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Determination of Carrying Angle of Elbow among Adult Pakistani Population

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Abstract

Objectives: To determine the carrying angle of elbow among adult Pakistani population presenting to a tertiary care hospital.

Materials and Methods: This descriptive cross-sectional study was done at The Indus Hospital and Health Network Karachi, a free of cost tertiary care facility. Participant who met with inclusion criteria were recruited and carrying angle of both elbow and length of the forearm was measured with the help of Goniometer and inch tape respectively.

Results: A total of 500 participants were enrolled in the study, out of which 353 (70.6%) were males, 142 (28.4%) were females and 5 (1%) had missing information regarding gender. The majority (96%) of the patients had right dominant limb. Men had a longer median length of the forearm ($p<0.0001$). Women were found to have a higher median of upper limb carrying angle ($p<0.0001$). The distribution of extension of arms was found more variable in women ($p=0.002$ and 0.023). Punjabis had higher carrying angles compared to other ethnicities. Right dominant hands had higher right hand carrying angle in comparison to left hand (Median (IQR): 10 (8-13) *vs.* 10 (8-12), $p=0.000$).

Conclusion: The present study showed that mean carrying angle was greater in females consistent with literature and in right hand in right-hand dominant people, not consistent with literature. We recommend a larger scale multicentric study to further substantiate our findings in our people and population at large.

Keywords: Goniometer; Carrying angle; Arthroplasty

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Introduction

The elbow joint, a compound synovial joint has two articulating surfaces, humero-ulnar and radioulnar [1]. As arm and forearm are not in a straight line, this helps the arm swing away from the body while walking and aids in carrying objects [2]. This frontal plane acute angle between the forearm and the long axis of the arm when the elbow is fully extended, and the forearm is supinated is known as "Carrying Angle" [3,4]. A greater carrying angle in females as compared to males has been considered a secondary sex characteristic [5]. As women on average have smaller shoulders and wider hips than men, this leads to the need for a more acute carrying angle.

The average value of the carrying angle is considered 12.5 ± 0.57 degrees in males and 15.26 ± 0.45 degrees in females in a clinical setup [4,7-11]. Increase in the carrying angle may manifest as elbow instability, reduced function, pain and a predisposing factor to elbow dislocation. This parameter can be measured by simple clinical and radiographic techniques [3,5,6]. The carrying angle varies according to age, gender, ethnicity, elbow hyperextension and hand dominance [4,7-11]. It has been shown in a recent study of healthy children (600 elbows) that range of motion of the elbow and carrying angle increase with age to skeletal maturity [12]. Another study has demonstrated increase in carrying angle till 15 years, after which there was a slight downward trend. The rate of carrying angle increase for boys and girls is 0.42 and 0.60 per year, respectively [13].

A more recent study from India has shown that carrying angle is a suitable secondary sexual characteristic [14]. Another study showed that there is a negative correlation of height with the carrying angle in both genders, but the greater angle was found in females [1]. The results of the study by Rajesh et al. also showed a similar pattern with mean carrying angle of 13.3 ± 2.4 in girls and 6.7 ± 1.0 in Boys [15].

Table 1: Ethnicity-wise characteristics of the study population.

		Punjabi[a]	Sindhi[b]	Urdu Speaking[c]	Pathan[d]	Other[e]	P-value
Height (cm)	Mean ± SD	162.1 ± 9.8	165.2 ± 7.4	163.4 ± 9.9	165.7 ± 8	160 ± 14.4	0.027*†
	Min-Max	140-182	150-185	127-190	141-180	72-185	
	Median (IQR)	162(156-168.8)	165(160-170)	165(156-170)	166(160.8-172.3)	161(155-167)[d]	
Weight (Kg)	Mean ± SD	62.6 ± 14.5	66.6 ± 14.1	65.1 ± 15.5	70.2 ± 15.3	60.4 ± 11.2	0.006*†
	Min-Max	37-105	46-104	35-122	43-99	38-99	
	Median (IQR)	61(52-73)[d]	64(55.8-78.3)	65(52-75)	73.5(55.8-82)	60(51.8-69)[d]	
BMI	Mean ± SD	23.8 ± 5.2	24.5 ± 5.2	24.4 ± 5.6	25.6 ± 5.4	24.6 ± 11.5	0.245†
	Min-Max	14.6-38.6	15.5-37.7	14-47.2	16-35.8	15.1-110	
	Median (IQR)	23.2(19.8-26.8)	23.5(20.3-28.6)	24(20.8-27.6)	26.3(21.2-29.3)	22.9(19.9-26.4)	
Age in years	Mean ± SD	29.3 ± 10.3	35.4 ± 11.1	33.3 ± 11	32.4 ± 10.8	30.8 ± 10.9	0.002*†
	Min-Max	18-60	18-60	18-70	18-65	18-60	
	Median (IQR)	26.5(22-36)[b,c]	35(25.8-45)	32(25-40)	30.5(24-40.3)	28(23-35)	
Length of right forearm(cm)	Mean ± SD	23 ± 1.6	23.7 ± 1.5[a,e]	23.3 ± 1.5	23.7 ± 1.4[a,e]	23 ± 1.5	0.011*‡
	Min-Max	19-28.5	20.5-28.5	18.5-27	20.5-26.5	20-26.5	
	Median (IQR)	23(22-24)	23.5(22.9-25)	23.5(22-24.5)	23.5(23-24.5)	23(22-24)	
Length of left forearm(cm)	Mean ± SD	22.8 ± 1.6	23.5 ± 1.5	23.1 ± 1.6	23.3 ± 1.3	22.7 ± 1.5	0.000*†
	Min-Max	19-29	20.5-28	19-29.5	20-26.5	19.5-27	
	Median (IQR)	23(21.5-24)	23.5(22.5-24.5)	23(22-24)	23.5(22.5-24)	22.5(21.5-23.6)[b]	
Upper limb carrying angle Right Arm (degrees)	Mean ± SD	12.3 ± 4.1	9 ± 3.2	11.2 ± 3.8	9.5 ± 3.1	10.9 ± 3.6	0.000*†
	Min-Max	3-21	2-20	3-22	2-18	4-18	
	Median (IQR)	12(9-16)	8(7-11)[a,c,e]	10(8-14)	9.5(7.8-11)[a,c,e]	10(8-14)	
Upper limb carrying angle Left Arm (degrees)	Mean ± SD	11.9 ± 3.9	8.5 ± 3	10.8 ± 3.9	8.7 ± 3.3	10.2 ± 3.4	0.000*†
	Min-Max	5-22	0-16	3-21	4-16	4-16	
	Median (IQR)	12(8-14.8)[b,c,d,e]	8(6-10.5)	10(8-14)[b,d]	8(6-10.3)	10(7-13.3)[b,d]	
Extension Right Arm (degrees)	Mean ± SD	1.7 ± 3.6	0.5 ± 1.8	1.8 ± 4.1	0.2 ± 1	1.2 ± 3.2	0.026*†
	Min-Max	0-15	0-9	0-15	0-5[a,c]	0-15	
	Median (IQR)	0(0-0)	0(0-0)	0(0-0)	0(0-0)	0(0-0)	
Extension Left Arm (degrees)	Mean ± SD	1.7 ± 3.8	0.3 ± 1.5	1.7 ± 4.1	0.2 ± 1.5	0.9 ± 2.8	0.005*†
	Min-Max	0-15	0-8	0-20	0-10[a,c]	0-12	
	Median (IQR)	0(0-0)	0(0-0)	0(0-0)	0(0-0)	0(0-0)	

*P-value<0.05, **P-value<0.0001, †Kruskal Wallis test, łOne-way ANOVA

Another study with significant sample size measured carrying angle on the dominant and non-dominant extremity in 1275 healthy volunteers (631 males, 644 females) with a mean age of 22.87 ± 15.99 years (range: 2 to 91 years). The carrying angle of the dominant arm was demonstrated to be higher than the non-dominant arm in either sex [7].

A study from Malaysia showed non-significant variation of carrying angle in people from Malay, Indian and Chinese population with a mean carrying angle of 8.49, 9.5 and 8.09 respectively [4].

Knowledge of carrying angle and its variations is very important for managing traumatic as well as pathological elbow conditions resulting in deformities [4,5]. It varies with certain physiological conditions like age, gender, hyperextension of the elbow, hand dominance, height, and intertrochanteric distance.

Determination of carrying angle in our population will assist in better understanding of elbow biomechanics, improvement in prosthetic designs and manufacturing of pre-contoured anatomic plates, resulting in better outcomes of reconstructive and replacement procedures in our population.

Material and Methods

This cross-sectional study was carried out at The Indus Hospital and Health Network, Karachi. The sample size was calculated using WHO calculator with the following assumptions mean (SD) Carrying angle: 10 ± 1.700 (average value of mean (SD) carrying angle in males 6.7 ± 1.0 and mean (SD) carrying angle in females 13.3 ± 2.4, margin of error as 0.3, the calculated sample size was 124. However, in this study, 500 participants were enrolled. Non-probability consecutive sampling technique was used [15].

Eligible candidates with a history of arm or elbow injury, having a history of any surgery, having any congenital/post-traumatic

Table 2: Gender wise characteristics of the study population.

	Gender						P-value
	Male			Female			
	n=353			n=142			
	Mean ± SD	Min-Max	Median (IQR)	Mean ± SD	Min-Max	Median (IQR)	
Height (cm)	166.7 ± 9.1	72-190	167 (162-172)	154.2 ± 7.1	139-176	155 (150-159.3)	0.000**†
Weight (kg)	66.8 ± 14	38-110	65 (56-76)	59.3 ± 14.7	35-107	56.5 (48-70)	0.000**†
BMI	24.2 ± 6.6	14-110	23.6 (20.4-27.3)	25 ± 6.3	14.6-47.2	24.3 (20.1-28.6)	0.291†
Age in Year	33.2 ± 11.3	18-70	30 (24-40)	30.9 ± 10.1	18-60	29.5 (22.8-38)	0.054*†
Length of right forearm(cm)	23.7 ± 1.4	20-28.5	23.5 (23-24.5)	22.3 ± 1.4	18.5-26.5	22.3 (21.5-23.1)	0.000**†
Length of left forearm(cm)	23.4 ± 1.4	20-29.5	23.5 (22.5-24.5)	22.1 ± 1.4	19-26	22 (21-23)	0.000**†
Upper limb carrying angle Right Arm (degrees)	9.5 ± 3.1	2-21	9 (8-11)	14.4 ± 3.2	6-22	14 (12-17)	0.000**†
Upper limb carrying angle Left Arm (degrees)	9 ± 3.1	0-20	9 (7-11)	13.8 ± 3.2	6-22	14 (12-16)	0.000**†
Extension Right Arm (degrees)	1 ± 3	0-15	0 (0-0)	2.4 ± 4.4	0-15	0 (0-5)	0.000**†
Extension Left Arm (degrees)	1 ± 3	0-18	0 (0-0)	2.1 ± 4.4	0-20	0 (0-0)	0.003*†
Extension right; n (%)							
<=5	324 (91.8)			116 (81.7)		440 (88.9)	0.005*ϒ
06-Oct	19 (5.4)			17 (12)		36 (7.3)	
>10	10 (2.8)			9 (6.3)		19 (3.8)	
Total	353 (100)			142 (100)		495 (100)	
Extension left; n (%)							
<=5	327 (95.9)			120 (89.6)		447 (94.1)	0.008*ϒ
06-Oct	14 (4.1)			14 (10.4)		28 (5.9)	
Total	341 (100)			134 (100)		475 (100)	

*P-value<0.05, **P-value <0.0001, ºP-value <0.10 (showing trend), †Mann-Whitney U test, Chi-square test

deformity were excluded from the study. Participants' characteristics like age, height, weight, and ethnicity were also asked and recorded.

A goniometer was used for measurement of carrying angle. The fixed arm of this instrument could be placed on the midline of the upper arm (landmark being biceps brachii tendon insertion) and the movable arm could be adjusted as to lie on the midline of the forearm (landmark being palmaris longus tendon at the wrist).

The data were entered in SPSS V.24.0 and analyzed using SPSS and R studio. Mean ± SD/Median (IQR) were computed for all the categorical variables as appropriate. Kruskal Wallis/ANOVA was applied as appropriate to assess the significant difference in age, height, weight, carrying angle, length of arm and extension among ethnicities. Independent sample T-test/Mann-Whitney U test was applied as appropriate to assess the significant difference in the aforementioned quantitative variables between both the genders. Chi-square test was applied to assess the significant difference in the distribution of arm extension between both the genders. Furthermore, linear quantile model was applied to assess the significant difference in carrying angle for all the pair wise combination of ethnicity adjusting for age, height, weight, and gender. Wilcox signed rank test was applied to assess dominant hand wise significant difference in right and left hand carrying angle. All the categorical variables were presented as frequency along with percentage. P-value <0.05 was considered statistically significant.

Results

A total of 500 participants were enrolled in the study, out of which 353 (70.6%) were males, 142 (28.4%) were females and 5 (1%) had missing information regarding gender (Figure 1). Approximately, half of the patients were Urdu speaking (49.2%) followed by Punjabi (16%), Sindhi (12.4%) and Pathan (9.2%) (Table 2). The majority (96%) of the patients had right dominant limb and only 4% had left dominant limb.

Men were found to be significantly taller and heavier than women (Median: 167 *vs.* 155 cm, 65 *vs.* 56.5 kg, respectively p=0.0001 Table 2. However, no significant differences were observed in BMI between both the genders (p=0.291, Table 2). Moreover, men had a longer median length of the forearm as compared to women (p<0.0001, Table 2), this is because men were taller than women. On the other hand, women were found to had a higher median degree of upper limb carrying angle as compared to men (p<0.0001, Table 1). In addition, the distribution of extension of arms was found more variable in women than men (p=0.000 and 0.003, Table 2). It was observed that higher proportion of women had arm extension >5 degrees in comparison to men (right arm: 18.3% *vs.* 8.2%; left arm: 10.4% *vs.* 4.1%, p=0.005 and 0.008, Table 2).

Furthermore, results showed that Punjabis had higher carrying angle followed by Urdu speaking, Pathan and Sindhi adjusting for age, height, weight, and gender (Table 1 and Figure 1).

Also, those who have right dominant hand were found to have higher right hand carrying angle in comparison to left hand (Median (IQR): 10 (8-13) *vs.* 10 (8-12), p=0.000, Table 3). Whereas no significant differences were observed in carrying angle of both the arms in those who had left dominant hand (Median (IQR): 10 (8.2-

Table 3: Difference in arm measurements according to dominant limb.

	Dominant limb									
	Right				P-value	Left				P-value
	n	Mean ± SD	Min-Max	Median (IQR)		n	Mean ± SD	Min-Max	Median (IQR)	
Length of forearm(cm) right arm	468	23.3 ± 1.5	19-28.5	23.5(0-24.5)	0.000*ǂ	32	23.1 ± 1.9	18.5-28.5	23.5(0-24)	0.031*ǂ
Length of forearm(cm) left arm	468	23 ± 1.5	19-28	23(0-24)		32	23.5 ± 2.3	19-29.5	23.8(0-24.4)	
Upper limb carrying angle (degrees) Right Arm	468	10.9 ± 3.9	2-22	10(0-14)	0.000*†	32	10.6 ± 3.6	5-21	10(0-12)	0.880*†
Upper limb carrying angle (degrees) Left Arm	467	10.4 ± 3.8	0-21	10(0-13)		32	10.5 ± 4	4-22	10(0-12)	
Extension (degrees) Right Arm	468	1.4 ± 3.5	0-15	0(0-0)	0.286†	32	1.4 ± 3.6	0-14	0(0-0)	1.000†
Extension (degrees) Left Arm	466	1.3 ± 3.5	0-20	0(0-0)		32	1.3 ± 3.4	0-14	0(0-0)	

*P-value<0.05, **P-value<0.0001, † Wilcoxon Signed Rank test, ǂ Paired T-test

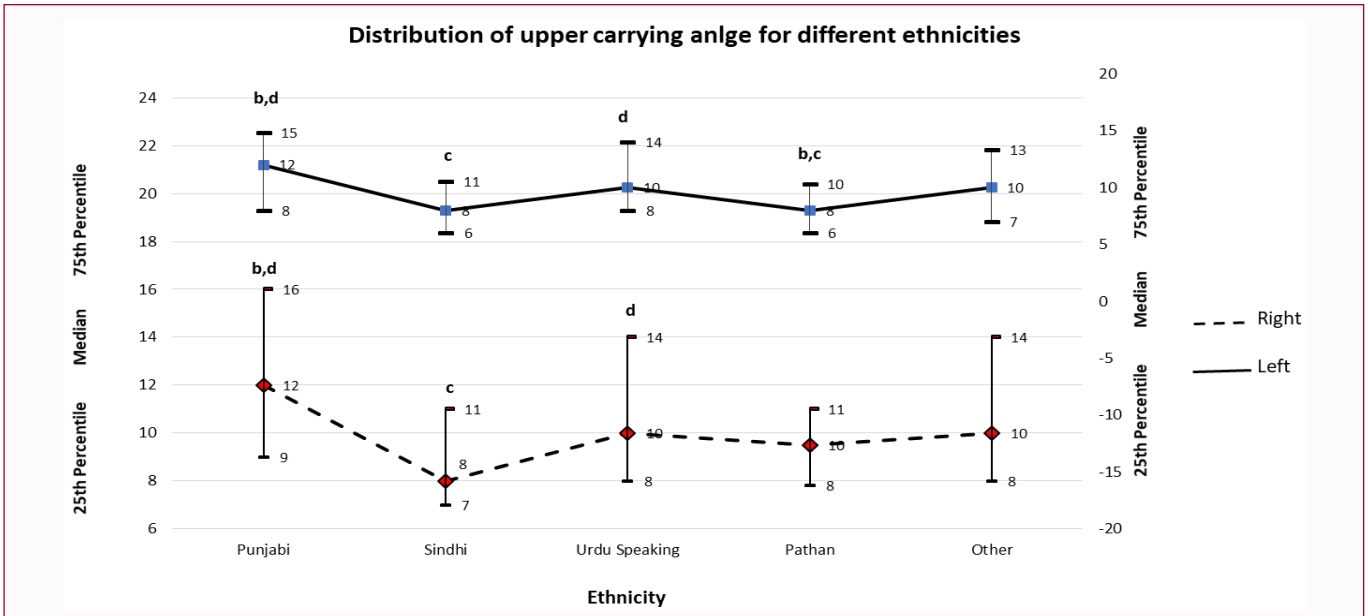

Figure 1: Linear quantile model was applied to assess difference in upper carrying angle adjusting for age, height, weight and gender. For each significant pair, the key of the category (a=Punjabi=Sindhi, c=Urdu speaking, d=Pathan, e=others) appears in the superscript.

12) *vs.* 10 (8-12), p=0.880, Table 3).

Discussion

Knowledge of the measurement of the elbow carrying angle and its variations is paramount to evaluate traumatic elbow injuries in all age groups. Its critical importance cannot be undermined when it comes to reconstruction using implants or arthroplasties [13,14,16]. Since the available literature is based on international studies, so one of the reasons for conducting this study was the fact that we do not have reference values established for the Pakistani population. This study will serve as a milestone step in regard to the Pakistani population and a reference for our Asian population in cases where corrective osteotomies are required in complex elbow trauma. Moreover, it will provide us the parameters of anatomical reduction and restoration of near normal alignment in our population and will help in the correct evolution of prosthetic designs for elbow arthroplasty. This will have a larger effect in improving the functional outcomes of our patients and shall increase the longevity of the implants reflecting better results.

In our study, statistically significant differences were observed in carrying angle among different races. These differences may be due to the marriages amongst people of specific races. Literature supports aging, possible racial influences, and developmental factors to the variability of the carrying angle [17]. It also supports the fact that the carrying angle tends to change with skeletal maturity and growth [18].

In our study, females were found to have greater carrying angle on average in comparison to males. Potter pioneered the investigation of the variation of carrying angle in males and females [19]. He observed the greater carrying angle in females than in males similar to our result. A later study by Mall had the same experience [20]. Perhaps this higher value of carrying angle in the female gender would be justified by the presence of ligamentous laxity. It is also reported

in the literature that this variable undergoes a progressive increase, whereas in puberty, it reaches its maximum value [21,22].

We did not encounter comparable carrying angle differences in dominant and non-dominant hand similar to other studies [19,23]. This can be further investigated on a larger scale study as it differs from the previously published data.

We agree that in order to produce greater relevance in the statistical data, a larger multicentric study should be conducted keeping this study as a reference study for our population.

Conclusion

Mean carrying angle of male is 9.5 ± 3.1 degree (dominant hand), whereas for female is 14.4 ± 3.2 degrees (dominant hand). This is consistent with published literature. One of the statistically significant finding that was different from previous literature was that population with right dominant hand were found to have higher right hand carrying angle in comparison to those with left hand. Whereas no significant differences were observed in carrying angle of both the elbows in those who had left dominant hand. We recommend a large multicentric study to substantiate our findings. This will assist the Pakistani orthopedic surgeons and implant manufacturers in the selection of elbow replacement implants and pre-contoured anatomical plates for our population.

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