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Radiographic assessment of age from epiphyseal fusion at knee joint of selected patients at a teaching hospital, Nepal

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Abstract:

Background: Determining age and sex in forensic science based on bone age estimation is becoming increasingly important because of the increase in unregistered documents and legal issues. For estimating the chronological age, radiographic analysis of knee is a reliable alternative with the assessment of three epiphyseal unions which includes distal femur, proximal tibia and proximal fibula at the same time.

Method: An observational prospective study, including 80 patients, was conducted based on the sample of the anteroposterior radiographs of the knee of the patients visiting for X-ray knee through Emergency or Out Patient Departments within a period of one year (January 2021 to December 2021) at Manipal College of Medical Sciences, Pokhara, Nepal. In this study, anteroposterior radiographs of the knee were reviewed in subjects aged between 10 and 21 years old; 48 males and 32 females. Epiphyseal union was evaluated based on the ossification and epiphyseal scar.

Result: The complete ossification of knee joint in males and females was first observed in all instances (100%) at the age groups of 18-19 and 17-19 years, respectively. Epiphyseal union in females occurred earlier than in males.

Conclusion: The radiographic assessment of knee joint offers a valuable alternative as a non-invasive method for estimation of age.

Keywords: Age estimation, Forensic anthropology, Knee, Radiographs

How to cite

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Introduction

Age estimation is essential in developing countries like Nepal, where many births go unregistered. Without birth certificates, individuals lack legal recognition, making them vulnerable to rights violations and improper age classification, which can lead to issues like child labor, military recruitment, and exploitation.^{1,2} Ensuring accurate age identification is crucial to protect minors from being misclassified as adults in legal and administrative processes.³ Regarding criminal cases, when there are doubts about a suspect's age, forensic age estimation is crucial to determine if they have reached the age of criminal responsibility.⁴ Forensic age estimation, a specialized area of forensic medicine, seeks to determine a person's chronological age using the most accurate methods available. However, no medical test can precisely determine an individual's age.⁵

Different bones begin and complete their ossification at specific, relatively fixed periods of life, which can be studied through x-rays.⁶ The knee is particularly suitable for this assessment because it allows for easy positioning for anteroposterior (AP) radiographs, providing information on three epiphyses: the distal femur (DF), proximal tibia (PT), and proximal fibula (PF).⁷ The process of epiphyseal union of knee joint can help estimate age between 10 and 20 years and is feasible as they are in close proximity.⁸

The aim of the present study was to assess the stages of epiphyseal union at the knee joint to estimate the chronological age in a Nepalese population.

Method

This was an observational prospective study based on the sample of the anteroposterior radiographs of the knee of the patients visiting for X-ray knee through Emergency or Out Patient Departments. The samples were obtained within a period of one year (January 2021 to December 2021) at Manipal College of Medical Sciences,

Pokhara, Nepal. The study was carried out after approval from the Institutional Review Committee of Manipal Teaching Hospital (MEMG/IRC/402/GA) was obtained.

Nepalese participants aged between 10 and 21 years who consented for the study, were analyzed and included in the study. We excluded radiographs showing fractures or dislocations involving the growth plate or those that showed surgical implants near the diaphyseal-epiphyseal junction. We also excluded radiographs obtained from subjects with a medical history of known endocrine, metabolic, or nutritional disorders which may significantly alter skeletal development.

Digital X-rays soft films of knee joint, anteroposterior view was collected from the radiology department and were brought to forensic department. The observer who was blinded to information on the subject's gender and age, assessed the staging of the union for each of the epiphysis.

The distal femur (DF), proximal tibia (PT), and proximal fibula (PF) epiphyses were separately evaluated for the degree of the ossification according to three different stages.

To assess the degree of ossification of the distal femur, proximal tibia and proximal fibula, classification into three stages for each bone was applied: stage I, epiphysis not fused; stage II, epiphysis fully ossified and visible epiphyseal scar; stage III, epiphysis fully ossified and epiphyseal scar not visible.⁹ All data obtained were collected, documented, and analyzed and then expressed in frequency tables.

Result

A total of 80 knee radiographs were assessed, 48 males and 32 females, for twelve age categories from the age of 10 to 21 years, Table 1.

In our study, distal end of femur, in males, showed complete fusion first in all 5 cases in 19 years of age. While among females, complete fusion was seen at 18 years of age in all 4 cases, Table 2 and 3. In males, proximal end of tibia showed complete fusion in all 5 cases at 18 years of age whereas, in females, complete fusion was

observed in all 4 cases at 17 years of age, Table 2 and 3.

Proximal end of fibula, in males showed complete fusion in all 5 cases at 19 years of age. While in females, complete fusion was observed in all 4 cases at 19 years of age, Table 2 and 3.

The complete ossification of knee joint in males and females was observed in all instances (100%) at the age of 18-19 years and 17-19 years, respectively. In all the cases of epiphyses studied, union were found to be earlier in girls than boys in femur and tibia.

Table 1. Age and sex wise distribution of the patients visiting for X-ray knee, n=80

Age	10	11	12	13	14	15	16	17	18	19	20	21	Total
Male	2	1	1	0	3	3	6	11	5	5	8	3	48
Female	0	0	2	1	0	2	1	4	6	4	9	3	32
Total	2	1	3	1	3	5	7	15	11	9	17	6	80

Table 2. Age of females and union observed at the knee joint for distal femur, proximal tibia and fibula, n=32

Age Y	Female n	Femur			Tibia			Fibula			
		I	II	III	I	II	III	I	II	III	
10	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0
12	2	0	2	0	0	2	0	0	2	0	0
13	1	0	1	0	0	1	0	0	1	0	0
14	0	0	0	0	0	0	0	0	0	0	0
15	2	0	2	0	0	2	0	0	2	0	0
16	1	0	1	0	0	1	0	0	1	0	0
17	4	0	4	0	0	0	4	0	4	0	0
18	6	0	0	6	0	2	4	0	1	5	0
19	4	0	0	4	0	0	4	0	0	4	0
20	9	0	0	9	0	0	9	0	0	9	0
21	3	0	0	3	0	0	3	0	0	3	0

Note: Stage I epiphysis not fused, II epiphysis fully ossified and visible epiphyseal scar, III epiphysis fully ossified and epiphyseal scar not visible

Table 3. Age of females and union observed at the knee joint for distal femur, proximal tibia and fibula, n=48

Age Y	Male n	Femur			Tibia			Fibula		
		I	II	III	I	II	III	I	II	III
10	2	1	1	0	1	1	0	1	1	0
11	1	1	0	0	1	0	0	1	0	0
12	1	0	1	0	0	1	0	0	1	0
13	0	0	0	0	0	0	0	0	0	0
14	3	0	2	1	0	2	1	0	2	1
15	3	0	3	0	0	3	0	0	3	0
16	6	0	5	1	0	5	1	0	5	1
17	11	0	9	2	0	9	2	0	7	4
18	5	0	2	3	0	0	5	0	3	2
19	5	0	0	5	0	1	4	0	0	5
20	8	0	0	8	0	1	7	0	0	8
21	3	0	0	3	0	0	3	0	0	3

Discussion

In our study, the complete union of femur, tibia and fibula was seen at 19, 18 and 19 years in 100% among males and at 18, 17 and 19 years among females. The findings of our study is consistent with other studies.^{10,11} However, studies in an Irish population observed completion of knee epiphyseal union in the range of 16-18 years for males and 14-19 for females.¹² Yet another study recorded complete union at a mean age of 16.55 years in males and 14.55 years in females.¹³ Determining age based on epiphyseal fusion is regarded as one of the most crucial scientific methods to date.¹⁴ Studies have demonstrated that examining the union of epiphyses in bones is a scientifically sound and widely accepted approach for age estimation, recognized by courts worldwide.¹⁵

The core principle behind age estimation techniques in younger individuals lies in the continuous, gradual changes occurring in the skeleton until it reaches full maturity.¹³ It is evident that the timing of epiphyseal union varies among individuals from different populations. This variation may result from population differences, secular trends, or the absence of standardized methodologies.¹² Since age determination is critical in practical scenarios such as clinical and forensic investigations, where high accuracy is essential, it is crucial to re-evaluate the data currently in use. In situations where contemporary collections of immature skeletal remains are limited, radiographs offer a viable alternative for analysis.¹⁶

Based on sex differentiation, our study revealed that the different scores of epiphyseal unions were higher in females than males indicating that skeletal maturation occurred earlier in females, like another study.¹⁷ Study suggests that maturation changes in knee stop after the age of 16 in females and 19 in males.¹⁸ Therefore, age estimation should be done differently for males and females.

The rate of maturation is influenced by numerous factors, including an individual's nutritional intake and overall health.⁴ Chronic disorders, particularly those related to metabolic or endocrine issues. Also, certain conditions can

speed up bone growth, causing it to surpass the individual's chronological age.⁷ Recent resonance imaging (MRI) studies of the knee have been conducted to assess the reliability of this technique for age identification.¹⁹ The magnetic MRI is a safer alternative to X-rays, but in many locations where resources are limited and MRI is not feasible, plain radiographs continue to be used. As a result, radiographs remain essential tools in forensic anthropological research.²⁰

An anteroposterior knee radiograph is a commonly used and accepted method for age assessment, particularly around the age of 18 years. Additionally, knee examinations are highly accurate, and in situations involving mass disasters or body remnants, they may be the only available method for determining age.¹¹ Numerous anthropological studies have examined skeletal maturation of the knee using dry bones, X-rays, and MRI. However, these studies vary significantly in several aspects, including the study population, gender, sample size, age range, and the number of bone fusion stages assessed.²¹

Crucially, research by various authors has shown that age estimation standards are most accurate when tailored to specific populations. Therefore, it's essential for the forensic community to continue developing and validating age estimation standards for their respective populations.⁶ This study provides a baseline data for fusion at knee joint and age estimation in local population. Studies with a larger number of cases including a varied ethnicity and geography is again a topic for further research.

Conclusion

With an increasing age there was a greater stage of fusion at the joint. The radiographic assessment offers a valuable alternative as a non-invasive method of estimation of age. This study provides support to use the stage of fusion as an alternative method for estimating the age in local population.

Author contribution

Conception, design: SRP, SK; Data acquisition: SRP, SM, NK; Data analysis, interpretation: SRP,

SM, SK; Drafting: SRP, NK, SM; Revision: SRP, SK, SM, NK; Final approval of the version to be published: All; Agreement to be accountable for all aspects of the work: All.

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Conflict of interest

None

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Supplementary material

The data and supplementary material that support the findings of this study are available from the corresponding author upon reasonable request.

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