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ORIGINAL ARTICLE

Forensic age estimation from secondary ossification centres of elbow joint: A digital radiographic study on South Indian metropolitan population in a tertiary care hospital

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Abstract

Age of an individual involving in crime or civil disputes takes immense significance in jurisprudence. In Medical field, a single criteria or technique is neither exhaustive nor reliable for age estimation across ages; hence we resort to multiple modes of determining age scientifically and conclude the achieved results. Most widely utilized technique in early years of life is radiographic assessment of long bones. This technique has been accepted scientifically because of its accuracy in +/- 06 months to 01 year which is very much needed in settling cases.

Keywords

Forensic anthropology; Age estimation; Elbow joint

Introduction

Age estimation is an important parameter of forensic human identification. Considerable research has been done on age estimation using epiphyseal fusion of the long bones. Conventional radiography is considered to the gold standard for age estimation studies. Sizeable amount of tests focuses on age estimation from X-rays. The technique of age assessment from X-rays, having been accepted by Courts, Medical doctors witnessing in Courts of law are often questioned upon the physiological variables, environmental influences and inconsistencies of the biological changes that would determine age of ossification in human bodies.

This study is an attempt to elicit the ages of ossification of long bone epiphyseal ends around elbow and the extent of its inconsistencies among young individuals of Chennai.

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Materials and Methods

Plain X-rays [1] of both elbow joints with antero-posterior and lateral views[2] of individuals with known age were studied for status of secondary ossification centres of lower end of Humerus and upper ends of Radius and Ulna. Radiological data was collected and the clinical records were back traced. A total of 50 samples were analysed in this cross-sectional study. The inclusion criteria was individuals of both sexes with definite date of birth (0-18 years of age). The exclusion criteria was cases with evidence of recent fractures, fracture in healing stage around the elbow joint including suspected epiphyseal injury, skeletal deformities on either side, preterm delivered new-borns, individuals with nutritional deficiencies or chronic illnesses. Age of appearance and fusion of the ossification centres around elbow viz. – capitulum, radial head, medial epicondyle, trochlea, olecranon, lateral epicondyle and status of conjoined epiphyses were recorded. Observations were entered into excel sheet and results derived. Results were then compared with Indian & foreign standards of age of ossification.

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Results

Of the samples collected, 21 were female and 29 were male. Age wise distribution of sample is given in the Table 1.

X ray appearance of secondary ossification centre for capitulum is observed as early as 1.5 years in female, 2 years in male, appearance is complete by 2 years in both sexes, and, non-appearance of capitulum is absent beyond 2 years of life. X ray appearance of secondary ossification centre for trochlea is observed as early as 8 years (7-8 years age group) in both males and females. Appearance is complete at 13-14 years in male. 50% of females in 11-12 years showed appearance. We observed that all cases in 17-18 years group show complete ossification centres (Tables 2).

X ray appearance of secondary ossification centre for lateral epicondyle is observed as early as 8 years (7-8 years age group) in females and 14 years (13-14 years age group) in males, appearance is complete by 17 years (17-18 years age group) in females and 14 years (13-14 years age group) in males (Tables 5). In females, percentage of appearance is 50 % at 11-12 years, but there is a lacuna of representation in 13-14- and 15-16-years group. For available sample data, appearance is complete in 17-

18 years group.

Ossification centres for capitulum, trochlea and lateral epicondyle fuse together to form conjoined epiphysis or composite epiphysis of lower end of Humerus as early as 11 years (11-12 years age group) in females and 14 years (13-14 years age group) in males and the formation is complete by 15-16-years in males, 17 18 years in females. Fusion (of conjoined epiphysis) with shaft is observed as early as 15-16 years in males, 17-18 years in females. Fusion process is complete at 19 years in males, but only 75% females show complete fusion at 17-18 years and 25 % show open conjoined epiphysis, after which no representation is available (Table 6).

X ray appearance of secondary ossification centre for medial epicondyle is observed as early as 4 years (3-4 years group) in females and 7 years in (7-8 years group) males, and appearance is complete after 7 years (7 to 8 years group) in females and after 8 years (9 to 10 years) in males. Centre of medial epicondyle fuses with Humerus shaft as early as (11-12 years group) in females and 16 years (15-16 years group) in males. Open medial epicondyle is observed up to 17 years in females and 18 years in males. Fusion is 100% complete at 19 years in males, whereas fusion is 75 % complete at 17-18 years group in females (Table 7).

X ray appearance of secondary ossification centre for olecranon is observed as early as 8 years (7-8 years group) in females and 10 years (9-10 years group) in males, appearance is complete by 8 years (7-8 years group) in females and 11 years (11-12 years group) in males. Centre of olecranon process of Ulna epicondyle fuses with Ulna shaft as early as 17 years (17-18 years group) in females and 16 years (15-16 years group) in males.

Figure 1: Secondary ossification centre for capitulum (appeared, open / not fused)

Figure 2: Secondary ossification centres for capitulum, medial epicondyle, radial head (appeared, open / not fused)

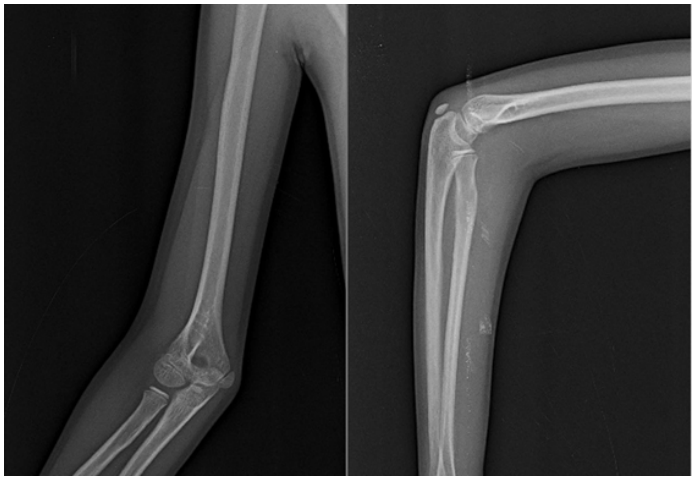

Figure 3: Secondary ossification centres for capitulum, trochlea, medial epicondyle & olecranon process (appeared, open / not fused)

Figure 4: Secondary ossification centre for olecranon (appeared, open / not fused)

Figure 5: All secondary ossification centres around elbow joint (fused)

Table 1: Age wise distribution of the study population

Age group	n	%
0 to 2 years	3	06 %
3 to 4 years	11	26 %
5 to 6 years	4	06 %
7 to 8 years	7	12 %
9 to 10 years	5	12 %
11 to 12 years	5	08 %
13 to 14 years	3	06 %
15 to 16 years	3	06 %
to 18 years	7	14 %
19 years	2	04 %

Table 2: Age of ossification for trochlea

Age group	Sex	n	Appearance	Fused
0 to 2 years	Male	NA	NA	NA
	Female	3	0	0
3 to 4 years	Male	6	0	0
	Female	5	0	0
5 to 6 years	Male	2	0	0
	Female	2	0	0
7 to 8 years	Male	5	1	0
	Female	2	1	0
9 to 10 years	Male	3	1	0
	Female	2	2	0
11 to 12 years	Male	3	0	0
	Female	2	1	0
13 to 14 years	Male	3	3	0
	Female	NA	NA	NA
15 to 16 years	Male	3	3	3
	Female	NA	NA	NA
17 to 18 years	Male	3	3	2
	Female	4	4	3
19 years	Male	2	2	2
	Female	NA	NA	NA

Open olecranon process is observed up to 17 years in females and 16 years in males. Fusion is complete after 16 years (15-16 years group) in males and fusion process is completed in only 75 % of cases in 17-18 years group (Table 8).

X ray appearance of secondary ossification centre for radial head is observed as early as 3 years (3-4 years group) in females and 5 years (5-6 years group) in males, appearance is complete by 7 years (7-8 years group) in females and 6 years (5-6 years group) in males. Centre of radial head fuses with radial shaft as early as 17 years (17-18 years group) in females and 16 years (15-16 years group) in males. An open radial head is observed up to 17 years (17-18 years group) in females and 14 years (13-14 years group) in males. Fusion is complete after 16 years (15-16 years group) in males and fusion process is completed in only 75 % of cases for 17-18 years group in females (Table 9). Figures 1-5 represent the various stages in the fusion process.

Table 3: Age of ossification for lateral epicondyle

Age group	Sex	n	Appearance	Fused
0 to 2 years	Male	NA	NA	NA
	Female	3	0	0
3 to 4 years	Male	6	0	0
	Female	5	0	0
5 to 6 years	Male	2	0	0
	Female	2	0	0
7 to 8 years	Male	5	0	0
	Female	1	1	0
9 to 10 years	Male	3	0	0
	Female	2	0	0
11 to 12 years	Male	3	0	0
	Female	2	1	1
13 to 14 years	Male	3	3	0
	Female	NA	NA	NA
15 to 16 years	Male	3	3	3
	Female	NA	NA	NA
17 to 18 years	Male	3	2	2
	Female	4	4	3
19 years	Male	2	2	2
	Female	NA	NA	NA

Table 4: Age of ossification for conjoined epiphysis

Age group	Sex	n	Appearance	Fused
0 to 2 years	Male	NA	NA	NA
	Female	3	0	0
3 to 4 years	Male	6	0	0
	Female	5	0	0
5 to 6 years	Male	2	0	0
	Female	2	0	0
7 to 8 years	Male	5	0	0
	Female	1	0	0
9 to 10 years	Male	3	0	0
	Female	2	0	0
11 to 12 years	Male	3	0	0
	Female	2	1	0
13 to 14 years	Male	3	1	0
	Female	NA	NA	NA
15 to 16 years	Male	3	3	3
	Female	NA	NA	NA
17 to 18 years	Male	3	2	2
	Female	4	4	3
19 years	Male	2	2	2
	Female	NA	NA	NA

Table 5: Age of ossification for medial epicondyle

Age group	Sex	Total No. of cases	N	Fused
0 to 2 years	Male	NA	NA	NA
	Female	3	0	0
3 to 4 years	Male	6	0	0
	Female	5	1	0
5 to 6 years	Male	2	0	0
	Female	2	1	0
7 to 8 years	Male	5	4	0
	Female	1	1	0
9 to 10 years	Male	3	3	0
	Female	2	2	0
11 to 12 years	Male	3	3	0
	Female	2	2	1
13 to 14 years	Male	3	3	0
	Female	NA	NA	NA
15 to 16 years	Male	3	3	2
	Female	NA	NA	NA
17 to 18 years	Male	3	3	1
	Female	4	4	3
19 years	Male	2	2	2
	Female	NA	NA	NA

Table 6: Age of ossification for olecranon

Age group	Sex	Total No. of cases	N	Fused
0 to 2 years	Male	NA	NA	NA
	Female	3	0	0
3 to 4 years	Male	6	0	0
	Female	5	0	0
5 to 6 years	Male	2	0	0
	Female	2	0	0
7 to 8 years	Male	5	0	0
	Female	1	1	0
9 to 10 years	Male	3	1	0
	Female	2	1	0
11 to 12 years	Male	3	2	0
	Female	2	2	0
13 to 14 years	Male	3	2	0
	Female	NA	NA	NA
15 to 16 years	Male	3	3	2
	Female	NA	NA	NA
17 to 18 years	Male	3	2	2
	Female	4	4	3
19 years	Male	2	2	2
	Female	NA	NA	NA

Table 7: Age of ossification for radial head

Age group	Sex	Total No. of cases	N	Fused
0 to 2 years	Male	NA	NA	NA
	Female	3	0	0
3 to 4 years	Male	6	0	0
	Female	5	2	0
5 to 6 years	Male	2	2	0
	Female	2	1	0
7 to 8 years	Male	5	5	0
	Female	1	1	0
9 to 10 years	Male	3	3	0
	Female	2	2	0
11 to 12 years	Male	3	2	0
	Female	2	2	0
13 to 14 years	Male	3	3	0
	Female	NA	NA	NA
15 to 16 years	Male	3	3	3
	Female	NA	NA	NA
17 to 18 years	Male	3	3	3
	Female	4	4	3
19 years	Male	2	2	2
	Female	NA	NA	NA

Discussion

Secondary ossification centres follow an approximate biological time scale. Their radiological appearance, simply referred as to 'appearance' of centre and its fusion with body of the bone, simply referred as 'fusion' of centre is used to assess biological age with a range of +/- 1 to 2 years. This technique is useful from birth till 21 to 22 years. By that time the last secondary ossification centre fuses in clavicle. Bone growth is influenced by sex hormones, nutrition, environmental factors like temperature, life style of the individual etc. Crowder[3], Koc[4], Loder[5] conducted independent studies on ossification patterns and age assessment from it. These three investigators in recent times insisted on having separate age standard scale of ossification for separate regions. Koc[4] and Loder[5] went one step ahead and insisted on reviewing the existing age standard scales from time to time. A Cross sectional sample attending Govt. Medical College Hospital, Omandurar Govt. Estate, Chennai between February 2018 and December 2018 were selected for the study. With due Institutional Ethics Committee approval, the study was initiated. Apparent healthy individuals comprised the study population. Even with the advent of computed tomography and sonographic views of articular surfaces, plain radiograph is still a gold standard technique to visualise ossification centres. [1] Antero-posterior (AP) and lateral views of both elbows were X-rayed. For antero-posterior view the elbow should be fully extended with the forearm supinated allowing optimal visualization of the medial and lateral epicondyles, [2] for lateral view the elbow should be in 90°flexion and the forearm in neutral (thumb up) position to visualize olecranon and radial head. Both sides were separately studied. Male and female participants were separately studied. After due analysis, both right and left sides of an individual showed same ossification status, hence further analysis and discussion were limited to right side X ray films.

Radiologically visible ossification centre was marked as 'Appeared'; when there was no radiolucent space between shaft and epiphyseal centre making a continuous periosteum on epiphyses and diaphysis, it is regarded as 'Fused'. If radiolucent space is visible between the ossification centre and its corresponding shaft of fusion, it is regarded as 'Open' / 'Non-Fused.' For practical purposes, signs of recent union is considered as 'Fused' and presence of a notch at the periphery of epiphysis is considered to be 'Open' / 'Non-Fused'. When the capitulum ossification centre was visible on X-ray, appearance was observed as early as 1.5 years in females, 2 years in males, appearance is 100 % complete by 2 years in both sexes, and, non-appearance of capitulum is absent after 2 years of age. These findings are in accordance with the accepted standards since there is only negligible difference in documented age of ossification with respect to capitulum.

X-ray appearance of secondary ossification centres for trochlea is completed by 13-14 years in males. 50% of females in the 11-12 years age group showed appearance of fusion centres and 100 % of females in 17-18 years showed appearance. Appearance age is contrary to the results by Miyazaki wherein the documented age is 5-11 years.[6] Nandy reported an age of 9-10 years in females and 10-11 years in males[7], 11 years was the documented age by Parikh[8] and Umadethan[9], Biswas noted an age of 9-10years[10], Rao reported an age of 9-11 years[11], Vij recorded the age as 9-11 years[12], Reddy as 9-11 year[13], and Aggrawal as 10 years.[14] X-ray appearance of secondary ossification centre for lateral epicondyle is completed by 17-18 years of age in females and 13-14 years of age in males. These results are closer to the studies by Miyazaki who reported an age of 8-13 years[6], Nandy who obtained an age of 10-12 years in female and 11-13 years in male in his study[7], Umadethan with 13 years as the documented appearance age[9], Biswas with 10-11 years[10], Rao observed appearance at 11 years[11], Vij[12], Reddy[13] and Aggarwal[14] at 11 years. Ossification centres for capitulum, trochlea and lateral epicondyle develop individually and unite to form conjoined epiphysis or composite conjoined epiphysis. Formation of conjoined epiphysis was observed first at 11-12 years in females, 13-14 years in males and fusion with shaft is completed in 100 % sample by the age of 17-18 years in females and before 19 years male. The results for fusion age is in agreement with the studies by Gupta[15], Singh[16] and Paterson.[17] Fusion age is contrary to results of the studies by Basu and Basu[18], Pillay[19], Hepworth[20], Gaulstaun[21], Lal and Townsend[22], Lal and Nat[23], Sangma[24], Jnanesh[25], Bhise[26], Nemade et al.[27], Gaddewar and Meshram[28], Sidhom and Derry[29], Barrett[30], Ledger and Wasson[31], Frazer[32] and Gray.[33]

X ray appearance of secondary ossification centre for Medial Epicondyle is complete after 7-8 years in females and after 9-10 years in male. Centre of medial epicondyle fuses with Humerus shaft as early as 11-12 years in females and 15-16 years in males and open medial epicondyle is observed up to 17 years in females and 18 years in males. Fusion was completed in 100% of the sample at 19 years in males, whereas fusion is 75% complete by 17-18 years in females. Appearance age is contrary to the results by Miyazaki[6], Nandy[7], Parikh[8], Galstaun[21], Umadethan[9], Biswas[10], Rao[11], Vij[12], Reddy[13], Aggrawal.[14] Fusion age is along the results of studies by Gupta[15], Singh[16], Jnanesh[25], Gaddewar and Meshram[28], Paterson[17], Sidhom and Derry[29], Gray.[33] Fusion age is contrary to results of the studies by Gaulstaun[21], Aggrawal and Pathak[34], Sangma[24], Sahni and Jit[35], Pillay[19], Bhise[26], Nemade et al.[27], Ledger and Wasson[31], Frazer[32], Barrett.[30]

X ray appearance of secondary ossification centre for Olecranon is complete by 7-8 years group in females and 11-12 years in males. Centre of olecranon process of Ulna epicondyle fuses with shaft of ulna by 15-16 years in males and fusion process is completed in only 75% of cases by 17-18 years age group.

Appearance age is along the studies by Parikh[8], Miyazaki[6], Umadethan[9], Biswas[10], Rao[11], Vij[12], Reddy [13], Aggrawal[14], Galstaun.[21]

X-ray appearance of secondary ossification centre for radial head is complete by 7-8 years in females and 5-6 years in males. Centre of Radial head fuses with Radial shaft by 15-16 years in males and fusion process is completed in only 75% of cases by 17-18 years in females. Appearance age is along the studies by Miyazaki[6], Nandy[7], Umadethan[9], Biswas[10], Rao[11], Vij[12], Reddy[13], Aggrawal[14], but contrary to Gaulstan.[21]

Fusion is complete by 15-16 years in males, but only in 75% cases by 17-18 years in females. Fusion age is along results of the studies by Hepworth[20], Gupta[15], Galstaun[21], Bhise[26], Singh.[16] This is in contrast to the results by Basu and Basu[18], Lal and Townsend[22], Sangma[24], Lal and Nat[23], Sahni and Jit[35], Pillay[19], Paterson[17], Sidhom and Derry[29], Barrett[30], Ledger and Wasson[31], Frazer[32] and Gray.[33]

There was an incidental finding of Harris lines or lines of arrested growth is seen in a one year boy. The case was excluded from the study. Though the study is region specific, equal distribution of sample in all age groups was not done. Equal representation of both males and females in all groups with more sample size would be required to generalise the study result.

Conclusion

In biology, variation is the rule and consistency is often variable. To find the extent of inconsistencies further studies are being undertaken at our institution at present. On increasing the sample size and arriving at radiological skeletal age in varied districts of a state / nation, age estimation from X-rays could be updated for recent times and thus scientifically more useful for solving crimes and at instances in determining type of treatment.

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