

ORIGINAL RESEARCH

The Epiphyseal Fusion of Distal End of Radius and Ulna: An Appropriate Tool for Age Determination

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ABSTRACT

Introduction: Law crime and punishment are entirely grounded on the criminal responsibilities and age of the person. In modern society, the crime by the children and adolescent against the children and adolescent are increasing enormously. Hence one of the most imperative responsibilities of forensic experts is age estimation in living as well as deceased ones.

Material and Methods: The present study was conducted in Government Medical College, Pali (Rajasthan), and attached Bangur Hospital during the year of 2017 to 2018 among 200 normal healthy adolescents of the age group 12-22 years.

Results: The fusion of the lower end of radius in the male population completes at 20-21 years whereas in females it completes at the age of 19-20 years. There is a marked difference of 1-2 years in males and females. The complete ossification of the lower end of the ulna is observed in 18-19 years females.

Conclusion: The distal end of the radius completely ossifies at the age of 20-21 years in males and 19-20 years in females. Some disparity in age of ossification from the study conducted in different regions of our country and western population at different time periods.

Keywords: Age Determination, Epiphysis, Epiphyseal Fusion Radius, Ulna.

INTRODUCTION

Law crime and punishment are entirely grounded on the criminal responsibilities and age of the person. In modern society, the crime by the children and adolescent against the children and adolescent are increasing enormously. Hence one of the most imperative responsibilities of forensic experts is age estimation in living as well as deceased ones. It is a crucial prerequisite for individual identification when the liability and punishment are related to the age of the individuals as in rape cases, nullity of marriage, child labor, or clinical examination and mutilated bodies. 101 Many parameters are there for the age estimation like the overall

development including height, weight, secondary sexual characteristics of individual, eruption and maturity of teeth, and also the growth in bone especially appearance and fusion of different ossification centers. In growing periods these are vital indices for evaluating the age, but the parameter is pretty reliable only up to 25 years of age, beyond that it becomes more uncertain. There are 3 steps for age estimation, Physical examination, Dental examination, and Radiological examination. The physical examination includes height, weight and body mass index with the appearance of secondary sexual characteristics. These are closely related to biological maturation but are not sufficiently precise. The period of eruption of deciduous and permanent teeth is reliable but by the age of 15-16 years, all the eruption is completed (except 3rd molar). So, the dental examination will not be of much help after the age of 16 years.

Since the invention of X-rays in 1895, they became the primary and most widely practiced modality for age estimation due to their easy availability and high reliability. The appearance and fusion of epiphysis with its respective diaphysis are detected by radiography and are the most accurate method. This process is complete by the age of 22 years as delineated by various authors. Various factors such as change in climate, hereditary, dietetic, economic conditions, or involving some unknown factors have an influence on bone growth, maturation, and age of fusion of epiphysis. A number of cases of false representation are made in the country, particularly in respect of the teenage group. The court of law approves the age estimation by epiphyseal fusion of inferior end of radius and ulna worldwide. Hence this study was undertaken to provide authentic and reliable data to aid medico-legal purposes. In the present study, we determine the bone age based on the fusion of epiphysis of the distal end of radius and ulna for apparently normal adolescents between the age group of 12-22 years in the Marwar region of Rajasthan.

MATERIALS AND METHODS

The present study was conducted in Government Medical College, Pali (Rajasthan), and attached Bangur Hospital during the year of 2017 to 2018 among 200 normal healthy adolescents of the age group 12-22 years attending the outpatient department. Out of 200 persons, 120 were males and 80 were females, irrespective of caste and religion.

We included only healthy people belonging to the middle socioeconomic families of the Marwar region of Rajasthan with their known age by showing the identity card like Aadhaar card, driving license, school certificate and birth certificate. Subjects with criteria affecting the epiphyseal fusion and growth of bones like congenital deformities, fracture cases, chronic illness, severe malnutrition, on steroid therapy were excluded from the study. The study subject was divided into 10 group with difference of one year like 12-13, 13-14, 14-15, 15-16, 16-17, 17-18, 18-19, 19-20, 20-21, 21-22.

All the physical growth parameters like height & weight along with gender were recorded for each case. Purpose and procedure were explained and proper written informed consent for X-ray was taken from all subjects. Digital x-rays of antero-posterior view of both wrist joint showing lower ends of radius and ulna was taken. Radiological assessment for fusion of lower end of radius and ulna with their respective diaphysis was done by findings of soft copies of X-rays and were grouped according to stage of fusion.

These stages of fusion were classified in four groups:

- 1. Degree 0:** A dark black radiolucent line seen throughout the length of diaphysis and epiphysis.
- 2. Degree 1:** The gap between diaphysis and epiphysis begins to decrease but complete union does not occur.
- 3. Degree 2:** The union between diaphysis and epiphysis is complete but white dense line still visible at diaphysis-epiphyseal junction.

4. Degree 3: The union between diaphysis and epiphysis is complete and no white dense line visible at diaphysis-epiphyseal junction.

The findings were recorded, tabulated, analyzed and compared with similar studies by different authors.

Image1: Radiograph of wrist joint (A-P view) showing nonunion of lower end of Radius & Ulna (Degree 0).



Image 2: Radiograph of wrist joint (A-P view) showing degree 1 union of lower end of Radius & Ulna.



Image 3: Radiograph of wrist joint (A-P view) showing degree 2 union (white dense line is present between epiphysis and diaphysis) of lower end of Radius & Ulna.



Image 4: Radiograph of wrist joint (A-P view) showing complete union of lower end of Radius & Ulna (degree 3).



OBSERVATIONS AND RESULTS

On the basis of our criteria, the study was conducted on 200 subjects with 120 males and 80 females between the 12-22 years of age groups of the Marwar region of Rajasthan. Data were tabulated and statistically analysed as follows.

The study subject was distributed according to their age group and gender. The majority of the study subject are males (60%). The maximum number of males (8%) were in the age groups 19-20 and 20-21 while females (5.5%) are in the age group 17-18 years.

In the case of males, the 1st degree of fusion starts at the age of 13 -14 years whereas the 2nd degree of fusion is observed at the age of 15-16 years. The 3rd degree of fusion is observed at the age of 16-17 years and it progressively increases with the age. The complete fusion is remarkable (81.25%) at the age of 19-20 years and 100% fusion of epiphysis is observed in all the individuals at 20-21 years of age. So, we can say in the male population of Rajasthan, the complete fusion of the distal end of the radius is seen at 19-20 years of age and the ossification is completed at the age of 20-21 years.

As it is evident in table number 3, the ossification of radius in females completely appears at the age of 14-15 years. The 2nd degree of fusion is observed in 20% of girls in the age group 14-15 years and it progresses and becomes maximum (80%) in the age group 16-17 years. The 3rd degree of fusion is observed in 10% of girls in the age group 16-17 years and the ossification progressively increases with age and becomes maximum (88.88%) in the age group 18-19 years. So, we can say in the female population, the complete fusion of the distal end of the radius is seen at 19-20 years of age and the ossification is completed at the age of 20-21 years.

In table number 4, the 1st degree of fusion of ulna in the male subjects (30%) starts at the age of 13-14 years. The remaining 70% of the subject does not show any sign of ossification. The 2nd degree of ossification starts at 14-15 years of age and increases progressively and reaches the maximum at the age group of 17-18 years. The 3rd degree of fusion is observed with 10% of subjects in the age group 15-16 years, increases progressively and the complete ossification is seen with 76.92% in the age group 18-19 years.

In table number 5, Epiphyseal fusion of the lower end of ulna started at the age of 13-14 years in 50% population. The 2nd degree of fusion started in 40% of females in the age group 14-15 years. The 3rd degree of fusion of the lower end of the ulna was observed in 8.33% population in the age group 15-16 years. It increases progressively and reaches 81.81%

population in the age group 17-18 years. The complete ossification of the lower end of the ulna is observed in females in the age group 18-19 years.

Table 1: Age and gender wise distribution of population

Age Group (in years)	Gender		Total Individual
	Male	Female	
12-13	8 (4%)	5 (2.5%)	13 (6.5%)
13-14	10 (5%)	4 (2%)	14 (7%)
14-15	12 (6%)	5 (2.5%)	17 (8.5%)
15-16	10 (5%)	12 (6%)	22 (11%)
16-17	13 (6.5%)	10 (5%)	23 (11.5%)
17-18	14 (7%)	11 (5.5%)	25 (12.5%)
18-19	13 (6.5%)	9 (4.5%)	22 (11%)
19-20	16 (8%)	10 (5%)	26 (13%)
20-21	16 (8%)	8 (4%)	24 (12%)
21-22	8 (4%)	6 (3%)	14 (7%)
Total	120 (60%)	80 (40%)	200

Table 2: Age wise epiphyseal fusion of distal end of radius in males

Age Group (in years)	STAGE OF EPIPHYSEAL FUSION OF RADIUS IN MALES								TOTAL X-ray
	Degree 0		Degree 1		Degree 2		Degree 3		
	RT	LT	RT	LT	RT	LT	RT	LT	
12-13	8 (100%)	8 (100%)	0	0	0	0	0	0	16
13-14	7 (70%)	7 (70%)	3 (30%)	3 (30%)	0	0	0	0	20
14-15	3 (25%)	3 (25%)	9 (75%)	9 (75%)	0	0	0	0	24
15-16	0	0	7 (70%)	7 (70%)	3 (30%)	3 (30%)	0	0	20
16-17	0	0	4 (30.76%)	4 (30.76%)	8 (61.53%)	8 (61.53%)	1 (7.69%)	1 (7.69%)	26
17-18	0	0	2 (14.28%)	2 (14.28%)	9 (64.28%)	9 (64.28%)	3 (21.42%)	3 (21.42%)	28
18-19	0	0	0	0	8 (61.53%)	8 (61.53%)	5 (38.46%)	5 (38.46%)	26
19-20	0	0	0	0	3 (18.56%)	3 (18.75%)	13 (81.25%)	13 (81.25%)	32
20-21	0	0	0	0	0	0	16 (100%)	16 (100%)	32
21-22	0	0	0	0	0	0	8 (100%)	8 (100%)	16

Table 3: Age wise epiphyseal fusion of distal end of radius in females

Age Group (in years)	STAGE OF EPIPHYSEAL FUSION OF RADIUS IN FEMALES								TOTAL X-ray
	Degree 0		Degree 1		Degree 2		Degree 3		
	RT	LT	RT	LT	RT	LT	RT	LT	
12-13	5 (100%)	5 (100%)	0	0	0	0	0	0	10
13-14	3 (75%)	4 (100%)	1 (25%)	0	0	0	0	0	8
14-15	1	2	3	2	1	1	0	0	10

	(20%)	(40%)	(60%)	(40%)	(20%)	(20%)			
15-16	0	0	6 (50%)	6 (50%)	6 (50%)	6 (50%)	0	0	24
16-17	0	0	1 (10%)	2 (20%)	8 (80%)	7 (70%)	1 (10%)	1 (10%)	20
17-18	0	0	0	0	4 (36.36%)	4 (36.36%)	7 (63.63%)	7 (63.63%)	22
18-19	0	0	0	0	1 (11.11%)	1 (11.11%)	8 (88.88%)	8 (88.88%)	18
19-20	0	0	0	0	0	0	10 (100%)	10 (100%)	20
20-21	0	0	0	0	0	0	8 (100%)	8 (100%)	16
21-22	0	0	0	0	0	0	6 (100%)	6 (100%)	12

Table 4: Age wise epiphyseal ossification of distal end of ulna in males

Age Group (in years)	STAGE OF EPIPHYSEAL FUSION OF ULNA IN MALES								TOTAL X-ray
	Degree 0		Degree 1		Degree 2		Degree 3		
	RT	LT	RT	LT	RT	LT	RT	LT	
12-13	8 (100%)	8 (100%)	0	0	0	0	0	0	16
13-14	7 (70%)	7 (70%)	3 (30%)	3 (30%)	0	0	0	0	20
14-15	1 (8.33%)	1 (8.33%)	9 (75%)	9 (75%)	2 (16.66%)	2 (16.66%)	0	0	24
15-16	0	0	6 (60%)	6 (60%)	3 (30%)	3 (30%)	1 (10%)	1 (10%)	20
16-17	0	0	3 (23.07%)	3 (23.07%)	8 (61.53%)	8 (61.53%)	2 (15.38%)	2 (15.38%)	26
17-18	0	0	0	0	11 (78.57%)	11 (78.57%)	3 (21.42%)	3 (21.42%)	28
18-19	0	0	0	0	3 (23.07%)	3 (23.07%)	10 (76.92%)	10 (76.92%)	26
19-20	0	0	0	0	0	0	16 (100%)	16 (100%)	32
20-21	0	0	0	0	0	0	16 (100%)	16 (100%)	32
21-22	0	0	0	0	0	0	8 (100%)	8 (100%)	16

Table 5: Age wise epiphyseal ossification of distal end of ulna in females

Age Group (in years)	STAGE OF EPIPHYSEAL FUSION OF ULNA IN FEMALES								TOTAL X-ray
	Degree 0		Degree 1		Degree 2		Degree 3		
	RT	LT	RT	LT	RT	LT	RT	LT	
12-13	5 (100%)	5 (100%)	0	0	0	0	0	0	10
13-14	2 (50%)	2 (50%)	2 (50%)	2 (50%)	0	0	0	0	8
14-15	1 (20%)	1 (20%)	2 (40%)	2 (40%)	2 (40%)	2 (40%)	0	0	10
15-16	0	0	4 (33.33%)	4 (33.33%)	7 (58.33%)	7 (58.33%)	1 (8.33%)	1 (8.33%)	24
16-17	0	0	2 (20%)	3 (30%)	7 (70%)	6 (60%)	1 (10%)	1 (10%)	20
17-18	0	0	0	0	2 (18.18%)	2 (18.18%)	9 (81.81%)	9 (81.81%)	22
18-19	0	0	0	0	0	0	9 (100%)	9 (100%)	18
19-20	0	0	0	0	0	0	10 (100%)	10 (100%)	20
20-21	0	0	0	0	0	0	8 (100%)	8 (100%)	16
21-22	0	0	0	0	0	0	6 (100%)	6 (100%)	12

DISCUSSION

In the present study, the age of epiphyseal fusion of inferior end of radius and ulna was studied in Marwar region of Rajasthan. It was observed that fusion of the lower end of the radius in the male population was completed at 20-21 years of age whereas in females it completes at the age of 19-20 years.

There is a marked difference of 1-2 years in males and females and the fusion of the lower end of the radius occurs earlier in females than males. The above age group corresponds with the age group reported by Loomba SD (1958) for the male population and Gupta et.al. (1974) for both the male and female population of Uttar Pradesh.

K S Nemade et.al (2010) reported the same age group for the complete fusion of the lower end of Radius in both males and females in the Vidarbha region of Maharashtra. Other studies by M.J.S. Pillai (1936) in South India & Banerjee and Agarwal (1998) in Uttar Pradesh establishes the age of fusion in females as 18-19 year which is 1 year earlier than our observation.

Table 6: Comparison of ages (years) of fusion of epiphysis around wrist joint given by various workers in India & Foreign country with present study.

Author (From India)	Lower end of Radius		Lower end of ulna	
	Male (in years)	Female (in years)	Male (in years)	Female (in years)
M.J.S. Pillai (1936) South India	18	18	18	18
Galstaun (1937) Bengal	18	16.5	18.5	17
Loomba S.D. (1958) UP	20-21	18-19	20-21	18-19
Ramjets Das and Grewal (1965) Punjab	Less than 18	-	Less than 18	-
Saksena and Vyas (1969) MP	19-20	17-18	19-20	17-18

Gupta et al (1974) UP	20-21	19-20	20-21	20-21
Sahni and Jit (1995) Punjab	-	Above 16	-	Above 16
Banerjee and Agarwal (1998) UP	19-20	18-19	19-20	18-19
KS Nemade (2010) Maharashtra	20-21	19-20	19-20	19-20
Authors (From Foreign Countries)				
Ledger and Wasson (1941) Pakistan	Above 20	18-19	18-19	16-17
Flecker (1942) Australian	19	18	19	17.5
Cunningham (1953) European	Above 21	19-20	21	19-20
Frazer (1958) European	19	17	19	17
Gray (1995) European	19	17	18	17
Present Study	20-21	19-20	19-20	18-19

It is evident in table 6 that the inferior end of ulna ossifies at the age of 19-20 years in males and 18-19 years in female subjects. The same age group of the male population was found in previous studies by Saksena and Vyas (1969) in Madhya Pradesh, Banerjee and Agarwal (1998) in Uttar Pradesh, and K S Nemade (2010) in Maharashtra.

Loomba S.D. (1958) and Gupta et al (1974) in Uttar Pradesh reported the age of fusion of ulna in males at 20-21 years, but M.J.S. Pillai (1936) in South India, Galstaun (1937) in Bengal, and Ramjets Das and Grewal (1965) in Punjab reported the age of fusion of the lower end of the ulna in males as 1 year less than our findings.

In the female population, a similar age group for the fusion of ulna (18-19 years) was shown by M.J.S. Pillai (1936) in South India, Loomba S.D. (1958), and Banerjee & Agarwal (1998) in Uttar Pradesh. Galstaun (1937) in his study on the Bengali female population reported the age of fusion of ulna at 17 years.

Saksena and Vyas (1969) in MP have reported the age of fusion of ulna at 17-18 years for the female population which is 1 year earlier compared to our study.

COMPARISON WITH THE FOREIGN STUDIES

The fusion of the distal end of the Radius in our study is similar to the findings of Cunningham (1953) in the European population for both genders. The same result was shown by Ledger and Wasson in 1941 in Pakistan for the male population. In the case of females, the age of fusion was reported at 18 years by Flecker (1942) in Australia and 17 years by Frazer (1958) in Europe.

For the fusion of the distal end of ulna, our observation is similar to the findings of Flecker (1942) on Australian and Frazer (1958) on European male populations. In the female population, the fusion of the distal end of ulna was observed at the age of 17 years by Ledger and Wasson (1941) in Pakistan, Flecker (1942) in Australia, Frazer (1958), and Gray (1995) in Europe which is slightly different from the present findings.

CONCLUSION

According to the observations of the present study, a conclusion was drawn that the distal end of the radius completely ossifies at the age of 20-21 years in males and 19-20 years in females. The complete fusion of the distal end of the ulna was observed at the age of 19-20 years in males and 18-19 years in females. There is a difference of 1-2 years as the fusion occurs earlier in females than males at all epiphysis in the study. Similar results were seen in almost all studies throughout the world, suggesting the hormonal factors as etiology. We observed some disparity in age of ossification from the study conducted in different regions

of our country and western population at different time periods. There was no appreciable difference in the age of complete union of the epiphysis on both the right and left sides of the body. Nutritional factor and more importantly the genetic factor plays a major role in the ossifications of bones. Therefore, the need of standard criteria for bone ossification in every state of India is required to solve all types of medicolegal cases in which determination of age is of utmost required.

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