

A STUDY OF OSSIFICATION OF HEADS OF 2ND TO 5TH METACARPALS IN FORENSIC AGE ESTIMATION IN THE KERALA POPULATION

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ABSTRACT: The current study aims to determine methods to determine age from ossification of heads of 2nd to 5th metacarpals in the Kerala population using 85 wrist X-Rays of children aged less than 5 years. ROC Curve analysis was the statistical tool employed in the study.

KEYWORDS: Age determination in the living, Forensic Age Estimation, Metacarpal, Head of Metacarpals, Kerala Data, Skeletal Change.

INTRODUCTION: In forensic setting along with secondary sexual characters, teeth eruption and other related changes; ossification data is considered to be a reliable indicator of age. Comprehensive approaches to age determination which use multiple indicators are taken as inherently superior to non-comprehensive methods^{1, 2}. There are differences between the timing of skeletal maturity between sexes and ethnic groups which also need to be taken into account while determining the age of a child.³

The legal standards of "preponderance of evidence" and "beyond reasonable doubt" require proof approaching 100% probability⁴. So the tests used in forensic age determination should predict the age with near 100% specificity under most circumstances. It should be kept in mind that in situations like testing whether a person is juvenile or not, higher sensitivity (rather than specificity) is warranted. So while devising the check lists for age determination (which are essentially diagnostic tests), specification sensitivity and specificity is essential.

This study attempts to devise a better test to determine the age of ossification of the centers of the heads of 2nd to 5th metacarpals as the data collated in a study conducted at Calicut^{5, 6} did not include the time of ossification of these centers under its purview.

MATERIALS AND METHODS: This study attempts to create diagnostic tests with high sensitivity and specificity. Wrist X-Rays of children aged less than five years taken in the period from January 2010 to June 2011 (18 month period) collected from the digital archives of Amrita Institute of Medical Sciences were used for the study. Since the X-Rays were taken for specific medical reasons, it included X-Rays of both hands; therefore, the study was not confined to one side. Differences in the ossification of centers between the right and left sides have been noted in literature⁷, but such difference was not considered in this study.

Those diagnosed with nutritional deficiency; genetic abnormalities; endocrine diseases; global developmental delay and those cases where stature fell below the 3rd percentile or went above 97th percentile were excluded from the study. The study was confined to residents of Kerala, Mahe and Lakshadweep.

There were some cases which were X-Rayed more than once. In such cases, the two X-Rays were considered as two cases if they were taken more than 6 months apart. In the present study,

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there was one such case in which two different X-Rays of the same child was taken 1 year and 16 days apart.

226 X-Rays were collected in all. Out of this, 156 X-Rays met the exclusion criteria and were discarded. The remaining X-Rays were read by two forensic medicine experts who did not have access to the chronological age. Five more cases were excluded because the positioning did not permit observation of all the centers covered in this study. After the multi tired exclusion process, only 85 X-Rays remained. These belonged to 43 boys and 42 girls (see Table 1).

Age Groups	Male	Female	Total
<6m	5	3	8
7m - 12m	9	10	19
13m - 18m	5	12	17
19m - 24m	8	6	14
25m - 30m	5	3	8
31m - 36m	2	2	4
37m - 42m	4	4	8
43m - 48m	1	2	3
49m - 54m	3	0	3
55m - 60m	1	0	1
	43	42	85

Table 1: Age and sex wise breakdown

The presence or absence of the ossification centers were recorded by the experts in separate work sheets. Stage 0 of the five stage classification system devised by Schmeling et al.⁸ was taken as absence of ossification and stages 2 and 3 were considered as presence of the center. Stages 4 and 5 were not encountered in the present age group.

As per the 'Kerala data'⁹ (the data used for forensic age determination widely in Kerala), the four centers under the purview of this study appear after 2 years, but before 4 years. This is at considerable variance with studies conducted in other parts of the country (Table 2). 'Kerala Data' does not give different values for males and females for the ossification centers studied.

Ossification data		Appearance of heads of 2 nd to 5 th Metacarpals
The Data currently used in Keala ⁹		2-4 years
Gaulston ¹⁰ (Bengalis)	♀	2-3 years
	♂	3-4 years
Bajaj et al 1967 Delhi mixed population ⁶	♀	1.6 (+/-0.8)
	♂	1.07 (+/-0.8)
Present study	2 nd	330 – 643 days (11 – 22 months)

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	3 rd	330 – 800 days (11 – 27 months)
	4 th	330 – 1101 days
	5 th	(11 – 37 months)

Table 2: Comparison of Kerala Data with studies from other parts of the country as well as the present study.

In the present study, we have attempted to formulate age cutoffs to be used for forensic age determination with maximum sensitivity (for the lower limit) and maximum specificity (for the upper limit). The statistical tool used was ROC curve analysis.

RESULTS: Even though 10 out of 14 districts in Kerala as well as union territories Mahe and Lakshadweep were represented in the study, a disproportionately large number of cases were from the Ernakulum and surrounding districts. 61 out of 85 cases (71.8%) were from Ernakulam, Thrissur and Kottayam districts. Four districts (Thiruvananthapuram, Malappuram, Wayanad and Kannur) were not represented in the study at all.

Studies in other states of India such as Bengal (Galstaun) has given the same age range of 2 – 4 years, but as per that study, the lower half of the age range (2-3 years) is when the centers ossify in females, but in male children, the centers ossify during the upper half of the age range (3 – 4 years)¹⁰. A study conducted in delhi gave an age range of 1.6+/-0.8 years for females and a lower age range of 1.7+/-0.8 years for males⁶ (Table 2).

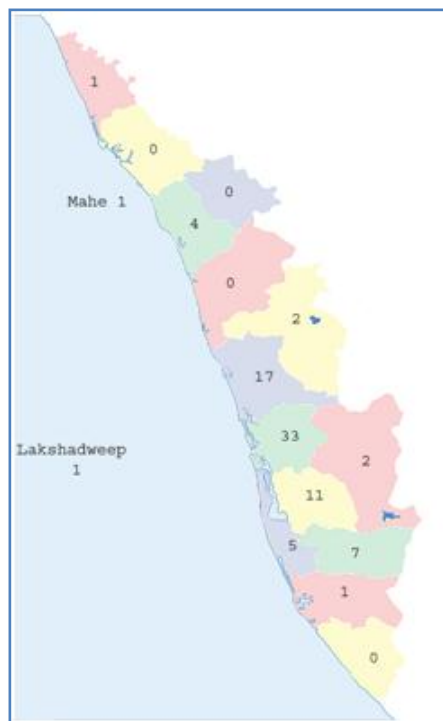


Fig. 1

Distribution of cases: Note that even though cases are concentrated around Ernakulum district, 10 out of 14 districts in Kerala as well as Mahe and Lakshadweep are represented.

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In the present study, the earliest age at which any of the centers had appeared was 1 year 1 month and 2 days (Figure 2). The oldest child whose wrist X-Ray did not show any of the centers was aged 1 year 9 months and 2 days.

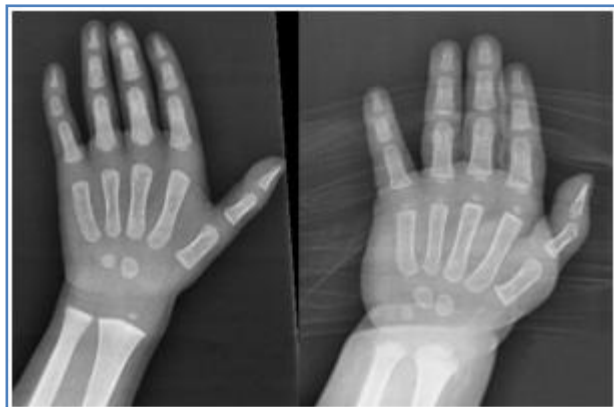


Fig. 2

The image on the left shows the oldest individual X-Ray in which ossification has not commenced for 2nd to 5th metacarpal heads (age: 1 year 9 months and 2 days). The image to the right shows the X-Ray of the youngest individual where all four metacarpal heads are radiologically visible (age: 1 year 1 month and 2 days).

There were 5 individual X-Rays in this group in which some of the centers under the purview of the study had showed beginning of ossification, but some hadn't (see Figure 3) The general trend observed was for the head of 2nd metacarpal to ossify first and the 5th to ossify last. The oldest individual who showed beginning of ossification of some of the heads, but where some heads of metacarpals were not ossified was aged 3 years.



Fig. 3

The image on the left shows that ossification has begun for the head of the 2nd metacarpal (age: 1 year 6 months and 4 days). The central image shows commencement of ossification for 2nd and 3rd metacarpals (age: 1 year 9 months and 25 days). The image to the right shows ossification of 2nd, 3rd and 4th metacarpals (age: 1 year 2 months and 4 days).

ROC curve was plotted for each of the centers (Figure 4). From the co-ordinates of ROC curve (Table 3), it can be seen that the age cutoff with the maximum sensitivity for appearance of 2nd to 5th metacarpal heads is the same, (330 days \cong 11 months). In the setting of forensic age estimation, if the heads of any of these centers has appeared, we can predict that the age is above 11 months.

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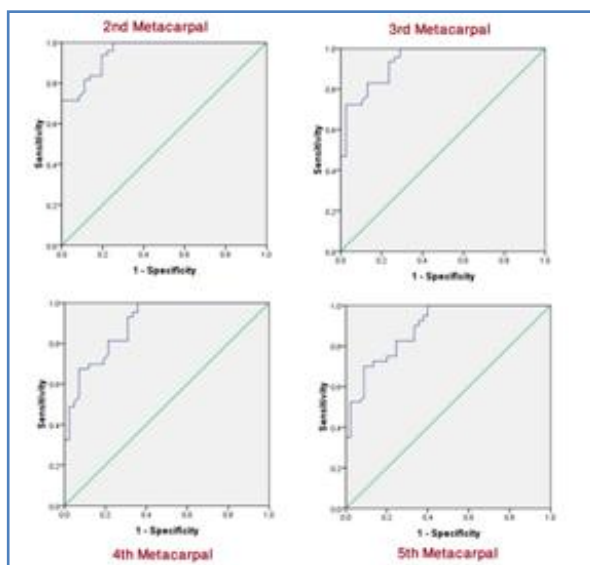


Fig 4

ROC curve for the appearance of the head of 2nd to 5th metacarpals.
Diagonal segments are produced by ties.

For the non-commencement of ossification of head of 2nd metacarpal, the age cutoff which gives maximum specificity is 643 days (\cong 22 months). If the 3rd metacarpal head has not started ossification yet, the age cutoff which gives maximum specificity is 800 days (\cong 27 months). For 4th and 5th metacarpal heads, the age cutoff which gives maximum specificity is the same (1101 days \cong 37 months) (Table 3). For converting the cutoffs in days to months (Table 2), the upper cutoffs were rounded up to the next complete months to preserve 100% specificity.

Positive if age (in days) is \geq	Head of 2 nd Metacarpal		Head of 3 rd Metacarpal		Head of 4 th Metacarpal		Head of 5 th Metacarpal	
	Sensi- tivity	Speci- ficity	Sensi- tivity	Speci- ficity	Sensi- tivity	Speci- ficity	Sensi- tivity	Speci- ficity
325.50	1.000	0.694	1.000	0.658	1.000	0.595	1.000	0.556
330.00	1.000	0.722	1.000	0.684	1.000	0.619	1.000	0.578
400.50	0.980	0.750	0.979	0.711	0.977	0.643	0.975	0.600
428.00	0.939	0.806	0.936	0.763	0.930	0.690	0.925	0.644
464.00	0.837	0.806	0.830	0.763	0.814	0.690	0.825	0.667
491.50	0.837	0.861	0.830	0.816	0.814	0.738	0.825	0.711
512.00	0.816	0.889	0.830	0.868	0.814	0.786	0.825	0.756
537.00	0.776	0.889	0.787	0.868	0.767	0.786	0.775	0.756
570.50	0.755	0.889	0.766	0.868	0.744	0.786	0.750	0.756
599.00	0.735	0.917	0.745	0.895	0.721	0.810	0.750	0.800
607.50	0.714	0.917	0.723	0.895	0.698	0.810	0.725	0.800
621.00	0.714	0.944	0.723	0.921	0.698	0.833	0.725	0.822
634.00	0.714	0.972	0.723	0.947	0.698	0.857	0.725	0.844

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643.00	0.714	1.000	0.723	0.974	0.698	0.881	0.725	0.867
654.00	0.694	1.000	0.702	0.974	0.674	0.881	0.700	0.867
670.50	0.653	1.000	0.660	0.974	0.674	0.929	0.700	0.911
702.50	0.571	1.000	0.574	0.974	0.581	0.929	0.600	0.911
727.50	0.551	1.000	0.553	0.974	0.558	0.929	0.575	0.911
756.50	0.531	1.000	0.532	0.974	0.535	0.929	0.550	0.911
779.00	0.490	1.000	0.489	0.974	0.512	0.952	0.525	0.933
787.50	0.469	1.000	0.468	0.974	0.488	0.952	0.525	0.956
800.00	0.449	1.000	0.468	1.000	0.488	0.976	0.525	0.978
808.50	0.429	1.000	0.447	1.000	0.465	0.976	0.500	0.978
838.00	0.408	1.000	0.426	1.000	0.442	0.976	0.475	0.978
934.00	0.388	1.000	0.404	1.000	0.419	0.976	0.450	0.978
1006.00	0.367	1.000	0.383	1.000	0.395	0.976	0.425	0.978
1053.00	0.327	1.000	0.340	1.000	0.349	0.976	0.375	0.978
1081.00	0.306	1.000	0.319	1.000	0.326	0.976	0.350	0.978
1101.00	0.286	1.000	0.298	1.000	0.326	1.000	0.350	1.000
1106.50	0.265	1.000	0.277	1.000	0.302	1.000	0.325	1.000

Table 3: Co-ordinates of ROC curve for appearance of the heads of 2nd to 5th metacarpals.*

* (The table starts at 325.5 days instead of the smallest cut of value is the minimum observed test value minus 1. The table is truncated at 1106.5 instead of 1746 which is the maximum observed test value plus 1). The age range of ossification of all four centers starts at 330.00 days. The upper age limit of ossification for the head of the 2nd metacarpal is 643 days; for the 3rd metacarpal, it is 800 days; for the 4th and 5th metacarpals, it is 1101 days (the cutoffs which limit the age range is highlighted).

DISCUSSION: Like the other ossification centers in the body, the ossification of the bony centers of hands and wrist is also subject to a lot of variation¹¹. It is important that this is taken into consideration when tests are devised for forensic age determination.

In the present study, the age range was is closer to the Delhi study⁶ since both the studies observed that ossification of the metacarpal heads starts at ages below 2 years. The 'Kerala Data'⁹ and the Bengal data¹⁰ on the other hand suggests that (Table 2) ossification starts at ages above 2 years.

The 'Kerala Data'⁹ does not take into account the sexual differences for appearance of the heads of metacarpals. It was also not considered in the present study. Further studies to look into this aspect is warranted.

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