Morphometric Measurements of Carrying Angle of the Elbow among Sample of Iraqi Medical Students: An Observational, Cross-Sectional Study

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Abstract

Background: The carrying angle (CA) is an acute angle occurring between the longitudinal axis of the upper arm and that of the extended and supinated forearm. CA allows swinging of the upper limb without hitting the pelvis. It appears to be larger in females than in males and also shows some variation to anthropometric parameters. Knowledge of CAs is valuable for orthopedic surgeons and biomedical engineers as well as for forensic specialists and anthropologists. **Aims:** The aim of the study is to evaluate the normal range of CA among Iraqi population. **Materials and Methods:** The CAs of the right and the left upper limbs was measured by a clinical goniometer in 200 medical students. Analysis for differences was performed according to gender, laterality, height, weight, and hip circumference (HC). **Results:** The mean right CA in men was 9° and in women was 10.75°, while the mean left CA was 8.76° in men and 10.51° in women. The mean CA in females is significantly larger than in males. The mean CA of the right elbow was greater than that of the left. The mean CA shows a positive correlation with the individual height, weight, and HC. **Conclusion:** The study fortifies the knowledge of the standard range of CA of the elbow in a study population of apparently healthy Iraqi medical students and tries to make a reference value to be used for orthopedic surgeons, biomedical engineers as well as for forensic specialists and anthropologists.

Keywords: Carrying angle, cubitus varus and valgus, goniometer, Iraq

Introduction

The elbow region is anatomically defined as the region of the upper limb lying between the arm and the forearm that surround the elbow joint.[1] The term elbow is precisely applied for human beings and other primates.[2]

In a fully extended arm, with the palm facing anteriorly, the bones of the arm and the forearm are not allied at a same axis. However, there is a slight radial deviation, and this deviation is termed the carrying angle (CA)[3] [Figure 1].[4]

The CA allows swinging of the upper arm without hitting the pelvis.[5] It is greater in females and it is also larger in the dominant limb.[6] Structural factors, aging, and probably ethnic influences may add additional variability in the CA measurement.[7]

The outer angle between the longitudinal axes of the arm and the fully-extended forearm is an obtuse angle[8] and its normal measure is about 175° in men and 165° in women. While the inner angle between the arm and the forearm (which is clinically termed the CA) is an acute angle, it ranges from 2° to 21° in males and 2° to 26° in females.[9]

The CA is produced partially by the projection of the medial trochlear edge about 0.6 cm passing its lateral edge and partially by the oblique alignment of the ulnar coronoid process, which is not perpendicular to the ulnar shaft.[10]

In males, the CA is very similar in children and in adults, however, in females, the angle varies greatly with age, proposing that hormonal changes may influence the CA in

Access this article online

Quick Response Code:

Website: http://www.mmjonweb.org

DOI: 10.4103/mj.mj_25_23

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Submitted: 21-Apr-2023 **Revised:** 03-May-2023 **Accepted:** 10-May-2023 **Published:** 07-Aug-2023

How to cite this article: Assi MH. Morphometric measurements of carrying angle of the elbow among sample of Iraqi medical students: An observational, cross-sectional study. Mustansiriya Med J 2023;22:132-7.

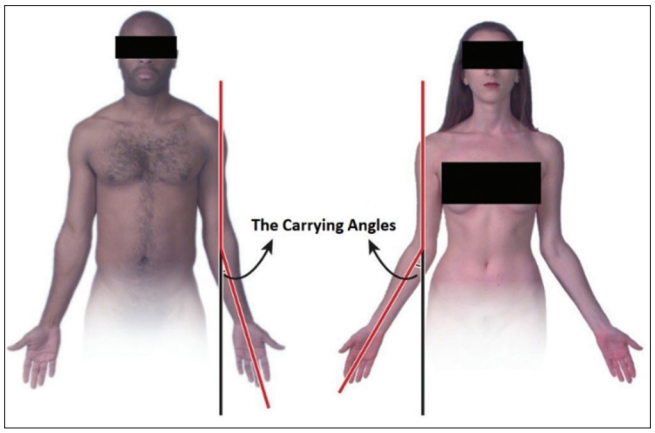

Figure 1: The CA among male and female. CA: Carrying angle

females.[11] The CA as well as displays a direct relationship with the pelvic breadth. Consequently, in females, the wide pelvis is considered to be a cause for greater CA.[12]

The CA also displays variation with several other anthropometrical indices, such as the height, shoulder, hip and waist circumferences, and the lengths of both arm and forearm.[13]

Increased CA may lead to instability of the elbow joint and discomfort during exercise.[14] It may also predispose to joint dislocation[15] and to an increased likelihood of fractures about the elbow joint when falling on an outstretched hand.[15]

Furthermore, the value of the CA may determine the type of fractures in children.[15] In addition, the degree of the CA may influence the type of abnormalities that accompany the healing of certain elbow fractures (i.e., cubitus varus or cubitus valgus).[16] A cubitus valgus may induce gradual ulnar nerve stretching posterior to the medial epicondyle of the femur and may produce an ulnar nerve paralysis.[17]

Knowledge of the CA of the elbow is valuable for forensic specialists and anthropologists for the determination of the gender and racial identity particularly in fragmentary bony remnants[18] and for orthopedic surgeons in their medical practice for the treatment of different elbow conditions and in elbow reconstructive procedures[19] and biomedical engineers for the preparations of elbow implants.[15]

Aim of the study

1. Evaluate normal CA ranges in Iraqi population
2. Compare their measurements in males and females
3. Correlate them to anthropometric parameters, such as height, weight, and hip circumference (HC).

Materials and Methods

Study design

The study is analytical, cross-sectional, and observational in the design conducted out in the Department of Human Anatomy at Al-Mustansiriyah Medical College, Baghdad, Iraq. It has been approved by the local ethical committee of Al-Mustansiriyah Medical College and informed consents were reserved from all participants.

The study includes 200 healthy adult medical students (100 males and 100 females) aged 17–22 years in Al-Mustansiriyah Medical College, Baghdad, Iraq, during the period from February to April 2023.

Inclusion criteria

Male and female medical students who are willing to join the study.

Exclusion criteria

1. Any individual with a history of trauma, disease, or surgery affecting the upper limb
2. Any individual with an endocrine disorder affects the skeletal system.

Materials

- A plastic goniometer (Passionate Care, Spain): Used for measuring the CA in degrees
- A tape rule (Butterfly, China): Used to measure of the HC in centimeters
- Portable stadiometer (Seca, Germany): Used to measure individual height in centimeters
- Digital weight scale (Seca, Germany): Used to measure individual weight in kilograms.

Methods

The height and weight of the participants were measured using appropriate instruments.

HC measured according to MRC Epidemiology Unit, as follows:

The participant stands in anatomical position, with the arm relaxed by sides, feet together, and all materials from pockets removed. The flexible tape is placed at the broadest level of the buttocks, on the femoral trochanters and wrapped snugly around the participant, keeping the measuring tape level parallel to the ground.

Measuring the carrying angle using a goniometer

The participants were asked to stand in an anatomic position on an even ground, with the forearm fully extended and supinated. The hinge of the goniometer was located on the ventral aspect of the elbow in a midline about 2 cm inferior to the line joining the two femoral epicondyles, and the fixed arm of the goniometer allied with the median axis of the arm (biceps tendon was used as landmark[13]), and the mobile arm of the goniometer was then adjusted to line up with the median axis of forearm (palmaris longus tendon at the wrist was used as a landmark[13]). The angle that was formed between these two axes was read as CA.[15] Measurement was read in degrees and taken for both right and left limbs. Three readings were measured from each side, and an average reading was calculated [Figure 2].

Statistical analysis

Statistical analyses were performed by the use of the SPSS "Statistical Package for the Social Sciences (SPSS Inc., Chicago, IL, USA)" version 26 for Windows and Microsoft Office Excel 2021. Continuous data were represented as mean ± standard deviation and their normal distribution was verified by the nonparametric test (Kolmogorov–Smirnov). For the nonnormally distributed data, comparisons between groups were executed using Wilcoxon signed-rank test for paired data and Mann–Whitney *U*-test for unpaired ones. The degree of the relationship between two continuous data was tested by using Spearman's correlation coefficient (*r*). Bivariate linear regression mode and R^2 (coefficient of determination) were also calculated. $P < 0.05$ was considered as statistically significant.[20]

Results

The total number of participants in this study was two hundred ($n = 200$). The percentile contribution of males and females was 50% and 50%, respectively (100 males and 100 females). Their age ranged from 17 years to 22 years with a mean age of 18.62 ± 1.167 years (18.76 ± 1.311 for males and 18.48 ± 0.99 for females). Their heights ranged from 155 cm to 180 cm, with a mean height of 166.36 ± 7.728 cm (171.20 ± 6.31 for males and 161.52 ± 5.74 for females). Their weights ranged from 59 kg to 90 kg with a mean weight of 71.92 ± 6.77 kg (74.56 ± 6.51 for males and 69.28 ± 5.97 for females). The HC ranged from 74 cm to 115 cm with a mean HC of 90.96 ± 9.78 cm (90.04 ± 9.84 for males and 91.88 ± 9.78 for females). The right carrying angle (RCA) ranged from 5° to 18° with a mean RCA of 9.88 ± 2.66 (9.00 ± 1.75 for males and 10.75 ± 3.09 for females).

The left CA (LCA) ranged from 5° to 17° with a mean LCA of 9.64 ± 2.54 (8.76 ± 1.66 for males and 10.51 ± 2.94 for females) [Table 1].

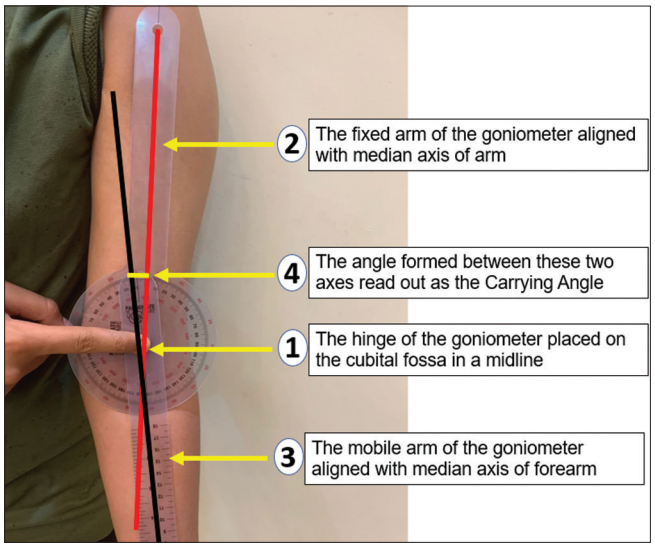

Figure 2: Measurement of CA (participant has consented for photograph publication). CA: Carrying angle

Kolmogorov–Smirnov test for all variables reveals a $P < 0.05$, which indicates that the distribution of data from all variables is not normal. Hence, intergroup comparison in this study was conducted by Wilcoxon signed-rank test and the Mann–Whitney *U*-test.

A Wilcoxon signed-rank test shows that RCA was significantly greater than the LCA in both genders (9° vs. 8.76°, $P < 0.001$ in males, 10.75° vs. 10.51°, $P < 0.001$ in females, and 9.88° vs. 9.64°, $P < 0.001$ in both genders) [Figure 3].

To study the effect of gender on the CA measurements, a Mann–Whitney *U*-test was executed, it exposes a significant difference in CA measurements between males and females, where the mean RCA and LCA are greater in females than in males (10.75° vs. 9.00°, $P < 0.001$ for RCA, 10.51° vs. 8.76°, $P < 0.001$ for LCA) [Figure 3].

A Spearman's correlation test was performed to investigate the effect of an individual's anthropometric parameters (height, weight, and HC) upon CA; the test concludes a positive correlation between height and CA, weight and CA, and HC and CA in both males and females [Table 2].

Bivariate regressions were conducted to see if any of the anthropometric parameters can predict the CAs. The results are summarized in Table 3 and Figure 4.

Discussion

Measuring the CA is imperative in managing conditions involving bones forming the elbow region. Knowing the CA and its variations are an essential step for preoperative surgical planning in trauma management and also for orthopedic correction of congenital deformations involving the elbow joint.[21] It also has an important role in designing elbow prostheses.[14]

Conventionally, the CA is measured in two ways (clinical and radiological). Clinical measurements involve use of clinical goniometer, full circle goniometer, protractor goniometer, universal goniometer, and digital (electronic) goniometer.

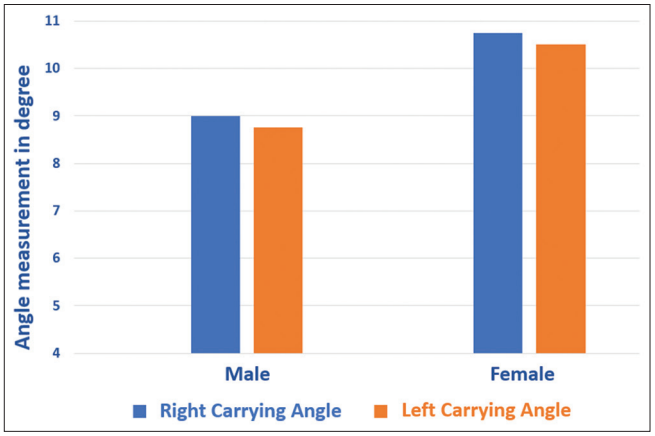

Figure 3: Comparison of right and left CA s in both genders. CA: Carrying angle

Table 1: Descriptive statistics of the cases

	Age (years)	Height (cm)	Weight (kg)	HC (cm)	RCA (°)	LCA (°)
Males						
Minimum	17	160	60	73	5	5
Maximum	22	180	90	113	12	12
Mean±SD	18.76±1.31	171.20±6.31	74.56±6.51	90.04±9.84	9.00±1.75	8.76±1.66
Variance	1.72	39.84	42.35	95.77	3.07	2.77
Females						
Minimum	17	155	59	74	6	6
Maximum	21	170	80	115	18	17
Mean±SD	18.48±0.99	161.52±5.74	69.28±5.97	91.88±9.78	10.75±3.09	10.51±2.94
Variance	0.98	32.90	35.68	96.62	9.56	8.66
Both genders						
Minimum	17	155	59	74	5	5
Maximum	22	180	90	115	18	17
Mean±SD	18.62±1.17	166.36±7.73	71.92±6.77	90.96±9.784	9.88±2.66	9.64±2.54
Variance	1.36	59.73	45.82	95.72	7.06	6.46

SD: Standard deviation, HC: Hip circumference, RCA: Right carrying angle, LCA: Left carrying angle

Table 2: Spearman's correlation–carrying angles versus anthropometric parameters

	Height	Weight	HC
RCA			
Male			
Correlation	0.700**	0.568**	0.950**
Significant (two-tailed)	0.000	0.000	0.000
Female			
Correlation	0.901**	0.291*	0.769**
Significant (two-tailed)	0.000	0.003	0.000
LCA			
Male			
Correlation	0.689**	0.684**	0.914**
Significant (two-tailed)	0.000	0.000	0.000
Female			
Correlation	0.669**	0.578**	0.920**
Significant (two-tailed)	0.000	0.000	0.000

*Correlation is significant at the 0.05 level (two-tailed). **Correlation is significant at the 0.01 level (two-tailed). HC: Hip circumference, RCA: Right carrying angle, LCA: Left carrying angle

Radiological methods involve plain X-ray, computed tomography scan, and magnetic resonance imaging. In this study, a clinical goniometer has been used to measure the CA as it is easy, available, and informative.

The study of CA and its relation to different anthropometric indices has been conducted by many researchers. In this study, we try to measure the CA in apparently healthy adult medical students and try to correlate this measurement with other parameters, such as gender, laterality, height, weight, and HC.

The study showed that the mean CA in both genders was larger on the right side than on the left one [9° vs. 8.76° in males, 10.75° vs. 10.51° in females, and 9.88° vs. 9.64° in both genders, Figure 3]. This finding was similar to most studies carried out on CA.[22-27] This may be attributed to the dominance of the right hand over the left one in most of the study group participants, and the differences in the CA between dominant and nondominant sides may be the result of ligamentous laxity of at the elbow.[28]

Another finding this study revealed that the mean CA is significantly greater in women than in men [10.75° vs. 9.00° for RCA and 10.51° vs. 8.76° for LCA, Figure 3]. This finding was similar to most, if not all studies carried out on CA.[29-33] This may be attributed to hormonal changes in women[11] and also due to the increase in ligamentous laxity among women allowing a larger degree of elbow extension and so a larger CA. In addition, in women, the medial trochlear lip extends more distally than the lateral one and the valgus incline of the distal humerus in respect to its long axis is more as compared to men.[7]

The study revealed a significant positive correlation between CA and the individual's height ($R^2 = 0.245$, $P < 0.01$ for the RCA and $R^2 = 0.239$, $P < 0.01$ for the LCA), and this finding agrees with the study done by Gabriel *et al.* in 2019.[34]

A significant positive correlation was also detected between CA measurements and the individual's weight in both genders ($R^2 = 0.076$, $P < 0.01$ for the RCA and $R^2 = 0.093$, $P < 0.01$ for the LCA).

Again, a significant positive correlation was found between CA and the individual's HC in both males and females ($R^2 = 0.618$, $P < 0.01$ for the RCA and $R^2 = 0.631$, $P < 0.01$ for the LCA), this may be attributed to the fact that females have a relatively greater HC than males, this agrees with the study done by Chinweife *et al*. in 2014.[35]

Conclusion

The study fortifies the knowledge of the standard range of CA of the elbow in a study population of apparently healthy Iraqi medical students using a clinical goniometer and tries

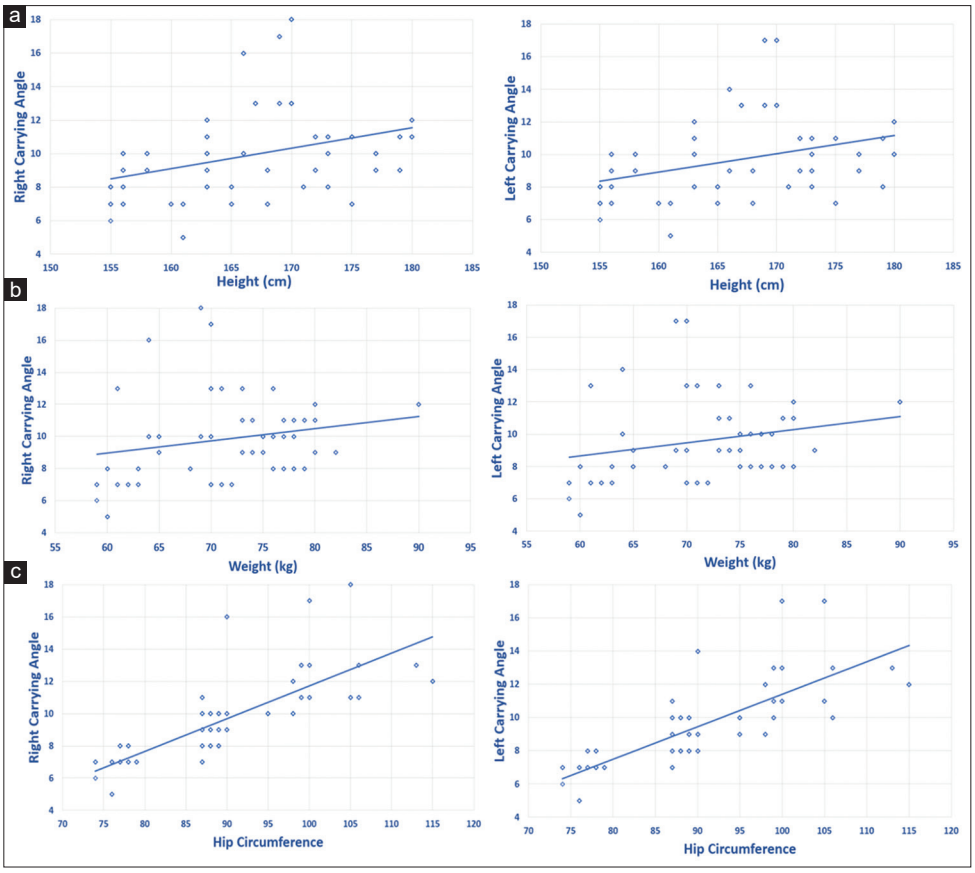

Figure 4: Scatter correlations and linear regressions: CA versus anthropometric parameters (in both genders). CA: Carrying angle. (a) Height vesus CA. (b) Weight versus CA. (c) Hip circumference versus CA

Table 3: Linear regression statistics: Carrying angles versus anthropometric parameters

Parameters	Gender	*R*	R^2	Adjusted R^2	*P*
RCA					
Height	Male	0.720	0.518	0.513	0.000
	Female	0.861	0.741	0.738	0.000
	Both gender	0.495	0.245	0.241	0.000
Weight	Male	0.673	0.453	0.448	0.000
	Female	0.208	0.043	0.034	0.038
	Both gender	0.276	0.076	0.071	0.000
HC	Male	0.769	0.592	0.588	0.000
	Female	0.926	0.857	0.856	0.000
	Both gender	0.786	0.618	0.616	0.000
LCA					
Height	Male	0.689	0.475	0.470	0.000
	Female	0.879	0.772	0.770	0.000
	Both gender	0.489	0.239	0.235	0.000
Weight	Male	0.684	0.468	0.462	0.000
	Female	0.262	0.069	0.059	0.008
	Both gender	0.304	0.093	0.088	0.000
HC	Male	0.792	0.628	0.624	0.000
	Female	0.914	0.835	0.833	0.000
	Both gender	0.794	0.631	0.629	0.000

HC: Hip circumference, RCA: Right carrying angle, LCA: Left carrying angle

to make a reference value to be used for orthopedic surgeons in their medical practice for the treatment of different elbow disorders and in elbow reconstructive procedures and for biomedical engineers for the preparations of elbow implants, as well as for forensic specialists and anthropologists for gender determination.

Acknowledgment

The author would like to thank all members in Human Anatomy Department of Al-Mustansiriyah University, College of Medicine for their fruitful support and for all medical students who participate in this study.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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