

A Cross-Sectional Study on Radiological Age Estimation According to Risser's Sign in Native of Jaipur at SMS Medical College Jaipur in Year 2024-2025

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DOI: <https://doi.org/10.5281/zenodo.21185179>

Received: 16 June 2026, Accepted: 02 July 2026, Online First: 04 July 2026

ABSTRACT

Background: Accurate age estimation is of considerable importance in forensic and medico-legal practice, particularly in cases involving disputed age, juvenile justice, criminal responsibility, and civil litigation. The Risser sign, based on iliac crest apophyseal ossification, is a reliable indicator of skeletal maturity; however, population-specific reference data for the Indian population remain limited. **Objective:** To evaluate the correlation between Risser stage and chronological age medico-legal age estimation among the native population of Jaipur, Rajasthan. **Materials and Methods:** This hospital-based cross-sectional observational study included 100 healthy native Jaipur participants aged 12–21 years. Standard anteroposterior pelvic radiographs were evaluated, and skeletal maturity was graded according to the American Risser staging system. The association between chronological age and Risser stage was analysed using the Chi-square test, with statistical significance set at $p < 0.05$. **Results:** A significant positive association was observed between chronological age and Risser stage in both sexes. Among males, Stage 4 was the most common Risser stage (50%), whereas Stage 5 predominated among females (46%). The association between age group and Risser stage was highly significant in males ($\chi^2 = 108.64$, $p < 0.001$) and females ($\chi^2 = 88.52$, $p < 0.001$). Females attained advanced skeletal maturity earlier than males, with mean ages for Stage 5 of 18.76 and 19.83 years, respectively. Complete iliac crest apophyseal fusion was observed in all females aged ≥ 18 years and predominantly in males aged 20–21 years. **Conclusion:** Risser staging demonstrates a strong correlation with chronological age and serves as a reliable tool for medico-legal age estimation. The findings provide regional reference data for the Jaipur population and support the use of the Risser sign in medico-legal age assessment, particularly around the legally significant age threshold of 18 years.

Keywords: Age estimation; Risser sign; Skeletal maturity; Iliac crest apophysis; Forensic medicine; Radiological assessment.

INTRODUCTION

Age estimation is an integral component of forensic medicine and plays a crucial role in both civil and criminal proceedings. Accurate determination of

chronological age is essential in cases involving juvenile justice, criminal responsibility, child labour, marriage, adoption, immigration, sports eligibility, employment, and identification of unknown individuals.

Although birth registration in India has improved substantially in recent years, age disputes continue to arise due to unavailable, inaccurate, or disputed documentary evidence. In such situations, medico-legal age estimation based on biological indicators becomes indispensable. Furthermore, legislations such as the Protection of Children from Sexual Offences (POCSO) Act, 2012 have increased the need for precise age determination, particularly around the legally significant age threshold of 18 years.

Skeletal maturity is influenced by several factors including genetics, sex, ethnicity, nutrition, socioeconomic status, hormonal status, and environmental conditions. Consequently, the timing of appearance and fusion of ossification centres varies among different populations, making population-specific standards essential for accurate forensic age estimation. Radiological assessment of skeletal maturity is considered one of the most reliable and objective methods because skeletal development follows a predictable pattern of ossification and epiphyseal fusion during growth.

Among various skeletal indicators, the iliac crest apophysis has considerable medico-legal importance because its ossification and fusion occur during late adolescence, around the age of legal majority. The Risser sign is a well-established radiological grading system that assesses the progressive ossification and fusion of the iliac crest apophysis from Stage 0 to Stage 5. Although originally developed to evaluate skeletal maturity in adolescents with idiopathic scoliosis, it has gained increasing recognition as a useful adjunctive method for forensic age estimation. Previous studies have demonstrated a significant correlation between Risser stage and chronological age; however, the timing of iliac crest ossification differs across ethnic and geographical populations. Therefore, findings from Western populations cannot be directly applied to the Indian population.

Limited research has evaluated the forensic applicability of the Risser sign in India, particularly among regional populations. Jaipur, located in Rajasthan, represents a population with distinct demographic and environmental characteristics that may influence skeletal maturation. Therefore, the present study was undertaken to evaluate the relationship between Risser stage and chronological age among native Jaipur adolescents and to assess the usefulness of the Risser sign as an adjunctive radiological tool for forensic age estimation, especially around the legally significant age of 18 years.

METHODOLOGY

AIM: To study the Radiological estimation of age according the value of Risser sign assessment with respect to chronological age at SMS hospital Jaipur of native of Jaipur.

OBJECTIVE:

PRIMARY OBJECTIVE:

- To assess Risser stages in individuals aged 12–21 years.
- To compare the Radiological age with respect to Risser sign.

SECONDARY OBJECTIVE:

- To evaluate gender differences in Risser stage progression.
- To assess the applicability of the Risser sign in medico-legal age estimation around the age of 18 years.

MATERIALS AND METHODS

A hospital-based cross-sectional observational study was conducted in the Departments of Forensic Medicine and Radiodiagnosis, SMS Medical College, Jaipur, Rajasthan, India, from October 2024 to September 2025.

Study Population The study included Natives of Jaipur of age between 12 to 21 yrs, living at Jaipur District as per Demarcation applicable by state Government on 01/01/2024, coming to OPD and IPD of SMS Hospitals, Jaipur

INCLUSION CRITERIA

1. Individual/Patients who provide written informed consent.
2. Individual/Patients age between 12 to 21 years,
3. Individual should be native of Jaipur, Rajasthan and living at Jaipur District as per Demarcation applicable by state Government on 01/01/2024.
4. Participants with authentic documentary proof of date of birth (Birth Certificate, Class X Certificate, Passport or Aadhaar Card).

EXCLUSION CRITERIA

1. Major ailments in the past affecting pelvic affecting growth and development.
2. History of injury leading to fracture of Pelvic bone,
3. Metabolic and endocrine disorder.

A total of 100 participants were included in the study. Radiological age estimation was performed using **Risser's sign**, which evaluates the ossification and fusion of the iliac crest apophysis.

Statistical Analysis

Data were entered in Microsoft Excel and analyzed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were expressed as mean $\pm$ standard deviation and percentages.

The iliac crest apophysis was assessed bilaterally and graded based on ossification progression. The iliac wing is divided into quarters and is composed of the following six Risser's grades (American).



Figure 1: Normal Pelvic X-ray Radio-graph

Risser Grading System (American Method)

- **Risser Grade 0:** No ossification center visible.
- **Risser Grade 1:** Ossification of lateral 25% of iliac crest.
- **Risser Grade 2:** Ossification of 26–50%.
- **Risser Grade 3:** Ossification of 51–75%.
- **Risser Grade 4:** Ossification of 76–100% without fusion.
- **Risser Grade 5:** Complete fusion of apophysis with iliac crest.

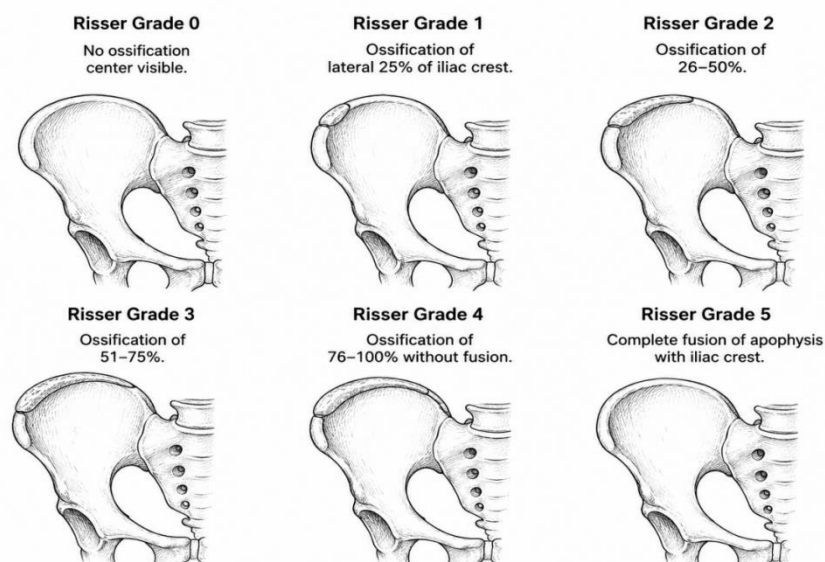


Figure 2. Risser's grading system.

Risser's sign is defined by the amount of calcification present in the iliac apophysis and it measures the progressive ossification from the anterolateral part to the posteromedial part. A Risser's grade 5 means the iliac apophysis has fused to the iliac crest after 100% ossification.

All radiographs were independently evaluated by the investigator under the supervision of faculty members from the Department of Radiodiagnosis and Department of Forensic Medicine. Risser grading was assigned based on the degree of ossification and fusion of the iliac crest apophysis.

RESULTS

A total of 100 participants were included in the study, comprising 50 males and 50 females. The distribution of participants according to Risser stage is presented in **Table 1**.

Table 1: Distribution of Participants according to Risser Stage

Risser Stage	Male (n=50)		Female (n=50)	
	n	%	n	%
Stage 0	5	10.00	3	6.00
Stage 1	1	2.00	7	14.00
Stage 2	0	0.00	2	4.00
Stage 3	7	14.00	4	8.00
Stage 4	25	50.00	11	22.00
Stage 5	12	24.00	23	46.00
Total	50	100.00	50	100.0

$\chi^2=16.72$, $df=5$ $P = 0.005$

Table 1 demonstrates the distribution of participants according to Risser stage and sex. Among male participants, the majority were classified as **Risser Stage 4 (50.0%)**, followed by **Stage 5 (24.0%)**, **Stage 3 (14.0%)**, **Stage 0 (10.0%)**, and **Stage 1 (2.0%)**, while no male participant was observed in Stage 2.

Among female participants, the highest proportion belonged to **Risser Stage 5 (46.0%)**, followed by **Stage 4 (22.0%)**, **Stage 1 (14.0%)**, **Stage 3 (8.0%)**, **Stage 0 (6.0%)**, and **Stage 2 (4.0%)**.

A statistically significant association was observed between sex and Risser stage ($\chi^2 = 16.72$, $df = 5$, $p = 0.005$), indicating that the distribution of Risser stages differed significantly between males and females. Females showed a higher proportion of advanced skeletal maturity (Stage 5) compared with males, suggesting earlier attainment of complete iliac crest apophyseal fusion among females.

Table 2: Distribution of Male Participants according to Risser Stage & Age Group

Age Group	Stage-0	Stage-1	Stage-2	Stage-3	Stage-4	Stage-5	Total
12-13	5	0	0	0	0	0	5
14-15	0	0	0	2	0	0	2
16-17	0	1	0	5	7	1	14
18-19	0	0	0	0	18	2	20
20-21	0	0	0	0	0	9	9
Total	5	1	0	7	25	12	50

$\chi^2 = 108.64$, $df = 16$, $p < 0.0001$

Table 2 demonstrates the distribution of male participants according to Risser stage and age group. A clear age-related progression in Risser staging was observed among males. All participants in the 12–13 years age group were classified as **Risser Stage 0**, indicating the absence of iliac crest apophyseal ossification. In the 14–15 years age group, all participants were observed in **Stage 3**.

Among males aged 16–17 years, the majority belonged to **Stages 3 and 4**, with Stage 4 being the most common. In the 18–19 years age group, most participants (90.0%) were classified as **Stage 4**, while a small proportion had attained **Stage 5**. All participants in the 20–21 years age group were classified as **Stage 5**, indicating complete fusion of the iliac crest apophysis.

Overall, **Stage 4 (50.0%)** was the most frequently observed stage among male participants, followed by **Stage 5 (24.0%)** and **Stage 3 (14.0%)**. The findings demonstrate a progressive increase in Risser stage with advancing age, reflecting increasing skeletal maturity and ossification of the iliac crest apophysis among males.

Statistical Interpretation:

A highly significant association was observed between age group and Risser stage among male participants ($\chi^2 = 108.64$, $df = 16$, $p < 0.001$), indicating that Risser stage increases significantly with age and can serve as a reliable indicator of skeletal maturity in males.

Table 3: Distribution of Female Participants according to Risser Stage & Age Group

Age Group	Stage-0	Stage-1	Stage-2	Stage-3	Stage-4	Stage-5	Total
12-13	3	4	0	0	0	0	7
14-15	0	3	2	4	5	0	14
16-17	0	0	0	0	6	6	12
18-19	0	0	0	0	0	8	8
20-21	0	0	0	0	0	9	9
Total	3	7	2	4	11	23	50

$\chi^2 = 88.52$, $df = 20$, $p < 0.001$

Table 3 demonstrates the statistically highly significant association was observed between age group and Risser stage among female participants ($\chi^2 = 88.52$, $df = 20$, $p < 0.001$). The findings suggest that Risser stage increases significantly with advancing age, reflecting progressive skeletal maturation. Complete iliac apophyseal fusion (Stage 5) was observed in all females aged 18 years and above, suggesting that females attain skeletal maturity earlier than males.

Table 3 demonstrates among the 50 female participants included in the study, a progressive increase in Risser stage was observed with advancing age. In the 12–13 years age group ($n=7$), 3 (42.9%) participants were classified as Stage 0, while 4 (57.1%) were in Stage 1. Among participants aged 14–15 years ($n=14$), a distribution across multiple stages was noted, with 3 (21.4%) in Stage 1, 2 (14.3%) in Stage 2, 4 (28.6%) in Stage 3, and 5 (35.7%) in Stage 4. In the 16–17 years age group ($n=12$), all participants had reached advanced stages, with 6 (50.0%) participants each in Stages 4 and 5. All participants in the 18–19 years ($n=8$) and 20–21 years ($n=9$) age groups were classified as Stage 5, indicating complete iliac apophyseal fusion.

Statistical Interpretation

A highly statistically significant association was observed between age group and Risser stage among female participants ($\chi^2 = 88.52$, $df = 20$, $p < 0.001$). This finding suggests that the distribution of Risser stages varies significantly across different age groups and confirms a strong positive relationship between chronological age and skeletal maturity in females.

Table 4: Distribution of Participants according to Risser Stage & Mean Age

Risser Stage	Male Mean Age	Female Mean Age
Stage 0	12.50	12.50
Stage 1	16.50	13.36
Stage 2	Not Observed	14.50
Stage 3	15.93	14.50
Stage 4	17.94	15.59
Stage 5	19.83	18.76

Table 4 demonstrates shows the distribution of participants according to Risser stage and corresponding mean age in males and females. A progressive increase in mean age was observed with advancing Risser stages, indicating a positive relationship between chronological age and skeletal maturity. The mean age at Risser Stage 0 was 12.50 years in both sexes. Females attained advanced Risser stages at younger ages than males. The mean age at Risser Stage 4 was 15.59 years in females and 17.94 years in males, while the mean age at Risser Stage 5 was 18.76 years in females and 19.83 years in males. No male participant was observed in Risser Stage 2. These findings demonstrate a clear age-related progression of iliac crest apophyseal ossification and fusion and suggest earlier skeletal maturation among females.

DISCUSSION

The present hospital-based cross-sectional study evaluated the relationship between chronological age and Risser stage among 100 native Jaipur participants aged 12–21 years. The findings demonstrated a significant positive correlation between advancing age and iliac crest apophyseal ossification in both males and females, confirming the usefulness of the Risser sign as

an adjunctive indicator of skeletal maturity for forensic age estimation.

A significant difference in the distribution of Risser stages was observed between males and females ($\chi^2 = 16.72$, $p = 0.005$). Risser Stage 4 was the most common stage among males (50.0%), whereas Stage 5 predominated among females (46.0%), indicating earlier skeletal maturation in females. This observation is consistent with the established biological pattern of

earlier pubertal development in females and agrees with the findings of Chowdhuri et al., Kumar et al., and Kim et al., who also reported earlier attainment of advanced Risser stages among females.

Among male participants, Risser stage showed a highly significant association with chronological age ($\chi^2 = 108.64$, $p < 0.001$). All males aged 12–13 years were classified as Stage 0, while complete iliac crest fusion (Stage 5) was predominantly observed in the 20–21 years age group. Similarly, female participants demonstrated a strong association between age and Risser stage ($\chi^2 = 88.52$, $p < 0.001$). Advanced stages appeared earlier in females, and all participants aged 18 years and above had attained Stage 5, indicating earlier completion of skeletal maturation than males. These findings are comparable with those reported by Lottering et al., Rezaei et al., and Duncombe et al., who demonstrated a predictable age-related progression of iliac crest ossification and earlier skeletal maturity among females.

The mean age at attainment of Risser Stage 4 and Stage 5 was lower in females (15.59 and 18.76 years, respectively) than in males (17.94 and 19.83 years, respectively), further supporting sex-related differences in skeletal maturation. Such differences should be considered while interpreting radiological findings in medico-legal age estimation.

The present findings support the forensic applicability of the Risser sign, particularly around the legally significant age of 18 years. However, because overlap exists between adjacent age groups, the Risser sign should not be used as a sole criterion for age estimation. It should be interpreted in conjunction with clinical examination and other radiological or dental indicators to improve the accuracy and reliability of medico-legal age assessment.

Limitations of the Study

- **Limited sample size:** The study included only 100 participants from a single tertiary care centre, which may limit the generalizability of the findings.
- **Single-centre, cross-sectional design:** As a hospital-based cross-sectional study, the findings represent a single time point and do not allow assessment of longitudinal changes in skeletal maturation.
- **Unequal age-group distribution:** Variation in the number of participants across different age groups may have influenced the distribution of Risser stages and statistical comparisons.
- **Limited evaluation of confounding factors:** Factors such as genetic background, hormonal status, physical activity, and socioeconomic conditions, which may influence skeletal maturation, were not assessed.
- **Population-specific findings:** Since the study was conducted among the native population of Jaipur, the results may not be directly

applicable to other ethnic or geographical populations.

CONCLUSION

The present study demonstrated a strong positive association between chronological age and Risser stage in both males and females. Progressive iliac crest apophyseal ossification with advancing age confirms that the Risser sign is a reliable indicator of skeletal maturity. Female participants attained advanced Risser stages and complete iliac crest fusion earlier than males, highlighting the importance of sex-specific interpretation during forensic age estimation.

The findings suggest that the Risser sign can serve as a valuable adjunctive radiological tool for medico-legal age estimation, particularly around the legally significant age threshold of 18 years. Nevertheless, it should be used in combination with other clinical, dental, and radiological parameters to enhance the accuracy of age assessment. The present study also provides baseline reference data for the native Jaipur population, which may be useful in future forensic and anthropological research.

Data Availability Statement

The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request. Informed Consent: Written informed consent was obtained from all participants included in the study.

Informed Consent

Written informed consent was obtained from all participants included in the study.

Author Contributions

Dr. Mahesh Soni, Data collection, manuscript preparation. Dr. Rajesh Kumar Verma, Conceptualization, supervision, manuscript review. Dr. Mahesh Soni, Data acquisition and analysis. Dr. N L Disania, Methodology and validation. Dr. Anil Solanki, Critical review and final approval.

Ethical Approval

The study was approved by the Institutional Ethics Committee and Institutional Research Review Board of SMS Medical College, Jaipur (Ref. No. 1178/MC/EC/2024).

Conflict of Interest:

Nil

Funding Source:

Nil

Acknowledgement:

The authors acknowledge the support of the Department of Forensic Medicine and Toxicology, SMS Medical College, Jaipur, Rajasthan, India.

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