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ORIGINAL PAPER

Software Tool in Digital Radiographs for Appearance and Fusion of Ossification Centres at Wrist Joint

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ABSTRACT

Radiographic study of long bones is hoar method for age estimation. Many studies have been carried out in the world using conventional radiographs but a very few using digital radiographs. Age of appearance and fusion of ossification centres show considerable variations due to factors like race, habitat, nutrition and the methods by which databases are prepared. So, it is the need of the hour that some local databases are made available for more precise age estimation in medicolegal cases. Present study was carried out by observing digital radiographs of wrist with incorporation of software tool Microsoft Office Picture Manager. Exhaustive statistical tests were applied to analyse the findings and an institutional database was created. Findings of present study are in consonance with other studies or in some cases, it detects appearance and fusion of ossification centres earlier than other studies. Digital images of radiographs with incorporation of software tool Microsoft Office Picture Manager yielding better visualisation and resultant better interpretation proved out to be useful. Such institutional databases can be formed at individual hospitals to cater to medico legal services of age estimation more precisely and thus acceptance of the opinions regarding age estimation by the court of law can be increased.

***Keywords:** Age estimation, wrist joint, ossification centre, digital radiographs, software tool*

INTRODUCTION

Age is one of the very important criteria for identification. Question of age estimation arises in various civil as well as criminal cases like consent for physical examination, employment in government sectors, criminal responsibility of an accused, rape, kidnapping, etc. Age estimation of the living as well as of cadavers relies heavily on data, regarding growth and developmental stages of the individual as obtained from dental and skeletal radiographs.[1] The most widely accepted method for determining skeletal bone age is that of Greulich-Pyle[2] described in the book *"Radiographic atlas of skeletal development of the hands and wrist"*. The atlas was derived from the American white children of upper class socio-economic level born during 1930s. Since then, a lot of studies have been carried out on estimation of age from radiological examination of epiphyseal fusion of bones. Whilst the time of these epiphyseal fusions is relatively well documented, it can show a considerable degree of person to person variation. It may depend on multiple factors like genetic makeup, race, geographical habitat and dietary habits, etc.[1,3-5] For this reason, a baseline data for a particular geographical population is

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required for comparison. Therefore the authors have carried out this study on the patients coming to GCS Medical College for routine check-up and living in Ahmedabad city since their birth.

OBJECTIVES

1. To observe average age of appearance of ossification centre at lower end of radius and ulna in digital radiographs by incorporating software tool.
2. To observe average age of epiphyseal fusion at lower end of radius and ulna in digital radiographs by incorporating software tool.
3. To compare findings of present study with other different studies.
4. To look for scientific explanation for variations; if any.
5. To evaluate medico legal application of observations in exercise of age estimation.

MATERIALS AND METHODS

A retrospective cross-sectional study was carried out on digital radiographs of wrist and hand collected in OPDs at GCS Medical College, Hospital and Research centre for clinical (Non research) purposes during 1-1-12 to 31-12-12.

Inclusion criteria:

- Subjects of known gender and age living in Ahmedabad since birth.

Exclusion criteria:

- Subjects with undefined gender and age in question or doubt.
- Subjects with history of trauma or diagnosed disease or pathology at wrist and/or hand.
- Subjects with congenital abnormality.

Out of 600 cases of X-ray examination at wrist joint during the period; 140 cases were excluded as per defined exclusion criteria and rest 460 cases were included in the study.

After blinding, the radiographs were studied in digital form in "JPEG format" in Microsoft Office Picture Manager 2007 version in 2505x3015 resolution with 60% zoom in.

For distal end of radius and ulna, appearance of the ossification centre was considered as "A". Radiographs showing

- Clear gap between the epiphysis and diaphysis, showing saw tooth like appearance were designated as "Non-fusion" (**NF**).
- A line replacing the hiatus between the epiphyseal and diaphysial ends and not showing saw tooth like appearance were designated as "Partial Fusion" (**PF**).
- Same bony architecture in the diaphysis and epiphysis and showing scar of the previous stage were designated as "Recent Fusion" (**RF**).
- Uniform architecture at the union site with absence of any scar were designated as "Complete fusion" (**CF**).[6]

The data was tabulated and analysed further to deduce observations and discussion.

OBSERVATIONS and RESULTS

Out of total 460 cases; 198 were below 23 years of age amongst which 148 were males and 50 were females. All the data in tabulated form are self explanatory without any text commentary further.

Table 1 Frequency distribution of ossification centre appearance of lower end of Radius and Ulna

Age group (yrs)	Total number of cases in age group	Lower end Radius No.(%)	Lower end Ulna No.(%)
0-1	6	0	0
1-2	10	8 (80)	0
2-3	16	8 (50)	0
3-4	8	8 (100)	0
4-5	8	8 (100)	0
5-6	4	4 (100)	0
6-7	4	4 (100)	0
7-8	4	4 (100)	0
8-9	8	8 (100)	6 (75)
9-10	8	8 (100)	4 (50)
10-11	10	10 (100)	10 (100)
11-12	6	6 (100)	6 (100)
12-13	4	4 (100)	4 (100)
13-14	4	4 (100)	4 (100)
>14	360	360 (100)	360 (100)
Total	**460**		

Table 2 Statistical parameters for appearance of ossification centre at lower end of Radius and lower end of Ulna

Statistical parameter	**Lower end Radius (n=34)**	**Lower end Ulna (n=26)**
Range	1-4	8-11
Mean Age	1.94	9.08
SD	0.74	0.84
Mean ± 3SD	-0.28 to 4.16	6.56 to 11.6
Co-efficient of Variance (SD/Mean)	0.38	0.09
% Beyond demarking point	0	0

Table 3 Frequency distribution of stage wise epiphyseal fusion of lower end of Radius in both sexes

Age group (years)	**Sex (M-Male, F-Female)**	**Non fusion (NF) No.(%)**	**Partial fusion (PF) No.(%)**	**Recent fusion (RF) No.(%)**	**Complete fusion (CF) No.(%)**	**Total**
<14	M	76 (100)	0	0	0	76
	F	24 (100)	0	0	0	24
14-15	M	6 (100)	0	0	0	6
	F	2 (100)	0	0	0	2
15-16	M	4 (33.33)	8 (66.66)	0	0	12
	F	0	2 (50)	2 (50)	0	4
16-17	M	0	0	0	0	0
	F	0	4 (100)	0	0	4
17-18	M	0	6 (75)	2 (25)	0	8
	F	0	0	2 (100)	0	2
18-19	M	0	4 (25)	10 (62.5)	2 (12.5)	16
	F	0	0	0	0	0
19-20	M	0	0	2 (33.33)	4 (66.66)	6
	F	0	0	2 (50)	2 (50)	4
20-21	M	0	0	2 (25)	6 (75)	8
	F	0	0	0	2 (100)	2
21-22	M	0	0	2 (25)	6 (75)	8
	F	0	0	0	4 (100)	4
22-23	M	0	0	0	8 (100)	8
	F	0	0	0	4 (100)	4
>23	M	0	0	0	136 (100)	136
	F	0	0	0	126 (100)	126
Total	**M**					**284**
	F					**176**
	Total					**460**

Table 4 Frequency distribution of stage wise epiphyseal fusion of lower end of Ulna in both sexes

Age group (years)	Sex (M-Male, F-Female)	Non fusion (NF) No. (%)	Partial fusion (PF) No.(%)	Recent fusion (RF) No. (%)	Complete fusion (CF) No.(%)	Total
<14	M	76 (100)	0	0	0	76
	F	24 (100)	0	0	0	24
14-15	M	6 (100)	0	0	0	6
	F	2 (100)	0	0	0	2
15-16	M	6 (50)	6 (50)	0	0	12
	F	0	2 (50)	0	2 (50)	4
16-17	M	0	0	0	0	0
	F	0	0	4 (100)	0	4
17-18	M	2 (25)	4 (50)	0	2 (25)	8
	F	0	0	0	2 (100)	2
18-19	M	0	2 (12.5)	8 (50)	6 (37.5)	16
	F	0	0	0	0	0
19-20	M	0	0	0	6 (100)	6
	F	0	0	0	4 (100)	4
20-21	M	0	0	0	8 (100)	8
	F	0	0	0	2 (100)	2
>21	M	0	0	0	152 (100)	152
	F	0	0	0	134 (100)	134
Total	**M**					**284**
	F					**176**
	Total					**460**

Table 5 Statistical parameters for sexual dimorphism of epiphyseal fusion at lower end of Radius and Ulna

	Lower end Radius		Lower end Ulna	
Statistical parameter	**Male (n=62)**	**Female (n=16)**	**Male (n=34)**	**Female (n=10)**
Range	15-23	15-21	15-20	15-18
Mean	18.74	17.12	17.47	15.8
SD	2.15	1.89	1.30	0.79
Mean ± 3SD	12.29-25.19	11.45-22.79	13.57 – 21.37	13.43 – 18.17
Co-efficient of variance (SD/Mean)	0.11	0.11	0.07	0.05
Demarcating point	>22.79	<12.29	> 18.17	< 13.57
% beyond demarcating point	0	0	6 (17.64%)	0
	't' value = 2.749, '*p*' value = 0.0075		't' value = 3.840, '*p*' value = 0.0004	

Table 6 Regression equations for epiphyseal fusion of lower end of Radius and Ulna in both sexes

Variable	Regression equation	Standard Error	Coefficient of Correlation
Lower end Radius			
Common (Both sexes)	Y = 10.03 + 3.73 (X)	2.72	0.87
Male	Y = 10.52 + 3.56 (X)	2.57	0.87
Female	Y = 7.81 + 4.51 (X)	3.22	0.85
Lower end Ulna			
Common (Both sexes)	Y = 13.70 + 1.55 (X)	1.48	0.79
Male	Y = 13.66 + 1.73 (X)	1.48	0.82
Female	Y = 14.29 + 0.66 (X)	0.71	0.73

DISCUSSION

Radiographic study of shoulder, elbow, wrist, hip, knee and ankle regions is a known method for age estimation. Many studies have been carried out in past in various regions of the world using conventional radiographs[4, 6-14] but research with digital radiographs of hip joint was first reported in biomedical literatures of India in 2012 only.[15]

Appearance of ossification centre for lower end of radius in present study occurs at 1½-2½ years which is in consonance with the studies done on population of central India (1-3 years) by Pawan Wankhede et al[14] and Rajasthan (1-3 years) by Ashutosh Srivastava et al.[8] Studies done on population of England (10-12 months) by Davies and Pearson[4], Bengal (1 year) by Galstaun[4] mention appearance of lower end of radius earlier than present study. Ossification centre for lower end of ulna appears at the age of 8½- 9½ years in present study which is in consonance with study done on Bengalis (8-10 years) by Galstaun.[4] Other studies showing appearance of lower end of ulna earlier than present study are studies done on population of England (7-8 years) by Davies and Pearson[4], Rajasthan (5-8 years) by Ashutosh Srivastava et al[8] and Central India (6-8 years) by Pawan Wankhede et al.[14] We could not find any data showing appearance of ossification centre of lower end of radius or lower end of ulna later than the present study in literature available with us.

Table 3 shows earliest fusion of lower end of radius at age of 15 years in both sexes where, in males 66.66% cases show partial fusion but 33.33% cases still show non-fusion; while at the same age in females, no case shows non-fusion but partial fusion is shown by 50% cases and recent fusion by 50% cases, indicating that fusion process of lower end of radius starts earlier in females than males. Looking at the completion of fusion process, 100% cases in females show complete fusion at the age of 21 years but in males complete fusion in 100% cases is seen at 23 years which suggests that completion of fusion process of lower end of radius also occurs earlier in females than males. This is supported by information given in standard textbooks of Forensic Medicine.

According to **Table 4**, earliest fusion of lower end of ulna is seen at the age of 15 years in both sexes where, in males 50% cases show partial fusion but 50% cases still show non-fusion; while at the same age in females, no case show non-fusion but partial fusion is shown by 50% cases and complete fusion by 50% cases, indicating that fusion process of lower end of ulna starts earlier in females than males. Looking at the completion of fusion process, 100% cases in females show complete fusion at the age of 18 years but in males complete fusion in 100% cases is seen at the age of 20 years which suggests that completion of fusion process of lower end of ulna also occurs earlier in females than males. This is supported by information given in standard textbooks of Forensic Medicine.

Age of fusion of lower end of radius in males in present study (18-19 yrs) is in consonance with study done on population of America done by Greulich and Pyle[2], Australians by Flecker[4], Central Karnataka by Kadam SS et al[10] and Rajasthani population by Kothari DR et al[9]. Lower end of radius in males fuses earlier than present study according to studies done on population of Bengal (16-17 years) by Galstaun[4] and North Karnataka (17-18 years) by Patil DT et al.[10] Fusion of lower end of radius occurs later than the present study according to the other studies done on English population (19-20 years) by Davis and Pearson[4], Rajasthani population (19-20 years) by Jain S et al[10] and population of Himachal Pradesh(21 years) by Sankhyan S et al.[10]

Age of fusion of lower end of radius in females in present study (16½-17½ years) is in consonance with studies on population of America done by Greulich and Pyle[2], Bengalis (16½ years) by Galstaun[4], Central India (16-17 years) by Pawan Wankhede et al[14], Central Karnataka (16-17 years) by Kadam SS et al[10] and North Karnataka by

Patil DT et al.[10] Lower end of radius in females fuses at age of 17-18 years in Maharashtrians according to Kangne RN et al[11] and Rajasthanis according to Kothari DR et al[9], at 18 years in North-east Indian population according to Sangma WBCh et al[12] and Australian females as per Flecker[4], at 18-19 years in population of Madhya Pradesh according to Saksena JS et al[9] and at age of 19-20 years in Rajasthani population according to Jain S et al[10], which comes out to occur later than the present study. We could not find data showing fusion of lower end of radius in females earlier than present study in literature available with us.

Lower end of ulna in males in present study gets fused at the age of 17-18 years which is in consonance with other studies done on Bengalis by Galstaun[4] and on North Karnataka population by Patil DT et al.[10] The fusion of lower end of ulna in males in present study occurs earlier compared to other studies on population of England (20 years) by Davies and Parson[4], Australia (18 years) by Flecker[4], America (19 years) by Greulich and Pyle[2], Rajasthan (18-19 years) by Kothari DR et al[9], Central Karnataka (18-19 years) by Kadam SS et al[10], Rajasthan (19-20 years) by Jain S et al[10], Madhya Pradesh (20-21 years) by Saksena JS et al[9] and Himachal Pradesh (21 years) by Sankhyan.[10] We could not find data showing fusion of lower end of ulna in males earlier than present study in literature available with us.

Lower end of ulna in females in present study gets fused at the age of 15½ -16½ years which is in consonance with other studies done on Bengalis by Galstaun[4] and Central Karnataka population by Kadam SS et al.[10] The fusion of lower end of ulna in females in present study occurs earlier than other studies on population of Australia (17 years) by Flecker[4], America (17 years) by Greulich and Pyle[2], Maharashtra (16-17 years) by Kangne RN et al[11], Central India (16-17 years) by Pawan Wankhede et al[14], Rajasthan (17-18 years) by Kothari DR et al[10], Rajasthan (18-19 years) by Jain S et al[10] and Madhya Pradesh (18-19 years) by Saksena JS et al.[9] We could not find data showing fusion of lower end of ulna in females earlier than present study in literature available with us.

Thus present study is able to detect a particular stage of fusion at the earliest compared to other studies overall. Credit can be given to the digital nature of radiographs in present study along with use of software tool Microsoft Office Picture Manager which provides more clear visualization of the radiographs resulting into better interpretation. Variation in ages of appearance and fusion of ossification centres of lower end of radius and ulna can be explained by interclass and intraclass variations in sample size, high quality of digital images, incorporation of software tool, application of exhaustive statistical tests yielding more accurate results in addition to general factors like racial differences and different geographical distribution of the sample population with nutritional status and varying diets.

Simple regression formula for estimation of age from stage of ossification can be derived where stage of ossification acts as independent variable while age in question becomes dependent variable.[12, 13]

CONCLUSION

We concluded that in the population of Ahmedabad, average age of appearance of lower end of radius & lower end of ulna is 1½ - 2½ years and 8½ - 9½ years respectively. Average age of fusion of lower end of radius is 18-19 years (in males) and 16½-17½ years (in females). Average age of fusion of lower end of ulna comes out to be 17-18 years (in males) and 15½ -16½ years (in females).

Use of digital radiographs with incorporation of the software tool Microsoft Office Picture Manager is proven more precisely. Findings of present study are more acceptable because of huge sample size, digital nature of radiographs with software tool and exhaustive statistical analyses.

Thus, two types of opinions can be formed:

1. Age of appearance of lower end of radius: 1½ - 2½ years or 2 years $\pm$ 6 months.
2. Age of appearance of lower end of ulna: 8½ - 9½ years or 9 years $\pm$ 6 months.
3. Age of fusion of lower end of radius: **Male**: 18-19 years or 18½ years $\pm$ 6 months; **Female**: 16½-17½ or 17 years $\pm$ 6 months
4. Age of fusion of lower end of ulna: **Male**: 17-18 or 17½ $\pm$ 6 months; **Female**: 15½ -16½ or 16 $\pm$ 6 months (These findings have to be correlated with findings of radius if age in question is 16 years)

We suggest to the department of Forensic Medicine in each medical college to carry out such study in their hospital so that an institutional database can be created which can help in catering medico legal services related to age estimation more precisely.

Ethical clearance: Done

Conflict of interest: None declared.

Contribution of authors: We declare that this work was done by the authors named in this article and all liabilities pertaining to claims relating to the content of this article will be borne by the authors. Conception and design: Mohammed Ziyauddin G Saiyed, Chetan B Jani. Collection and analyses: Swati S Shah in addition.

REFERENCES

1. Tsokos M, editor. Forensic pathology reviews. 1st ed. Totowa (NJ): Humana Press Inc.; 2005. vol 3 p. 444-54.
2. Gerulich W.W., Pyle, S.I. Radiographic atlas of skeletal development of the hand and wrist. 2nd ed. Stanford: Stanford University press; 1959. p. 61-183.
3. Krogman WM, Iscan MY. The human skeleton in forensic medicine. 2nd ed. Illinois (USA): Charles C Thomas Publisher; 1986. p. 50-102.
4. Mathiharan K, Patnaik AK, editors. Modi's medical jurisprudence and toxicology. 23rd ed. Nagpur: Lexis Nexis Butterworths Wadhwa; 2005. Sec I p. 285.
5. Schmit A, Cunha E, Pinherio J, editors. Forensic anthropology and medicine: Complementary science from recovery to cause of death. 1st ed. Totowa (NJ): Humana press; 2006. p. 58-77.
6. Schmidt S, Baumann U, Schulz R, Reisinger W, Schmeling A. Study of age dependence of epiphyseal ossification of the hand skeleton. Int J Legal Med 2008;122:51-4.
7. Jit I, Kulkarni M. Time of appearance and fusion of epiphysis at medical end of clavicle. Indian J Med Res 1976 May; 64(5):773-82.
8. Srivastav A, Saraswat PK, Agarwal SK, Gupta P. A study of wrist ossification for age estimation in pediatric group in central rajasthan. J Ind Acad Forensic Med 2004;26(4):132-5.
9. Patel DS, Agarwal H, Shah JV. Epiphyseal fusion at lower end of radius and ulna valuable tool for age determination. J Ind Acad Forensic Med 2011;33(2):125-9.
10. Kadam SS, Viswanathan KG. Age estimation radiologically from epiphyseal union at wrist joint among subjects in devanagere district. Ind J For Med and Tox 2012;6(2):195-8.
11. Kangne RN, Sami SA, Deshpande VL. Age estimation of adolescent girls by radiography. JFMT 1999;16(1):20-6.
12. Sangma WBCh., Marak FK, Singh MS, Kharrubon B. Age determination in girls of north-eastern region of India. J Ind Acad Forensic Med 2007;29(4):102-8.
13. Ragui S, Singh TB, Meera TH, Nabachandra H. Age determination in Manipuri subjects from the eruption of teeth and epiphyseal union of upper limb. J Ind Acad Forensic Med 2015;37(1):41-5.
14. Wankhede PA, Tirpude BH, Murkey PN, Zopate PR, Survade V, Nagarale N. A study of wrist joint ossification by radiological examination for age estimation in the female population of central India. J For Med, Sci and Law 2011;20(2):9-18.
15. Patel G, Prajapati P, Dodiya D, Doshi B. Study of fusion of ischial tuberosity in gujarati population by using digital X-ray method. J Ind Acad Forensic Med 2012;34(2):120-3.