Radiological Assessment of Chronological Age Using Epiphyseal Fusion of the Pelvic Bones in a subset of Pakistani Adults Aged 18-25 Years.

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ABSTRACT:

Objective: To evaluate the stages of epiphyseal fusion around the pelvis using radiographic imaging in individuals aged 18 to 25 years within a subset Pakistani population.

Methodology: The current study was a radiological prospective study, carried out at the Dow Institute of Radiology, Karachi from Dec 2025 till Feb 2026. Radiographs of the Pelvis of the enrolled patients were taken in AP (anterio-posterior) view and the epiphysis of Iliac crest and ischial tuberosity were examined at the pelvic bone for 4 stages of fusion. Data was entered and analyzed in computer software SPSS 21.0.

Results: In the current study, there were 105 (50%) males and 105 (50%) female patients. Degree 3 fusion of iliac crest was observed amongst 34 (32.38%) males and 36 (34.29%) females. Degree 3 fusion of Ischial tuberosity was observed amongst 34 (32.38%) males and 36 (34.29%) females. All the subjects' (100%, n=27) shows degree 3 fusion of iliac crest and Ischial tuberosity in age group 25 years.

Conclusion: Our study concludes that epiphysis of iliac crest and Ischial tuberosity fused in majority of the cases in age group 24-25 years. Earliest fusion of iliac crest occurs at the age of 22 in both males and females. Complete fusion of Ischial tuberosity occurs at the age of 23 years in males while in females it occurs at the age of 22 years.

Key words: Radiological; Epiphyseal fusion; Pelvis; Iliac crest; Ischial tuberosity.

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Introduction:

Estimation of age is a crucial stage in the identifying individuals and unidentified remains.[1] A medical jurist struggles with disintegrating and decomposing deceased bodies, remains of skeletal or fragments in both criminal and civil proceedings.[2] It is also crucial in osteoarchaeology , clinical forensic medicine, physical anthropology, and as a component of the investigation in medico-legal activities.[3] Utilizing dental development, ossification centre fusion, long bone lengths, epiphyseal union and by comparing findings to general growth patterns, juveniles and adults' ages are estimated based on their developmental maturity.[4] The hip joint is the 3rd most efficient joint for estimating age, after the elbow and wrist joints. Ilium, ischium, and pubis, the three bones that make up the hip bone that are separated at birth by hyaline cartilage, make up the largest bone in the body. In the acetabulum, they connect in a Y-shaped area of cartilage. By the end of puberty, three areas will ossify, and by the end of age 25, they will fuse together. At the pubic symphysis, the two hip bones connect. The pelvis is made up of the hip bones, the sacrum, and the coccyx.[5,6] The auricular surface of the ilium and pubic symphysis are two of the greatest markers for determining adult age, and they may be seen on pelvic radiographs that show the iliac and ischial boundaries.[3, 4]

In order to determine the age of Manipuri females, a radiological analysis of epiphyseal union around the knee, elbow, wrist joint and pelvis was conducted. In order to estimate the age of majority in this research, X-rays of the knee, elbow, wrist joint and pelvis were collected in 100 Manipuri females. For each joint, the regression formulas with standard errors were constructed. This research determined that the minimal age for complete epiphyseal and metaphyseal fusion was between 12 and 16 years. In the instance of the pelvis, it was observed that Manipuri females between the ages of 17 and 20 had completely fused epiphyseal and metaphyseal bones.[7] At Rajindra Hospital in Patiala, Punjab, X-ray examinations were recorded on 100 participants between the ages of 16 and 25 years, 50 were males and 50 were females, who were studied in two original research-based studies by the same author. The goal of the research was to determine when the ischial tuberosity epiphysis and iliac crest epiphyses fused. Both studies' findings revealed that by 20-21 years of age in both sexes, the iliac crest epiphysis and the ischial tuberosity epiphysis were generally fused. However, in rare instances, the earliest time for the iliac crest and ischial tuberosity epiphyses to fuse was 19 years for men and 17 years for women.[2, 8] As roentgenographic age estimation is occasionally the only method of identification in de-

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veloping countries with poor documentation and frequently unavailable records.[9] Therefore, this study was carried out with the goal to assess the age order of epiphyseal union around the Pelvis in Adult Males & Females of 18 – 25 years age group.

Methodology:

This prospective radiological study was conducted at Dow University of Health Sciences (DUHS) following approval from the Institutional Review Board (IRB #: 4091/DUHS/Approval/2025/481, dated December 1, 2025). The study spanned three months, from December 2025 to February 2026, and included patients visiting the Dow Institute of Radiology, Dow University Hospital, Karachi. A total of 210 participants were enrolled using consecutive sampling technique. Inclusion criteria comprised patients of both genders aged 18-25 years with no bone deformity. Exclusion criteria included a history of pelvic trauma, surgery, congenital pelvic bone abnormalities, chronic bone-related diseases, steroid use, and poor-quality radiographs that hindered visualization of epiphyseal f Participants were stratified into eight age groups (18-25 years). Pelvic radiographs in anteroposterior (AP) view were obtained, and the epiphyses of the iliac crest and ischial tuberosity were examined. Fusion stages were categorized into four degrees: Degree 0 (fusion not commenced), Degree 1 (fusion initiated), Degree 2 (fusion incomplete), and Degree 3 (fusion complete).[2]

Data were analyzed using SPSS version 21.0. Frequency tables were generated for all variables. For quantitative data, mean and standard deviation were calculated, while qualitative data such as sex were expressed as percentages. Associations and differences between categorical variables were assessed using the chi-square test, with a p -value <0.05 considered statistically significant.

Results:

In our study, a total of 210 patients were enrolled. There were 105 (50%) males' patients and 105 (50%) were female's patient. Based on the distribution of age, 26 (12.4%) patients were observed in each age group of 18, 19, 20 and 21, 23 and 24 years respectively while 27 (12.9%) patients were observed in age group of 22 and 25 years as shown in table 1.

Table No 1: Demographic data.

Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	105	50.0
	Female	105	50.0
Age (years)	18	26	12.4
	19	26	12.4
	20	26	12.4
	21	26	12.4
	22	27	12.9
	23	26	12.4
	24	26	12.4
	25	27	12.9
Total		210	100.0

Degree 3 fusion of iliac crest was observed amongst 34 (32.38%) males and 36 (34.29%) females. Degree 2 fusion was observed amongst 20 (19.05%) males and 19 (18.01%) females. Degree 1 fusion was observed amongst 26 (24.76%) males and 27 (25.71%) females while degree 0 fusion was observed amongst 25 (23.80%) males and 23 (21.90%) females. All the subjects' (100%, n=27) shows degree 3 fusion of iliac crest in age group 25 years. There were 17 (62.96%) cases of degree 2 fusion in age group 22 while in age group 21, degree 1 fusion was observed in 21 (80.76%) patients. The association of age and gender with all the degree of fusion of iliac crest was significant statistically (p=0.000). (Table 2).

Degree 3 fusion of Ischial tuberosity was observed amongst 34 (32.38%) males and 36 (34.29%) females. Degree 2 fusion was observed amongst 21 (20%) males and 19 (18.01%) females. Degree 1 fusion was observed amongst 23 males and 27 females while degree 0 fusion was observed amongst 27 (25.71%) males and 23 (21.90%) females. All the subjects' (100%, n=27) shows degree 3 fusion of Ischial tuberosity in age group 25 years. There were 19 (70.37%) cases of degree 2 fusion in age group 22 while in age group 21, degree 1 fusion was observed in 19 (73.08%) patients. The association of age and gender with all the degree of fusion of Ischial tuberosity was significant statistically (p=0.000). (Table 2).

Discussion:

In both civil and criminal proceedings, age is a key parameter to identify initial identity both of the living and the dead.[10] In most developing areas, proper age estimation has been a challenge, usually because of the low birth registration rates that are attributed to socio-economic conditions such as illiteracy.[11] This can be done in different ways such as skeletal and dental examination and also analysis of general physical appearance. But morphological features like height and weight have a significant amount of individual variation thus their use in trying to estimate the age is not highly reliable. Conversely, the radiological evaluation of the appearance of the ossification centers and the following epiphyseal incorporation is a logical and scientifically valid methodology that is supported by medical and legal experts.[12] Radiographic studies on bone maturation up to the completion of ossification is regarded as a very precise and reproducible method, which makes it especially appropriate to use in a forensic environment.[13] Accordingly, the research was planned to be conducted to radially analyze epiphyseal fusion in males and females of the ages 18-25 years in a Pakistani cohort.

Degree 3 fusion of the iliac crest was also studied in the current study and it was found in 34 (32.38) males and 36 (34.29) females. Fusion of Degree 2 was observed in 20 (19.05) and 19 (18.01) male and female respectively and Degree 1 fusion was observed in 26 (24.76) and 27 (25.71) male and female respectively. There was a degree 0 fusion in 25 (23.80) males and 23 (21.90) females. These results are consistent with the existing studies that suggest that the ossification centers in females occur earlier and develop earlier than in males.[14] We also found our findings to be similar to the other study which found that the incidence of iliac crest fusion was higher among females.[15]

In the present investigation, 100 percent of subjects (n=27) had Degree 3 fusion of iliac crest at age 25. At the age of 22, Degree 2 fusion was found in 17 (62.96) individuals and Degree 1 fusion was found in 21 (80.76) individuals at the age of 21. The relationship between age, gender and the level of iliac crest fusion was significant (p=0.000). The results were congruent with past studies.[16] The results were also in line with the findings of a study conducted Rajasthan that found full iliac crest fusion in both the sexes at the age of 25.[8]

Table 2: Fusion extent of Ischial tuberosity in association with age and gender

Age group	Gender	Degree 0		Degree 1		Degree 2		Degree 3		Pvalue
		Yes	No	Yes	No	Yes	No	Yes	No	
18	Male	13 (100%)	0 (00)	0 (00)	13 (100%)	0 (00)	13 (100%)	0 (00)	13 (100%)	
	Female	13 (100%)	0 (00)	0 (00)	13 (100%)	0 (00)	13 (100%)	0 (00)	13 (100%)	
19	Male	10 (76.9%)	3 (23.1%)	3 (23.1%)	10 (76.9%)	0 (00)	13 (100%)	0 (00)	13 (100%)	
	Female	8 (61.5%)	5 (38.5%)	4 (30.8%)	9 (69.2%)	1 (7.7%)	12 (92.3%)	0 (00)	13 (100%)	
20	Male	2 (15.4%)	11 (84.6%)	9 (69.2%)	4 (30.8%)	2 (15.4%)	11 (84.6%)	0 (00)	13 (100%)	
	Female	2 (15.4%)	11 (84.6%)	9 (69.2%)	4 (30.8%)	2 (15.4%)	11 (84.6%)	0 (00)	13 (100%)	
21	Male	0 (00)	12 (100%)	10(76.9%)	3 (23.1%)	3 (23.1%)	10 (76.9%)	0 (00)	13 (100%)	
	Female	0 (00)	13 (100%)	11(84.6%)	2 (15.4%)	2 (15.4%)	11 (84.6%)	0 (00)	13 (100%)	0.000
22	Male	0 (00)	13 (100%)	4 (30.8%)	9 (69.2%)	8 (61.5%)	5 (38.5%)	1 (7.7%)	12 (92.3%)	
	Female	0 (00)	14 (100%)	3 (21.4%)	11 (78.6%)	9 (64.3%)	5 (35.7%)	2 (14.3%)	12 (85.7%)	
23	Male	0 (00)	13 (100%)	0 (00)	13 (100%)	5 (38.5%)	8 (61.5%)	8 (61.5%)	5 (38.5%)	
	Female	0 (00)	13 (100%)	0 (00)	13 (100%)	4 (30.8%)	9 (69.2%)	9 (69.2%)	4 (30.8%)	
24	Male	0 (00)	13 (100%)	0 (00)	13 (100%)	2 (15.4%)	11 (84.6%)	11 (84.6%)	2 (15.4%)	
	Female	0 (00)	13 (100%)	0 (00)	13 (100%)	1 (7.7%)	12 (92.3%)	12 (92.3%)	1 (7.7%)	
25	Male	0 (00)	14 (100%)	0 (00)	14 (100%)	0 (00)	14 (100%)	14 (100%)	0 (00)	
	Female	0 (00)	13 (100%)	0 (00)	13 (100%)	0 (00)	13 (100%)	13 (100%)	0 (00)	

Table No 2: Fusion extent of Ischial tuberosity in association with age and gender

Age group	Gender	Degree 0		Degree 1		Degree 2		Degree 3	
		Yes	No	Yes	No	Yes	No	Yes	No
18	Male	13 (100%)	0 (00)	0 (00)	13 (100%)	0 (00)	13 (100%)	0 (00)	13 (100%)
	Female	13 (100%)	0 (00)	0 (00)	13 (100%)	0 (00)	13 (100%)	0 (00)	13 (100%)
19	Male	10(76.9%)	3 (23.1%)	3 (23.1%)	10 (76.9%)	0 (00)	13 (100%)	0 (00)	13 (100%)
	Female	8 (61.5%)	5 (38.5%)	5(38.5%)	8(61.5%)	0 (00)	13 (100%)	0 (00)	13 (100%)
20	Male	4 (30.8%)	9 (69.2%)	8 (61.5%)	5 (38.5%)	1 (7.7%)	12 (92.3%)	0 (00)	13 (100%)
	Female	2 (15.4%)	11(84.6%)	10(76.9%)	3 (23.1%)	1 (7.7%)	12 (92.3%)	0 (00)	13 (100%)
21	Male	0 (00)	13 (100%)	9(69.2%)	4(30.8%)	4(30.8%)	9 (69.2%)	1 (7.7%)	12 (92.3%)
	Female	0 (00)	13 (100%)	10(76.9%)	3 (23.1%)	3(23.1%)	10 (76.9%)	0 (00)	13 (100%)
22	Male	0 (00)	13 (100%)	3 (23.1%)	10 (76.9%)	9(69.2%)	4(30.8%)	0 (00)	13 (100%)
	Female	0 (00)	14 (100%)	2(14.3%)	12 (85.7%)	10(71.4%)	4 (28.6%)	2 (14.3%)	12 (85.7%)
23	Male	0 (00)	13 (100%)	0 (00)	13 (100%)	5(38.5%)	8(61.5%)	8 (61.5%)	5 (38.5%)
	Female	0 (00)	13 (100%)	0 (00)	13 (100%)	4 (30.8%)	9 (69.2%)	9 (69.2%)	4(30.8%)
24	Male	0 (00)	13 (100%)	0 (00)	13 (100%)	2 (15.4%)	11 (84.6%)	11 (84.6%)	2(15.4%)
	Female	0 (00)	13 (100%)	0 (00)	13 (100%)	1 (7.7%)	12 (92.3%)	12 (92.3%)	1 (7.7%)
25	Male	0 (00)	14 (100%)	0 (00)	14 (100%)	0 (00)	14 (100%)	14 (100%)	0 (00)
	Female	0 (00)	13 (100%)	0 (00)	13 (100%)	0 (00)	13 (100%)	13 (100%)	0 (00)

The same findings were also documented in another study on young adults which observed the highest fusion of iliac crest at age 25.[11] In our study, total fusion (Degree 3) was observed to occur at age 22 in the male and female. Conversely, radiological research indicated that complete fusion occurred earlier, 21 years in males and 20 years in females.[9] Fusion around 21 years was also suggested in another study in males.[8] Our results could be similar to the previous ones due to the fact that similar socioeconomic position, nutrition patterns, and climatic factors could affect the populations of the research.

Concerning the ischial tuberosity, Degree 3 fusion was found in 34 (32.38) males, and 36 (34.29) females. The fusion was observed in 21 (20) males and 19 (18.01) females. Degree 1 fusion was observed in 23 males and 27 females and Degree 0 fusion was observed in 27 (25.71) males and 23 (21.90) females, showing that females were fused earlier. Degree 3 fusion was observed in the ischial tuberosity of all subjects (100%, n=27) at the age of 25. At age 22 Degree 2 Fusion was noted in 19 (70.37%) and Degree 1 Fusion was noted in 19 (73.08). Age and gender as variables were found to be statistically significant concerning the extent of ischial tuberosity fusion (p=0.000). Such findings are consistent with the past studies that found previously that the ischial tuberosity has been fused earlier in females.[17] As opposed to ours, a study on sportspersons found that fusion happened in males earlier on.[18] A study on age range among south Indian adolescents found a similar age range of fusion.[14] In a forensic context, the age of victims is a critical variable; research indicates that sexual violence victimization patterns are strongly associated with specific age groups.[19]

The major weakness of this research was its small sample size non-probability sampling technique. It is advisable that future studies need to use bigger cohorts to have stronger and more generalizable findings.

Conclusion

Our study concludes that epiphysis of iliac crest and Ischial tuberosity fused in majority of the cases in age group 24-25 years. Earliest fusion of iliac crest occurs at the age of 22 in both males and females. Complete fusion of Ischial tuberosity occurs at the age of 23 years in males while in females it occurs at the age of 22 years.

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Ramlah Naz	Literature search, study design and concept, critical review of manuscript
Arshad Khan	study design, data interpretation, data analysis, manuscript drafting
Binish Rasheed	Data Collection, data interpretation, data analysis, manuscript drafting