The reliability of Fishman method of skeletal maturation for age estimation in children of South Indian population

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Abstract

Introduction: Determining the age of a person in the absence of documentary evidence of birth is essential for legal and medico-legal purpose. Fishman method of skeletal maturation is widely used for this purpose; however, the reliability of this method for people with all geographic locations is not well-established. **Aims and Objectives:** In this study, we assessed various stages of carpal and metacarpal bone maturation and tested the reliability of Fishman method of skeletal maturation to estimate the age in South Indian population. We also evaluated the correlation between the chronological age (CA) and predicted age based on the Fishman method of skeletal maturation. **Materials and Methods:** Digital right hand-wrist radiographs of 330 individuals aged 9-20 years were obtained and the skeletal maturity stage for each subject was determined using Fishman method. The skeletal maturation indicator scores were obtained and analyzed with reference to CA and sex. Data was analyzed using the SPSS software package (version 12, SPSS Inc., Chicago, IL, USA). **Results:** The study subjects had a tendency toward late maturation with the mean skeletal age (SA) estimated being significantly lowers ($P < 0.05$) than the mean CA at various skeletal maturity stages. Nevertheless, significant correlation was observed in this study between SA and CA for males ($r = 0.82$) and females ($r = 0.85$). Interestingly, female subjects were observed to be advanced in SA compared with males. **Conclusion:** Fishman method of skeletal maturation can be used as an alternative tool for the assessment of mean age of an individual of unknown CA in South Indian children.

Key words: Age estimation, chronological age, forensic radiology, hand-wrist radiograph, skeletal age

INTRODUCTION

Radiological images are essential tools in age determination in forensic science. However, this technique is also useful when a birth certificate is not available and records are suspected. Human beings show considerable variations during growth, but show certain patterns, which has led to the concept of assessing biological or physiological maturity. Accurate assessment of chronological age (CA) is provided by developmental stages such as skeletal maturation, secondary sexual characters and dental development. [1] The degree of skeletal development reflects the degree of physiological maturation, which is judged on the basis of degree of bone ossification.[2] Skeletal maturity is a measure of development basing on the size, shape and degree of mineralization of bone to define its proximity to full maturity and can be seen radiologically. The sequence of changes is relatively consistent for a given bone in every person. However, the timing of these changes varies because each person has his or her own biological clock.[3] The use of skeletal age (SA) has been shown to be more reliable and precise than CA

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in assessing the progress of an individual toward maturity. Skeletal maturity is influenced in each individual by a combination of genetic factors, environmental conditions, socio-economic status, nutrition and health status.[4,5] Skeletal maturation assessed on hand-wrist radiographs is classically considered as the best indicator of maturity and has been found to be closely related to the growth spurt.

Biological age, SA, bone age and skeletal maturation are nearly synonymous terms used to describe the stages of maturation of a person.[2] SA or bone age are the most common measure for biological maturation of the growing human and can be derived from the examination of successive stages of skeletal development as viewed in hand-wrist radiographs. This is currently the only available indicator of development that spans the entire growth period, from birth to maturity. The technique for assessing SA consists of visual inspection of bones, their initial appearance and their subsequent ossification changes in shape and size. Basically, three common approaches are used in the past to assess the hand-wrist radiographs. First was the atlas system involved the matching of a hand-wrist radiograph with a standard series of chronologically oriented radiographic images. A second assessment variation involved matching features of many individual bones and then assigning point scores to the stages revealed. Third method emphasized alteration in bony shapes and establishes ratios between linear measurements of the long bones of the hand and wrist; the grading of the indicators and ratios was then calculated to determine the SA.[6,7]

Fishman developed a system of skeletal maturation assessment based upon skeletal maturity indicators (SMI) demonstrated on hand-wrist radiographs for the assessment of the pubertal growth spurt. This sequence of events provides a methodological approach for identifying specific maturational stages that cover the entire adolescent period. The SMI is an organized and relatively simple way to observe skeletal maturity: It uses 11 anatomical sites on the phalanges, adductor sesamoid and radius, excluding the carpal bones.[4,5]

Objectives of this study

- To assess the maturation of carpal and metacarpal bones to estimate SA in young adults and adolescents at different ages
- To test the reliability of Fishman method for age determination in South Indian population
- To assess whether the estimated SA correlates with the CA.

MATERIALS AND METHODS

The study consisted of 330 randomly selected subjects (165 males and 165 females) aged 9-20 years, divided into 11 groups [Table 1]. Informed consent was taken from all the individuals participated and the study was approved by the ethical committee of GITAM Dental College and Hospital, Visakhapatnam, Andhra Pradesh, India. Patients with serious medical illness, history of trauma to hand and wrist region were excluded from the study.

Clinical examination of subjects was performed, patient details and date of X-ray was recorded. 330 right hand-wrist digital radiographs were taken with a Planmeca promax digital machine. CA of an individual was calculated by subtracting the birth date from the date on which the radiographs were exposed for that particular individual. Decimal age was taken for simplicity of statistical calculation and ages were estimated on a yearly basis (For example, 9 years 9 months as 9.09 years and it was considered in 9 years age group).To avoid observer bias, each digital hand-wrist of an individual was coded with only a numerical Identity number (1-330) to ensure that the examiners were blind to sex, name and age of subjects. Three examiners (one maxillofacial radiologist and two orthodontists) were given compact discs of images and instructed to complete staging for all images and relevant age for all individuals. To test intraexaminer reliability, each examiner unknowingly re-evaluated 20 of their images after 1 month.

Assessment of staging of skeletal maturation using SMIs from hand-wrist radiograph with Fishman method

To evaluate the maturational patterns of the indicators in the hand-wrist, Fishman's (1982)[5] eleven-grade system was used [Table 2]. Eleven discrete adolescent skeletal maturational indicators covering the entire period of adolescent development is found on these six sites [Figure 1]. A systematic observational scheme [Figure 2] was used to facilitate SMI evaluation. Referring with this approach, key stages were checked first. A useful first step was to determine the detection of adductor sesamoid of the thumb or alternatively presence of early epiphyseal widening rather than capping. If the sesamoid was visible,

Table 1: Distribution of the sample according to age and sex

Age	Males	Females	Total
9-9 years 11 months	15	15	30
10-10 years 11 months	15	15	30
11-11 years 11 months	15	15	30
12-12 years 11 months	15	15	30
13-13 years 11 months	15	15	30
14-14 years 11 months	15	15	30
15-15 years 11 months	15	15	30
16-16 years 11 months	15	15	30
17-17 years 11 months	15	15	30
18-18 years 11 months	15	15	30
19-20 years	15	15	30
Total	165	165	330

then either the sesamoid or an SMI based on capping or fusion was applicable. Skeletal maturity was converted in to SA by using specific tables [Table 3].[5,15]

Statistical analysis

Data was analyzed using the SPSS software package (version 12, SPSS Inc., Chicago, IL, USA).The significance of the difference between the means of different ages was determined using a paired sample *t*-test. Pearson's correlation between means of different ages was also calculated. Felli's Kappa statistics was performed to test interobserver variability.

RESULTS

The sample consisted of 165 males and 165 females whose ages ranged from 9 to 20 years. The SMI scores were obtained and analyzed with reference to CA and gender. In males, mean values of actual age did not differ significantly from mean values of age derived from hand-wrist in all age groups except in Groups 4, 6,7 ($P > 0.05$). In males, mean age for initiation of skeletal maturation commenced around 11.5 ± 0.5 years and completed around 16.9 years [Table 4] while in females mean age for initiation of skeletal maturation commenced around 10 years and completed at 16 years [Table 5] indicating females mature earlier than males [Graphs 1 and 2].

Significant inter and intra-observer correlation coefficient of 98.5% and 98% was observed [Tables 6 and 7 respectively]. Significant correlation was observed between CA and SA in females ($r = 0.85$) and

Table 2: Skeletal maturity indicators [Fishman]

Stages (SMI)	Description of hand-wrist maturation stage
1	The proximal phalanx of the third finger shows equal width of the epiphysis and diaphysis
2	The middle phalanx of the third finger shows equal width of the epiphysis and diaphysis
3	The middle phalanx of the fifth finger shows equal width of the epiphysis and diaphysis
4	Appearance of adductor sesamoid of thumb
5	Capping of the epiphysis of distal phalanx on the third finger
6	Capping of the epiphysis on the middle phalanx of the third finger
7	Capping of epiphyses of the middle phalanx on fifth finger
8	Fusion between the epiphysis and diaphysis of the distal phalanx on the third finger
9	Fusion between the epiphysis and diaphysis of the proximal phalanx of the third finger
10	Fusion between the epiphysis and diaphysis of the middle phalanx on the third finger
11	Fusion of the epiphysis and diaphysis seen in the radius

SMI: Skeletal maturation indicator

Table 3: Assessment of skeletal age from hand-wrist maturation stages

Skeletal maturation indicators	Males	Females
1	11.3	10.2
2	11.9	10.7
3	12.1	10.8
4	12.3	11.0
5	13.0	11.7
6	13.7	11.9
7	14.4	12.5
8	15.1	13.2
9	15.4	13.9
10	16.1	14.8
11	17.2	16.5

SM: Skeletal maturation

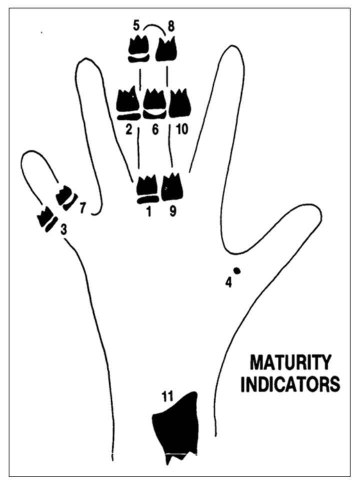


Figure 1: Eleven skeletal maturity indicators

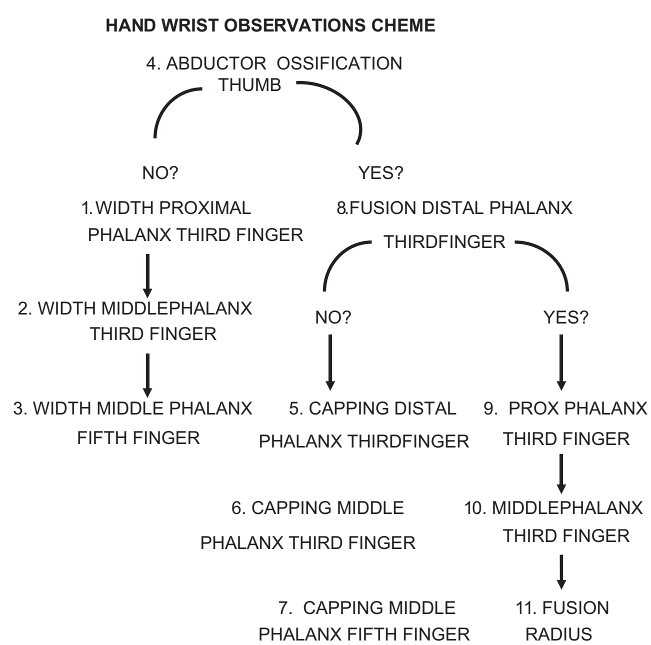


Figure 2: Observational scheme for assessing skeletal maturation indicator's on a hand-wrist radiograph

Table 4: Comparison between SA using the Fishman method and CA (in years) in males

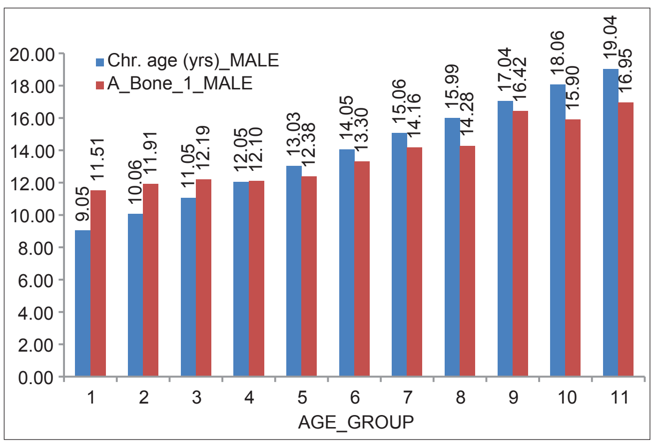
Group	Mean CA (±SD)	Mean SA (±SD)	Mean difference (SD)	95% CL	t-statistics (df)	*P* value
1	9.04 (0.014)	11.5 (0.49)	−2.46 (0.48)	−2.7-−2.1	−19.5 (14)	0.00
2	10.05 (0.039)	11.9 (0.63)	−1.84 (0.61)	−2.1-−1.5	−11.6 (14)	0.00
3	11.05 (0.028)	12.1 (0.79)	−1.14 (0.8)	−1.6-−0.6	−5.1 (12)	0.00
4	12.04 (0.023)	12.1 (0.69)	−0.05 (0.7)	−0.4-0.3	−0.28 (14)	0.78
5	13.03 (0.017)	12.3 (0.89)	0.65 (0.8)	0.16-1.15	2.8 (14)	0.01
6	14.04 (0.024)	13.3 (1.39)	0.74 (1.39)	−0.02-1.5	2.0 (14)	0.05
7	15.05 (0.028)	14.1 (2.12)	0.89 (2.11)	−0.2-2	1.64 (14)	0.12
8	16.05 (0.028)	14.2 (1.37)	1.76 (1.38)	1.02-2.5	5.09 (15)	0.00
9	17.04 (0.029)	16.4 (0.9)	0.62 (0.9)	0.11-1.13	2.62 (14)	0.02
10	18.05 (0.016)	5.9 (1.65)	2.15 (1.65)	1.27-3.04	5.2 (15)	0.00
11	19.03 (0.03)	16.9 (0.26)	2.08 (0.25)	1.9-2.2	31.2 (14)	0.00

SA: Skeletal age, CA: Chronological age, CL: Confidential limit

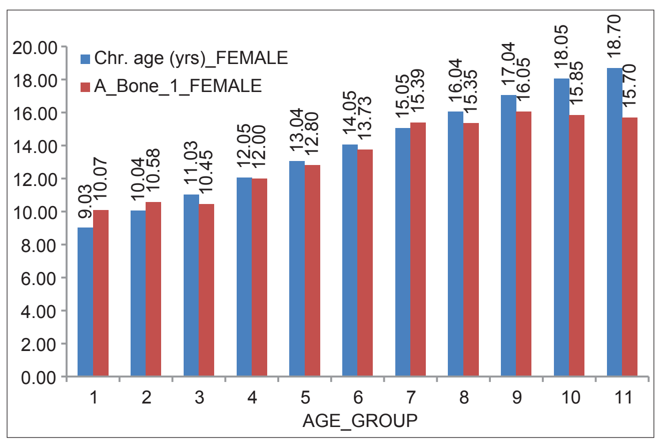
Table 5: Comparison between SA using the Fishman method and CA (in years) in females

Group	Mean CA (±SD)	Mean SA (±SD)	Mean difference (SD)	95% CL	t-statistics (df)	*P* value
1	9.02 (0.015)	10.07 (0.015)	−1.04 (0.02)	−1.0-−1.03	−160.1 (13)	0.00
2	10.03 (0.029)	10.5 (0.8)	−0.53 (0.78)	−0.9-−0.1	−2.72 (15)	0.01
3	11.03 (0.027)	10.4 (1.08)	0.58 (1.08)	0.0-−1.1	2.14 (15)	0.00
4	12.05 (0.019)	12.0 (2.2)	0.05 (2.21)	−1.17-1.28	0.09 (14)	0.92
5	13.04 (0.026)	12.6 (2.1)	0.41 (2.13)	−0.7-1.5	0.7 (15)	0.45
6	14.05 (0.029)	13.7 (1.83)	0.32 (1.82)	−0.69-1.3	0.67 (14)	0.5
7	15.05 (0.022)	15.3 (0.9)	−0.34 (0.95)	−0.87-0.1	−1.39 (14)	0.18
8	16.04 (0.03)	15.3 (0.9)	0.69 (0.98)	0.12-1.26	2.6 (13)	0.02
9	17.04 (0.028)	16.0 (0.0)	0.99 (0.02)	0.97-1.0	124.9 (12)	0.00
10	18.04 (0.02)	15.8 (0.76)	2.19 (0.76)	1.77-2.62	11.0 (14)	0.00
11	19.04 (0.027)	16.05 (0.00)	2.99 (0.02)	2.9-3.1	439.0 (15)	0.00

SA: Skeletal age, CA: Chronological age, CL: Confidential limit



Graph 1: Correlation between chronological age and skeletal age in males (Abbreviation: A Bone1 means skeletal age (X-axis – age group, Y-axis –Mean values)



Graph 2: Correlation between chronological age and skeletal age in females (Abbreviation: A Bone1 means skeletal age. (X-axis-age group, Y-axis –Mean values)

males (r = 0.82) [Table 8]. The reliability of intra and inter-examiner radiographic interpretation was indicated by the high correlation between readings recorded by the three different examiners.

Mean CA in males and females was 14 ± 3.3 years and 14 ± 3.2 years respectively. Mean SA was underestimated in both males (13.7 ± 1.9 years) and females (13.4 ± 2.3 years) compared with CA. Fishman method underestimated the mean age of males and females by 0.4 and 0.3 years respectively [Table 9].

DISCUSSION

The present study was conducted with an aim to assess the SA of an individual by interpretation of hand-wrist radiograph and to correlate it with CA in South Indian population. Many investigators[5,8-11] have delineated several specific ossification stages that occur before, at or after peak height velocity. The identification of these skeletal maturation levels provides a useful means of identification of specific points along the progressive path of adolescent growth. Hand-wrist radiographs are used to indicate

Table 6: Inter observer correlation (Cohen Kappa)

Three examiners	Observer 1	Observer 2	Observer 3
Observer 1	1	0.989**	0.987**
Observer 2	0.989**	1	0.988**
Observer 3	0.987**	0.988**	1

**Correlation is significant at the 0.01 level (2-tailed)

Table 7: Intraobserver correlation (Pearson)

Three examiners	A2	B2	C2
A1			
Pearson correlation	0.985	0.92	0.994
Significant (2-tailed)	0.004	−0.023	−0.002
B1			
Pearson correlation	0.902	0.982	0.917
Significant (2-tailed)	0.028	0.005	0.023
C1			
Pearson correlation	0.912	0.997	0.915
Significant (2-tailed)	0.025	0.001	0.024

A1, B1, C1: First reading by examiners 1, 2, 3: A2, B2, C2: Second reading by examiners 1,2,3

Table 8: Pearson correlation between SA and CA for females and males

Correlation between CA and SA	CA	Skeletal age (females)	Skeletal age (males)
Chronological age (years)			
Pearson correlation	1	0.852**	0.821**
Significant (2-tailed)		0.000	0.000
N		165	165

**Correlation is significant at the 0.01 level (2 failed). SA: Skeletal age, CA: Chronological age

Table 9: Descriptive statistics for the entire sample

Gender	Mean	Standard deviation	Standard error	95% confidence interval for mean	
				Lower bound	Upper bound
Chronological age (years)					
Males	14.04	3.31	0.99	11.81	16.26
Females	14.01	3.26	0.98	11.81	16.20
Total	14.02	3.21	0.68	12.60	15.45
Skeletal age					
Males	13.73	1.95	0.58	12.42	15.04
Females	13.45	2.37	0.71	11.85	15.04
Total	13.59	2.12	0.45	12.65	14.53

the stage of skeletal maturity and predict the onset of maximum pubertal growth. The coexistence of a large number of bony structures with distinct and yet predictable sequence of maturation has made hand-wrist radiographs a useful clinical tool to assess skeletal maturity.[12,13]

In this study, SA for each subject was assessed using hand-wrist radiograph according to the Fishman method.[4] This method offers an organized and relatively simple approach to determine the level of skeletal maturation from hand-wrist radiograph. We observed a significant difference between mean values of CA and SA in the entire sample indicating SA is advanced than CA. Our results are in concurrence with the previous reports[1,5,14-17] and suggest that South Indian children tend to be late maturers when CA is used as an index of skeletal maturity. Further our study indicated that females were advanced in skeletal maturation compared with males in all age groups, which is consistent with previous reports.[5,10,14-16,18-20]

In this study, when Fishman method of skeletal maturation was used to assess SA, mean difference between true and assessed age was found to be minimal for both males (0.4 years) and females (0.3 years). The simplicity of the Fishman method and the use of distinct and clear SMIs perhaps may have contributed to the high reproducibility of the readings in our study. Interestingly, significant correlation was observed between SA and CA in both males and females. Thus, SA assessment using Fishman method is a reliable technique for estimating age.

It is essential to note that in this study, the SA were derived from only a part of the skeleton, which may or may not be representative of whole skeleton and increased radiation exposure to an individual, which is further emphasized by International study Group on Forensic Age Diagnostics to consider alternative measures when necessary.[21] Importantly comprehensive age estimation should utilize all available methods when necessary, nevertheless hand-wrist maturation data compliments the individual maturational status to give a complete assessment of age.

CONCLUSION

Bones represent useful material for age estimation. Digital radiographic assessment of maturation of carpal and metacarpal bones can be used a reliable choice for predicting biological age. Fishman method of skeletal maturation can be reliably used to generate mean age and the estimated age range for an individual of unknown CA in South Indian population.

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