The Normal Reference Values of Carrying Angle from Birth to Adolescence

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ABSTRACT

Objective: The aim of this study was to establish normal carrying angle reference values from birth to adolescence, and to identify variations in carrying angle relative to age, gender, and elbow side.

Methods: The prospective cross-sectional study was performed in normal healthy children aged newborn to sixteen years during May 1959 to April 1961. Children were recruited from newborn units, nurseries, and schools located in Bangkok, Thailand. There was a total of 17 groups – one for each year of age from 0 (at birth) to 16. The carrying angles of both arms were measured using a clear plastic full-circle orthopedic goniometer. The data of age, side, and gender of each child were recorded.

Results: A total of 921 children with 1,842 measurements were included. There were 407 boys and 514 girls. The mean carrying angle was lowest at birth and highest in the 15- year and 16-year age groups. The increase in the carrying angle was observed to progress to valgus 6 degrees at 6 years of age, and to valgus 11 degrees and stabilization at 15 years of age. There was no statistically significant difference between the mean carrying angle of the left and right side for any of the 17 evaluated age groups. Girls demonstrated a significantly greater carrying angle than boys (p<0.001). The intraclass correlation coefficient (ICC) of inter-observer variation between two observers was 0.848.

Conclusion: This study established normal carrying angle reference values from birth to adolescence. Our results revealed that the elbow is slightly varus at birth, then increases in carrying angle until reaching stabilization of skeletal growth and development at 15 years of age. The carrying angle is slightly greater in girls than in boys. This normal reference value data will benefit orthopedists who take care of the pediatric patients with elbow-related disorders.

Keywords: Reference value; carrying angle; birth; adolescence; elbow (Siriraj Med J 2018;70: 284-288)

INTRODUCTION

The carrying angle is clinically defined as the angle made by the longitudinal axis of the arm and the forearm in full extension with the elbow supinated. In children, the carrying angle is an important outcome measure that is routinely used during treatment of fractures around the elbow. Increased carrying angle is referred to as cubitus valgus, and decreased carrying angle is termed cubitus varus. Cubitus varus deformity is one of the common complications of supracondylar humeral fracture, lateral condyle fracture, and transphyseal fracture in children. For the body to appear cosmetically normal, the carrying angle of both elbows should be equal or nearly equal.[1] Normal carrying angle reference values can help us determine the cosmetically-acceptable limits of deformity in specific age groups.

Of the studies that have reported on normal carrying angle reference values, few have focused on

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children.[2] One study from Northern Thailand measured carrying angle in adults aged 18-35 years.[2] It is often reported that the carrying angle increases with age, and is greater in girls than boys[2,3,4]; however, conflicting data has been reported.[5] In studies that have reported on carrying angle in children, most focused a specific age range (e.g., 3-19 years of age), but none studied children from birth to adolescence.[2-13]

To our knowledge and based on our review of the literature, no previous reports have been published that describe normal carrying angle reference values throughout childhood in pediatric population. Accordingly, the aim of this study was to establish normal carrying angle reference values from birth to adolescence, and to identify variations in carrying angle relative to age, gender, and elbow side.

MATERIALS AND METHODS

The prospective cross-sectional study was performed in normal healthy children aged newborn to sixteen years at the Department of Orthopaedic Surgery, Faculty of Medicine Siriraj Hospital, Mahidol University during the May 1959 to April 1961 study period. Children with any history of elbow trauma, deformity, or disease that affects the elbow, such as skeletal dysplasia and rickets, were excluded. Children from newborn units, nurseries, and schools located in Bangkok, Thailand were included. There were a total of 17 groups – one for each year of age from 0 (at birth) to 16. The study and all of the measurement methods and protocols were approved by the Siriraj Institutional Review Board (SIRB), Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok, Thailand (Si 684/2013).

The carrying angle was measured using a clear plastic full-circle orthopedic goniometer (Fig 1) according to the method previously described by Amis and Miller.[8] This method was used in several other studies[9,10,11], and was reported to be accurate, with an error margin of ≤1 degree.[9] The arm was abducted to 90 degrees over a straight table, with the forearm in full extension and supination. The hinge of the goniometer was positioned at the center of the cubital crease, and the arms of the goniometer arms were positioned parallel to the middle longitudinal axes of the arm and forearm. A minus sign (-) indicates varus angle, and a plus sign (+) indicates valgus angle. Both arms were measured, and the age, side, and gender of each child were recorded.

Statistical analysis

All data analyses were performed using SPSS Statistics version 18 (SPSS, Inc., Chicago, IL, USA). Mean normal carrying angle reference values were calculated and statistically compared between and among age groups to identify differences relative to age, gender and elbow side. Data are presented as number, percentage, or mean ± standard deviation. Intraclass correlation coefficients were calculated and analyzed to measure interrater agreement. A *p*-value less than 0.05 was regarded as being statistically significant.

Fig 1. The carrying angle was measured using a clear plastic full-circle orthopedic goniometer. The upper extremity was abducted to 90 degrees over a straight table, with the forearm in full extension and supination. The hinge of the goniometer was positioned at the center of the cubital crease, and the arms of the goniometer arms were positioned parallel to the middle longitudinal axes of the arm and forearm. Both arms were measured. A minus sign (-) indicates varus angle, and a plus sign (+) indicates valgus angle. The carrying angle measured in this right elbow was +23 degree.

RESULTS

The 921 children that were included had both elbows measured for a total of 1,842 sides. There were 407 boys and 514 girls that were divided into 17 groups by year from 0 (at birth) to 16 years.

The mean normal carrying angle reference values for each age group by elbow side from birth to age 16 years are shown in Table 1. The mean carrying angle was lowest at birth (mean varus: 1.49 degrees) and highest in the 15- and 16-year age groups (mean valgus: 11

TABLE 1. Mean normal carrying angle reference values for each age group by elbow side from birth to age 16 years

Age (yrs)	Arm side	Number of sides	Mean carrying angle (degrees)	SD	*P*-value*
0 (at birth)	Right	74	-1.3	1.7	0.06
	Left	74	-1.6	1.7	
	Both	148	-1.5	1.7	
1	Right	15	+4	2.8	0.8
	Left	15	+3.8	2.4	
	Both	30	+3.9	2.5	
2	Right	34	+5.9	2.6	0.5
	Left	34	+5.7	2.4	
	Both	68	+5.8	2.4	
3	Right	26	+6.9	2.5	0.6
	Left	26	+6.7	2.8	
	Both	52	+6.8	2.6	
4	Right	31	+6	2.2	0.9
	Left	31	+6	2.6	
	Both	62	+6	2.4	
5	Right	39	+6.1	3.2	0.9
	Left	39	+5.9	3.2	
	Both	78	+6	3.2	
6	Right	26	+5.9	2.1	0.4
	Left	26	+6	2.6	
	Both	52	+6	2.4	
7	Right	22	+7.6	3.3	0.6
	Left	22	+7.3	3.5	
	Both	44	+7.4	3.4	
8	Right	79	+8.2	2.3	0.9
	Left	79	+8.2	2.3	
	Both	158	+8.2	2.3	
9	Right	143	+8.6	2.7	0.06
	Left	143	+8.3	2.8	
	Both	286	+8.4	2.7	
10	Right	126	+8.9	2.6	0.3
	Left	126	+9.1	2.7	
	Both	252	+9	2.7	
11	Right	79	+9.6	2.7	0.3
	Left	79	+9.4	2.7	
	Both	158	+9.5	2.7	
12	Right	54	+10.3	2.8	0.8
	Left	54	+10.2	2.7	
	Both	108	+10.3	2.7	
13	Right	77	+9.7	2.2	0.4
	Left	77	+9.7	2.1	
	Both	154	+9.7	2.1	
14	Right	40	+10.5	2.6	0.4
	Left	40	+10.6	2.5	
	Both	80	+10.6	2.5	
15	Right	37	+11.1	3.2	0.6
	Left	37	+11	3.4	
	Both	74	+11	3.2	
16	Right	19	+11.1	2.5	0.2
	Left	19	+11.5	2.9	
	Both	38	+11.3	2.7	

A *p*-value<0.05 indicates statistical significance

*The *p*-value is the statistical difference compared the mean carrying angle of right and left side in the same group.

Abbreviations: SD, standard deviation; '-', the angle is in varus of the elbow; '+' the angle is in valgus of the elbow

degrees). Increase in the carrying angle was observed to progress to valgus 6 degrees at 6 years of age, and to valgus 11 degrees and stabilization at ≥15 years of age. There was no statistically significant difference between the mean carrying angle of the left and right side for any of the 17 evaluated age groups ($p>0.05$).

The mean carrying angle among all age groups, with the angle values of the left and right side added together, was valgus 7.8±4.1 degrees. In comparison of mean carrying angle between age group, the statistically significant difference was obtained between age group ($p<0.001$).

The mean carrying angle was valgus 6.9±3.8 degrees in boys, and valgus 8.5±4.1 degrees in girls. Girls demonstrated a significantly greater carrying angle than boys ($p<0.001$) (Table 2).

A graph describing the mean (±2 standard deviations) normal carrying angle reference value for each age group is shown in Fig 2.

The intraclass correlation coefficient (ICC) of interobserver variation between two observers in 537 cases was 0.848 (95% confidence interval: 0.818-0.872), which indicated minimal variation between observers.

TABLE 2. Comparison of carrying angle between boys and girls (N=921)

Gender	Number of children	Number of sides	Percent	Mean carrying angle	SD	*P*-value
Boys	407	814	55.8%	+6.9	3.8	<0.001
Girls	514	1,028	44.2%	+8.5	4.1	

A p-value<0.05 indicates statistical significance
Abbreviation: SD, standard deviation

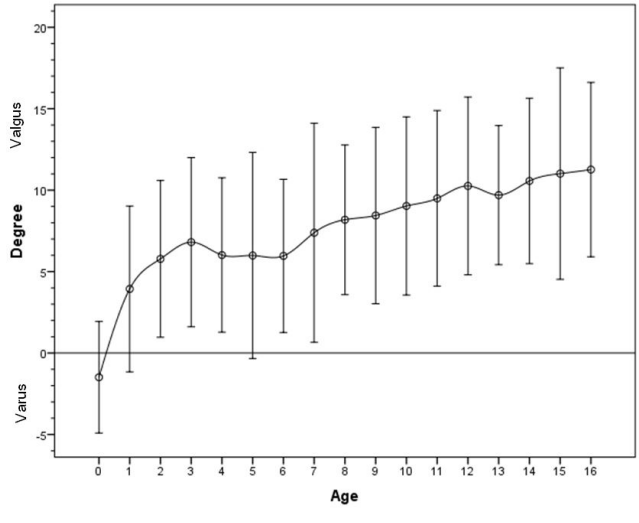

Fig 2. Normal carrying angle reference values (mean ± 2 standard deviations) from birth to 16 years. Degree values less than and greater than zero indicate varus of the elbow and valgus of the elbow, respectively.

DISCUSSION

This study provides new knowledge about normal carrying angle values from birth to adolescence, and about the development and progression of angle from slightly varus at birth to valgus and stable at 15-16 years of age (Table 1, Fig 2). The next study in carrying angle should focus on age group given the differences among age groups, especially in young children and adolescents. The present study and other studies found and reported age-dependent changes in the carrying angle.[3,6,7] The findings of this study confirm the reported findings of other studies that the carrying angle increases with age as a result of skeletal growth and development.[9,10,12]

With the exception of the study by Beals[5] who reported equality of carrying angle between genders, the present study and many others found a slightly greater carrying angle in girls than in boys.[2-4,6,7,10-13] The difference in findings between Beals' study and others may be due to differences in angle measurement method (measurement from radiographic imaging vs. measurement by goniometer), race of the study population, and sample size.

Some studies reported a greater carrying angle on the dominant side.[7,10] Since dominant side is not yet determined in very young children, and it could be

difficult to elicit from other age groups, we decided not to include this factor in our analysis.

The pediatric carrying angle data yielded by this study can be used as a comparative benchmark against clinical measurement in routine practice, or against radiographic measurement of the elbow.

CONCLUSION

This study established normal carrying angle reference values from birth to adolescence. Our results revealed that the elbow is slightly varus at birth, with increases in carrying angle until stabilization of skeletal growth and development at 15 years of age. The carrying angle is slightly greater in girls than in boys. This normal reference value data will benefit orthopedists that treat and follow pediatric patients with elbow-related disorders.

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