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EXPLORING HAND RADIOGRAPH OSSIFICATION PATTERNS IN ADOLESCENT FEMALES (14-16 YEARS) IN BAGALKOT CITY, KARNATAKA: A COMPREHENSIVE STUDY ON SKELETAL DEVELOPMENT

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Abstract

Background: Bone age, a valuable indicator of biological and structural maturity, often surpasses chronological age in significance. The hand and wrist radiograph is a prevalent modality for determining bone age, with forensic applications necessitating precise age estimation. **Aim & Objective:** This study delved into the ossification status at elbow and wrist joints in female adolescent. **Methods:** A radiological study of hand was conducted on total 100 girls of age group 14–16 years, healthy school-going girls in Bagalkot city district, Karnataka, India. **Results:** The radiographs were studied in detail and the findings were recorded. a cohort of 100 Our observations revealed that, by ages 14-16, all epiphyseal centers around the elbow joint, barring conjoint epiphyses, were undergoing fusion. Notably, by age 14, ossification around the elbow joint in girls reached 90% completion, culminating in full ossification by age 15. **Conclusion:** By the age of 14, girls typically exhibit complete fusion of the conjoint epiphysis, medial epicondyle, proximal end of the radius, and in 94% of cases, the proximal end of the ulna. Furthermore, by age 15, the distal end of the radius achieves complete fusion in 96% of girls, indicating advanced skeletal maturation.

Keywords: Ossification, Epiphysis, Forensic Age estimation, wrist joints, Radiograph.

INTRODUCTION

Bone, an intricately vascular and dynamic connective tissue, undergoes constant change and mineralization, showcasing a distinctive growth mechanism. The assessment of growing ends of long bones serves as a means to determine the age of the bone[1]. Accurate age determination holds significance in both general legal contexts, such as power of attaining maturity, and specific cases like homicides involving body mutilation or dismemberment, use of corrosive substances, or actions of fire. In situations where murder occurred long ago, and only skeletal remains are available, age determination becomes crucial[2]. In the living, it proves valuable for resolving various medico-legal issues. Precision is paramount, as errors in age estimation can lead to serious consequences, potentially resulting in a miscarriage of justice. While the eruption of teeth is a commonly preferred method, after the emergence of second molars at the age of 14, X-ray of bones becomes the sole

reliable method for age estimation. Age serves as a crucial identifier for individuals, particularly in cases lacking legal documentation, prompting authorities to enlist expert assistance for forensic age estimation. This task is especially challenging in countries like India, where despite birth registration laws, many births go unreported due to illiteracy and ignorance. Forensic practitioners face the essential responsibility of age estimation not only for the living but also for the deceased, playing a vital role in positive identification, particularly in mass disasters. The age group of 14-16 holds medico-legal importance in various cases involving juveniles in conflict with the law, child labor, sexual assaults, kidnapping, criminal responsibility, and sports. While medical opinions are sought in such cases, it's recognized that medical examinations provide age estimates within a range, as exact age determination is deemed impossible by higher courts[3].

Despite technological advancements, Forensic practitioners still cannot provide an exact age, with the judiciary acknowledging the ability to estimate only a range. Medical opinions on age are regularly sought in cases involving child labor, juveniles in conflict with the law, and sexual violence. Epiphyseal ossification, observed radiologically, is considered a reliable guide for age determination, but variations exist due to factors like race, geography, and climate[4]. The studies by various workers show that the factors like race, geography, climate, diet, heredity and endocrine factors do affect the physiological changes occurring at puberty. Appreciable variations have been recorded not only by workers from different countries but also by the workers from various provinces of Indian subcontinent. So it becomes an obvious necessity to have a local data for each population so that a doctor determining age and attending the court of law can give a fairly accurate range of age, thus helping in administration of justice. Through this study an attempt is made to know the status of ossification at elbow and wrist joints, in school girls between 14 -16 years age group in Bagalkot City Schools.

METHODOLOGY

Permission from the Institutional Ethics Committee was obtained. Informed consent was taken from the subjects after explaining the purpose and procedure of the study. A proforma was prepared to collect all relevant information from the subjects. This is Simple Random Sampling technique. The study was carried out involving 100 Girls of age group of 14-16 years from Basaveshwar English Medium High School, Bagalkot. These subjects were further classified into 50 females of 14 years age and 50 females of 15 years age. The inclusion criteria for the study encompassed healthy and normal girls aged between 14 and 16 years. Participants needed to have documentary evidence of their age, such as a birth certificate from the municipal authority or school records, and had to be born and raised in Bagalkot district. The exclusion criteria for the study included subjects with skeletal deformities, diseases, malformations, or injuries. Additionally, individuals with severe malnutrition, endocrine disorders, or chronic illnesses were excluded from participation.

Method of Collection of Data:

The 100 selected subjects were divided into two groups: the 14 years age group (14 to 15 years) and the 15 years age group (15 to 16 years). Each individual was assigned a unique code number from 1 to 100, ensuring that both the proforma and X-ray film of a subject shared the same number. Informed consent was obtained from all

participants after explaining the study's purpose and procedures. A questionnaire was administered to gather information on dietary habits, socio-economic status, and exercise habits, with socio-economic status determined using the Modified B.G. Prasad classification[5].

Physical Examination:

Standard height measuring instrument was used to measure the height in centimeters where the subject was asked to stand straight without footwear, heels together, shoulder, buttocks and heel touching the scale and subject looking straight. The weight was calculated in kilograms on the standardized weighing machine without footwear. For knowing the appearance and development of secondary sexual characteristics, the subjects were examined in a private room with cubicle curtain.

Radiological Examination:

The subjects were subjected to the X-ray examination of the elbow and wrist joints of right hand at the Department of Radiodiagnosis and Imaging, HSK Hospital, Bagalkot.The X-rays of the right Elbow and Wrist joints were taken in both anteroposterior (AP) view and lateral view using a factor of 50 KVP and 8 MAS. Care was taken for the centering of X ray tube over the epiphyses as it is quite easy to give ununited epiphyses the appearance of union by directing the cone of rays obliquely. Adequate precautions were taken to avoid unnecessary X-ray exposure of subjects by providing them Lead gown.

The Staging of Epiphyseal Union:

As the process of ossification starts, earliest appearance of epiphyses can be easily detected when it is no bigger than size of pin head. Its position can be recorded and its direction of spread can be watched.8 Keeping this in mind and taking into consideration stages of ossification as given by Galstaun (1930)[6], McKern and Stewart (1957)[7] and Kothari (1974)[8]; in the present study stages of ossification of epiphyses are noted as follows:

Stage 0: Not appeared - When epiphyseal cartilage did not begin to decrease in thickness.

Stage 1: Beginning - Epiphyseal cartilage begins to decrease in thickness.

Stage 2: Active - Thickness of epiphyseal cartilage was found to be reduced appreciably.

Stage 3: Advanced - When epiphysis started to fuse with the shaft and complete union was well underway.

Stage 4: Recent union- When epiphyseal cartilage was bony in architecture and density indistinguishable from the epiphysis and diaphysis in its surroundings but an epiphyseal line called an epiphyseal scar could still be appreciated.

Stage 5: Complete union with absence of epiphyseal scar.

Statistical Analysis:

The collected findings were organized into tables and subjected to statistical analysis using the SPSS software version 17.0. To enhance the interpretability of the results, comparisons were made with similar studies conducted in different regions of India

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and abroad. The statistical methods employed for analysis included percentages, mean calculations, the Chi-square test, and Fisher's exact test. These methods aimed to derive meaningful insights and identify any significant patterns or associations within the data.

RESULTS

For the purpose of comparison and analysis, equal number of females in each age group of 14 years (14 yrs+364 days) and 15 years (15 yrs+364 days) were selected for the present study. the distribution of study subjects according to socioeconomic status (SES), using the Modified B.G. Prasad Classification. The classification system divides the population into five classes, with Class I being the highest SES and Class V being the lowest SES.The majority of the study subjects (49%) belonged to Class II SES, followed by Class III SES (24%). Class I SES accounted for 22% of the subjects, and Class IV SES accounted for 25%. There were no subjects in Class V SES. In our study maximum (62%) of them were having mixed diet and 38% were vegetarian.

Table No 1: Ossification status around Elbow joint

Ossification Status	14-15 Years Girls		15-16 Years Girls		Total	
	n	%	n	%	N	%
Conjoint Epiphysis						
Stage 0	0	0	0	0	0	0
Stage 1	0	0	0	0	0	0
Stage 2	0	0	0	0	0	0
Stage 3	0	0	0	0	0	0
Stage 4	0	0	0	0	0	0
Stage 5	50	100	50	50	100	100
Total	50	100	50	100	100	100
Medial Epicondyle						
Stage 0	0	0	0	0	0	0
Stage 1	0	0	0	0	0	0
Stage 2	0	0	0	0	0	0
Stage 3	5	10	0	0	5	5
Stage 4	0	0	0	0	0	0
Stage 5	45	90	50	100	95	95
Total	50	100	50	100	100	100
Proximal end of Radius						
Stage 0	0	0	0	0	0	0
Stage 1	0	0	0	0	0	0
Stage 2	0	0	0	0	0	0
Stage 3	1	2	1	2	2	2
Stage 4	4	8	1	2	5	5
Stage 5	45	90	48	96	93	93
Total	50	100	50	100	100	100
Proximal end of Ulna						
Stage 0	0	0	0	0	0	0
Stage 1	0	0	0	0	0	0
Stage 2	0	0	0	0	0	0
Stage 3	1	2	0	0	1	1
Stage 4	2	4	0	0	2	2
Stage 5	47	94	50	100	97	97
Total	50	100	50	100	100	100

Table 1 presents the ossification status around the elbow joint in girls aged 14-15 years and 15-16 years. The table is organized into sections for different ossification stages (e.g., Conjoint Epiphysis, Medial Epicondyle, Proximal end of Radius, Proximal end of Ulna). I Table no.1 shows the ossification status around elbow joint among girls in 14 and 15 years age groups. Conjoint epiphysis was fused completely (Stage 5) to the lower end of humerus in all the 100 girls. So we can say that complete union of conjoint epiphyses with shaft of humerus in this area (Bagalkot city) is more likely to occur by 14-15 years of age group. The two age group are found to be significantly different with respect to ossification (p=0.02). Hence, in girls epiphyseal union of medial epicondyle in this area (Bagalkot city) takes place at 15-16 years.For the proximal end of radius, Stage 5 of epiphyseal union was seen in 45 subjects (90%) of 14 years age. 2% of 14 years age group girls had reached Stage 3 and 4 girls (8%) had reached Stage 4. In 15 years girls, 2% had Stage 3, 2% were in stage 4 and 48 subjects(96%) had Stage 5 (complete union).

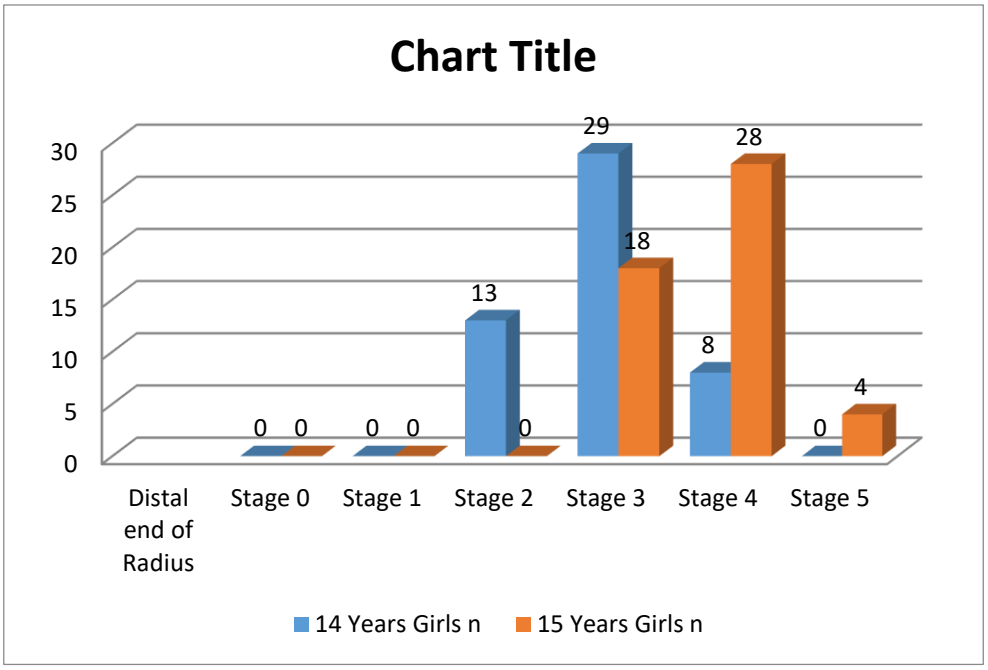
Since the two age groups are found to be similar with respect to ossification (p=0.24), it is concluded that complete union of proximal end of radius in this area occurs at 14-15years in girls of this region. Olecranon process or the proximal end of ulna was in Stage 3 in 2%, Stage 4 in 4% individuals and in Stage 5 in 94% of individuals of 14 years. Complete union was seen in all 50 girls (100%) of 15 years.

Since, the two age groups are found to be similar with respect to ossification (p=0.24) it can be said that complete ossification of proximal end of ulna does occur at 14-15 years among girls of this area.

Table No 2: Ossification status around Wrist joint in Girls

Ossification status	14-15 years Girls		15-16 years Girls		Total	
	n	%	N	%	n	%
Distal end of Radius						
Stage 0	0	0	0	0	0	0
Stage 1	0	0	0	0	0	0
Stage 2	13	26	0	0	13	13
Stage 3	29	58	18	36	47	47
Stage 4	8	16	28	56	36	36
Stage 5	0	0	4	8	4	4
Total	50	100	50	100	100	100
Distal end of ulna						
Stage 0	0	0	0	0	0	0
Stage 1	0	0	0	0	0	0
Stage 2	24	48	2	4	26	26
Stage 3	20	40	16	32	36	36
Stage 4	3	6	17	34	20	20
Stage 5	3	6	15	30	18	18
Total	50	100	50	100	100	100

Above table 2 shows the ossification status around wrist joint among girls in 14 and 15 years age groups. In 14-15 years girls, epiphyses for distal end of radius was in Stage 3 union among 58% of individuals while 26% individuals were in stage 2 and 16% were in Stage 4 union. None of the girl showed complete union (Stage 5). In the 15-16 years age group only 4 girls showed stage 5 of epiphyseal union while 56% of girls were still in the stage 4 and 36% were in stage 3 of epiphyseal union. It can be concluded that in girls complete union of distal end of radius in this area takes place at later age, more than 16 years.



Graph 1: Distribution of the study subjects according to the Ossification status At Distal end of Radius

Graph 1 shows for the distal end of ulna, at 14 years, 48% of the girls were in Stage 2 of union while 40% girls were observed in Stage 3 of epiphyseal union. At age 15, 34% of girls had epiphyses for distal end of ulna in Stage 4 of union and 32 % in Stage 3 while 30% of girls showed complete union. As 36% of all the girls were in Stage 3 and only18% in Stage 5 of epiphyseal union, it is concluded that complete fusion of distal end of ulna in this area takes place at later age, more than 16 years.

Styloid process of Ulna: in one girl of age group 14-15 years and two girls of age group 15-16 years had a separate ossicle representing the detached styloid process of the ulna was seen.

In subsequent tables used for statistical analysis, the ossification status categories were grouped as follows:

- Stage 0: Not appeared
- Stages 1 and 2 were combined as Active union
- Stages 3 and 4 were combined as Advanced union
- Stage 5: Complete union

Additionally, for socioeconomic status, Class I and Class II were combined as Upper class, while Class III, Class IV, and Class V were combined as Lower class for analytical purposes.

Table No 3: Factors affecting ossification of Conjoint epiphysis

	Ossification status of conjoint epiphysis				
	Not appeared (Stage 0)	**Active (Stage 1, 2)**	**Advanced (Stage 3,4)**	**Complete (Stage 5)**	**Total**
Age (for age, n×2= %)					
14-15 years	0	0	0	50	50
15-16 years	0	0	0	50	50
Total	0	0	0	100	100
Socioeconomic Status					
Upper class	0	0	0	73	73
Lower class	0	0	0	27	27
Total	0	0	0	100	100
Exercise					
Never	0	0	0	93	93
Daily	0	0	0	7	7
Total	0	0	0	100	100
Diet					
Veg	0	0	0	38	38
Mixed	0	0	0	62	62
Total	0	0	0	100	100

Above table 3 shows the association of different factors affecting the ossification of conjoint epiphysis. The two age group are found to be similar with respect to ossification. There is no representative of active, advanced union. All 100 girls (100%) showed complete union. There was no statistically significant association of exercise, diet and socioeconomic status with ossification of conjoint epiphysis.

Table No 4: Factors affecting ossification of epiphysis of Medial epicondyle

	Ossification status of medial epicondyle				
	Not appeared (Stage 0)	**Active (Stage 1, 2)**	**Advanced (Stage 3,4)**	**Complete (Stage 5)**	**Total**
Age (for age, n×2= %)					
14-15 years	0	0	5	45	50
15-16 years	0	0	0	50	50
Total	0	0	5	95	100
	Fisher exact test,		**p =0.02**		
Socioeconomic Status					
Upper class	0	0	3	70	73
Lower class	0	0	2	25	27
Total	0	0	5	95	100
	Chi square test=0.45		**p=0.5**		
Exercise					
Never	0	0	1	6	7
Daily	0	0	4	89	93
Total	0	0	5	95	100
	Chi square test=1.37		**p=0.24**		
Diet					
Veg	0	0	3	35	38
Mixed	0	0	2	60	62
Total	0	0	5	95	100
	Chi square test=1.08		**p=0.30**		

Table no.4 shows the association of the different factors affecting the ossification of medial epicondyle. The two age group are found to be significantly different with respect to ossification as shown by p value 0.02.There was no statistically significant association of socio-economic status, exercise and diet on ossification of medial epicondyle with p= 0.5, p= 0.24 and p= 0.30 respectively.

Table No 5: Factors affecting ossification of epiphysis of Distal end of Ulna

	Ossification status of distal end of ulna				
	Not appeared (Stage 0)	**Active (Stage 1, 2)**	**Advanced (Stage 3,4)**	**Complete (Stage 5)**	**Total**
Age (for age, n×2= %)					
14-15 years	0	24	23	3	50
15-16 years	0	2	33	15	50
Total	0	26	56	18	100
	Chi square test=28.4		**p = 0.0001**		
Socioeconomic Status					
Upper class	0	16	43	14	73
Lower class	0	10	13	4	27
Total	0	26	56	18	100
	Chi square test=2.34		**p=0.30**		
Exercise					
Never	0	22	55	16	93
Daily	0	4	1	2	7
Total	0	26	56	18	100
	Chi square test=5.61		**p=0.06**		
Diet					
Veg	0	12	21	5	38
Mixed	0	14	35	13	62
Total	0	26	56	18	100
	Chi square test=1.53		**p=0.46**		

Above table 5 shows the association of different factors affecting the ossification of distal end of ulna. The two age groups are found to be significantly different with respect to ossification as shown by p value = 0.0001.

There was no statistically significant association of Socio-economic status, exercise and diet on ossification of distal end of ulna with p= 0.30, p= 0.06 and p= 0.46 respectively as shown in table no.5.

DISCUSSION

Ossification of bones, teeth eruption and development of secondary sexual characteristics are influenced by various factors like geographical location, climate, diet, hereditary, socioeconomic status, habits, etc. There are considerable variations in development of these characteristics not only in different countries but also in different regions of the same country.

Until now, many workers around the world have done a lot of research regarding age estimation based on ossification of bones, eruption of teeth and pubertal changes. Most of the studies in past have taken into consideration one of these three criteria. Considerable discrepancy regarding the ages at which the different ossification centers fuse with their respective shafts is observed after perusal of these researches.

Particularly in multiethnic country like India, it is difficult to follow single standard data for determination of age for the entire country. There is no exhaustive data for the

Bagalkot city in regards to estimation of age in the age group of 14 – 16 years girls based on various parameters of age estimation, thus this study was undertaken including all three criteria together so that an effective age estimation could be given.

In 1895, Röntgen unearthed X-rays, introducing a ground breaking avenue for age estimation in living individuals. The swift integration of his discovery into forensic medicine ensued, initially categorizing ossification as either fused or not fused. However, recognizing the protracted nature of complete epiphyseal ossification, it became evident that delineating distinct stages would yield enhanced age correlation [9-14].

A substantial time interval is noticeable between the onset of ossification and the initiation of union. Leveraging this temporal gap holds the potential to enhance the precision of age estimation. In this study, we have incorporated six stages of ossification to account for this phenomenon[15].

In numerous international studies, the ossification age at the lower end of the radius and ulna generally exceeded 19 years, except for a German study where ossification was noted above 18 years. In Indian studies, the age of ossification at the lower end of the radius and ulna varied between 17 to 21 years, contingent on the region. In our current study, only 1% exhibited complete ossification at the lower end of the radius, and 2% at the lower end of the ulna, suggesting that full union in this region likely occurs after the age of 16[16-25]. Unfortunately, the precise age range for epiphyseal union in this area couldn't be determined due to limitations in the age range of the study groups.

In the present study medial epicondyle was found to be fused with the shaft of the humerus in 90% of girls aged between 14-15 years and in 100% of girls aged between 15-16 years. Hence it is concluded that age of fusion of medial epicondyle in girls is by 15-16 yrs.

Comparing with other Indian studies, our observations were consistent with the study by Galstaun[6] in Bengal, where 76.4% girls of 14-15 yrs and 100% girls of 15-16 years had their medial epicondyle completely fused.

CONCLUSIONS

By the age of 14-16 years fusion of all epiphyseal centres around the elbow joint is completed in females of this region. While distal end of radius and distal end of ulna are not completely united. Epiphyseal union is not affected by factors like socio-economic status, exercise and diet.

Limitation

This study was limited by its small sample size, which means that the results may not be generalizable to the wider population. Therefore, it is important to replicate this study in other settings with larger samples to confirm the findings.

Ethical approval

This study was conducted in accordance with the Declaration of Helsinki-Ethical principle for medical research involving human subjects. Accordingly, the ethical clearance was obtained from a joint ethical review committee intuitional ethical committee KLE JGMM Medical College, KLE Academy of Higher Education and Research, Hubli, Karnataka. All individuals who took part in the study gave their informed consent, and data confidentiality was ensured.

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Authors' Contributions:

Dr.S.Nandakumar (SN)and ***Dr. Priyanka Murgod(PM)*** had the idea for this study. ***Dr Rekha rani Kumbar (RRK)*** is the principal investigator of the research work. **Dr.Mallikarjun.S Ballur(MSB)** and ***Dr. M. Nithya (MN),***designed the study protocol. ***RRK*** and ***MSB*** performed data collection and ***Dr Doddabasappa S Belavagi (DSB)*** and ***PM*** conducted the analyses and ***SN, MN*** drafted the manuscript. ***MSB, DSB*** and ***RRK*** further edited the manuscript. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work. All authors have read and agreed to the published version of the manuscript.

Data avaılabılıty:

All datasets generated or analyzed during this study are included in the manuscript.

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Conflicts of interest:

There are no conflicts of interest.

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