck-shaft angle	0.03	0.750
Articular surface angle	-0.33	0.002
Inter-epicondylar diameter	0.09	0.410

correlation was found between the radial neck-s using standard deviation crossover haft angle and carrying angle in men (r = 0.097, *P* = 0.21) and women (r = 0.03, *P* = 0.75), although it was not significant (Table 4). However, significant negative correlations were found between the carrying angle and articular surface angle in males (r = -0.29, *P* = 0.001) and also in females (r = -0.33, *P* = 0.002), as illustrated in Table 4.

Discussion

Radiographic measurement techniques are important for evaluating disorders and traumatic injuries in the elbow. In this study, we examined the carrying angle, radial neck-shaft angle, articular surface angle, and inter-epicondylar distance on elbow radiographs. We also dealt with the observations on the carrying angle and its correlation with other measurement parameters.

Goldfarb et al have displayed that radiographic measurement techniques such as carrying and articular surface angles are substantially reliable (4). We conducted this study due to the lack of established reference values for the Iranian population as current data is based on international studies.

Measurement parameters

Radial neck- shaft angle: Previous studies have reported mean value of 7 (15) and 12 (4), while our study found a value of 11.27 degrees.

Articular surface angle: The previously reported normal value for both sexes was 85 degree (4). However, our results showed a value of 85.43° in males and 86.99° in females. Increasing this angle to 90 degrees, indicates a decrease in valgus in the distal part of the humerus(4).

Inter-epicondylar distance: Previous studies have reported a minimum range of 5.5 centimeters and a maximum of 7.9 centimeters (11). In contrast, our results showed a range of 5.3- 9.2 centimeters, and the mean inter-epicondylar distance between males and females was significantly different (4).

Carrying angle: The Previously reported normal value for carrying angle shows considerable differences in adults, ranging from 0 degrees (10) to 27 degrees (16).

In the present study, the minimum range of carrying angle is 4.27°, and the maximum is 38.09°. This represents a wide range of findings. This observation is almost similar to the findings of Paraskevas et al whose findings ranged between 3-25° (17). The disparate findings in our results might be explained, at least in part, by considerable individual variability of carrying angle in Iranian people.

Some authors have reported significant differences between gender (4,17,18) and arm side (8,17,19-21). In this study, the mean carrying angle was 19.91° ± 7.18° in males and 19.58° ± 7.35° in females, and statistically significant differences were not found between males and females ($P > 0.05$). This corresponds with the findings of Sharma et al (right hand) (10) and Sadacharan et al (9). Regarding gender, it has been reported that the carrying angle is usually greater in females than in males. However, this consideration cannot be generalized due to large differences in individual variations (11,22). Using standard deviation crossover, Van Roy et al confirmed that some males have greater carrying angles than some females (22). This corresponds with our findings that the mean and left side carrying angle in males is larger than those in females.

In the present study, the carrying angle was found to be 20.46° ± 7.09° in females on the right (dominant) side and 18.55° ± 7.61° on the left (non-dominant) side, while in males, it was 19.56° ± 6.67° on the right and 20.28° ± 7.69° on the left side. Previous studies have reported statistically significant differences in carrying angle values between dominant and non-dominant arms (10,23), but in our study, there were no significant differences between both sides. It was also found that the mean carrying angle is greater in the dominant arm than that in the non-dominant side for both genders (23,24). Interestingly, our study found that the left carrying angle in males is greater than the right one. Sharma et al also observed that the carrying angle of the dominant limb was lesser than that of the non-dominant limb (10).

The current study also studied the correlation between the carrying and radial neck-shaft angles, articular surface angles, and inter-epicondylar distances. A significant inverse correlation was observed between the carrying

and articular surface angles. Furthermore, there was an insignificant positive correlation between the carrying angle, the radial neck-shaft angle, and inter-epicondylar distance. Allouh et al (11) showed a negative correlation between the carrying angle and inter-epicondylar distance, while Shiva Prakash et al and Verma et al found a positive correlation (14,25).

Conclusion

The present study revealed the mean value of the carrying angle in a group of Iranian individuals. No statistically significant differences were found between males and females in the carrying angle, articular surface angle, and radial neck-shaft angle. This could be attributed to variations in anthropometric parameters such as physical characteristics among different populations. However, a negative correlation was observed between the carrying and articular surface angles. The literature on this correlation is currently limited. The findings of this study could be useful in managing elbow disorders such as fractures, displacement, and elbow reconstruction surgery procedures.

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Authors' Contribution

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Competing Interests

The authors declare that they have no conflict of interests regarding the authorship or publication of this article.

Ethical Approval

The study protocol was approved by the Ethics Committee of Hamadan University of Medical Sciences (Ethical Code: IR.UMSHA.REC.1397.803).

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