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## RESEARCH ARTICLE

### BONE AGE ASSESSMENT BY EPIPHYSEAL FUSION OF THE DISTAL END OF THE FEMUR BY USING RADIOGRAPHS OF 10-22 YEARS AGE SUBJECTS AT GEZIRA STATE, SUDAN

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#### ABSTRACT

**Background:** Age estimation in the living is one of the most important tasks of a forensic practitioner especially in developing countries where birth records are often not well-maintained.

**Objective:** Prospective cross-sectional study was carried out in Wad Medani Teaching Hospital, Wad Medani orthopedic Center and Gezira National Center for Pediatric Surgery with the objective to assess the bone age by epiphyseal fusion of the distal end of the femur by using radiographs of Sudanese subject at Gezira State.

**Methods:** A total of 113 Subjects comprising of 62 females and 51 males, free from any musculoskeletal, nutritional and endocrinal disorder and confirmed dates of births were enrolled in the current study, The Subjects were divided into 12 groups on the basis of their age. Radiographs of knee joint were taken and a classification into four group on fusion base was applied, Stage I: No fusion; Stage II: Partial fusion; Stage III: Recent fusion; Stage IV: Complete fusion.

**Results:** It was found that the lower end of femur united completely with shaft in age group of 19- 20 years in males and 17- 18 years in females. The epiphysis average age of fusion is higher in males as compared to females.

**Conclusion:** The sequence of fusion of distal end of femur was almost similar with other workers.

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## INTRODUCTION

The determination of age of an individual has a considerable importance in Medico legal field, It is also essential to establish the identity of a person at the time of admission to schools, colleges, institutes, or while competing in sports tournaments at regional, state or national levels. The bones of human skeletons develop from separate ossification centers. From these centers ossification progresses till the bone is completely formed. These changes can be studied by means of X-rays and these changes are age related (Bhise *et al.*, 2015). It is therefore possible to determine the approximate age of an individual by radiological examination of bones till ossification is complete (Sharma Yogesh *et al.*, 2013). Extensive works on the estimation of age of epiphyseal union has been carried out in different parts of the world (Sharma Yogesh *et al.*, 2013) and most data of appearance and fusion of ossification centers are based on White children from the upper socioeconomic level. (Francis, 1940; Francis *et al.*, 1939) The Sudan population

differs widely from the western population in hereditary, dietary, socioeconomic and ethnic factors and there is a considerable lack of interesting about this field, as there were no modern studies concerning about the age estimation of bones of the knee joint. This study tried harder to put a piece of light in this field, concerning knee bones estimation, particularly the distal end of the femur. This present work is carried out with an attempt to study epiphyseal fusion in lower end of femur in the age-group of 10-22 years among the people of Gezira State in Central Sudan.

#### Study objectives

- To find out average age of fusion of ossification center of distal end of femur in males and females.
- To compare age of fusion of lower epiphysis to the shaft of femur in male and female.
- To compare the results of present study with other workers.

## MATERIALS AND METHODS

This cross-sectional study was carried out at Wad Medani Teaching Hospital, Wad Medani Orthopedic Center and Gezira

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National Center for Pediatric Surgery during 2012-2014. A total of 113 (51 males, 62 females) in the age group of 10-22 years attended the outpatient departments of these centers were selected randomly on cross-sectional basis and involved in the study. The criteria of sample selection were:

- They should be free from any physical disability involving lower limbs, nutritional and endocrinal disorders at the time of radiography
- They should be from all social classes, with variable socioeconomic status
- All the samples had documentary evidence of birth
- They should be natives of Gezira State

An informed consent was taken from all subjects prior to radiography. For purposes of the study, subjects of either sex were grouped into 12 age-groups from 10 to 22 year with difference of 1 year each year. Age group from 10-11 is considered as that who have completed 10 years of age but yet to complete 11 years of age and similarly for other age groups. X-ray of right knee joint with both antero-posterior and lateral view in all 113 samples were taken at departments of radiology in Wad Medani Teaching Hospital, Wad Medani orthopedic Center and Gezira National Center for Pediatric Surgery. Radiographs were captured using a digital camera (Kodak 8.2 megapixel, ISO 1250, Digital IS) and saved electronically on a computer for analysis and were studied in detail by a radiologist and the author with respect to fusion of ossification centre of the distal end of the femur. The different phases of fusion were graded into four stages:

**Stage I:** No fusion, complete gap between epiphysis and shaft of the bone;

**Stage II:** Partial fusion, partial closure of gap between epiphysis and shaft of the bone;

**Stage III:** Recent fusion, complete closure of gap between epiphysis and shaft of the bone with presence of white line (scar) between them;

**Stage IV:** Complete fusion, complete union between epiphysis and shaft with disappearance of the scar. The finding were recorded on a predesigned Performa and tabulated for discussion.

## OBSERVATIONS AND RESULTS

The present study was undertaken prospectively for assessment of age in the population of Gezira State in Central Sudan from epiphyseal fusion of the distal end of femur, radiographically. Radiographs (AP and Lateral view) of right sided knee joint of 113 subjects including 51 males and 62 females (Table 1) were studied and observations recorded separately for males and females. In the present study regarding fusion of distal end of femur to shaft in males, stage I was seen in 100% of cases at age groups 10- 11 years age, 11- 12 years age and 12- 13 years age. It was seen in (40%) of cases in age group 13- 14 years age. Partial fusion (stage II) was seen in (60%) of cases at 13- 14 years age group, in (80%) of cases at 14- 15 years age group and in (83.3%) of cases at 16-17 years age group. (Table 2)

Recent fusion (stage III) was seen in 20%, 33.3%, 16.7%, 60% and 75% of cases at age groups 14- 15 years, 15- 16 years, 16- 17 years, 17- 18 years and 18-19 years respectively. It was seen in only one case (16.7%) at 19-20 years age group. Complete fusion (stage IV) was seen in the majority of cases (83.3%) at 19- 20 years age group. Age group at which 100% cases showing complete fusion in males was 20- 21 years age upward.

From our study regarding fusion of lower end of femur to shaft in females, stage I of fusion was seen in 100% of cases at 10- 11 and 11- 12 years age groups, and in (60%) and (25%) of cases at 12- 13 and 13-14 years age groups respectively. (Table 3). Partial fusion (stage II) in females commenced at 12-13 years age group and it was seen in (75%) of cases at 13- 14 years age group, in (71.4%) of cases at 14-15 years age group. Stage III of fusion was seen in (71.4%) of cases at 15-16 years age group, in (71.4%) of cases at 15- 16 years age group and in (80%) of cases at 16- 17 years age group. Complete fusion was seen in (83.3 %) of cases at 17-18 years age group and in (85.7%) of cases at 18-19 years age group. Age group at which 100% cases showing complete fusion in females was 19- 20 years age upward. Table (4) showing a summary of average age of each stage of fusion in male and female. The findings of the present work were compared with other available works in this field in (Table 6).

**Tables 1. Total number of samples selected for study in different age groups**

Age group	No. of cases in each age group		Total
	Males	Females	
10 – 11	3	3	6
11 – 12	3	4	7
12 – 13	2	5	7
13 – 14	5	4	9
14 – 15	5	7	12
15 – 16	6	7	13
16 – 17	6	5	11
17 – 18	5	6	11
18 – 19	4	7	11
19 – 20	6	6	12
20 – 21	4	5	9
21 – 22	2	3	5
Total	51	62	113

## DISCUSSION

The present study was undertaken to estimate the bone age from epiphyseal fusion of the distal end of femur in Gezira State population at Central Sudan and was carried out in the departments of Radiology at Wad Medani Teaching Hospital, Wad Medani Orthopedic Center and Gezira National Center for Pediatric Surgery. It consisted of 113 subjects (51 males and 62 females) in age group 10- 12 years age, However in this age group, x-ray of upper and lower end of femur to see epiphyseal fusion is most accurate method. According to Gray (Richard *et al.*, 2015), the femur is ossified from five centers: one for the body, one for the head, one for each trochanter, and one for the distal end. The centers in the epiphyses appear in the following order: in the distal end of the bone, at the ninth month of fetal life; in the head, at the end of the first year after birth; in the greater trochanter, during the fourth year; and in the lesser trochanter, between the thirteenth and fourteenth years.

**Table 2. Distribution of study samples based on the fusion of lower end of femur in 51 males of different age groups**

Age group (yrs)	Sex	No. of cases	Various stages of fusion in the lower end of femur								Total Cases	
			Stage I		Stage II		Stage III		Stage IV		No	%
			No	%	No	%	No	%	No	%		
10-11	M	3	3	(100)	-	-	-	-	-	3	(100)	
11-12	M	3	3	(100)	-	-	-	-	-	3	(100)	
12-13	M	2	2	(100)	-	-	-	-	-	2	(100)	
13-14	M	5	2	(40)	3	(60)	-	-	-	5	(100)	
14-15	M	5	-	-	4	(80)	1	(20)	-	5	(100)	
15-16	M	6	-	-	4	(66.7)	2	(33.3)	-	6	(100)	
16-17	M	6	-	-	5	(83.3)	1	(16.7)	-	6	(100)	
17-18	M	5	-	-	2	(40)	3	(60)	-	5	(100)	
18-19	M	4	-	-	-	-	3	(75)	1	(25)	4	(100)
19-20	M	6	-	-	-	-	1	(16.7)	5	(83.3)	6	(100)
20-21	M	4	-	-	-	-	-	-	4	(100)	4	(100)
21-22	M	2	-	-	-	-	-	-	2	(100)	2	(100)
No. of cases in each stage			10		18		11		12		51	

**Table 3. Distribution of study samples based on the fusion of lower end of femur in 62 females of different age groups**

Age group (yrs)	Sex	No. of cases	Various stages of fusion in the lower end of femur								Total Cases	
			Stage I		Stage II		Stage III		Stage IV		No	%
			No	%	No	%	No	%	No	%		
10-11	F	3	3	(100)	-	-	-	-	-	3	(100)	
11-12	F	4	4	(100)	-	-	-	-	-	4	(100)	
12-13	F	5	3	(60)	2	(40)	-	-	-	5	(100)	
13-14	F	4	1	(25)	3	(75)	-	-	-	4	(100)	
14-15	F	7	-	-	4	(71.4)	3	(28.6)	-	7	(100)	
15-16	F	7	-	-	2	(28.6)	5	(71.4)	-	7	(100)	
16-17	F	5	-	-	-	-	4	(80)	1	(20)	5	(100)
17-18	F	6	-	-	-	-	1	(16.7)	5	(83.3)	6	(100)
18-19	F	7	-	-	-	-	1	(14.3)	6	(85.7)	7	(100)
19-20	F	6	-	-	-	-	-	-	6	(100)	6	(100)
20-21	F	5	-	-	-	-	-	-	5	(100)	5	(100)
21-22	F	3	-	-	-	-	-	-	3	(100)	3	(100)
No. of cases in each stage			11		11		14		26		62	

**Table 4. Summary of the observations of epiphyseal fusion of the distal end of femur in males and females**

Sex	Age group showing commence of stage II in $\geq 70\%$ of cases	Age group showing stage III in $\geq 70\%$ of cases	Age group showing stage IV in $\geq 70\%$ of cases
Male	14-15	18-19	19-20
Female	13-14	16-17	17-18

The age at which 70% cases showing different stages of fusion was considered as average age.

**Table 5. Age of fusion of distal end of femur in males and females by different workers**

No	Author	Year	Subjects	Age of fusion ( yrs)	
				Male	Females
1	Flecker	1932	Australia	19	17
2	Galastaun	1737	Bengalis	14 - 17	14 - 17
3	Homi S. Mehta	1963	Mumbai (Indian)	18 - 19	16.5 - 17
4	Bhise <i>et al</i>	2010	Mumbai (Indian)	18 - 19	16 - 17
5	Kausar & Varghese	2012	Bangalore (Indian)	18 - 18.5	16 - 16.5
6	Anja Singh <i>et al</i>	2014	Agra ( Indian)	17 - 18	16 - 17
7	Bipinchandra Tirude <i>et al</i>	2015	Central India	18 - 20	16 - 20
8	Present study	2016	Gezira State (Sudanese)	--	--

The order in which the epiphyses are joined to the body is the reverse of that of their appearance; they are not united until after puberty, the lesser trochanter being first joined, then the greater, then the head, and, lastly, the distal end of femur, which is not united until the twentieth year. In the present work, it was found that the lower end of femur united completely with shaft in more than 70 % of cases in the age group of 19- 20 years in males and 17- 18 years in females as

can be seen from Table (4). Exact age group beyond which all cases found united was 20- 21 years in males and 19- 20 years in females. Recent fusion was seen in age group 18-19 years in male and 16-17 years in females. According to Saxena & Vyas (Saxena and Vyas, 1969) and Banerjee and Aggarwal (1997) epiphyseal union of lower end of femur occurred at age of 16 - 17 years and 18 - 19 years in females and males respectively, which is one year earlier in both males and

females as compared to our study. Variance may be is due to as Saxena & Vyas taken the age group showing fusion of 85% as the average for age of fusion and in present study the criterion taken for fusion of age at which 70% is showing fusion. In similar study, Das Gupta (Das Gupta, 1974) have found epiphyseal union at lower end of femur at age of 17 – 18 and 18 – 19 in females and males respectively, These findings is consistent to the present study in females and one year lower in males. Aggarwal & Pathak (Aggarwal and Pathak, 1957) have found epiphyseal union at lower end of femur at age of 14½ - 16½ years in females, which is two and half years earlier compared to our study, the discrepancy may be attributed to exposure time, sample size, geographical location and so on. In Bhise study (Bhise *et al.*, 2015) which done in Mumbai, India, males showed epiphyseal union at 18-19 years age group and earliest union occurred at 18 years. Females showed epiphyseal union at 16-17 years age group and earliest union occurred at 16 years. These finding is also nearly similar to our finding with one year later in our finding in males and females.

The epiphysis average age of fusion is higher in males as compared to females as shown in (Table 5). Female subjects commence fusion (13- 14 years age) and complete (17- 18 years age) it earlier. While male subjects commence fusion at 14-15 years age and complete it at 19-20 years age. The present study signifies that the epiphysis of the lower end of femur in Central Sudan population completely fuse with shaft in the age of 19-20 and 17- 19 years in males and females respectively. These observations compared with the previous studies. Comparison of observations of present study has been made with other workers (Flecker, 1933; Galstaun, 1937; Mehta Homi, 1963; Asma Kausar and Varghese, 2012; Anju Singh *et al.*, 2014) with reference to age fusion of the distal end of femur in males and females (Table 5).

## Conclusion

It is concluded that, majority of cases show complete fusion for lower end of femur at 19-20 years for males and at 17- 18 years for females and female subjects complete fusion earlier than males. The sequence of fusion was almost similar with other workers, however the range varied, which can be attributed to many among other reasons i.e. geographical variation, nutritional factors etc.

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