EVOLUTION OF THE CARRYING ANGLE OF THE ELBOW: A CLINICAL AND RADIOGRAPHIC STUDY

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ABSTRACT

Objective: This paper has the purpose of evaluate the elbow carrying angle by clinic and radiographic examination in normal children and determine the range of normality according to age from childhood to skeletal maturity and also check if there is a statistically significant difference between the clinical and radiographic measurements. Methods: We evaluated 510 persons with ages varying from 1 to 18 years distributed in groups with 30 subjects according to the age group with 1-year interval. We performed radiographic examination of the elbow and measured the angle formed by the long axis of the humerus and ulna. The data were statistically analyzed using the student t-test. Results: We determined a normal curve of the study population where there was an increase of this parameter with the progression of age. No statistically significant difference between the clinical and radiographic measures. Conclusion: The average of the elbow carrying angle was 12,78 ± 5,35 degrees for females and 11,20 ± 4,45 degrees for males. This values increase progressively from childhood until 16 years when we notice stabilization. There was no statistical difference between the clinical and radiographic measurements.

Keywords: Elbow joint. Child. Adolescent. Radiography. Anthropometry. Cross-sectional studies. Age factors.

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INTRODUCTION

The evaluation of valgus deformity or of the elbow carrying angle and the knowledge of its variations is essential, especially for the handling and monitoring of traumatic lesions that affect the pediatric elbow.[1]

In physiological conditions this parameter varies according to age,[2] gender,[1,3] hyperextension of the elbow,[4] dominant upper limb,[5] anthropometric characteristics such as height[6] and intertrochanteric distance[7] and can be measured by simple clinical and radiographic techniques.[1]

Examining the various databases of orthopedic literature, we identified few articles that study the elbow carrying angle and did not recognize any national reference determining the evolution of normality in our population that presents a distinctive trait of miscegenation among different ethnic groups.

Therefore, we prepared a paper aimed at evaluating the elbow carrying angle by clinical and radiographic examination in individuals without disorders of the musculoskeletal system to determine a normality curve according to age brackets, from childhood to skeletal maturity, and also to verify if there is statistically significant difference between the clinical and radiographic measurements.

CASUISTRY AND METHODS

This study was developed in the Pediatric Orthopedic Discipline of the Department of Orthopedics and Traumatology of UNIFESP (Universidade Federal de São Paulo).

Initially the project of this study was examined by the Institutional Review Board and approved for execution under protocol 0356/09. We drew up the informed consent term that was submitted and signed by the guardians of the patients involved.

We evaluated 510 individuals (1020 elbows), in a group consisting of 255 (50%) male and 255 (50%) female patients with ages ranging from 1 to 18 years. These were distributed according to annual age brackets, where each group consisted of 30 elements with strictly 15 (50%) of each gender.

The patients included in the study were treated at the Orthopedics and Traumatology ER of Hospital São Paulo with a history of trauma in the upper limbs. We adopted positive results for the

All the authors declare that there is no potential conflict of interest referring to this article.

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following situations as exclusion criteria in our survey: fractures, sequela of traumatic injuries, presence of congenital deformity of the upper limb, positive results for rheumatic, inflammatory or genetic diseases, and ligamentous laxity.

Ligamentous laxity was assessed through clinical examination, using measurements of the articular range of motion as advocated by Carter and Wilkinson with the modification proposed by Beighton and Horan[8]. According to this method, articular mobility is determined by the sum of whole numbers, which vary from 0 to 9 points. One point is given to the ability to make specific movements, considering the dominant and non-dominant side, and trunk mobility, according to the following criteria:

1. Passive extension of the minimum chierodactyls beyond 90˚.
2. Passive apposition of the thumb to the flexor side of its respective forearm.
3. Passive hyperextension of the elbows, beyond 10˚.
4. Hyperextension of the knees, beyond 10˚.
5. Flexion of the trunk from the erect position, with the knees fully extended, so that the palms of the hands rest on the floor.

Positive results for ligamentous laxity are considered when the individuals totalize five or more points.

The bilateral, clinical measurement of elbow valgus deformity was performed using a goniometer. We measured the elbow carrying angle applying one of the goniometer arms on the arm axis and the other on the forearm axis with the elbow kept fully extended and in supine position. (Figure 1)

When the individual was seen by the physician the radiographic examination of the affected elbow was required. We also performed the contralateral radiographic examination of the upper limb for comparison, since the physes and ossification nuclei could be confused with physiary fractures or lesions, a practice supported by orthopedic literature. The elbows were positioned in extension, with forearm supination in the anterior posterior view, on 30cmx40cm chassis film. The radiographic measurement was taken tracing straight lines on the radiograms over the light table along the long axis of the humeral and ulnar diaphysis for obtainment of the humero-ulnar angle measured with a protractor during the visit. (Figure 2)

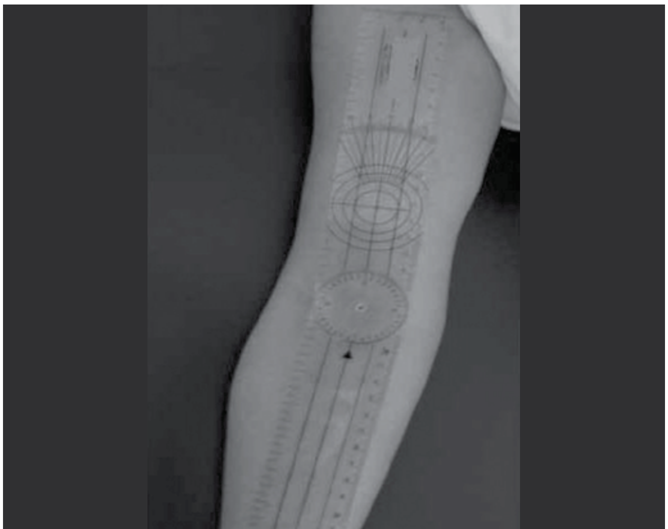

Figure 1. *Representation of the measurement of the right elbow carrying angle by the clinical method*.

All the clinical and radiographic measurements were obtained by two different examiners and the acquired values were compiled in a spreadsheet. The mean values were then considered for the performance of the necessary analyses.

For the statistical analysis of results a specialized professional from the area of medical statistics considered the nature of the distributions and the variables studied, applying the student's t-test. The level of rejection of the null hypothesis was set at 0.05 or 5% in all the tests, marking significant values with an asterisk (*).

Figure 2. *Computerized representation of the measurement of the elbow carrying angle by radiography*.

RESULTS

The angular values of the right and left elbows were evaluated initially without finding any statistically significant difference. Therefore their values were compiled in a single group.

The mean value of the carrying angle was 12.78˚ ± 5.35 for the females and 11.20˚ ± 4.45 for the males in the population studied. Tables 1 and 2 present the results of the minimum, maximum and mean values of the elbow carrying angle according to the age brackets with an interval of 1 year, between 1 year and 18 years according to gender. The evolution of the elbow carrying angle according to age progression can be observed in Figure 3, considering specific curves for the male and female individuals. We did not observe statistically significant difference over 16 years of age or between the clinical and radiographic measurements.

Table 1. *Results of the minimum, maximum and mean values of the elbow carrying angle according to the age brackets with an interval of 1 year, from 1 to 18 years. Male Gender.*

♂	Clinical Method			Radiographic Method		
Age (years)	Mean	Minimum	Maximum	Mean	Minimum	Maximum
1	6.8º	6.1º	7.3º	6.7º	6.0º	7.6º
2	7.4º	7.0º	7.8º	7.6º	7.3º	7.8º
3	7.6º	6.5º	7.9º	7.8º	7.8º	7.9º
4	8.2º	7.1º	8.8º	8.1º	7.4º	8.4º
5	8.0º	7.0º	8.5º	8.0º	7.2º	8.5º
6	7.9º	6.8º	9.0º	8.1º	7.0º	9.0º
7	9.0º	7.6º	9.2º	9.2º	7.4º	9.5º
8	8.8º	7.2º	9.4º	9.3º	7.0º	9.4º
9	10.5º	8.3º	10.8º	10.8º	8.4º	11.4º
10	10.5º	7.6º	11.0º	12.0º	7.7º	12.6º
11	10.4º	8.0º	11.2º	12.5º	8.0º	12.9º
12	11.2º	8.1º	11.5º	12.5º	8.2º	12.8º
13	11.1º	8.2º	11.9º	12.7º	8.8º	12.9º
14	11.1º	10.5º	12.1º	13.0º	10.8º	13.1º
15	11.2º	10.6º	12.5º	13.0º	10.8º	13.5º
16	11.9º	11.0º	12.6º	13.2º	11.0º	13.6º
17	12.7º	11.2º	12.8º	13.4º	11.1º	13.8º
18	12.5º	11.4º	13.0º	13.8º	11.6º	14.0º

Table 2. *Results of the minimum, maximum and mean values of the elbow carrying angle according to the age brackets with an interval of 1 year, from 1 to 18 years. Female Gender.*

♀	Clinical Method			Radiographic Method		
Age (years)	Mean	Minimum	Maximum	Mean	Minimum	Maximum
1	6.8º	6.1º	7.3º	7.5º	6.1º	8.3º
2	7.5º	7.0º	7.8º	7.9º	7.0º	8.8º
3	7.7º	6.5º	7.9º	8.09º	6.5º	8.9º
4	8.2º	7.1º	8.8º	8.8º	7.1º	9.8º
5	8.1º	7.0º	8.5º	8.5º	7.0º	9.5º
6	8.0º	6.8º	9.0º	9.2º	6.8º	10.0º
7	9.0º	7.6º	9.2º	9.1º	7.6º	10.2º
8	9.1º	7.2º	9.4º	9.5º	7.2º	10.4º
9	10.6º	8.3º	10.8º	10.7º	8.3º	11.8º
10	11.7º	7.6º	11.0º	11.3º	7.6º	12.0º
11	11.8º	8.0º	11.2º	11.1º	8.0º	12.2º
12	12.2º	8.1º	11.5º	11.4º	8.1º	12.5º
13	12.5º	8.2º	11.9º	11.8º	8.2º	12.9º
14	12.9º	10.5º	12.1º	12.2º	10.5º	12.7º
15	12.8º	10.6º	12.5º	12.4º	10.6º	12.8º
16	13.0º	11.0º	12.6º	12.7º	11.0º	12.9º
17	13.8º	11.2º	12.8º	12.9º	11.2º	13.8º
18	13.9º	11.4º	13.0º	13.1º	11.4º	13.4º

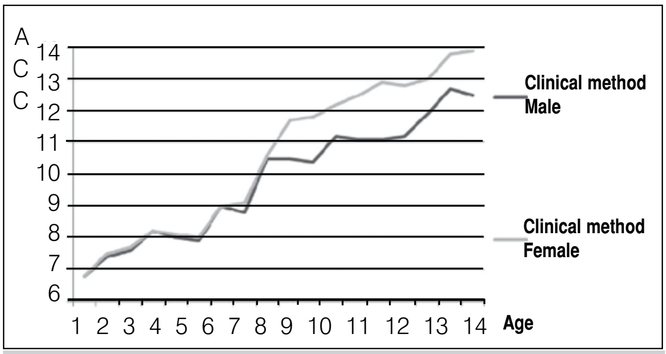

Figure 3. *Evolution, by the clinical method, of the elbow carrying angle (degrees) with age (years).*

DISCUSSION

Knowledge of the measurement of the elbow carrying angle and of its variations is important when evaluating traumatic elbow injuries in childhood and in adolescence[1] and other elbow disorders that require reconstruction[9] or arthroplasties (surface and semiconstrained).[10]

One of the reasons that determined the performance of this study was the fact that we do not have reference values established for the Brazilian population, since the available literature is based on international studies. The difference of these values in the different studies may result from the fact that we present a peculiar characteristic, which is miscegenation.

We observed mean values for the elbow carrying angle of 12.88 degrees +/-5.92,with 10.97 degrees +/-4.27 in males and 15.07 degrees +/-4.95 in females.[7,3] In another study, similar to the one conducted by us, the mean value of this variable was 12.42 +/- 4.06 when using a conventional goniometer.[10]

It is reported in literature that this variable undergoes a progressive increase when, in puberty, it reaches its maximum value;[1,4,5] according to some authors this fact is allegedly related to gender, and is higher in female individuals.[1,4,5] However there are others that did not encounter this relationship.[2,6] Observing Figure 3, at the age of 9 years there was a significant difference of the value of the elbow carrying angle between genders. This difference is approximately 1.5˚ and remained until its stabilization at the end of adolescence.

The highest value of this angle in the female gender would be justified by the presence of ligamentous laxity.[2] To avoid this bias, in our survey we excluded the individuals with this clinical characteristic, as this variable could determine alterations in the measurements obtained. We also took the precaution of using the values determined by the clinical and radiographic measurement twice, applying the means of these values.

Some researchers believe elbow carrying angle values to be higher on the dominant side,[5,7] yet we did not encounter such correlation in our study. Statistically, the comparison between right and left sides did not show any difference.

We observed that the influence of anthropometric parameters was analyzed by the various authors of literature whose results do not appear to be definitive, since they are found in a small number.

A studied relation correlates this angle with the intertrochanteric distance,[7] the values of which are said to be inversely proportional to the elbow angle, yet we did not evaluate this correlation. The elbow carrying angle appears not to be directly related to the height, weight or length of the ulna or humerus.[1] However we came across authors that relate this variable with the stature of individuals, indicating that the elbow carrying angle is higher in shorter people.[6] We believe that the maximum extension of the elbow should contribute to the increase of the elbow carrying angle, in conformity with the study by Golden *et al*.[4] influenced by ligamentous laxity.

In our study we sought to exclude any individual that did not fulfill the prerequisites determined in the initial planning before the execution of this investigation. We agree that the performance of a population study requires an analysis of a large sample, which hinders the production of investigations of greater relevance where the option to resolve this set of problems would be to execute a multicentric study.

Another application of this parameter would be to evaluate the possible genesis of specific fractures of the elbow region according to some authors[6], where this angular parameter would suffer the influence of forearm pronation and of the arm and forearm length determining different moments of force. The shorter length of the forearm bones would determine values inversely proportional to the elbow carrying angle.

We found biomechanical studies[11] that evaluated the elbow carrying angle during flexion-extension of the elbow with the intention of applying the findings of this study in rehabilitation where the results demonstrated that the accuracy of this method would be higher than 94%. Unfortunately, the knowledge acquired with the studies in biomechanics laboratories is not applicable in our field as they are extremely expensive and depend on specific logistics.

We believe that the reproduction of the elbow carrying angle measurement is simple and easily applicable in the daily practice of the orthopedist.1 In spite of the challenges made by others that consider its applicability of little practical importance.[10]

In our analysis we found that this clinically analyzed parameter did not indicate significant statistical differences when compared with the radiography. Thus we were able to infer that, in considering this measure in the regular practice of the orthopedist, a systematic clinical measurement should provide us with sufficient information to evaluate the status of the elbow of an individual in progressive growth. Consequently, from the socioeconomic point of view, we would waive the use of the radiography for this purpose which, although simple, determines an unnecessary cost. For the planning of corrections of deformities of this segment, we believe that there is no doubt about the performance of this exam.

CONCLUSION

This parameter shows a gradual increase from childhood up to the age of 16 years when the skeletal maturity is attained and demonstrated by its stabilization.

There was no significant statistical difference between the clinical and radiographic measurements.

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