ORIGINAL ARTICLE

Age of fusion of epiphysis at distal end of radius and ulna

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ABSTRACT

BACKGROUND: Though the general development including height, weight, secondary sexual characteristics are helpful, eruption and maturity of teeth are quite reliable data for estimation of age, changes in bones specially time related appearance and fusion of different ossification centers in growing periods are valuable indices for assessing the age. **MATERIALS AND METHODS:** The study was conducted in the Department of Forensic medicine and Toxicology at Govt. Medical College & New Civil Hospital, Surat during the year from April 2009 to March 2010 in 218 cases of 14 to 21 years by taking digital x-rays of lower end of radius and ulna. **RESULTS:** In the study, we observed that fusion in the lower end of Radius started in the age group of 14-15yrs which is completed at 20 to 21 years, while fusion in the lower end of Ulna started in the age group of 14-15yrs which is completed at 19 to 21 years. **CONCLUSION:** In the present study from the observations, conclusions were drawn that fusion of epiphysis of distal end of radius occurs at 21 years in male and at 20 years in female. The fusion of epiphysis of distal end of ulna occurs at 21 years in male and 19 years in female. Thus in female, the ossification centers of distal end of radius and ulna occurs earlier than males by one to three years.

Keywords: Epiphysis, Fusion, Radius, Ulna

INTRODUCTION

Estimation of age is an important task for forensic medicine experts especially in developing countries where birth records are often not well maintained; and even where these are maintained, there have been incidences of forgery. Forensic medicine experts have to evaluate age in different medico legal situations, for eg. when the identity is not known or when the liability and punishment are related to the maturity, age of the individuals as in cases of criminal responsibility, rape, kidnapping, nullity of marriage, child labour disposal of properties etc.

Though the general development including height, weight, secondary sexual characteristics are helpful, eruption and maturity of teeth are quite reliable data for estimation of age, changes in bones specially time related appearance and fusion of different ossification centers in growing periods are valuable indices for assessing the age, but that is quite reliable only up to 25years of age; beyond that it becomes more uncertain.[1] According to Banerjee KK and Aggarwal BBL[2], the study of epiphyseal union of bones is considered a reasonable scientific and accepted method for estimation of age by the courts of law all over the world. There are many factors which affect the appearance and fusion of various bony centers like environmental, nutritional etc., so it is necessary to gather and follow the latest data available for a particular place for estimation of the age of the population of that place. A number of cases of false representation are made in the country particularly in respect of Teen age group.

The Indian population differs widely from the western population in hereditary, dietary, socio-economic and ethnic factors. Studies done in India are few. Galstaun[3, 4] in 1930 and 1937 has done a study in Bengali population. Bajaj[5]in 1967 has done a study in Delhi. Other studies done in India are Pillai[6] (Madarasis) in 1936, Hepworth[7] (Punjabis) in 1929, Basu and Basu[8] (Bengalis) in 1938, Agarwal and Pathak (Punjabis) in 1957, Das, Thapar and Grewal

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(Punjabis) in 1965, Jit (Punjabis) in 1971, Kalpesh shah [9] in 1991and G. J. Patel[10]in 2009 (in Gujaratis), which are all based on the fusion of ossification centres. Most of the data generated till now, is based on the routine X-ray method and not using digital X-Rays. Moreover no such study as per our current knowledge has been conducted in this region, using modern technology i.e. Digital X-Ray.

MATERIALS AND METHODS

The present study was conducted in the Department of Forensic medicine and Toxicology at Govt. Medical College & New Civil Hospital, Surat during the year from April 2009 to March 2010. This study was carried out on 218 persons between the age group of 14-21 years and of both sex attending the outpatient department of the New Civil Hospital, Surat. The aim of study was to finalise the age of epiphyseal union in persons of Gujarat state (esp. Surat city), so only those persons were selected who are residing in the state, since long. Only the persons having the exact date of birth were selected with documentary proof like birth certificate, school leaving certificate, S.S.C. mark sheet etc.

Permission from Ethical committee and the Radiology department, New Civil Hospital, Surat for digital X-ray had been taken. Written consent for X-ray was taken from all subjects (as they were above 12 years of age). Xerox copy of documentary proof of birth date was collected. Information for address, handedness, native of subject, monthly income, no. of family members and any habit was gathered from the subjects. Their identification marks, height, weight and sex were recorded. In Male and Female subjects' relevant growth and colour of scalp, beard, moustache, Axillary and pubic hairs was examined. In female subjects development of breast was examined and menstrual history was also taken. Dental examination was done and dental charts were prepared. Digital x-rays of antero-posterior view of the wrist and hand showing lower ends of radius and ulna was taken and the cassettes were submitted back.

Radiological assessment of the fusion of centres of lower end of radius and ulna was done by reading the X-ray findings of soft copies of X-rays and were grouped according to stage of fusion as:- **Degree 0**: A dark radiolucent line seen throughout the length of epiphyseal and metaphyseal joining surfaces. (Union not yet commenced). **Degree 1**: Radio-opaque area is seen in the middle of or on either side of, but occupies less than half of, the epiphyseal and metaphyseal joining surfaces. (Union commenced). **Degree 2**: Radio-opaque area is seen in more than half of the epiphyseal and metaphyseal joining surfaces, but the cortical shadow is not yet continuous. (Union incomplete). **Degree 3**: Radio-opaque area is seen in the entire length of the epiphyseal and metaphyseal joining surfaces and the cortical shadow is continuous, without any notch. (Union complete).

After this Comparison of the study with other studies was done and critical evaluation of the results were carried out.

RESULTS

This study was hospital based Cross sectional study. It was conducted at Department of Forensic medicine and Toxicology at Govt. Medical College & New Civil Hospital, Surat. This study was carried out on 218 participants who belonged to the age group of 14-21 years attending the outpatient department of the New Civil Hospital, Surat. We had also included few participants below 14 years and above 21 Years.

Table 1: Age and sex wise distribution

AGE GROUPS	SEX		TOTAL
	Females	Males	
<14 yrs.	1 (0.46%)	1 (0.46%)	2 (0.92%)
14-15 yrs.	2 (0.92%)	10 (4.59%)	12 (5.51%)
15-16yrs.	5 (2.29%)	14 (6.42%)	19 (8.72%)
16-17yrs.	8 (3.67%)	7 (3.21%)	15 (6.88%)
17-18 Yrs.	7 (3.21%)	15 (6.88%)	22(10.09%)
18-19 Yrs.	6 (2.75%)	25 (11.47%)	31 (14.22%)
19-20 Yrs.	31 (14.22%)	38 (17.43%)	69 (31.65%)
20-21 Yrs.	8 (3.67%)	36 (16.51%)	44 (20.18%)
>21 yrs.	1 (0.46%)	3 (1.38%)	4 (1.84%)
TOTAL	69 (31.65%)	149(68.35%)	218 (100%)

As we can see from above table no-2 the fusion in the lower end of radius started in the age group of 14-15yrs and below that age, none of the cases showed any fusion. The number of candidates showing greater degrees of fusion increased with the advancing age and 3rd degree of fusion was seen in 5.26% of the cases in the age group of 15-16yrs, in 6.66% of cases in 16-17yrs group, in 18.18% cases in 17-18yrs group,

in 54.84% cases in 18-19yrs group, in 86.96% cases in 19-20yrs group and in 90.91% cases in 20-21yrs group. Third degree fusion in 100% of the cases was seen only in the participants above 21yrs of age. Thus, if we consider the value of statistical significance to be 95%, the lower end of Radius fuses completely with the shaft by the age of 21yrs. Also, no great disparity was observed in fusion process between the two hands.

Table 2: Age wise fusion of lower end of radius

Age Groups	Degrees of fusion				Total
	Degree 0	Degree 1	Degree 2	Degree 3	
<14 yrs.	2 (100%)	0	0	0	2 (100%)
14-15 yrs.	8 (66.66%)	4 (33.33%)	0	0	12 (100%)
15-16yrs.	10(52.63%)	5(26.32%)	3 (15.8%)	1 (5.26%)	19(100%)
16-17yrs.	2 (13.33%)	4(26.66%)	8 (53.33%)	1(6.66%)	15(100%)
17-18 Yrs.	1(4.55%)	7(31.82%)	10(45.45%)	4(18.18%)	22(100%)
18-19 Yrs.	0	2(6.45%)	12(38.71%)	17(54.84%)	31(100%)
19-20 Yrs.	0	2(2.99%)	7(10.14%)	60(86.96%)	69(100%)
20-21 Yrs.	0	1(2.27%)	3(6.82%)	40(90.91%)	44(100%)
>21 yrs.	0	0	0	4(100%)	4 (100%)
TOTAL	23(10.55%)	25(11.47%)	43(19.73%)	127(58.26%)	218(100%)

Table 3: Age wise fusion of lower end of radius in females

Age Groups	Degrees of fusion				Total
	Degree 0	Degree 1	Degree 2	Degree 3	
<14 yrs.	1(100%)	0	0	0	1(100%)
14-15 yrs.	0	2(100%)	0	0	2(100%)
15-16yrs.	1(20%)	0	3(60%)	1(20%)	5(100%)
16-17yrs.	0	1(12.5%)	6(75%)	1(12.5%)	8(100%)
17-18 Yrs.	0	1(14.29%)	5(71.43%)	1(14.29%)	7(100%)
18-19 Yrs.	0	0	2(33.33%)	4(66.66%)	6(100%)
19-20 Yrs.	0	0	2(6.45%)	29(93.55%)	31(100%)
20-21 Yrs.	0	0	0	8(100%)	8(100%)
>21 yrs.	0	0	0	1(100%)	1(100%)
TOTAL	2(2.9%)	4(5.8%)	18(26.1%)	45(65.2%)	69(100%)

As is evident from the above table no-3, fusion doesn't begin below 14yrs of age as was observed earlier also and the number of candidates showing greater degrees of fusion increased with the advancing age and 3rd degree of fusion was earliest seen in 20% of the cases in the age group of 15-16yrs, 12.5% of the cases in the age group of 16-17yrs, 14.29% of cases in the age group of 17-18yrs, 66.66% cases in the age group of 18-19yrs, 93.55% in the age group of 19-20yrs and in 100% of the cases above the age of 20yrs. Thus, if we consider the value of

statistical significance to be 95%, the lower end of Radius fuses with the shaft by the age of 20yrs.

Table 4: Age wise fusion of lower end of radius in females

Age Groups	Degrees of fusion				Total
	Degree 0	Degree 1	Degree 2	Degree 3	
<14 yrs.	1(100%)	0	0	0	1(100%)
14-15 yrs.	8(80%)	2(20%)	0	0	10(100%)
15-16yrs.	9(64.29%)	5(35.71%)	0	0	14(100%)
16-17yrs.	2(28.57%)	3(28.57%)	2(42.86%)	0	7(100%)
17-18 Yrs.	1(6.66%)	6(40%)	5(33.33%)	3(20%)	15(100%)
18-19 Yrs.	0	2(8%)	10(40%)	13(52%)	25(100%)
19-20 Yrs.	0	2(5.26%)	5(13.16%)	31(81.58%)	38(100%)
20-21 Yrs.	0	1(2.77%)	3(8.33%)	32(88.88%)	36(100%)
>21 yrs.	0	0	0	3(100%)	3(100%)
TOTAL	2114.1%)	21(14.1%)	25(16.78%)	82(55.03%)	149(100%)

Thus, we find in table no-4 that the fusion doesn't begin below 14yrs of age as was observed earlier also and the number of candidates showing greater degrees of fusion increased with the advancing age and 3rd degree of fusion was earliest seen in 20% of the cases in the age group of 17-18yrs (i.e. 2yrs later than that of females), 52% cases in the age group of 18-19yrs, 81.58% in the age group of 19-20yrs, 88.88% cases in the age group of 20-21yrs and in 100% of the cases above the age of 21yrs. Thus, if we consider the value of statistical significance to be 95%, the lower end of Radius fuses with the shaft by the age of 21yrs in males i.e. one year later than that of females.

Table 5: Fusion of lower end of Ulna

Age Groups	Degrees of fusion				Total
	Degree 0	Degree 1	Degree 2	Degree 3	
<14 yrs.	1(50%)	1(50%)	0	0	2(100%)
14-15 yrs.	6(50%)	5(41.66%)	1(8.33%)	0	12(100%)
15-16yrs.	10(52.63%)	4(21.05%)	4(21.05%)	1(5.26%)	19(100%)
16-17yrs.	2(13.33%)	3(20%)	4(26.66%)	6(40%)	15(100%)
17-18 Yrs.	0	2(9.1%)	11(50%)	9(40.1%)	22(100%)
18-19 Yrs.	0	1(3.23%)	9(29.03%)	21(67.74%)	31(100%)
19-20 Yrs.	0	1(1.45%)	6(8.7%)	62(89.85%)	69(100%)
20-21 Yrs.	0	1(2.27%)	2(4.54%)	41(93.18%)	44(100%)
>21 yrs.	0	0	0	4(100%)	4(100%)
TOTAL	19(8.72%)	18(8.26%)	37(16.97%)	144(66.06%)	218(100%)

So here we see that from table-5, the fusion begins even below the age of 14yrs and the number of candidates showing greater degrees of fusion increased with the advancing age and 3rd degree of fusion was seen in 5.26% of the cases in the age group of 15-16yrs for the first, in 40%

of cases in 16-17yrs group, in 40.1% cases in 17-18yrs group, in 67.74% cases in 18-19yrs group, in 89.85% cases in 19-20yrs group and in 93.18% cases in 20-21yrs group. Third degree fusion in 100% of the cases was seen only in the participants above 21yrs of age. Thus, if we consider the value of statistical significance to be 95%, the lower end of Ulna fuses completely with the shaft by the age of 21yrs. Also, no great disparity was observed in fusion process between the two hands.

Table 6: Fusion of Lower end of Ulna in Females

Age Groups	Degrees of fusion				Total
	Degree 0	Degree 1	Degree 2	Degree 3	
<14 yrs.	0	1(100%)	0	0	1(100%)
14-15 yrs.	0	2(100%)	0	0	2(100%)
15-16yrs.	1(20%)	0	3(60%)	1(20%)	5(100%)
16-17yrs.	0	0	4(50%)	4(50%)	8(100%)
17-18 Yrs.	0	1(14.29%)	2(28.57%)	4(57.14%)	7(100%)
18-19 Yrs.	0	0	0	6(100%)	6(100%)
19-20 Yrs.	0	0	1(3.23%)	30(96.77%)	31(100%)
20-21 Yrs.	0	0	0	8(100%)	8(100%)
>21 yrs.	0	0	0	1(100%)	1(100%)
TOTAL	1(1.45%)	4(5.8%)	10(14.49%)	54(78.26%)	69(100%)

Here we find in table no-6 that, the fusion has begun even before 14yrs of age and the number of candidates showing greater degrees of fusion increased with the advancing age and 3rd degree of fusion was earliest seen in 20% of the cases in the age group of 15-16yrs, 50% of the cases in the age group of 16-17yrs, 57.14% of cases in the age group of 17-18yrs, 100% cases in the age group of 18-19yrs, 96.77% in the age group of 19-20yrs and in 100% of the cases above the age of 20yrs. Thus, if we consider the value of statistical significance to be 95%, the lower end of Ulna fuses with the shaft by the age of 19yrs; i.e. in females, the lower end of Ulna fuses one year earlier than the Radius.

Thus, we find from table no-7 that the fusion doesn't begin below 14yrs of age and the number of candidates showing greater degrees of fusion increased with the advancing age and 3rd degree of fusion was earliest seen in 28.57% of the cases in the age group of 16-17yrs (i.e. 1yr later than that of females), 33.33%of the cases in the age group of 17-18yrs, 60% cases in the age group of 18-19yrs, 84.21% in the age group of 19-20yrs, 91.66% cases in the age group of 20-21yrs and in 100% of the cases above the age of 21yrs. Thus, if we consider the value of statistical significance to be 95%, the lower end of Ulna fuses with the shaft by the age of 21yrs in males i.e. two years later than that of females and at the same age as that of fusion of lower end of Radius.

Table 7: Fusion of Lower end of Ulna in Males

Age Groups	Degrees of fusion				Total
	Degree 0	Degree 1	Degree 2	Degree 3	
<14 yrs.	1(100%)	0	0	0	1(100%)
14-15 yrs.	6(60%)	3(30%)	1(10%)	0	10(100%)
15-16yrs.	9(64.29%)	4(28.57%)	1(7.14%)	0	14(100%)
16-17yrs.	2(28.57%)	3(42.86%)	0	2(28.57%)	7(100%)
17-18 Yrs.	0	1(6.66%)	9(60%)	5(33.33%)	15(100%)
18-19 Yrs.	0	1(4%)	9(36%)	15(60%)	25(100%)
19-20 Yrs.	0	1(2.63%)	5(13.16%)	32(84.21%)	38(100%)
20-21 Yrs.	0	1(2.77%)	2(5.55%)	33(91.66%)	36(100%)
>21 yrs.	0	0	0	3(100%)	3(100%)
TOTAL	18(12.08%)	14(9.4%)	27(18.12%)	90(60.4%)	149(100%)

DISCUSSION

Table 8: Comparison of our study with studies carried outside India

Study of fusion	Lower end of Radius		Lower end of Ulna	
	Male	Female	Male	Female
Pryor J.W.[14]	20	19	19	16
Davies & Parsons[15]	19-20	19-20	20	20
Paterson[16]	21	19-20	21	19-20
Borovansky& Hnevkovsky[17]	19	19	18-19	18-19
Sidhom& Derry[18]	18-19	18-19	19-20	19-20
Flecker[19]	19	18	19	17
Barret[20]	17-18	17-18	17-18	17-18
Greulich& Pyle[21]	18	17	18	17
OUR study	21	20	21	19

As is evident from the table no-8, in our study, we have found that Radius and Ulna fuse completely in males in statistically significant number of cases by the age of 21yrs, which is in accordance with the findings of Paterson (England, 1929) but not with that of other authors, whose studies suggest fusion at lower ages. In females, Radius fuses by 20yrs and Ulna by 19yrs, as per our study, which is again in accordance with that of Paterson (England, 1929), Davis and Parsons (as far as Radius is concerned) and Sidham and Derry (as far as Ulna is concerned) but not with that of other authors, whose studies suggest fusion at lower ages.

As far as the relation of sex with fusion of centers of wrist and hand are concerned, the findings of my study are very much in accordance with the findings of all other studies, both foreign and Indian studies, that we have come across, i.e. fusion of these centers occurs earlier in females by one to three years as compared to males.

Table 9: Comparison of our study with studies carried out in India

Study of fusion	Lower end of Radius		Lower end of Ulna	
	Male	Female	Male	Female
Hepworth[7]	16-17	16-17	16-17	16-17
Galstaun G[3, 4]	16-17	16.5-18	18	17
Lall R. & Nat B.S.[12]	19	19	19	19
Pillai M.J.[6]	14-18	14-18	14-18	14-18
Basu S.K. &Basu S.[8]	16-17	16-17	16-17	16-17
Lall R. & Townsend R.[13]	19	19	19	19
Mittal[11]	16-17	18	17-18	16-17
OUR study	21	20	21	19

CONCLUSION

In the present study from the observations, conclusions were drawn that fusion of epiphysis of distal end of radius occurs at 21 years in male and at 20 years in female. The fusion of epiphysis of distal end of ulna occurs at 21 years in male and 19 years in female. Thus in female, the ossification centers of distal end of radius and ulna occurs earlier than males by one to three years.

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