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Evaluation of Skeletal Maturation in Lingayat Children

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Abstract:

Background: The success of orthodontic treatment depends on the time at which treatment is planned, which further depends on parameters like skeletal maturation.

Materials and Methods: The study sample included 110 boys and 110 girls of Lingayat community, aged 11-13 years. For all the subjects, left hand and wrist radiographs, chronological age, height, weight, and date of onset of menarche nine for girls were recorded.

Results: Both Lingayat boys and girls showed advanced skeletal age (SA) than chronological age and were found to mature earlier than the standard British and the Australian (Melbourne) population. Lingayat girls had a mean of 4 months advanced SA than the Lingayat boys.

Conclusion: Our study can act as standard indicator for assessing skeletal maturity on which timing of orthodontic treatment can be planned.

Key Words: Bone age, cervical spine, hand wrist radiographs, orthodontics, skeletal maturity

Introduction

Orthodontics primarily involves with the study of growth and development of the maxillofacial region. To prevent abnormalities in maxillofacial complex, one should know about the nature of skeletal maturation, as successful orthodontic treatment can be done during periods of growth spurts.[1]

Children of same chronological age may show different skeletal development. Physical growth of children is determined by parameters such as height, weight, dentition status, pubertal markers, and skeletal maturation. Skeletal maturation plays an important role in individual growth and development and it is influenced by genetic and acquired factors. These can be measured by some biometric tests and evaluated by comparing them with that of healthy subjects. Studies have shown that to assess skeletal maturity; cervical spine, frontal sinus can be used, but many authors prefer hand wrist complex.[1-3]

Hand wrist complex consists of 28-30 separate centers of bone growth and maturation, and this area is easy to take radiograph, hence generally used to assess skeletal maturation. Wrist bones develop in a clear pattern and experts have made an atlas of these bones in various stages and individual images are compared with this atlas. Orthodontists thus can predict the next growth spurt and make a treatment plan accordingly.[4]

Tanner suggested to develop standards for every pertinent population so that one can compare it that of intra or intergroup population. Various studies have been carried out to measure skeletal maturation among different races and also among persons of the same race. Since there are very few Indian studies, still we are using western standards for our treatment planning.[5,6] Lingayat is a major community in South India, especially in Karnataka state. We carried our study to assess skeletal maturity using cephalometry in Lingayats, and ours is the first such study in this community which has a major influence in South India.

Aims and objectives

1. To evaluate norms of skeletal maturation for Lingayat community in hand and wrist radiographs
2. To compare Lingayat norms with other population
3. To compare SA with chronological age.

Materials and Methods

The sample consisted of 110 boys and 110 girls of Lingayat community, well-nourished, aged 11-13 years, selected from schools in Bagalkot area, Karnataka, India. Hand wrist radiographs of the left hand were obtained as advocated by Tanner and white house (TW) method. Chronological age, height, weight, and date of onset of menarche were recorded. After taking consent, the left hand wrist radiographs of 220 children were taken.

Radiographic technique

Left hand and wrist radiographs were taken with palm facing downward in contact with the cassette and with the axis of the middle finger in direct line with the axis of the forearm. Upper arm and forearm were kept in the same horizontal plane. Palm was placed in such a way that the fingers did not touch each

other and the thumb was placed in the comfortable, natural degree of rotation with its axis making an angle of about 30° with the forefinger. The tube was centered above the head of the 3rd metacarpal. All the radiographs taken in this study were exposed, developed, and fixed under similar conditions to achieve uniformity in results.

Collection of data

In addition to the left hand and wrist radiograph, chronological age, height, weight, and date of onset of menarche were collected.

Chronological age was estimated from the date of birth of the child till the date on which radiograph was taken. Date of birth was collected from the school records and cross-checked by asking the student.

Height was measured without shoes, the child "standing straight" against an accurately calibrated vertical pole. Weight was measured with the child standing on weighing machine and without shoes. Female sample was asked whether menstrual cycle had started and the date of onset of menarche if yes.

Assessing the radiographs

Left hand and wrist radiographs were assessed for SA by TW method. Every bone undergoes certain progressive stages to reach maturity and this method matches bones with that of standard stages. Here, definite point score is assigned to each stage, and these scores are separately assigned for females and males. All the scores are added to give skeletal maturity score. SA was obtained by matching the maturity score to that of standard tables.

The bones examined in TW method were radius, ulna, metacarpals I, III, and V, proximal phalanges III and V, middle phalanges I, III, and V, capitate, hamate, triquetral, lunate, scaphoid, trapezium, and trapezoid.

We could derive three scoring systems:
1. Radius, ulna, and finger bones (RU),
2. Carpals only and
3. Both 1 and 2 combined.

Statistical analysis

Mean and standard deviations (SD) were used to measure the chronological age, bone-SA (B-SA), RU-SA, and carpal-SA. 95% confidence test was used for difference of means. 95% confidence limits were prepared (mean ± 2 SD) for the study population.

Formulae used for statistical analysis:

Mean $(X) = X_i/n$

$i = 1, 2, \ldots, n$

Standard deviation $(SD) = \sqrt{(X_i\text{-}X)/n}$

Standard error $(SE) = SD/\sqrt{n}$

95% CI (norms): X ± 2 SD

Results

Left hand and wrist radiographs of 20 males and 20 females randomly selected were reassessed after 3 months to calculate intraobserver error. Method error was calculated in the form of Cohen's kappa statistic for agreement.

$K = I_o - I_e / 1 - I_e$, values showed 0.80 agreement, method error was 0.20.

Mean chronological age in boys was compared with bone age, RU, and carpal bone age (Table 1). Statistically significant difference was found between chronological age and bone age and carpal bone age ($P < 0.001$), whereas difference between chronological age and RU bone age was insignificant.

Mean chronological age in girls was compared with bone age, RU, and carpal bone age (Table 2). Statistically significant difference was found between chronological age and RU and carpal bone age ($P < 0.001$), whereas the difference between chronological age and bone age was insignificant.

Table 3 shows the mean bone age and SD (± 2 SD) using 95% confidence limits for every 6 months of corresponding 11-13 years chronological age for both male and female Lingayat children.

Table 4 shows the mean RU-SA and SD (± 2 SD) using 95% confidence limits for every 6 months of corresponding 11-13 years chronological age for both male and female Lingayat children.

Table 1: Comparison of mean chronological age with the mean skeletal ages of bone, RU, and carpal in boys.

Comparison	Mean±SD	Difference
B-SA	10.98±1.31	−0.96±1.17
Chronological age	11.94±0.71	*P*<0.001
RU-SA	12.10±1.60	0.16±1.47
Chronological age	11.94±0.71	Not significant
Carpal-SA	10.15±1.12	−1.79±1.02
Chronological age	11.94±0.71	*P*<0.001

SD: Standard deviation, B-SA: Bone-skeletal age, RU-SA: Radius, ulna, and finger bones-skeletal age

Table 2: Comparison of mean chronological age with the mean B-SA, RU-RA, and carpal-SA in girls.

Comparison	Mean±SD	Difference
B-SA	12.20±1.00	0.19±1.08
Chronological age	12.01±0.64	Not significant
RU-SA	13.62±0.99	1.61±1.10
Chronological age	12.01±0.64	*P*<0.001
Carpal-SA	11.04±0.88	−0.97±1.00
Chronological age	12.01±0.64	*P*<0.001

SD: Standard deviation, B-SA: Bone-skeletal age, RU-SA: Radius, ulna, and finger bones-skeletal age

Table 5 shows the mean carpal-SA and SD (± 2 SD) using 95% confidence limits for every 6 months of corresponding 11-13 years chronological age for both male and female Lingayat children.

Table 6 shows the standards of height (in feet) and weight (in kg) of 110 Lingayat males with corresponding chronological age.

Table 7 shows the standards of height (in feet) and weight (in kg) of 110 Lingayat females with corresponding chronological age.

Comparison of chronological age between Lingayat, Australian, and British Norms in boys and girls showed more skeletal maturation in Lingayat children (Tables 8 and 9).

Table 3: B-SA and 95% CI for corresponding chronological age.

Chronological age	Boys		Girls	
	B-SA	95% CI (norms)	B-SA	95% CI (norms)
11	10.17	8.7-11.6	11.90	10.9-13.1
11½	10.60	9.2-12.0	12.05	10.7-13.3
12	11.02	9.6-12.5	12.30	11.0-13.5
12½	11.45	10.0-12.9	12.75	11.4-14.0
13	11.87	10.4-13.3	13.50	12.2-14.7

B-SA: Bone-skeletal age, CI: Confidence intervals

Table 4: RU-SA and 95% confidence intervals for corresponding chronological age.

Chronological age	Boys		Girls	
	RU-SA	95% CI (norms)	RU-SA	95% CI (norms)
11	11.25	9.8-12.6	13.45	12.2-14.7
11½	11.70	10.3-13.1	13.56	12.3-14.8
12	12.15	10.7-13.5	13.67	12.4-15
12½	12.60	11.2-14	13.78	12.5-15
13	13.05	11.6-14.4	13.89	12.6-15.2

RU-SA: Radius, ulna, and finger bones-skeletal age, CI: Confidence intervals

Table 5: Carpal-SA and 95% CI for corresponding chronological age.

Chronological age	Boys		Girls	
	Carpal-SA	95% CI (norms)	Carpal-SA	95% CI (norms)
11	9.48	8-10.9	10.59	9.3-11.9
11½	9.83	8.4-11.2	10.82	9.5-12.1
12	10.19	8.8-11.6	11.04	9.7-12.3
12½	10.55	9.1-11.9	11.26	9.9-12.5
13	10.90	9.5-12.3	11.49	10.2-12.7

SA: Skeletal age, CI: Confidence intervals

Table 6: Boys - Height and weight with corresponding chronological age.

Chronological age	Height	Weight
11	4.51	27.81
11½	4.56	29.61
12	4.60	31.40
12½	4.64	33.20
13	4.69	34.99

Table 7: Girls - Height and weight with corresponding chronological age.

Chronological age	Height	Weight
11	4.36	31.88
11½	4.49	32.42
12	4.63	32.96
12½	4.76	33.50
13	4.90	34.04

Discussion

Skeletal maturity is a dynamic process involving transformation of fetal membranous and cartilaginous skeleton to the fully ossified bones seen in adults. It is vital to know about skeletal development as it acts as a child developmental indicator and also based on its successful treatment planning can be done. Skeletal maturity status in orthodontics plays role in selection of the patients as well as treatment procedure.[1,7]

Hand wrist complex is the most common area used to assess skeletal maturity as many investigators assume that it represents general body skeletal changes, especially facial growth. Earlier, size of the shadows of bones in the radiographs was used to assess skeletal maturity, as the procedure was slow and inaccurate, not used nowadays. Inspectional method is used most commonly, which compares radiograph film with a series of films which represent various age groups.[8,9]

Skeletal maturity in hand wrist complex is assessed by two ways:[1,10,11]

1. Atlas method, which involves matching of a given film with a series of standard plates corresponding to progressive maturation levels of skeletal development at specified chronological ages (Greulich-Pyle [GP] method).
2. Bone specific method involves matching of individual bones on a film to a series of written criterion for standard stages of bone progression toward maturity (Tanner *et al*).

Tanner *et al.* gave a scoring method to determine skeletal maturity from hand wrist radiographs named it as TW method. Each stage in TW method indicates maturity status of bone and was given a particular score. This method was preferred to GP technique as it was bone specific and precise. Drawback of hand wrist radiographs is the additional radiation exposure to the patients.[11-13]

Radiographs of randomly selected 20 males and 20 females were reassessed by the same observer after 3 months to calculate method error in assessing maturity stages. In this study, intra observer error was calculated by reassessing the stages and not by reassessing the SA. We found 80% agreement, whereas Medicus *et al.*, Helm, and Taranger *et al.* reported 80.6%, 78.7%, and 83.5% of agreement, respectively.[10,12]

As our sample was prepubertal (11-13 years), RU-SA did not show significant difference with chronological age in boys, but

Table 8: Comparison of chronological age between Lingayat, Australian and British norms (boys).

Lingayat chronological age	Australian		Present study	
	Bone weight	Estimated chronological age (British norms)	Bone weight	Estimated chronological age (British norms)
11	337	11.5	363.0	12.2
11½			378.5	12.6
12	361	12	382.0	12.6
12½			405.0	13
13	400	13	429.0	13.4

Table 9: Comparison of chronological age between Lingayat, Australian, and British norms (girls).

Lingayat chronological age	Australian		Present study	
	Bone weight	Estimated chronological age (British norms)	Bone weight	Estimated chronological age (British norms)
11	838	11.0	930.2	12.6
11½			940.5	12.8
12	898	11.11	950	12.10
12½			955.2	13
13	960	13.2	980.7	13.9

showed a significant difference ($P < 0.001$) with chronological age in girls due to early acceleration. Our results coincide with that of Prakash and Cameron.[14]

Carpal-SA showed a significant difference ($P < 0.001$) with chronological age both in boys and girls. This difference might be due to the fact that carpal bones reach maximum velocity by 10-11 years in boys and 8-10 years in girls. Due to this early maturation of carpal bones, stages lasts for long time, so they are given a lower weight. Carpal-SA results of our sample showed less skeletal maturation. In this age range in Lingayat population, carpal bone should not be considered (for both boys and girls) in assessing skeletal maturity. This finding is an agreement with other studies such as Garn *et al.*[15]

Bone-SA showed a significant difference ($P < 0.001$) with chronological age in boys and no significant difference in girls. In TW method, Bone-SA bone score was one-half of the RU plus one-half of the carpal weights. This may be the reason that Bone-SA showed significant difference due to under rating of skeletal maturity of carpal bones in boys. Whereas, in girls, there was no significant difference, this could be due to more rating of SA for RU-SA and less rating of SA in carpal-SA. Our results coincide with that of Beunen *et al.*[16]

TW and Kealy suggested that the difference between RU and carpal bone ages might be of differential diagnostic significance in certain clinical cases.[5] Although RU-SA and B-SA appeared reliable method in assessing prepubertal Lingayat male and female children, respectively, we have established norms for all the three SAs in our sample for differential diagnosis. We have given standards of height and weight with corresponding chronological age for boys and girls (Tables 6 and 7), which we suggest to be used as standards in future for further studies.

Bone stages and their individual sequences are the same in all population. Rate of skeletal maturation reflects the inter action of genetic and environmental forces, just like rate of growth in height. Thus, populations differ both in mean skeletal maturity at a given age and in the pattern of increments age to age. Standards, therefore, have to be developed for each relevant population.[1-3]

Kimura suggested that skeletal maturity scores should be used rather than the SAs for comparing the skeletal maturity between different ethnic population. We compared chronological age of Lingayat standards, Australian standards, and British standards for girls with the help of bone weight scores. Australian standards showed very close relation with British standards. This finding coincides with Tanner *et al.* Whereas Lingayat children showed 6 months more skeletal maturation in boys and 12 months more skeletal maturation in girls than Australian (Melbourne) population and 11 months more skeletal maturation with British population. On average Lingayat girls are 4 months more mature than Lingayat boys. Our results coincide with the results of Prakash and Cameron which was done on Chandigarh population by TW method.[14,17,18]

We compared the SA in Lingayat population with that of Delhi population which was assessed by GP method. We found no difference in skeletal maturation in boys, but Lingayat girls showed 2 years and 5 months less skeletal maturation.[11-13]

Tanner *et al.* were of opinion that standards have to be developed for each relevant population. Since in most countries, children are growing up faster than 20 years ago, the skeletal maturity standards should be revised from time to time. To know exactly where the skeletal maturity of Lingayat population stands, more longitudinal studies and revised standards of skeletal maturity are needed.[5]

Skeletal stages showed close association with the onset, peak velocity and the end of the pubertal growth spurt. In Lingayat boys only MP3 - F stage is seen at 11.9 years and in Lingayat girls, stages appeared are S (Sesamoid bone of thumb) at 11.8 years, H.2 (Hook of Hamate) at 12.1 years, MP3 - G at 11.9 years, MP3 - H at 12 years, and DP3 - I at 12.2 years. In our study, date of birth was collected from school records and some Indian parents may record less age during admission. This could be a reason why four girls and one boy showed adult skeletal maturity score.

Appearance and ossification of stages of Lingayat girls and boys were compared with that of Swedish population and Australian population. MP3 - G, MP3 - H, and DP3 - I in girls showed more maturation than the Swedish and Australian population. But S (Sesamoid of thumb), hi and H2 (Hook of Hamate) showed less maturation than Swedish and Australian population. In boys, all the three MP3 - F, hi and H2 were less matured than Swedish and Australian population. This could be due to wide range of variability for the ossification timing of sesamoid bone, as it appears in girls between the 8th and 13th year and in boys between 10th and 16th year.[19-21] As our study was cross-sectional and consisted of age group of only 11 to 13 years, it was difficult to conclude the onset, peak, and end of pubertal growth spurt.

Since ours is the first such study on Lingayat community, we suggest for further studies on a larger sample with wider criteria to know exactly where the skeletal maturity of Lingayat population stands.

Summary and Conclusion

Skeletal maturity was assessed by TW on 110 Lingayat males and 110 Lingayat females of prepubertal age (11-13 years). We found that:

1. Both Lingayat boys and girls showed advanced SA than chronological age
2. Both Lingayat males and females are 11 months more matured than the standard British population
3. Lingayat males are 6 months and females are 12 months more matured than the Australian (Melbourne) population
4. Lingayat girls had a mean of 4 months advanced SA than the Lingayat boys.

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