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Original Research Article

Age Estimation Using Digital X-Ray Imaging of the Shoulder Joint in the Bihar population

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Abstract:

Background: Age estimation is essential in forensic medicine, legal investigations, and therapeutic assessments. Although a variety of methods are employed, such as biochemical indicators and dental examination, radiographic evaluation is still a dependable and non-invasive approach. The shoulder joint, which includes the humerus, clavicle, and scapula, has distinctive epiphyseal alterations that make it useful for estimating skeletal age. Data on region-specific populations, such those in Bihar, India, where socioeconomic and environmental variables might affect bone formation and maturation, are few.

Aim: To evaluate the accuracy of shoulder joint digital radiography imaging in determining the chronological age of Bihar's youth and young adults.

Methodology: The present study was conducted in the Department of Forensic Medicine and Toxicology NMCH, Patna, Bihar, India. 92 people between the ages of 14 and 20 participated in a cross-sectional research. Using Jit and Kulkarni's four-stage categorization, digital X-rays of the shoulder joint were examined for epiphyseal fusion of the acromion process, coracoid process, and humeral head. Simple random selection was used to choose participants who satisfied certain inclusion requirements.

Results: As age increased, the research showed a gradual pattern of ossification and fusion. By the time they were 18 to 20 years old, stage 3 (full fusion) was the most common. In accordance with known developmental tendencies, females had somewhat earlier epiphyseal fusion than males.

Conclusion: A valid and useful method for estimating age in the Bihar population is the radiographic evaluation of shoulder ossification. Skeletal maturity data particular to a region improves the precision of forensic and medico-legal investigations.

Keywords: Age Estimation, Bihar Population, Epiphyseal Fusion, Forensic Radiology, Shoulder Joint.

Introduction

Age estimation is an important portion of forensic examination, legal proceedings, and clinical assessment. It is an essential part in the identification of victims in criminal proceedings, mass disasters, and immigration cases [1]. Various methods of age estimation are employed, which are dental examination, evaluation of skeletal maturation, and biochemical markers. Out of these, radiographic evaluation of skeletal structures has emerged as a very crucial method of age estimation since it is a reliable and non-invasive method [2]. The shoulder joint comprising the clavicle, scapula, and humerus undergoes characteristic developmental changes from infancy to death and is a valuable anatomical region for age estimation [3].

With advancement in medical imaging technology, digital radiography has emerged as a precise and effective method of skeletal age estimation [4]. High-resolution images by digital X-rays enable thorough assessment of ossification centers in the bone and fusion patterns in the epiphyses [5]. These are the determinants of chronological age, particularly in the age group of adolescents and young adults. Though large-scale studies on age estimation by radiographic images of the hand, wrist, and knee have been conducted, studies on the shoulder joint are relatively fewer, particularly in some geographic populations like Bihar, India. Bihar is a population with heterogeneous determinants of genetics and environment on the growth of bones. Socioeconomic status, nutritional status, and lifestyle are all likely to affect the growth of bones and, by extension, the accuracy of age estimation. Therefore, region-specific studies need to be conducted to develop uniform age estimation standards for forensic and medical purposes.

The purpose of this research is to assess the feasibility and reliability of age estimation based on digital X-ray images of shoulder joint of the Bihar population. Through the exploration of the amount of epiphyseal ossification and fusion at different age groups, we will attempt to create reference data beneficial for age estimation by forensic experts and doctors. The outcome of this study could offer improved age estimation models for the population of Bihar with increased precision, enhancing forensic inquiry, judicial cases, and health care.

Methodology

Study Design: The present study utilized a cross-sectional observational study to evaluate skeletal maturity and estimate chronological age based on radiographic examination of the shoulder joint. The present study was conducted in the Department of Forensic Medicine and Toxicology NMCH, Patna, Bihar, India for one year

Sample Size: A total of 92 individuals aged 14 to 20 years were recruited in the study.

Sampling Method: A simple random sampling technique was used to choose participants.

Inclusion & Exclusion Criteria

Inclusion Criteria: Inclusion criteria of the study were patients from Bihar state, referred to the Department of Forensic Medicine for age estimation, such as medico-legal cases (MLC) and Chief Medical Officer (CMO) referred cases from the casualty department. Participants must have valid documentary proof of their date of birth and must be between the age group of 14 to 20 years. Participation was limited to those individuals who had no physical disability, bone or cartilaginous diseases, and no history of past or present fractures of the shoulder joint. Participation was further limited to those individuals who were willing to provide informed consent to participate in the study.

Exclusion Criteria: Exclusion criteria comprised pregnant women, patients with a history of bone and cartilage diseases or shoulder joint fractures, and patients with any other severe health issues or physical disabilities. Other individuals from other regions of the state of Bihar and individuals who couldn't comprehend the study language were also excluded.

Data Collection: Demographic and personal details of participants like address, education, medical history, lifestyle, age, sex, physical growth, nutrition status, occupation, handedness, diet, family size, and socio-economic status were recorded. Documentary evidence of age was verified by birth certificates, school leaving certificates, ration cards, election IDs, Aadhaar cards, school IDs, hospital records, and driving licenses.

Radiographic Technique: Digital X-ray radiography was employed to investigate the appearance and union of acromion process, coracoid process, and humeral head ossification centers. Anteroposterior view of shoulder joint was obtained with an exposure factor of 55 KVP and 9 MAS. All possible care was taken to position the X-ray tube over epiphyses in a manner that it would not result in misdiagnosis of union of epiphysis due to obliquely projected ray. Proper precautions, e.g., the use of lead apron, were taken to avoid unnecessary exposure.

Radiological Features and Classification

Bone maturity was graded in terms of Jit and Kulkarni's grading, which represents epiphyseal fusion into four stages:

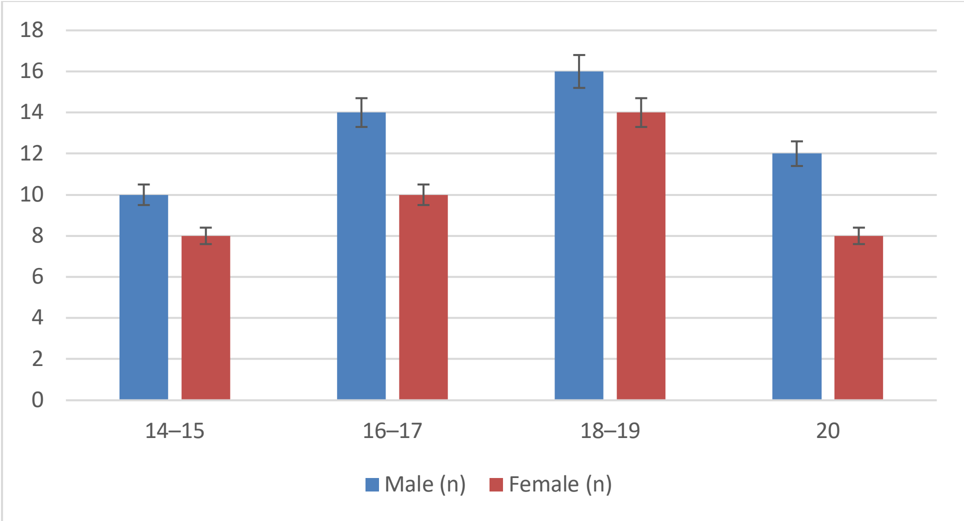
- **Stage 0:** No thinning of epiphyseal cartilage thickness ("Not appeared").
- **Stage 1:** Open gap between epiphysis and diaphysis with saw-tooth appearance ("Non-fusion").
- **Stage 2:** Line replacing the hiatus between epiphysis and diaphysis, without saw-tooth appearance ("Partial fusion").
- **Stage 3:** Uniform bone structure of epiphysis and diaphysis with remnants of earlier stages of fusion ("Complete fusion").

Results

Table 1 presents the age and gender distribution of the 92 study participants. The majority of the participants were between the ages of 18–19 years and comprised 30 participants (16 males and 14 females), followed by 24 participants between the ages of 16–17 years (14 males and 10 females). The 20-year age group comprised 20 participants (12 males and 8 females), while the 14–15-year age group had the lowest representation with 18 participants (10 males and 8 females). In total, there were more male participants (52) than female participants (40), reflecting a slight male predominance in the study population.

Table 1: Age and Gender Distribution of Study Subjects (n=92)

Age Group (Years)	Male (n)	Female (n)	Total (n)
14–15	10	8	18
16–17	14	10	24
18–19	16	14	30
20	12	8	20

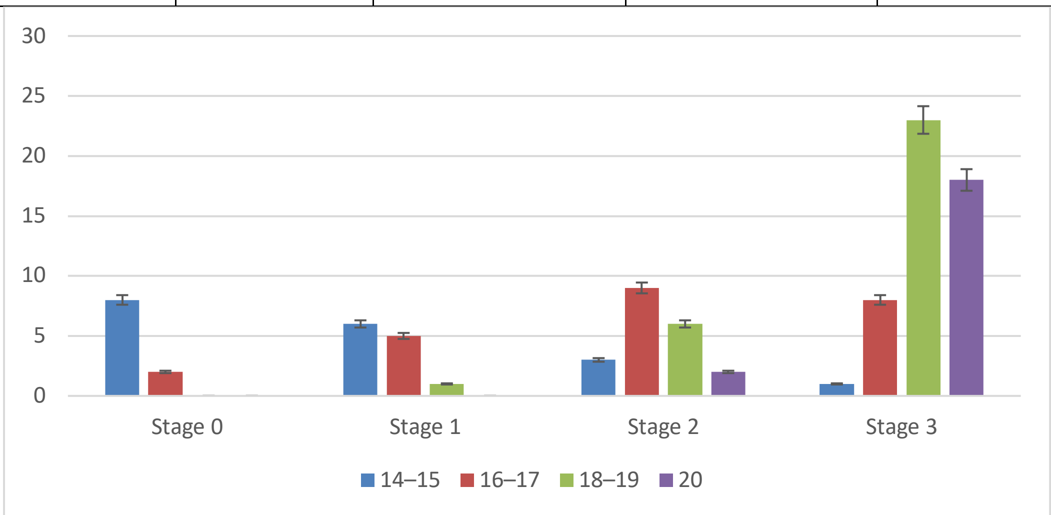


Graph 1. Age and Gender Distribution of Study Subjects

Table 2 depicts the distribution of epiphyseal fusion of the acromion process in stages for different age groups. In the youngest age group (14–15 years), most of them were in Stage 0 (not appeared) and Stage 1 (non-fusion), 8 and 6 respectively, showing initial ossification stages. A progressive development towards maturity is seen in the 16–17 years group, wherein partial fusion (Stage 2) and complete fusion (Stage 3) were seen in 9 and 8 subjects, respectively. At the 18–19-year age group, complete fusion (Stage 3) was seen in a large number (23 cases), with distinct skeletal maturity, with only one case at Stage 1 and six at Stage 2. In the participants aged 20 years, the ossification of the acromion process was almost complete in all, with 18 having complete fusion and only 2 having the stage of partial fusion. This pattern reflects a very high correlation between rising age and the progression of epiphyseal fusion.

Table 2: Stage-wise Distribution of Epiphyseal Fusion of Acromion Process

Age Group (Years)	Stage 0	Stage 1	Stage 2	Stage 3
14–15	8	6	3	1
16–17	2	5	9	8
18–19	0	1	6	23
20	0	0	2	18



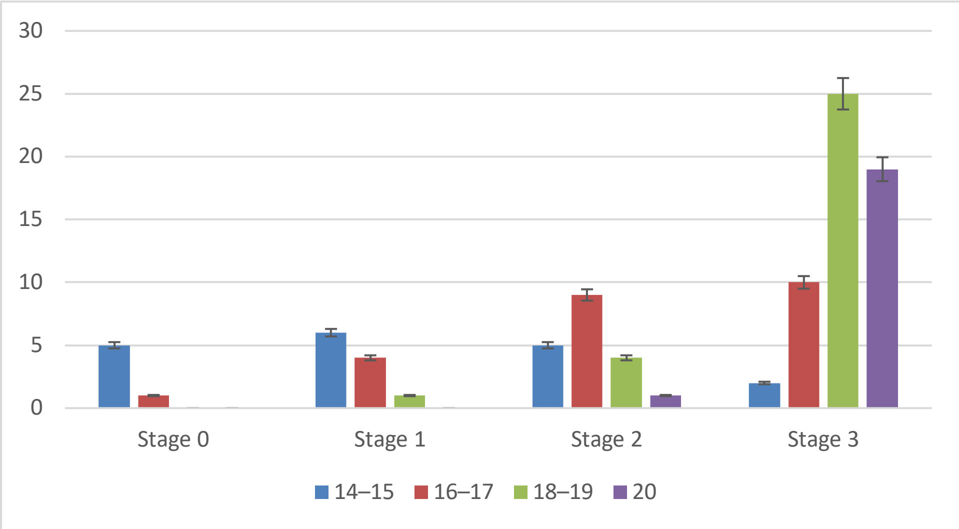
Graph 2: Stage-wise Distribution of Epiphyseal Fusion of Acromion Process

Table 3 depicts the stage-wise distribution of epiphyseal fusion of the coracoid process across different age groups. Among the 14–15 year age group, most participants were in the early phases of fusion, with 6 in Stage 0 (not present) and 7 in Stage 1 (non-fusion), while fewer exhibited partial fusion (4 cases) or full fusion (1 case). In the 16–17 year age group, a tendency of maturation was seen, with 10 participants in Stage 2 (partial fusion) and 8 in Stage 3 (full fusion), indicating progressive ossification.

A significant rise in skeletal maturity was seen in the 18–19 year age range, with 24 participants exhibiting full fusion, whereas only a few were in the preliminary phases.

Table 3: Stage-wise Distribution of Epiphyseal Fusion of Coracoid Process

Age Group (Years)	Stage 0	Stage 1	Stage 2	Stage 3
14–15	6	7	4	1
16–17	2	4	10	8
18–19	0	1	5	24
20	0	0	1	19



Graph 3: Stage-wise Distribution of Epiphyseal Fusion of Coracoid Process

Discussion

In the current research, the pattern of shoulder epiphyseal fusion of the acromion process, the coracoid process, and the head of the humerus in a population sample comprising 92 people between the age group of 14 and 20 years was examined. A consistent age pattern in the fusion of the epiphyses was seen with the majority of the population being fully fused by the age of 18 and 20. It agrees with a number of studies done previously but shows some variation among the studies, possibly resulting from variations in population samples, ethnicity, gender, and environmental conditions.

In the current study, completion of the fusion of the acromion process (Stage 3) starts becoming evident from the age group 16–17 and approaches universality by the age group 18–20. It agrees with the observation by the study done by Saravanan et al. (2022) who assessed radiographic images of the shoulder joint and found that in males, completion of the shoulder epiphysis's fusion occurred in 33.33% by the age group 18–19, increasing up to 100% at the age group of 20 [6]. In the same way, in females, completion in the age group of 18–19 years occurred in 50%. Authors have highlighted the prior maturation in females, similar to the observation in the current study that females mature slightly earlier than males.

Comparatively, Funk (2022) documented delayed patterns of fusion of the acromion in some groups, with the observation that the resultant incomplete fusion may last as long as 25 years in some instances, especially among athletes or people with repetitive overhead activities [7]. This emphasizes the contribution of physical exercise and biomechanical stress toward determining the timing in the closure of the epiphyses.

In our study, the ossification of the coracoid process advances gradually with age and the majority attain complete fusion by the age of 18–20. This agrees with Ogawa et al. (2020), who conducted a detailed radiographic assessment and concluded that the coracoid process and the associated subcoracoid ossification centers are normally visible between the age of 9–12 and complete fusion occurs between the age of 16–17 [8]. Nevertheless, the review highlighted considerable variation according to sex, ethnicity, as well as observation methods.

In our study, slightly delayed fusion in accordance with Ogawa et al., potentially owing to regional or genetic variation in skeletal maturation. In addition, socioeconomic status as well as dietary intake—particularly found in resource-poor environments—may have an impact on skeletal development, potentially explaining the protracted timeline in our data.

The progressive sequence of humeral head ossification with the majority of the subjects attaining Stage 3 fusion by the age of 18–20. This correlates with the 5-stage ossification classification system by Li et al. (2018), which examined the ossification process in the humeral head and how it relates to peak height velocity (PHV). It concluded that partial and complete closure in the physis were completed around 2.27 and 4.02 years after PHV, respectively [9]. Given that PHV among adolescents normally occurs at the age of 12–14, these durations are in line with our observation for complete fusion at the age of 18–19.

Another work by Choudhary et al. (2022) centered on the lower end of the humerus and determined the medial epicondyle's fusion between the age of 14 and 17 years. While this involves a different location, it mirrors the advancing epiphyseal fusion pattern seen in late adolescence [10].

In our study, there was slightly greater ratio of males in the sample population (52 males and 40 females), and though the gender-specific analysis was not statistically significant, observationally, the females had more rapid epiphyseal fusion in all ossification centers. This pattern supports the documented literature. Farr (2015) determined that females tend to become skeletally mature slightly before males through the earlier timing of puberty, hormonal effects, and variation in the growth plate senescence [11].

Conclusion

The current study proves radiographic examination of the shoulder joint ossification centers as a useful and non-invasive tool for age estimation in adolescents and young adults in the population of Bihar. The correlation between advancing age and the sequence of epiphyseal fusion, especially the completion by the age of 18–20, indicates the utility of shoulder radiographs in forensic applications. Early completion of fusion in females corroborates the accepted patterns and trends in biological maturation. These findings support the use of region-specific skeletal reference data for increasing the reliability and accuracy of age estimation in medico-legal as well as forensic applications.

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