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Research Article

Is it Possible to Estimate Adult Ulna and Radius Length? A Radiological Evaluation

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Objective: Many reasons during childhood may affect the length of the forearm bones, resulting in the need for surgical intervention. Estimating the patient's forearm length during these surgical interventions can aid in surgical planning. The purpose of our study; To evaluate the relationship between the forearm lengths of children and the forearm lengths of their biological parents.

Materials and Methods: Forearm anteroposterior radiographs taken in accordance with the standards of young people aged 15-18 years old and their parents aged 30-60 years, who were admitted to our hospital for any reason between 2020-2023 and whose growth was completed, were evaluated.

Results: A total of 120 people were included in this study; 40 young people, 80 parents were evaluated. A highly correlated correlation was detected between the radius and ulna lengths of young men and women and the radius-ulna lengths of their mothers ($p<0.001$ and $r>0.7$ for each). A moderate correlation was detected between the radius and ulna lengths of young women and the radius-ulna lengths of their fathers ($p<0.001$ and $r>0.5$ for each). A very high (strong) relationship was found between the radius length of young men and the radius length of their fathers ($p<0.001$ and $r=0.927$) and a high degree of relationship between the ulna length of young men and their fathers' ulna length ($p<0.001$ and $r=0.841$).

Conclusions: Based on these results, it can be said that the length of the children's forearm bones when they reach adulthood can be predicted by taking into account the forearm bone length of the mother and father. Especially in boys, the forearm length is directly related to the forearm length of their fathers.

Keywords: Forearm, Radius, Ulna, Estimate

1. INTRODUCTION

The most prevalent fractures in childhood are distal radius and ulna fractures, accounting for 19.9-35.8% of pediatric fractures.[1,2] It has been documented in literature that 10% of physeal injuries may result in growth arrest.[3] This arrest typically manifests 2-6 months following the initial fracture.[4] A multitude of factors, including childhood trauma, congenital malformations, tumors, metabolic diseases, and prior surgical interventions, can influence the appearance and function of the forearm, leading to length discrepancies or various deformities in the radius or ulna.[5,6] The management of these deformities typically involves close observation and conservative treatment, with the expectation of spontaneous resolution through remodelling.[7,8] However, numerous surgical interventions, including epiphysiodesis, bone lengthening, and deformity correction, may be necessary to address these deformities or length discrepancies.[9,10] The primary consideration in planning surgical intervention is the patient's ongoing growth. The treatment plan is contingent on the magnitude and anatomical location of the deformity, the involvement of the physis, the age of the patient, and the anticipated length discrepancy at skeletal maturity.[7] Consequently, it is imperative to predict the patient's anticipated forearm length in the treatment of length discrepancies.

It is necessary for both the surgeon and the patient's family to answer questions such as which surgical method will be used to obtain the ideal forearm bone length in adulthood and how many

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surgical operations the patient will undergo.[11] Failure to lengthen forearm bone deformities at the optimal time and in the necessary amount may result in wrist pain, joint impaction, limited joint function or repeated surgeries.[7,12] Even after the expected length is estimated and the amount of lengthening is done appropriately, the deformity in the radius and ulna may recurrence.

A plethora of studies have been conducted in recent times to ascertain the residual growth potential of upper and lower extremity bones. Paley et al. accepted Maresh's radiographic data as the gold standard and described the multiplier method for limb length estimation.[13] The multiplier method is an easily applicable method to determine the timing of epiphysiodesis and bone length at skeletal maturity for both the lower and upper extremities and to calculate remaining growth. However, it should be noted that the data evaluated in the study by Paley et al. were collected prior to 1935. Although Paley stated in her study that the multiplier method was independent of race, nationality and generation, the population evaluated lived under different conditions than today's children.

This issue continues to be of interest to pediatric orthopaedic surgeons, as the extent of lengthening required in forearm surgeries and the range of surgical interventions remain uncertain. To the best of our knowledge, there is an absence of any definition in the literature that can predict the individual forearm length of children in adulthood. The objective of this study is to assess the correlation between the forearm bone lengths of children and their biological mothers and fathers.

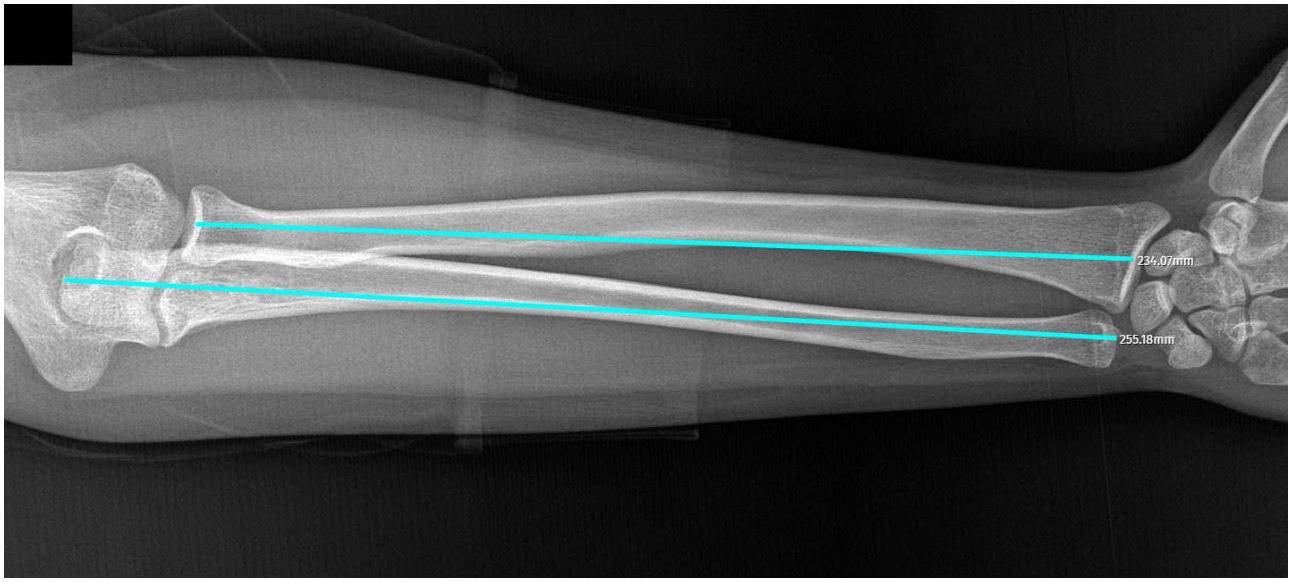
2. METHODS

The present study was approved by the Scientific Research Ethics Committee of our hospital on 19.12.2023 with the decision number E-46059653-050.99-232014053. The inclusion criteria for the study were determined as follows: Individuals between the ages of 15 and 18 who had forearm anteroposterior (AP) radiographs taken at our hospital for any reason between 2020-2023, and whose growth was radiographically confirmed to be complete, were included. Subsequently, we conducted a retrospective review of the archived radiographs of the parents of the subjects, irrespective of the indication for imaging. The radiographs were meticulously selected to meet the standards outlined in the literature. This included ensuring that the wrist was in the anteroposterior (AP) position, there was minimal superposition of the distal radius and ulna, there was no visible motion, and the trochlea, the capitellum, and the radial head were visible.[14] Radiographs that did not meet these standards were excluded from the study. Individuals with a history of upper extremity fracture, bone lesion, congenital deformity, or infection, and those whose parents' radiographs were unavailable in the system, were also excluded from the study. Considering the inclusion and exclusion criteria, the study involved the analysis of AP forearm radiographs from 40 young individuals (20 boys, 20 girls) and their parents. Informed consent forms were obtained from all individuals participating in the study and their parents.

The evaluation of right and left forearm radiographs in the hospital's radiology database was conducted independently. The length of the radius and ulna bones was measured on the radiographs using the length meter in the radiology system. The evaluation of the radiographs was conducted by two experienced orthopaedic surgeons. Statistical analysis was conducted by calculating the mean of the two measurements. In young subjects, measurements were taken on the radiograph as AP from the proximal midpoint for the radius to the distal midpoint including the epiphysis; for the ulna, it was measured as AP from the proximal most protruding point to the midpoint including the distal epiphysis and recorded in millimeters (mm) (Figure 1).

Figure 1.

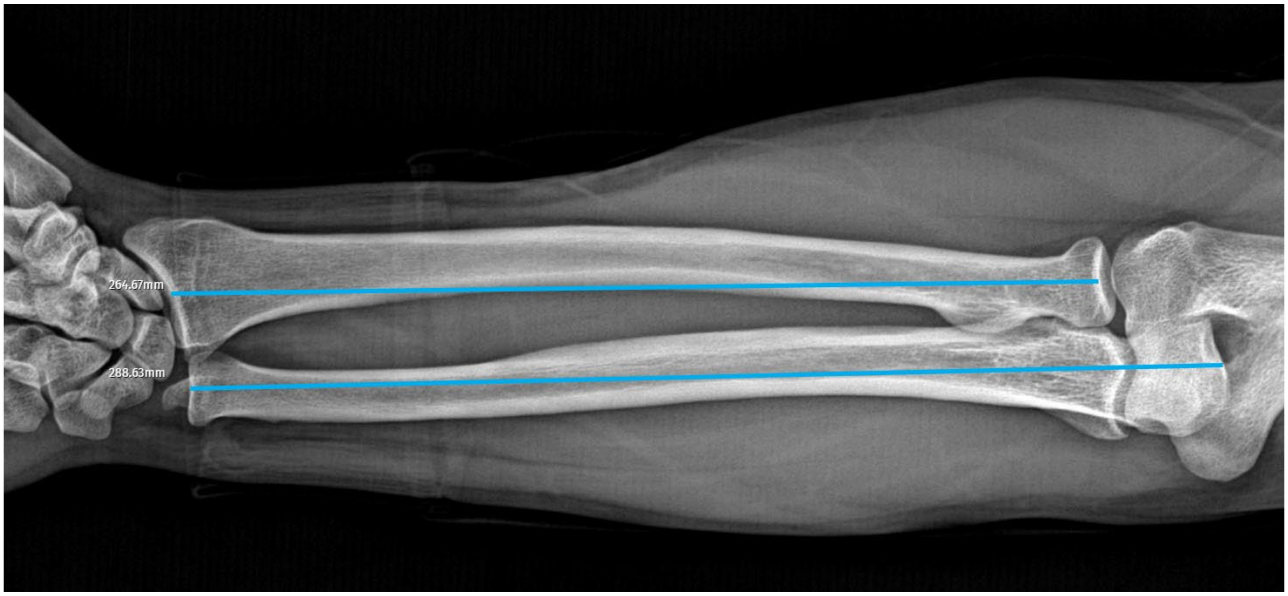
Measurement pattern in forearm radiographs of young individuals



In the case of young individuals, the physis line was also included in the total length. In the case of parents, radius bone length was recorded by measuring the middle of the proximal and distal extreme points (see Figure 2). Ulna bone length was measured and recorded from the most proximally protruding midpoint to the most distally protruding midpoint (see Figure 2).

Figure 2.

Measurement type in forearm radiographs in parents



Statistical analysis was performed using IBM® SPSS® Program version 26.0. The conformity of the variables to normal distribution was examined by visual (histogram and probability plots) and analytical (Kolmogorov Smirnov Test) methods. Since the evaluated datasets conformed to normal distribution, descriptive statistics were expressed as mean, standard deviation and minimum-maximum values. The presence of correlation between the individuals' and their parents' ulna and radius lengths was questioned Pearson Correlation Analysis. The correlation variable "r" was used to evaluate the strength of the correlation. Statistical significance was considered significant when the "p" value was below 0.05.

3. RESULTS

All individuals included in the study were between the ages of 15-18 years and the mean age of the individuals was calculated as 16.35 ± 0.975 years. The mean radius and ulna lengths of the individuals were 233.5 ± 18.193 mm (Range: 201-272) and 255 ± 19.449 mm (Range: 218-294), respectively. Demographic distribution of the participants included in the study is given in Table 1.

Table 1.

Demographic profile of the patients

		Mean	St. Deviation	Minimum Value	Maximum Value
All Individuals (n=40)	**Age** (years)	16.35	0.975	15	18
	Length of the Radius (mm)	233.5	18.193	201	272
	Length of the Ulna (mm)	255	19.449	218	294
Boys (n=20)	**Age** (years)	16.3	0.923	15	18
	Length of the Radius (mm)	247.2	13.037	224	272
	Length of the Ulna (mm)	269.45	13.782	242	294
Girls (n=20)	**Age** (years)	16.4	1.046	15	18
	Length of the Radius (mm)	219.8	10.690	201	234
	Length of the Ulna (mm)	240.55	12.120	218	258
Mothers (n=40)	**Age** (years)	41.9	3.514	38	51
	Length of the Radius (mm)	233.9	11.286	196	241
	Length of the Ulna (mm)	244.08	11.321	216	262
Fathers (n=40)	**Age** (years)	43.68	4.028	38	54
	Length of the Radius (mm)	246.08	9.341	220	265
	Length of the Ulna (mm)	268.25	11.406	241	291

N: Number of patients, St. Deviation: Standard Deviation, All Individuals; boys and girls.

Forearm lengths of all young individuals were found to have a moderately significant relationship ($p<0.001$ and $r>0.5$) with the forearm lengths of their mothers and fathers (Table 2). The subgroup analyses based on gender revealed that; the radius and ulna lengths of boys and girls were found to be strongly correlated with those of their mothers ($p<0.001$ and $r>0.7$ for each). Furthermore, a highly strong correlation was found between the radius length of boys and their father's ($p<0.001$ and $r=0.927$) (Table 2).

Table 2.

Correlations and interpretation of forearm lengths of individuals and their parents

		Length of the Radius of the Mothers (mm)			**Length of the Radius of the Fathers** (mm)		
		P	**R**	**Comment**	**P**	**R**	**Comment**
All Individuals	**Length of the Radius** (mm)	<0.001	0.663	*Moderate*	<0.001	0.679	*Moderate*
Girls	**Length of the Radius** (mm)	<0.001	0.862	*Strong*	<0.001	0.692	*Moderate*
Boys	**Length of the Radius** (mm)	<0.001	0.756	*Strong*	<0.001	0.927	*Highly Strong*
		Length of the Ulna of the Mothers (mm)			**Length of the Ulna of the Fathers** (mm)		
		P	**R**	**Comment**	**P**	**R**	**Comment**
All Individuals	**Length of the Ulna** (mm)	<0.001	0.681	*Moderate*	<0.001	0.704	*Strong*
Girls	**Length of the Ulna** (mm)	<0.001	0.810	*Strong*	0.002	0.646	*Moderate*
Boys	**Length of the Ulna** (mm)	<0.001	0.737	*Strong*	<0.001	0.841	*Strong*

N: Number of patients, St. Deviation: Standard Deviation, P: Statistical significance value, R: Correlation coefficient, All Individuals; boys and girls. The comments were made according to the correlation coefficient "R".

4. DISCUSSION

Predicting the forearm length that children will achieve after completion of growth is of critical importance to pediatric orthopedic surgeons in the management of forearm length differences and deformities. Although the methods described in the literature have advantages over each other, they all have crucial limitations.[5,13,15] The main problem is that no reference point allows us to predict children's forearm lengths after their growth is complete. The main strength of this study, and its greatest contribution to the literature is that it can identify exactly this reference point. Our hypothesis was that the children's forearm lengths are strongly correlated with their mothers' and fathers' forearm lengths. The most important finding of our study was that there is an extremely strong correlation between the radius length of boys and the radius length of fathers.

Anderson and Green first introduced their chart showing the amount of remaining growth in the lower extremity using skeletal age.[7] Moseley developed the straight line chart method to estimate lower extremity length difference and timing of epiphysiodesis.[16] While many studies support that calculating the remaining growth using chronological age is superior before a growth spurt, it has been mentioned that the skeletal age during a growth spurt will give more accurate results.[15,17,18] Currently, there are many studies investigating the remaining growth length of the lower limb, but there is a lack of literature for the upper limb.[16,19]

Sanders et al. have stated that the Paley multiplier method based on chronological age performs poorly in predicting limb length during

adolescence.[15] In the calculation of the method described by Paley, the radiographic data of Maresh dating back to 1935 have been accepted as the gold standard.[13] At the same time, Paley examined data on healthy middle and upper class children in the northwestern European region. Since the children evaluated by Paley lived under different conditions than today's children, new data are needed. Although the multiplier method described by Paley has its critics, it still remains popular for limb length estimation due to its accurate and simple calculation.[7,13]

In a study conducted by Sanders et al. with twenty-four patients, the Greulich and Pyle method, which determines the skeletal age, was used to estimate the mature limb length of the lower extremity. As stated by the author, the weakest aspect of this study is the small number of patients.[15] Menelaus defined the method that bears her name (White-Menelaus method) as a method that can quickly estimate limb length and does not require special radiography and the Greulich and Pyle atlas. The advantage of the method is that it is simple to calculate and does not require additional special examinations.[20]

In his study investigating the amount of remaining growth in the upper extremity, Stahl evaluated the x-rays of one hundred and two patients between the ages of 7-16 from the normal population and prepared graphs containing the amount of remaining growth. Looking at the graphs in his study, it is determined that after the age of 14, there is approximately 1 centimeter of growth left for the radius and ulna bones of both girls and boys.[21] Gauld et al. estimated the height of school-age children by clinically measuring the ulna bone length and evaluated their growth charts.[22] In a large population study examining the effect of parental height on child development, it was concluded that the mother's height has a very high relationship with the child's adult height.[23] Our study also showed that parent and child forearm bones may be related.

Prior to the implementation of corrective surgical treatment for childhood forearm bone deformities, a comparison with the unaffected opposite limb can be made to obtain an estimation of the required lengthening or correction method. However, in such cases, it is imperative to take into account the child's age and the closure status of the epiphyseal plate.

Our study is not without its limitations. Primarily, there is an absence of data regarding forearm bone lengths obtained after a long-term follow-up of children as they reach adulthood. This precludes the calculation of true individual forearm bone length. Secondly, the study is confined to a radiological evaluation, excluding crucial parameters such as comprehensive blood analysis and nutritional status. Conversely, factors such as growth and elongation are influenced by numerous confounding variables, including hormone balance, vitamin intake and diet. Finally, although the individuals' parents' previous fractures were questioned during the measurement, it should be recognized that people tend to forget childhood fractures that may have occurred many years ago.

5. CONCLUSION

The prediction of final forearm length in children is of the utmost importance. A review of the extant literature reveals that each method has its advantages and disadvantages, and no study assessing the amount of residual growth of the forearm bones is universally accepted as the gold standard. The present study proposes a novel approach by leveraging the forearm bone length of both the mother and father as a reference point to estimate the final forearm length of their offspring. It is crucial to emphasize that, particularly in the case of boys, forearm length exhibits a strong correlation with that of the father.

Article Information Form

Authors Note

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Authors' Contribution

Writing – review & editing, writing – original draft, visualization, conceptualization, methodology (Hakan Eskara), writing – review & editing, methodology, original draft preparation, project administration, data curation (Batuhan Gencer), material preparation, review and editing, software, data collection and analysis (Alper

Sukru Kendirci), writing – review & editing, validation, Project administration (Tolga Sezer), review and editing, writing, supervision, resources, formal analysis, methodology (Ogulcan Unsalan) writing – review & editing, validation, project administration (Hayri Sucu). All authors read and approved the final version of the manuscript.

The Declaration of Conflict of Interest/ Common Interest

No conflict of interest or common interest has been declared by authors.

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