

Epiphyseal Fusion of Iliac Crests in Male and Female Adolescents: An Age Estimation Criterion

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ABSTRACT

Background: Determination of age depends upon physical examination, dental assessment, and skeletal evaluation. The radiological examination of bone for appearance and fusion of ossification centers helps in the assessment of skeletal maturity as the process occurs in a particular sequence which is almost constant for that particular bone.

Objectives: The objective of this study was to determine the age of fusion of iliac crest by radiological examination of subjects of age bracket 17-25 years coming to Shalamar Hospital Lahore

Materials & Methods: In this cross-sectional study, radiological examinations (Digital X-Rays) were performed to evaluate the fusion of Iliac Crest in 200 subjects of both genders of 17 – 25 years. Data analysis was done using SPSS Version 23. Conclusions were drawn and compared with available results of previous work done in this field.

Results: Out of 200 subjects, there were 132 males (66 %) and 68 females (34%). The mean \pm SD age of both genders was 20.41 ± 2.55 . There were 93 cases (70.45%) of complete fusion among males, showing 100 % union in the age groups of 21-25 years, while 40 cases (58.83%) of complete union among females were observed during 20-25 year of age groups. The mean \pm SD age of complete union for males was 20.67 ± 2.61 years and for females 19.90 ± 2.38 years, with a significant p value of <0.05 . Similarly, a statistically significant difference was observed among people of different socio-economic statuses. No difference was observed among different ethnic groups.

Conclusion: The fusion of the iliac crest is not affected by ethnicity. Factors like diet and nutrition directly affect bone growth and hence bone age. More studies should be conducted across the country to formulate

Key Words: Iliac crest, ossification, age of medico-legal importance, skeletal radiography

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INTRODUCTION

Personal identity means ‘establishment of the identity of a person’¹. It is a very important task assigned to forensic experts particularly in legal matters where criminal responsibility has to be considered to impose punishment or to grant privileges of civil rights according to the age group

of the claimant². To achieve the task of personal identification required in civil and criminal cases, during life and after death, many parameters or biometric identifiers are used. One of these parameters is the determination of age, a very important task and tool³.

In underdeveloped countries, age estimation becomes problematic due to the ignorance of the public towards the importance of registration of births mostly because of illiteracy³. Different methods are in use for the determination of age. These include general appearance, dental and skeletal examination. General appearance including height, weight, and other body measurements are not very helpful in the estimation of age due to wide variations in body size. Dental data is very helpful but not after 16 years of age as most of the dentition has erupted by this time. The eruption of the third molar tooth shows a wide variation from person to person³. Assessment of age of a person based on appearance and subsequent union of ossification centers of bones provides a reasonably methodical and logical technique which is well acknowledged by the medical and legal authorities⁴. Amongst all the determinants of age, radiological examination of bone from ends to completion of the process of ossification is a very accurate and reliable method by the medial experts hence comfortably acceptable to the legal authorities⁵.

Several studies conducted in various parts of the world on the estimation of age have revealed that there is a reasonable variation amongst the populations. Such variations also exist between the population of the subcontinent and the West⁶. Hepworth et al, observed that Indians precede English and American people in the union of bones because of hereditary, dietary and socioeconomic factors⁷.

The degree of maturation of the iliac crest helps estimate age after 18 years of age due to its relatively late completion of maturation⁸. Radiological examination of the iliac crest of a person can be helpful to assess the age in civil and criminal proceedings like identification of an individual, age of attainment of majority for boys and girls for marriage, capital punishments, participation in the election through vote casting, and consent for participation in risky sports⁹.

Due to the paucity of data about this age group from the local population, this study was designed to determine the Roentgen graphic appearance of epiphyseal centers and complete union of iliac crest on the right side of subjects between 17 to 25 years of age of both genders coming to Shalamar Hospital, Lahore. Hence, the main objective of this study was to provide a basic guideline for identification and assessment of the correct age of fusion of iliac crest in the local population. This may ultimately be useful in making criteria at the national level for assessing the age of fusion of iliac crest. This study will help to contribute to the better administration of justice in many civil and criminal cases in Pakistan.

MATERIALS AND METHODS

In this cross-sectional study, radiological examinations (Digital X-Rays) were performed to evaluate the fusion of Iliac Crest in 200 subjects of both genders of 17 – 25 years. The study was conducted at Shalamar Hospital, Lahore.

Inclusion Criteria:

- Individuals, both male and female of all ethnicities and socio-economic groups, with age range of 17 to 25 years with any known documentary evidence of birth as CNIC, Form B, birth certificate of the municipal committee or hospital, school certificate, driving license.

- Individuals with Normal Body Mass Index (BMI) (18.5 to 24).

Exclusion Criteria:

- Subjects suffering from any chronic illness e.g. congenital heart disease, pulmonary disease, bone disease, or endocrinal disorders. This was excluded by taking history and clinical examination.
- Chronic drug intake that may interfere with bone growth directly or indirectly e.g. steroids or anti-epileptic drugs.
- Foreign nationals or children of foreign nationals excluded by history.
- Subjects having congenital bony deformities.
- Fractures of Pelvic bone, recent or old.
- Pregnant women.
- Individuals having severe malnutrition –weight age less than 60%.

Informed written consent was obtained from these selected subjects before X-ray exposure. Their height, weight, gender, age, and other features were recorded on predesigned Performa. X-rays of the pelvic bone showing an iliac crest in anteroposterior view were taken using a digital X-ray machine. Changes in the epiphysis and diaphysis and the extent of the union were visualized on the right side of the pelvic bone for the iliac crest on the X-ray film. The radiological findings were confirmed by a single consultant radiologist of the Radiology Department Shalamar Hospital Lahore. Skeletal maturity was assessed from stages of the epiphyseal union of the iliac crest and divided into three stages described by Singh and Stevenson as under^{9,10}.

Non-Union: There is a clear gap between epiphyseal and diaphyseal ends which appear as translucent areas on X-rays (Image 1).

Partial union: There is a ‘bridging over’ or ‘knitting together’ of the two margins. On X-rays, intervening translucent areas between or on the sides of the bridged areas are distinguishable (Image 2).



Image 1: Non Union

Legend; Date of Birth: 13-4-98

Chronological age: 17 Years, 01 Month, 00 Days



Image 2: Partial Union of Iliac Crest

Legend; Date of Birth: 11-05-98

Chronological age: 17 Years, 00 Months, 02 Days

Complete union: White line formed by fusion of the two fusing layers of epiphysis and diaphysis disappear completely and become merged with normal trabeculae in this region. X-rays reveal the same bony architecture in the epiphyseal and diaphyseal ends and absent epiphyseal scar (Image 3).

Statistical Analysis

Estimation of age from the fusion of iliac crest in both genders is the primary outcome of our study.



Image 3: Complete Union of Iliac Crest

Legend; Date of Birth: 01-10-94

Chronological age: 19 Years, 8Months, 22 Days

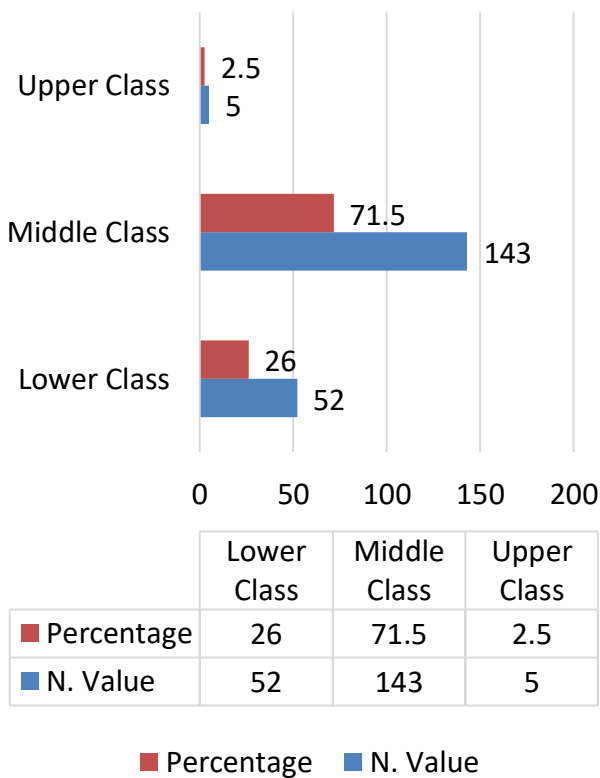


Figure 1: Descriptive Statistics of Socio-economic Status (n=200)

This data was analyzed by using SPSS 23.0 (Statistical Package for Social Sciences). In our

study, dependent variables are epiphyseal center appearance and its union.

Independent variables are age in years, gender, and ethnicity. Qualitative data like gender, ethnicity, SES, occupation, and stage of union were described statistically in frequencies and percentages. Quantitative data like age was described statistically after finding median, mean, and standard deviation.

The age of study subjects was divided into 9 groups starting from 17 through 25 years. Age group 17 was considered as those who had completed their 16 years and few days or months above 16 years but they were less than 17 years, same for the other age groups. Stages of non-union, partial union, and complete union were compared with these age groups for both genders (Tables 3, 4). Socioeconomic status is divided into three levels (high, middle, and low) based on three variables (income, education, and occupation) (Diemer et al., 2013) (Figure 1). Chi-Square test was used to determine the association of different categorical factors statistically, with the fusion of the iliac crest. P value of less than 0.05 was considered significant.

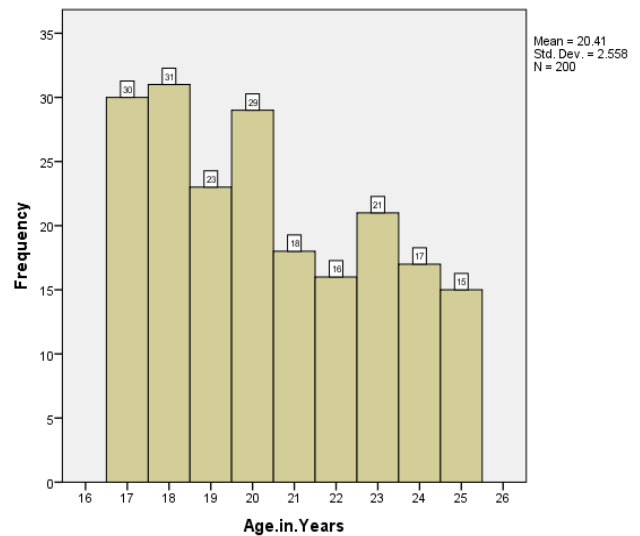


Figure 2: Histogram depicting Age Distribution in Sample Population (n=200)

RESULTS

1. Age of the subjects:

200 subjects participated in this study between the ages of 17 through 25 years. For both genders mean \pm SD age was 20.41 ± 2.55 years and the median age was 20.00 years as shown in Figure 2 of the Age Histogram with mean and SD values.

2. Age and sex distribution:

The subjects with reference to age were divided into 9 age groups starting from 17 through 25 years. The frequency distribution of the subjects with reference to gender is 132 males (66 %) and 68 females (34%) (Table1).

Gender-wise comparison of descriptive statistics of the numerical variable of this study has been shown in Table 2. The mean \pm SD age was 20.67 ± 2.61 years for males and the median age was 20.00 years, while the mean \pm SD age was 19.90 ± 2.38 years for females and the median age was 19.00 years. The BMI of all subjects was within the normal range (maximum 25 and minimum 19) (Table 2).

3. Extent of fusion of iliac crest in different age groups among males:

Table 3 shows that out of 132 males, there were 93 cases (70.45%) of complete fusion with the frequency of (10.5%) in the 17-year age group which gradually increased to 100% in 21-25 years of age groups. There were 21 cases (15.91%) of partial union and all were in 17 to 20 years age groups with the highest frequency (56.3%) in the 18 years age group. While there were only 18 cases (13.64%) of non-union and all were in the 17 to 19-year age groups. The mean \pm SD age of complete fusion in males was 20.67 ± 2.61 years and the median age was 20.0 years. The p value comes out to be 0.000 for males which are significant as it is < 0.05 .

4. Extent of fusion of iliac crests in different age groups among females:

Table 4 shows that out of a total of 68 females, there were 40 cases (58.83%) of complete fusion

Table 1: Age and Sex Distribution of the Subjects

Gender		n	Min.	Max.	Mean	S.D.
Male	Age	132	17	25	20.67	2.611
	Height (cm)	132	155	193	172.39	7.386
	Weight (kg)	132	45	92	64.41	9.112
	BMI	132	19	25	21.55	2.359
Female	Age	68	17	25	19.90	2.389
	Height (cm)	68	141	183	158.93	6.712
	Weight (kg)	68	40	71	52.91	6.300
	BMI	68	19	25	20.81	1.879
Total	Age	200	17	25	20.41	2.558
	Height (cm)	200	141	193	167.81	9.589
	Weight (kg)	200	40	92	60.50	9.891
	BMI	200	19	25	21.30	2.230

Table 2: Gender Wise Comparison of Descriptive Statistics of Numerical Variables in This Study (n=200)

Age (years)	Male		Female		Total	
	n	%	n	%	n	%
17	19	63.3	11	36.7	30	100.0
18	16	51.6	15	48.4	31	100.0
19	14	60.9	9	39.1	23	100.0
20	21	72.4	8	27.6	29	100.0
21	11	61.1	7	38.9	18	100.0
22	10	62.5	6	37.5	16	100.0
23	16	76.2	5	23.8	21	100.0
24	13	76.5	4	23.5	17	100.0
25	12	80.0	3	20.0	15	100.0
Total	132	66.0	68	34.0	200	100.0
Mean					20.41	
Median					20.00	
Std. Deviation					2.558	

with the frequency of (33.3 %) in 19-years age group which was up to 100% in age groups of 20-25 years. There were 21 cases (30.88%) of partial union and all were in the 17 to 19-years age groups with the highest frequency (66.7%) in the 19-year age group. There were only 7 cases (10.29 %) of non-union and all were in the 17 to 18-year age groups. The mean \pm SD age of complete fusion in females was 19.90 ± 2.38 years and the median of age was 19.0 years. The p value comes out to be 0.000 for females which is significant.

An incidence of complete fusion in 104 males (78.8%) out of 132 subjects and 47 females (69.1%) out of 68 cases was observed (Table 3-4). It was noted that females were one year ahead (20 years) for the fusion of the iliac crest as compared to males (21 years). It was also observed that with the advancement of age, the percentage of complete fusion increased and the percentage of partially fused cases decreased. It was also seen that there was a symmetrical fusion of the iliac crest bilaterally on both the right and left sides of the pelvic bone.

5. Association of complete fusion of iliac crests with socioeconomic status, occupation and ethnicity:

Subjects were divided into 3 groups for socioeconomic status – upper, lower, and middle class. 52 cases were belonging to the lower class out of which 37 (71.2%) cases showed complete fusion. 143 cases belonged to the middle class out of which 95 (66.4%) cases showed complete fusion of iliac crest. There were only 5 cases (100%) of non-fusion in the upper class. Chi-square test was applied and it was found that it is statistically significant (0.006) relationship between socioeconomic status and fusion of iliac crest in both male and female (Table 5).

The subjects were divided into 3 groups for occupation- students, employees and laborers. In our study students were in majority in number (134) followed by 34 employees and 32 laborers. There was a complete union of the iliac crest in 82 students (61.2%) followed by 26 employees (76.5%) and 24 (75.0%) workers. Chi-square test was applied to know the association between nature of occupation with age group in relation to complete fusion of iliac crest and it was found to be statistically non-significant (0.123%) both in males and females (Table 5). The subjects were divided into 3 groups for Ethnicity, Pathan, Punjabi and Urdu speaking. In our study, Punjabi were in majority in number (137) followed by 58 Urdu speaking and 5 Pathan. Complete Union of iliac

Table 3: Frequency of Extent of Fusion of Iliac Crest in different Age Groups among Males

Age group (years)	Non union		Partial Union		Complete Union		Total	
	n	%	n	%	n	%	n	%
17	11	57.9	6	31.6	2	10.5	19	14.39
18	4	25.0	9	56.3	3	18.8	16	12.12
19	3	21.4	2	14.3	9	64.3	14	10.61
20	0	0.0	4	19.0	17	81.0	21	15.91
21	0	0.0	0	0.0	11	100.0	11	8.33
22	0	0.0	0	0.0	10	100.0	10	7.58
23	0	0.0	0	0.0	16	100.0	16	12.12
24	0	0.0	0	0.0	13	100.0	13	9.85
25	0	0.0	0	0.0	12	100.0	12	9.09
Total	18	13.64	21	15.91	93	70.45	132	100.0
Mean							20.67	
Median							20.00	
Std. Deviation							2.611	

Table 4: Frequency of Extent of Fusion of Iliac Crest in Different Age Groups among Females

Age group (years)	Non union		Partial Union		Complete Union		Total	
	n	%	n	%	n	%	n	%
17	3	27.3%	6	54.5%	2	18.2%	11	16.18%
18	4	26.7%	9	60.0%	2	13.3%	15	22.06%
19	0	0.0%	6	66.7%	3	33.3%	9	13.24%
20	0	0.0%	0	0.0%	8	100.0%	8	11.76%
21	0	0.0%	0	0.0%	7	100.0%	7	10.29%
22	0	0.0%	0	0.0%	6	100.0%	6	8.83%
23	0	0.0%	0	0.0%	5	100.0%	5	7.35%
24	0	0.0%	0	0.0%	4	100.0%	4	5.88%
25	0	0.0%	0	0.0%	3	100.0%	3	4.41%
Total	7	10.29%	21	30.88%	40	58.83%	68	100.0%
Mean							19.90	
Median							19.00	
Std. Deviation							2.389	

Table 5: Association of Fusion of Iliac Crest with Gender, Socio-Economic Status, Occupation and Ethnicity Variables

		Non –Union		Complete Fusion		p value
		n=68	%	n=132	%	
Gender	Male	39	29.5%	93	70.5%	0.064
	Female	28	41.2%	40	58.8%	
S.E. Status	Upper Class	5	100.0%	0	0.0%	0.006*
	Middle Class	48	33.6%	95	66.4%	
	Lower Class	15	28.8%	37	71.2%	
Occupation	Student	52	38.8%	82	61.2%	0.123
	Worker	8	25.0%	24	75.0%	
	Employee	8	23.5%	26	76.5%	
Ethnicity	Pathan	1	20.0%	4	80.0%	0.751
	Punjabi	46	33.6%	91	66.4%	
	Urdu Speaking	21	36.2%	37	63.8%	

* The Chi-square test is significant at the p value < 0.05 level

crest was seen in 4 cases (80%) out of 5 Pathan, 91 cases (66.4%) out of 137 Punjabi and 37 cases (63.8%) out of 52 Urdu speaking subjects. There is no statistically significant association between complete fusion of iliac crest and ethnicity. As p value is 0.751 (Table 5).

DISCUSSION

The results in our study are higher than that of Flecker who observed complete union of the iliac crest at 18 years in males and 15-16 years of age

in females of Australia in 1932¹¹. Patel G has shown a lower level of age for ossification i.e. 19-20 for males and 18-19 for females in Gujarat¹². Gupta¹³ noticed complete ossification at 16 years in males and 15 years in females of Kanpur. In Pakistan, only one study had been conducted in Hyderabad city and adjoining areas by Memon et al giving an age of fusion of iliac crest to be 18 years -10 months for males and 17 years-10 months for females².

The age of fusion in our study is lower than those of Davis and Parson who studied such results in English in 1927 at the age of 23 years in both genders and Stevenson who studied White and Black populations in 1924 where the age of fusion was found to be at 22 -24 years^{10,14}. Bilkey, W. et al noticed complete union at 22 years of age in females without mentioning males in the North East region of India. Cardoso documented the age of complete fusion at 22 years for females and 23 years for males in Portuguese skeletal samples^{15,16}.

Our findings are very much in tandem with those of Singh (9) showing 20-21 years and Bhise giving the age of fusion to be 21-22 for males and 20-21 for females in Mumbai⁴. Kalpesh noticed fusion of iliac crest in males at 19-20 years and in females at 18-19 years in Gujrat¹⁷. Galastan also noticed in Bengalis the ossification at 19-20 years in males and 17-19 years in females¹⁸.

The mean age of fusion of iliac crest in our study is higher in males (20.67±2.61) than females (19.90±2.38). A significant difference with a significant p value less than 0.05 was found for both genders. Although this is in agreement with the generally accepted pattern of earlier fusion in females it is in disagreement with a difference of about 2 years given by various authors over the world¹⁹.

1. Association of fusion of iliac crest with socio-economic status:

The difference between the mean ages of the iliac crest was statistically significant for different socio-economic statuses as seen in Figure 2 and Table 5 where p value is 0.006

According to the list of countries by Human Development Index (HDI) 2014²⁰. Pakistan stands at 2nd position in low human development and 146th among 169 countries on United

Nation's HDI 2014. The human development index (HDI) is the reflection of the comparative index of life expectancy, literacy, education, and standard of living for countries globally. It is a standard parameter of measuring well-being, which helps to distinguish whether a country is developed, developing, or under developing. It also reflects impact of economic policies on quality of life. Higher HDI means a higher socioeconomic status while low HDI indicates low socio-economic status. Bones of the people having poor socio-economic status tend to delay maturation of bone^{18, 21}. Malnutrition plays an important role in the maturation of the skeleton. If the nutritional deficiencies become extreme, skeletal maturation is delayed²². This finding conforms with other studies all over the world^{21, 22, 23}. Patel et al³ did not notice any such relationship of socioeconomic status with the ossification of the iliac crest in his study.

2. Association of fusion of iliac crests with Ethnicity:

Ethnicity has no significant impact on the fusion of the iliac crest as shown in Table 5. There is no statistically significant difference between the mean age of fusion of iliac crest among various ethnicities i.e. Punjabi, Pathan and Urdu speaking persons as p value is > 0.751 which is insignificant. These findings are consistent with those of the previous researchers. Todd and Errico studied Black Americans; Owing Webb researched White and Black Americans^{24,25}. They did not notice any interethnic differences in their studies.

3. Association of fusion of iliac crest with occupation:

Occupation did not appear to significantly influence the probability of having a completely fused iliac crest as the p value is 0.123 which is

not significant. The work to see the effect of occupation on the fusion of iliac crest was based on assumption that increased physical activity associated with higher metabolic rate in hard workers may affect the timing of fusion. These findings are exactly similar to the findings done by previous researchers³. Theintz studied the effect of physical training in swimmers and gymnastics and found delayed fusion as compared to their adult height and chronological age²⁶. Patel did not notice any such relationship of occupation with the ossification of the iliac crest in his study³.

The factors which affect the skeletal maturity and time of union of ossification centers of the iliac crest must be kept in mind during the assessment of age. For medico-legal purposes, forensic age diagnostics has recommended combining a physical examination of the subject with radiological examination of the iliac crest, left hand and medial and of the clavicle with a dental examination. The factors which need to be considered are the socio-economic factors or HDI, geography and climate as warmer climates tend to have an earlier fusion of the bones. Asians have been reported to have an earlier fusion of the epiphysis as compared to Westerns²⁷. In addition, a new trend for earlier fusion over the last few decades has been reported which could be up to 0.22-0.66 years per decade from the 1960s to 1990s¹⁹.

Several methods are used to evaluate the skeletal maturity that involves different parts of the human skeleton. Oxford and Risser's method is based on the pelvis; Risser's method is the only standard method that is used for the determination of skeletal maturity in adolescents over 18 years old. Amongst all the determinants of age, radiological examination of bone ends has

shown accuracy and reliability acceptable to the medical profession and the legal fraternity²⁸.

CONCLUSION

1. Based on the results of this study, it is concluded that the mean age of fusion of iliac crest is 20.41 ± 2.55 in the healthy population coming to Shalamar Hospital, Lahore.
2. Mean age for the fusion of iliac crest for males is 20.67 ± 2.61 and for females is 19.90 ± 2.38 .
3. There is a difference in the time frame of ossification of the iliac crest in both genders. The females tend to show a difference of about one year earlier than males in respect of fusion of iliac crest.
4. The complete union of the iliac crest in our study is 1-2 years earlier than the population of England and America but almost in tandem with the population of India.
5. The union of the iliac crest occurs symmetrically on both sides of the pelvic bone.
6. Interethnic differences do not appear to have any role in the timing of ossification of the iliac crest.
7. The important role of factors like diet, socio-economic status, HDI, nutritional status in the maturation of skeleton should not be omitted while doing age estimations in criminal proceedings.

Recommendations:

1. It is recommended that more elaborate research studies be conducted in different parts of the country on subjects with different socio-economic and nutritional status to find out the difference if any in timeframes of fusion of iliac crest so that a uniform national standard be formulated. This will also help us in establishing the role of nutrition, climate, and geographical factors in ossification times.
2. A group of experts comprising of a forensic expert, dentist, radiologist, and anthropologist should be involved for

estimation of age in criminal proceedings and personal identification.

3. More studies should be conducted on the time frame of ossification of iliac crest using a larger sample size.
4. Extensive research should be carried out to formulate national guidelines for bone age assessment for children in Pakistan, using different methodologies.

Conflicts of interest

The authors have no conflicts of interest to declare.

Contributors

Dr. M. Maqsood designed the study and drafted the manuscript. Dr. M. Zahid Bashir, Dr. Kashif Butt, and Dr. Faizan Maqsood collected and analyzed the data. All authors critically revised and approved the final manuscript.

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