Variations in Sex and Laterality in the Ossification Process of the Proximal Epiphyseal Plate of Humerus among People Aged Between 14-25 Years in Western Kenya

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ABSTRACT

Radiological examination of the shoulder joint is a method used to determine age by analyzing the skeletal changes that occur in the joint with aging. This study investigates the effectiveness of this technique in estimating age within the population of western Kenya. The study focused on examining variations in sex and laterality in the ossification process of the proximal epiphyseal plate of the humerus among individuals aged 14 to 25 years in western Kenya. The study was conducted in western Kenya, with data sourced from Jaramogi Oginga Odinga Teaching and Referral Hospital (JOOTRH), located in Kisumu city along the Kisumu-Kakamega Road. A retrospective cross-sectional research design was utilized, targeting 864 chest radiographs of individuals aged 14 to 25 years taken within the past year. A sample size of 273 chest X-rays was estimated, and data were obtained through purposive sampling. A data collection form was designed and employed to gather information. The collected data were analyzed using both descriptive and inferential statistics, with the findings presented through tables, charts, and graphs. Most females (29.8%) achieve complete fusion of the proximal epiphyseal plates at 16-17 years, while males (25.4%) reach it at 18-19 years. Partial fusion and non-fusion are observed at 14-15 years. Females fuse earlier than males, correlating closely with age and stages of ossification. This variation aligns with biological differences in skeletal maturation.

Keywords: Age Estimation; Variation; Humerus; Ossification; Proximal Epiphyseal Plate; Humerus; Sex and Laterality.

1. Introduction

Age estimation using the radiological examination of the shoulder joint has been extensively studied and has been found to be a reliable method for estimating age in individuals. However, there are still some uncertainties associated with this method. According to a study by Liversidge et al. (2019), radiological examination of the shoulder joint can provide a standard deviation of +/- 5 years when estimating age. Another study by Kellinghaus et al. (2018) reported that the age estimation using the radiological examination of the shoulder joint has an accuracy rate of around 70%.

In the United States, radiological examination of the shoulder joint is widely used for age estimation. According to a study by De Greef et al. (2019), age estimation using the radiological examination of the shoulder joint has been shown to be reliable for individuals up to the age of 25 years. The same study also reported that radiological examination of the shoulder joint can provide a standard deviation of +/- 4.3 years when estimating age. Another study by Sartori et al. (2020) found that the accuracy of age estimation using the radiological examination of the shoulder joint is affected by the ethnicity of the individual.

In Europe, radiological examination of the shoulder joint is also commonly used for age estimation. According to a study by Thevissen et al. (2018), radiological examination of the shoulder joint is a reliable method for estimating age in individuals up to the age of 21 years. The same study also reported that radiological examination of the shoulder joint can provide a standard deviation of +/- 3.6 years when estimating age. Another study by Pfeiffer et al. (2020) found that age estimation using the radiological examination of the shoulder joint is more accurate in females than in males.

Radiological examination of the shoulder joint is a popular method for age estimation. According to a study in Asia, by Ma et al. (2019), radiological examination of the shoulder joint is a reliable method for estimating age in individuals up to the age of 23 years. The same study also reported that radiological examination of the shoulder joint can provide a standard deviation of +/- 4.9 years when estimating age. Another study by Chen et al. (2021) found that age estimation using the radiological examination of the shoulder joint is more accurate in individuals with a Chinese ethnicity. Bilateral asymmetry in the ossification of the shoulder epiphysis has been observed in various populations across the world. Several studies have reported that the degree of asymmetry can vary significantly between individuals, making it challenging to accurately estimate age based on skeletal remains alone. For example, a study by Liversidge et al. (2019) found that the degree of bilateral asymmetry in the ossification of the shoulder epiphysis was greater in females than in males. Similarly, a study by Ferrario et al. (2018) reported that there was a significant correlation between the degree of asymmetry and chronological age in a sample of Italian individuals.

A study by Halcrow and Tayles (2019), conducted in New Zealand, investigated bilateral asymmetry in the ossification of the shoulder epiphysis and found that it can have a significant impact on age estimation. The study included individuals aged between 16 and 30 years and found that in males, the left shoulder epiphysis was more advanced in ossification than the right, while in females, the right shoulder epiphysis was more advanced. These findings suggest that age estimation using the shoulder epiphyses should consider the possibility of bilateral asymmetry to increase accuracy.

Another study by Park et al. (2018) in South Korea, found that there was significant bilateral asymmetry in the ossification of the shoulder epiphysis in individuals aged between 14 and 23 years. The study found that in both males and females, the left shoulder epiphysis was more advanced in ossification than the right. These findings have implications for age estimation in forensic anthropology in South Korea, as the left shoulder epiphysis may not accurately represent the individual's age.

In a study conducted in Brazil by Oliveira et al. (2020), the authors investigated the ossification of the shoulder epiphysis in individuals aged between 14 and 25 years. The study found that there was significant bilateral asymmetry in the ossification of the shoulder epiphysis in both males and females, with the left side being more advanced in ossification than the right. The authors suggest that age estimation using the shoulder epiphyses should consider the possibility of bilateral asymmetry to increase accuracy.

Furthermore, the impact of bilateral asymmetry on age estimation may also vary between populations from different regions of the world. For instance, a study by Kim et al. (2019) investigated the degree of bilateral asymmetry in the ossification of the shoulder epiphysis in a sample of Korean individuals and reported that the degree of asymmetry was significantly lower compared to previous studies conducted on other populations. This highlights the importance of population-specific studies to accurately estimate age from skeletal remains.

Unfortunately, there is a lack of studies on age estimation using radiological examination of the shoulder joint in Africa, particularly in East Africa. However, a study by Briers et al. (2020) reported that the radiological examination of the shoulder joint is a reliable method for estimating age in individuals up to the age of 21 years in

South Africa. The same study also reported that radiological examination of the shoulder joint can provide a standard deviation of +/- 4.4 years when estimating age. Another study by Du Plessis et al. (2021) found that the accuracy of age estimation using the radiological examination of the shoulder joint is affected by the development stage of the epiphysis.

2. Methodology

This study took place at Jaramogi Oginga Odinga Teaching and Referral Hospital, selected for its extensive catchment area and well-equipped radiology department. Before commencing, all necessary ethical approvals were obtained. A research assistant from the radiology Department was recruited and trained to accurately complete the data collection tool.

The study followed a retrospective cross-sectional design, with the sample size calculated using the Yamane Taro formula (1967). This formula provides a straightforward way to estimate a reliable sample size for populations under 10,000 with a high degree of precision:

$$n = \frac{N}{1 + N e^2}$$

Where:

n = sample size

N = study population

e = maximum acceptable margin of error (5%)

From a population of 864 chest X-rays taken between April 2022 and March 2023, the sample size was determined to be 273. Purposive sampling was employed to select the radiographs.

The study included radiological records meeting specific criteria, such as clear documentation of date of birth, gender, contact details, and the date of X-ray acquisition. Only chest X-rays with distinct outlines of the glenohumeral joints from individuals aged 14 to 25 years were included. Records were excluded if patients had a history of skeletal growth disorders, fractures, or conditions like gigantism or osteogenesis imperfecta.

Data analysis was performed using SPSS version 26, applying descriptive and inferential statistics, including independent t-tests. A significance level of less than 0.05 ($p < 0.05$) was considered statistically significant, and findings were presented visually through graphs and charts.

3. Results

3.1. Variations in sex and laterality in the ossification process of the proximal epiphyseal plate of humerus

Out of the total (273) cases, 46 (16.8%) cases that showed complete union of proximal epiphyseal plates of humerus were females while 64 (23.4%) were males (Table 1).

Among the total (46) cases of complete union in females, 29 cases (63%) showed dominance in right proximal epiphyseal plate of the humerus while 17 cases (37%) showed left humerus dominance.

Among the total (64) cases of complete unions in males, 46 cases (71.9%) showed dominance in the right proximal epiphyseal plate of the humerus while 18 cases (28.1%) showed left humerus dominance.

Table 1. Sex and laterality in the ossification process of the proximal epiphyseal plate of humerus

Age group	No. of cases	Males			Females		
		CF	RL	LL	CF	RL	LL
14-15	140	0	0	0	0	0	0
16-17	66	11	8	3	39	24	15
18-19	46	36	28	8	3	2	1
20-21	7	6	4	2	1	0	1
22-23	7	4	2	2	3	3	0
24-25	7	7	4	3	0	0	0
TOTAL	273	64	46	18	46	29	17

Key: CF=complete fusion, RL=right laterality, LL=left laterality.

A crosstab analysis of the relationship between gender and laterality yields the results in table 2 below:

Table 2. Variations in sex and laterality in the ossification process of the proximal epiphyseal plate of humerus

Chi-Square Tests									
	Value	df	Asymptotic Significance (2-sided)		Exact Sig. (2-sided)		Exact Sig. (1-sided)		
			Right Humerus	Left Humerus	Right Humerus	Left Humerus	Right Humerus	Left Humerus	
Pearson Chi-Square	4.579[a]	1	.032	.941					
Continuity Correction[b]	4.021	1	.045	1.000					
Likelihood Ratio	4.620	1	.032	.941					
Fisher's Exact Test					.043	1.000	.022	.542	
Linear-by-Linear Association	4.562	1	.033	.941					
N of Valid Cases	273								
a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 36.95.									
b. Computed only for a 2x2 table.									

The results showed that at 95% confidence level, the Pearson Chi-Square, Community Correction, Likelihood Ratio and Linear-Linear Association asymptotic significance values are 0.032, 0.045, 0.032 and 0.033 respectively for the right humerus and 0.941, 1.000, 0.941 and 0.941 respectively for the left humerus. The exact significance values (2-sided and 1-sided) also show a strong relationship (0.043 and 0.022) for the right humerus as compared

to the left humerus (1.000 and 0.542). The results show that there is a high probability of complete fusion occurring earlier in the right as compared to the right humerus for both genders.
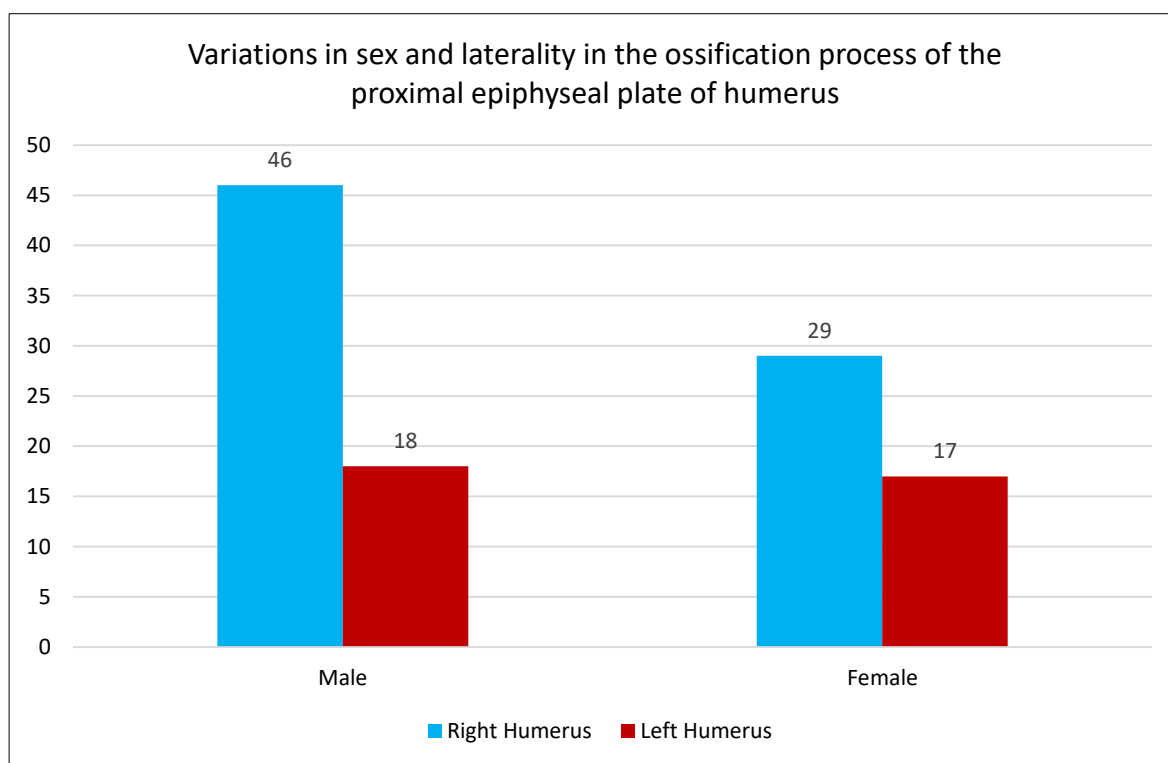

Figure 1. Variations in sex and laterality in the ossification process of the proximal epiphyseal plate of humerus

4. Discussion

4.1. To determine variations in sex and laterality in the ossification process of the proximal epiphyseal plate of humerus

The study in the union of bones has taken shape globally as it is considered an ideal scientific way of age estimation (Schemling, 2013). Radiological changes in bones can be evaluated over time up to the age of 25 years of age. The present study shows variation in sex in terms of stages of union of epiphyseal plate. On examination of the radiographs, fusion among females was observed to occur at an earlier age (18-19 years) compared to males (20-21 years) as shown in Figure 1.

These findings correlate with the observation by Menom et al (2012) who reported that majority of cases showed complete union of the shoulder by 17-18 years in females and 18-19 in males. The slight variations are attributed to the fact that it takes about one year for a particular stage of fusion to progress to the next one. Additionally, they are also attributed to hormonal, environmental or genetic factors.

The results from the data collected showed that the right shoulder joint fused earlier for both genders with 32 cases at age group 16-17 as compared to 18 cases for the same age group. Fewer cases of males (8 for the right humerus and 3 for the left humerus) were recorded as compared to females (25 for the right humerus and 15 for the left humerus) at age group 16-17.
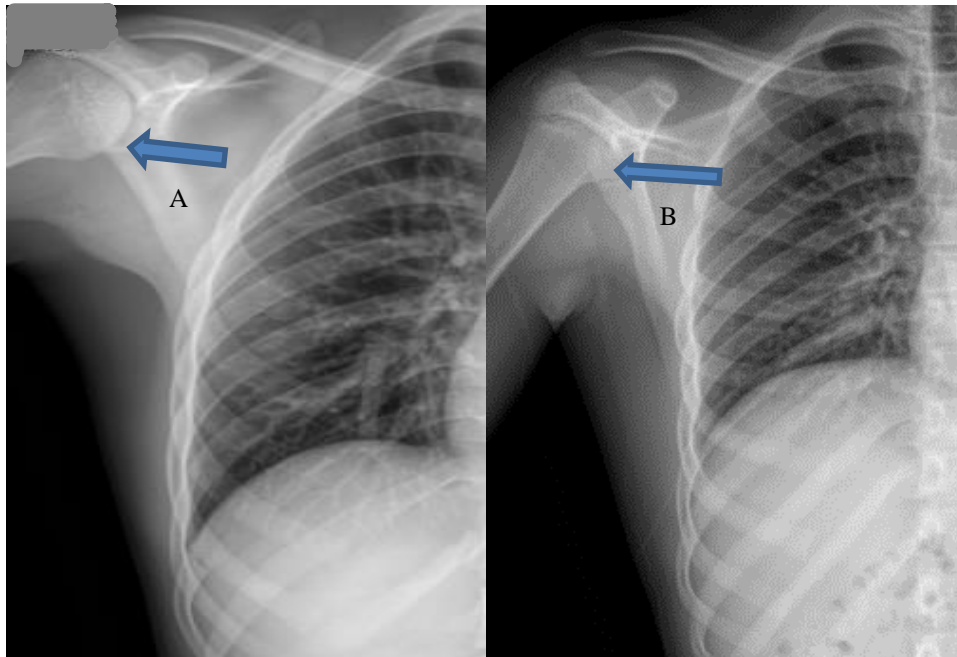
Figure 2. A-radiograph showing complete fusion in female; B-radiograph showing incomplete fusion in male

Studies have reported variations in laterality as a result of fixation of a plate or screw to the humerus bone due to fracture. Kvist et al. (2020) conducted MRI studies on growth plate and he observed that the female gender showed earlier fusion compared to male gender and all these findings were attributed to be influenced by sex, pubertal development and basal metabolic rate.
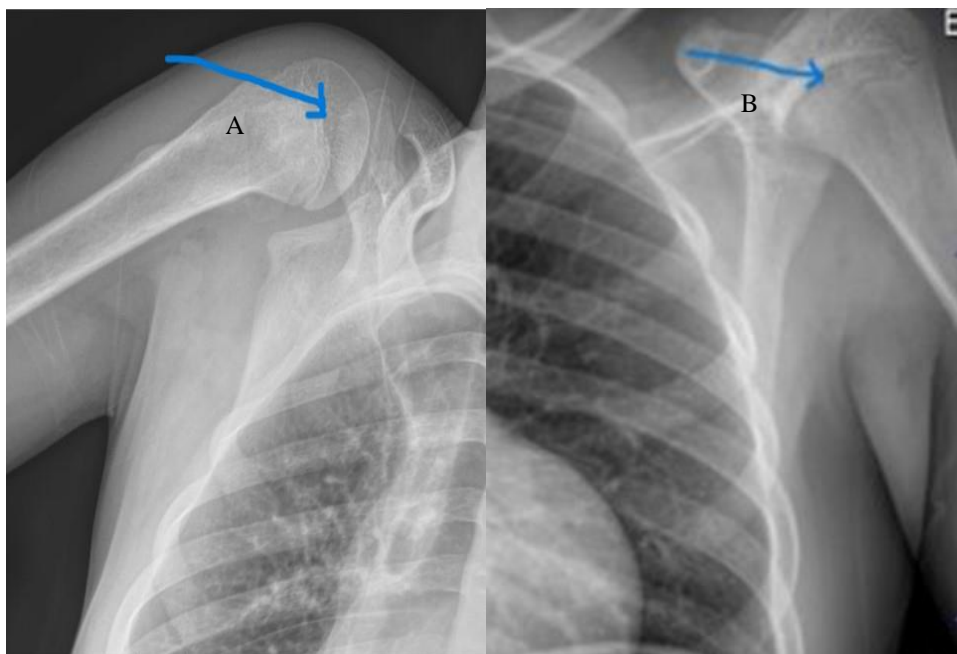

Figure 3. A-radiograph showing right complete fusion of epiphyseal plate in female; B-radiograph showing left complete fusion of epiphyseal plate in males

5. Conclusion

1. Females show earlier epiphyseal fusion (18-19 years) than males (20-21 years), influenced by hormones, genetics, and environment.

2. Fusion stages progress over about one year, explaining slight age differences in studies.

3. Right shoulder joints fuse earlier than left, with more early fusion cases in females.

4. Factors like fractures and metabolic rates also impact fusion timing.

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