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# The carrying angle: racial differences and relevance to inter-epicondylar distance of the humerus

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*The human carrying angle (CA) is a measure of the lateral deflection of the forearm from the arm. The importance of this angle emerges from its functional and clinical relevance. Previous studies have correlated this angle with different parameters including age, gender, and handedness. However, no reports have focused on race-dependent variations in CA or its relation to various components of the elbow joint. This study aimed to investigate the variations in CA with respect to race and inter-epicondylar distance (IED) of the humerus. The study included 457 Jordanian and 345 Malaysian volunteers with an age range of 18–21 years. All participants were right-hand dominant with no previous medical history in their upper limbs. Both CA and IED were measured by well-trained medical practitioners according to a well-established protocol. Regardless of race, CA was greater on the dominant side and in females. Furthermore, CA was significantly greater in Malaysian males compared to Jordanian males, and significantly smaller in Malaysian females compared to their Jordanian counterparts. Finally, CA significantly decreased with increasing IED in both races. This study supports effects of gender and handedness on the CA independent of race. However, CA also varies with race, and this variation is independent of age, gender, and handedness. The evaluation also revealed an inverse relationship between CA and IED. These findings indicate that multiple factors including race and IED should be considered during the examination and management of elbow fractures and epicondylar diseases.* (Folia Morphol 2016; 75, 3: 388–392)

**Key words: elbow, handedness, race**

## INTRODUCTION

The carrying angle (CA) of the human elbow joint is the angle formed between the long axes of the arm and forearm in the coronal plane when the forearm is fully extended and supinated [1]. It was first described by Braune and Kyrklund in 1879 [6] and has been termed as Ellenbogenwinkel, Armwinkel, totale Cubitalwinkel, and cubitus valgus [16]. The angle was redefined by Steel and Tomlinson [20] as the acute angle formed by the lateral deviation of the long axis of the forearm from the long axis of the arm, and most later studies have followed this new definition [3, 5, 16, 21, 24, 25]. From an anatomical point of view the CA represents the valgus deviation of the forearm in the anatomical position, which has been explained by the more distal location of the trochlea

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humeri compared with the capitulum humeri [25] and by the slight valgus angulation of the trochlear notch of the ulna in relation to its shaft [16].

The CA holds both functional and clinical importance. The CA plays an important role in load carrying, where it helps avoid contact with lower limb bones and allows positioning of the hand directly above the centre of mass of the carried weight, thus producing a comfortable lever arm [22]. Unilateral changes in the angle may indicate previous trauma, developmental anomaly, or may relate to repetitive stress in athletes [7, 13]. Information regarding the CA and its variation across different populations is important for aetiological studies of fractures around the elbow, diagnosis of epicondylar diseases, i.e. tennis and golf elbow, management of elbow fractures, and the design of elbow replacement implants [12, 16, 25]. Moreover, a previous study reported that increased CA values appear to be a risk factor for nontraumatic ulnar neuropathy at the elbow [8].

The basal values of the CA have been documented in a wide spectrum of reports in the literature. Older studies are valuable in this regard. The values for the original definition of CA range from approximately 160–175° [4, 6, 11, 18, 23]. Later studies have generally reported measurements of the CA according to its newer definition, which range from 5° to 25° [1, 2, 16, 20, 25]. Many of these studies have assessed the relationship between the CA and parameters including age; gender; dominant side; and body characteristics such as height, weight, and constitution. However, racial differences in the CA have not been reported to date. Furthermore, we speculated that the CA may be inversely correlated with the inter-epicondylar distance (IED) of the humerus.

The present study aimed to investigate race-dependent variation in the CA while accounting for the factors of age, gender, and handedness and to validate the hypothesized inverse relationship between the CA and IED in both Arab and Malay racial groups.

## MATERIALS AND METHODS

### Study populations

This study included 457 (253 male/204 female) Jordanians representing the Arab race and 345 (183 male/162 female) Malaysians representing the Malay race. Malaysian volunteers from Chinese and Indian racial backgrounds were excluded from the study. All participants were students at Jordan University of Science and Technology (JUST) and Yarmouk University in Jordan. The participants had an age range between 18 and 21 years. All participants were right-hand dominant with no medical record of previous trauma or fractures in the upper limbs.

### Measurement protocols

Measurement procedures were performed with the approval of the institutional research board at JUST (IRB # 46-89-2015). A proper consent report was distributed before starting the measurements (**Suppl. 1 — see journal website**). In addition, a specific investigation sheet was used to collect demographic information about each volunteer's nationality, racial background, gender, age, height, weight, and dominant hand and record their CA and IED measurements (**Suppl. 2 — see journal website**). The investigation sheet and measurement methods were fully explained to each participant.

A full-circle universal manual goniometer made of clear plastic was used to measure the CA according to the method described by Amis and Miller [2] and applied by several other studies [1, 24, 25]. This method has been reported to produce accurate measurements with an error margin of ± 1° [24]. In brief, the upper limb was abducted to 90° over a straight table, and the forearm was placed in a fully extended and supinated position. The hinge of the goniometer was located in the centre of the cubital fossa, and the goniometer arms were adjusted to parallel the long axes of the arm and forearm. Both sides were measured for each individual. To increase the reliability, each measurement was taken 3 times by well-trained medical examiners, and the mean value was calculated.

A manual calliper scaled from 0 cm to 20 cm and with a marginal error of ± 1 mm was used to measure the IED of the humerus. The arm was first lifted to the level of the shoulder, and the forearm was flexed 90°. At this position, the humeral epicondyles become prominent and easily palpable. The fixed arm of the calliper was placed on the lateral epicondyle, and the movable arm was then adjusted to the medial epicondyle. The IED measurement for each side was determined and recorded in the participant's investigation sheet. After collection, the data were transferred into a computer for statistical analysis.

### Statistical analysis

After applying the Levene test to determine the homogeneity of variance, the data were evaluated

**Table 1.** Measurements of the carrying angle (CA) with respect to gender and side in Arab and Malay participants

| Gender | Arab | | Malay | |
|---|---|---|---|---|
| | Right CA | Left CA | Right CA | Left CA |
| Male | $13.0 \pm 0.2^{**}$ | $10.4 \pm 0.2$ | $14.1 \pm 0.2^{**}$ | $12.5 \pm 0.2$ |
| Female | $17.5 \pm 0.3^{\ddagger *}$ | $16.0 \pm 0.6^{\ddagger}$ | $15.7 \pm 0.4^{\ddagger **}$ | $14.3 \pm 0.3^{\ddagger}$ |

$^{\ddagger}p < 0.01$, significantly greater than the corresponding side in males (*t*-test); $^{*}p < 0.05$; $^{**}p < 0.01$ significantly greater than the corresponding left side (*t*-test).

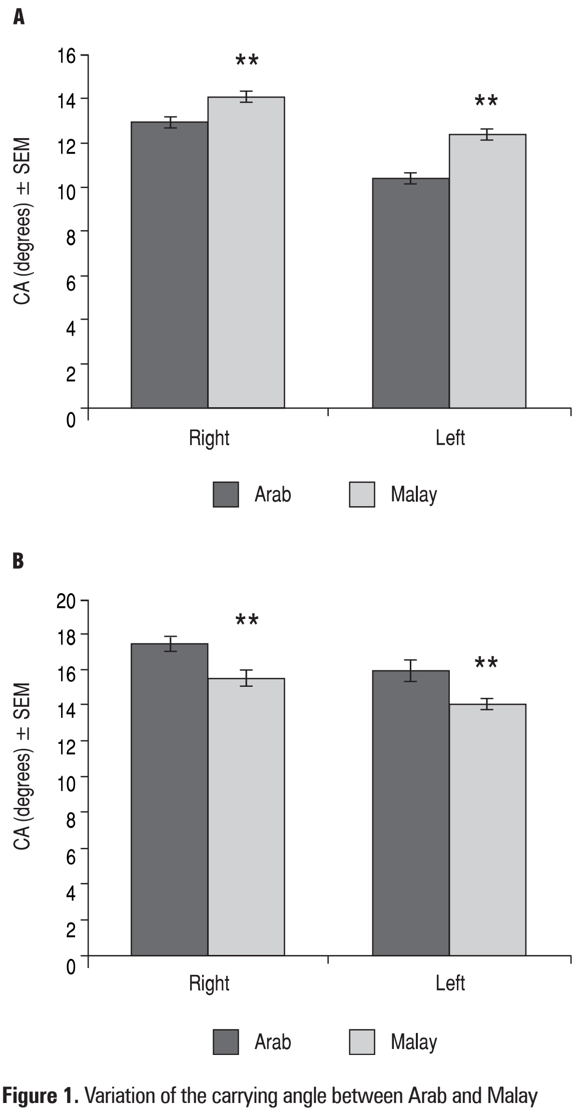


**Figure 1.** Variation of the carrying angle between Arab and Malay racial groups; **A.** Males; **B.** Females. Each column represents the mean carrying angle (CA) ± standard error of the mean (SEM); $^{**}p < 0.01$ compared to the same side and gender of the other race (*t*-test).

by independent samples *t*-test or one-way analysis of variance (ANOVA) at 5% and 1% levels of significance. Fischer's (LSD) *post hoc* test was performed, when needed, to examine statistical differences between the groups. The data are presented as mean ± standard error of the mean (SEM).

**Table 2.** Variation of the carrying angle (CA) with inter-epicondylar distance (IED) of the humerus in Arab participants

| IED [cm] | Right CA | Left CA |
|---|---|---|
| 5.5–5.9 | $16.9 \pm 0.5^{a}$ | $15.0 \pm 0.4^{a}$ |
| 6–6.4 | $16.9 \pm 0.3^{a}$ | $15.2 \pm 0.8^{a}$ |
| 6.5–6.9 | $13.7 \pm 0.3^{b}$ | $11.5 \pm 0.3^{b}$ |
| 7–7.4 | $13.5 \pm 0.4^{b}$ | $10.8 \pm 0.4^{bc}$ |
| 7.5–7.9 | $11.1 \pm 0.6^{c}$ | $9.2 \pm 0.6^{c}$ |

In each column, different letters indicate significantly ($p < 0.01$) different values (ANOVA, LSD *post hoc*).

## RESULTS

### Variation in CA with race

Both Arab and Malay races demonstrated variation in CA with gender and handedness similar to previous reports (Table 1). When the two racial groups were compared, the CA was significantly ($p < 0.01$) greater on both sides in Malay males compared to Arab males (Fig. 1A). By contrast, the CA was significantly ($p < 0.01$) smaller on both sides in Malay females compared with Arab females (Fig. 1B).

### Variation in CA with IED

Each race was studied separately to assess the relationship between CA and IED. The Jordanian Arabs were divided into five groups according to the length of their IED. Each group included an IED interval of 5 mm. A significant ($p < 0.01$) reduction in CA with increased IED was observed (Table 2). The Malay participants were divided into three groups according to IED length, also with each group having a 5-mm IED interval. Similar to Arabs, a significant ($p < 0.01$) reduction in CA with increased IED was observed in the Malay participants (Table 3).

## DISCUSSION

This study provides new information about race-dependent variations in the CA. Furthermore, it demonstrates a correlation between the CA and IED of

**Table 3.** Variation of the carrying angle (CA) with inter-epicondylar distance (IED) of the humerus in Malay participants

| IED [cm] | Right CA | Left CA |
|---|---|---|
| 5.5–5.9 | 16.4 ± 0.6[a] | 14.6 ± 0.5[a] |
| 6–6.4 | 14.7 ± 0.3[b] | 12.9 ± 0.3[b] |
| 6.5–6.9 | 14.4 ± 0.4[b] | 12.7 ± 0.4[b] |

In each column, different letters indicate significantly ($p < 0.01$) different values (ANOVA, LSD *post hoc*).

the humerus. Lastly, it corroborates the previous data that has been published regarding the variation of this angle with gender and handedness.

A number of studies have investigated the association of CA with various parameters, most notably age, gender, and handedness, due to its anatomical, physiological, and clinical implications. Several studies have addressed age-dependent changes in the CA. In general, it is agreed that CA increases with age because of skeletal growth and development [1, 16, 24]. In regard to gender, CA is usually greater in females than males; however, this tendency cannot be generalised because of large inter-individual differences [22]. Some earlier studies reported a greater value of the CA on the dominant arm in both Turkish and Greek populations [16, 21, 24]. In the present study, CA was significantly greater on the dominant arm of males and females in each racial group. Thus, CA appears to be more pronounced on the dominant side of the human body regardless of gender and race.

It has long been speculated that CA may differ in relation to race [15]. Moreover, differences between studied populations have been suggested to underlie conflicting data about CA in the literature [12]. In a recent study, Lim et al. [14] reported some new observations about the role of ethnicity on the variation of CA. However, their findings were inconclusive because of the small sample size studied and inadequate protocol applied. The present study confirms that CA varies with race, and this variation is independent of age, gender, and handedness. It could be argued that this variation might be due to differences in physical parameters such as height and weight between the Arab and Malay participants. However, our statistical analysis revealed no significant relationship between CA and height or weight in either male or female participants of the two races.

We found an inverse relationship between the CA and IED in both Arab and Malay participants. It has been well established that the capitulum and medial epicondyle are formed much earlier than the trochlea during growth [9, 17, 19]. Furthermore, as the capitulum ossifies, it grows more medially and crosses the border of the proximal radioulnar joint toward the trochlear space [10], leaving a limited space for the trochlea to develop later on. As the trochlea ossifies, it will grow farther distally in order to compensate for the space shortage, thereby contributing to the formation of the CA. In fact, it has been reported that the CA is partially present because the trochlea extends farther distally than the capitulum [16, 25]. These findings provide a plausible explanation for the inverse relationship between CA and IED, as a greater IED can provide more space for the trochlea to grow horizontally and become less distally inclined, thus producing a smaller CA.

## CONCLUSIONS

In summary, this study supports a role of gender and handedness in influencing the value of CA regardless of race. In addition, it offers new evidence about the variation of the CA between different races, independent of the factors of age, gender, and handedness. Finally, it demonstrates the presence of an inverse relationship between the IED of the humerus and the CA. These data are clinically important for the examination and management of elbow fractures in orthopaedics and may help in the prediction of race in forensic medicine. Future investigations that include more racial groups and larger populations are warranted to further confirm the influence of race and IED on CA.

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