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Forensic Science International: Reports

journal homepage: www.elsevier.com/locate/fsir

Forensic Anthropology

Radiological assessment of age from epiphyseal fusion at the wrist and ankle in Southern Nigeria



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ARTICLEINFO	A B S T R A C T
Keywords: Epiphysis Radius Ulna tibia fibula	Objectives: This cross-sectional study aims to examine the variation between stages of epiphyseal fusion at the distal end of radius, ulna, tibia, and fibula and its usefulness in the evaluation of age. Methods: Anterior-posterior and lateral radiographs of the distal end of bones at the wrist and ankle of 199 males and 185 females aged 9–19 years were investigated. Four stages of fusion were observed, as described by Jit and Kulkarnis, stage 0: non fusion, stage 1: appearance, stage 2: partial fusion, and stage 3: complete fusion. The Delta State University Teaching Hospital, Oghara approved this research with Ethical Number: DELSUTH/HREC/2018/050/0347. Data obtained were analyzed with the aid of a Chi-square test via Statistical Package for Social Sciences and a p-value less than 0.05 was considered as statistically significant. Results: showed that the appearance of the epiphyseal centres at the distal tibia and fibula of males began at the age of 9–16, while the appearance of epiphyseal centres in the distal tibia and fibula at age 19, while females showed complete fusion from 15 to 19 years of age. This indicates that females have consistently developed epiphyseal fusion at a younger age relative to males. Conclusion: From these results, it can be inferred that radiographic examination of the distal end of bones in the wrist and ankle is a beneficial alternative for age assessment. This will be a useful tool to forensic experts and biological anthropologist.

Introduction

Estimation of age is an important activity for forensic medicine experts, particularly in developing countries where birth records are often not well archived; and even where they are archived, there are incidences of forgery and assumptions. Forensic specialists therefore, try to establish exact age in various medico-legal conditions for example, when liability and punishment are related to maturity and age, criminal responsibility, kidnapping, abduction, nullity of marriage and child labour. According to Srivastav & Tirpude [1] crime and discipline are based primarily on criminal responsibility in law, and this in turn depends on the age of the person. Sangma et al. [2] also emphasize that age is useful for defining an individual and in turn, are useful in legal cases.

Several methods were therefore put forward in establishing age correctly and accurately. The common ones are those of tooth morphology and radiology. Changes observed on radiographs are often used to establish age. O'Connor et al. [3] established that radiographs of ankles and wrist joints are appropriate anatomical targets for the assessment of age from fusion observed at epiphyseal joints. Igbigbi et al.

[4] observed age and gender can be determined from epiphyseal fusion at the elbow and wrist joint. Ebeye et al. [5] on the knee joint found that epiphyseal bonding occurred earlier in females than in males (Figs. 1-4).

Variations have been observed in the timing of epiphyseal fusion among individuals from different populations, according to the previous research [6]. Eveleth and Tanner relate variations in population variability to climate, diet, secular growth change, or contradictory methodology [7]. Therefore, differences observed can be used to differentiate one population from the other.

Scanty literature exists on the radiological assessment of the age from epiphyseal fusion of long bones in Nigeria. The goal of this study is to examine the differences between the stages of epiphyseal fusion at the distal end of the radius, ulna, tibia, and fibula, with age consideration.

Materials

The research included both male and female radiographs of the ankle and wrist joint aged 9-19 whose cases were registered in the Delta State University Teaching Hospital; 384 radiographs, including 199 males and

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http://doi.org/10.1016/j.fsir.2020.100164

Received 3 October 2020; Received in revised form 6 December 2020; Accepted 6 December 2020

Available online 7 January 2021

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(a) Stage 0(non fusion) (b) Stage 1(appearance)





(a) Stage 2: partial fusion (b) Stage 3: complete fusion Fig. 2. Radiographic images of wrist joint showing stage 2 labeled as (a) and stage 3 labeled as (b) (DELSUTH ARCHIVE, 2014-2018).



(a) Stage 0: non fusion



Fig. 3. Radiographic images of ankle joint showing stage 0 labeled as (a) and stage 1 labeled as (b) (DELSUTH ARCHIVE, 2014-2018).



(a) Stage 2: partial fusion (b) Stage 3: complete fusion Fig. 4. Radiographic images of ankle joint showing stage 2 labeled as (a) and stage 3 labeled as (b) (DELSUTH ARCHIVE, 2014-2018).

185 females. The inquiry was accompanied by an objective review process. All available ankle and wrist joint X-ray films from 2014 to 2018 (five years) were evaluated.

Methods

Four (4) stages of epiphyseal union as expressed by Jits and Kulkarni have been established; [8]. Anterior-posterior and lateral radiographs were used together in the assessment of union and, where there was a discrepancy in the stages of union between the radiographic perspectives, the developmental plate radiograph showing the least mature view was chosen. Skeletal maturity was assessed resting on the four-stage classification by Jits and Kulkarni; stage 0: non-fusion, stage 1: appearance, stage 2: partial fusion, and stage 3: complete fusion ('AP,' 'NF,' 'PF' and CF' respectively).

Stage 0: X-rays that showed a clear gap between the epiphyseal and diaphysial, demonstrating a sawtooth-like appearance end were designated as "Non-fusion" (NF).

Stage 1: X-rays that showed a clear gap between the epiphyseal and diaphysial, without demonstrating a sawtooth-like appearance end were designated as just appearance (AP).

Stage 2: X-rays that showed a line replacing the gap connecting epiphyseal and diaphysial ends and not showing sawtooth-like appearance were designated as "Partial Fusion" (PF).

Stage 3: X-rays that showed same bony architecture in the diaphysis and epiphysis and showing scar of the previous stage was designated as "Complete Fusion" (CF).

Ethical consideration

This research was accepted by the Delta State University Teaching Hospital Research and Ethics Committee with Ethical Number: DELSUTH/HREC/2018/050/0347. Chi-square was used to illustrate association in epiphyseal fusion. The data obtained was analyzed with the aid of the StatisticalPackage for Social Sciences. A p-value that is not greater than 0.05 was deemed statistically significant.

Results

Tables 1 and 2 revealed that partial fusion at the radius and ulna was observed for males at age 17and occurred at an earlier age of 16 in females. However, an entire fusion of the radius and ulna for males and females occurred uniformly between the ages of 18 and 19.

From Table 3; the first appearance of fusion at the distal ends of tibia and fibula in males occurred at age 9, partial fusion at age 18, and complete fusion was only visible at age 19.

As shown for females in Table 4; the first appearance of fusion at the distal ends of tibia and fibula also occurred at age 9, however partial

Table 1

Number of male subjects (n) at each stage of fusion for the distal end of radius and ulna in each age group (years).

Age (vears)	Number of Subjects	Radi	us Staş	ge of F	usion	Ulna Stage of Fusion			
(Jeans)	N	0	1	2	3	N 0	1	2	3
9	11	11	-	-	-	11	-	-	-
10	3	3	-	-	-	33	-	-	-
11	4	4	-	-	-	44	-	-	-
12	6	6	-	-	-	66	-	-	-
13	3	3	-	-	-	22	-	-	-
14	4	4	-	-	-	33	-	-	-
15	2	2	-	-	-	22	-	-	-
16	6	6	-	-	-	22	-	-	-
17	7	-	-	-	-	2 –	-	2	-
18	2	-	-	-	2	3 –	-	-	3
19	12	-	-	-	12	4 –	-	-	4

Table 2

Number of female subjects (n) at each stage of fusion for the distal end of radius and ulna in each age group (years).

Age	Number of	Radius Stage of Fusion				Ulna Stage of Fusion			
(years)	N	0	1	2	3 N	0	1	2	3
9	11	0	-	-	- 0	0	-	-	-
10	11	11	-	-	-	11	-	-	-
					11				
11	2	2	-	-	- 1	1	-	-	-
12	4	4	-	-	- 4	4	-	-	-
13	9	9	-	-	- 7	7	-	-	-
14	2	2	-	-	- 2	2	-	-	-
15	9	9	-	-	- 7	7	-	-	-
16	3	-	-		- 2	2	-	-	-
17	3	-	-	3		-	-	7	-
18	3	-	-	-	3 –	-	-	-	5
19	3	-	-	-	3 –	-	-	-	6

Table 3

Number of male subjects (n) at each stage of union for the distal end of tibia and fibula in each age group (years).

Age (years)	Number of Subjects	Tibia Stage of Fusion				Fibula Stage of Fusion			
	Ν	0	1	2	3 N	0	1	2	3
9	10	10	-	-	- 5	5	-	-	-
10	9	9	-	-	- 8	8	-	-	-
11	9	9	-	-	- 8	8	-	-	-
12	4	4	-	-	- 5	5	-	-	-
13	3	3	-	-	- 2	2	-	-	-
14	2	2	-	-	- 1	1	-	-	-
15	4	4	-	-	- 4	4	-	-	-
16	3	3	-	-	- 4	4	-	-	-
17	2	2	-	-	- 4	4	-	-	-
18	2	-	-	2	- 5	5	-	5	-
19	2	-	-	-	24	4	-	-	4

Table 4

Number of female subjects (n) at each stage of union for the distal end of tibia and fibula in each age group (years).

Age (years)	Number of Subjects	Tibia Stage of Fusion				Fibula Stage of Fusion			
	Ν	0	1	2	3 N	0	1	2	3
9	0	0	-	-	- 0	0	-	-	-
10	0	0	-	-	- 0	0	-	-	-
11	0	0	-	-	- 0	0	-	-	-
12	4	4	-	-	- 2	2	-	-	-
13	3	3	-	-	- 2	2	-	-	-
14	3	-	-	3	- 2	-	-	2	-
15	1	-	-	-	11	-	-	-	1
16	3	-	-	-	34	-	-	-	4
17	3	-	-	-	33	-	-	-	3
18	3	-	-	-	34	-	-	-	4

fusion was observed at age 14 and complete fission was first seen at age 15. This occurred much earlier than what was observed in males.

Discussion

This research has shown that radiographic examination of the bones at the wrist and ankle is useful in forensic investigations in the identification of age precisely in cases of young, unidentified bodies and disparity in age.

From this study, presence of epiphyseal fusion at the distal ulna and radius of males and females began at age 9 and continued to 16. Similar trend was observed by Hassan et al. [9] who expressed that the underlying phase of epiphyseal fusion at the lower end of the ulna was found between 14–15years in 10 % of the male populace and 13–14years in 10 % of the female populace inspected. Garn et al. [10] and Hepworth [11] also agrees with this finding and reported that epiphyseal fusion at the lower end of the radius and ulna progresses bilaterally symmetrical, begins at age of 16years. All the studies correspond to our study showing appearance of fusion occurs between the ages of 9–16, however we observed that appearance began at age 9 and continued to 16. The differences observed may be owing to age range of the population studied. It is obvious from all the studies that age can be decided from radiographic observation of bones at joints

Furthermore, our study reveals, the distal end of the radius in males showed partial fusion at age 17 but partial fusion was not seen at the distal end of ulna at this age. In females partial fusion at the distal end of the radius occurred betweenages 16–17 and the distal end of ulna showed partial fusion at age 17 as well. This has been linked to higherestrogen levels in girls as compared to boys [12]. The findings from this study are in harmony with prior studies by Rajdev et al. [13] who reported that females showed partial fusion in the distal end of radius and ulna in advance compared to that of the males.

Complete fusion at the distal end of the radius and ulna of males and females was observed at identical age of 18–19. This finding is in keeping with previous studies by Igbigbi et al. [4] and Hassan et al. [9] who reported the wrist joint epiphyseal union to be completed in ages 18 and 19 for males. The establishment of complete fission at age 18–19 shows the importance of using radiographs in establishing chronological age. This is because similar result was observed from different races and ethnic groups

This study further demonstrated that females were constantly developing epiphyseal fusion at a younger age compared to their male counterparts, which was visible at age 16, 17, 18, and 19. This difference may be owing to adolescent development spurt in girls beginning at an average of 12 years, preceding that of boys by approximately 2 years. This finding concurs with prior studies by Nida et al. [14], and Hassan et al. [9] who reported that females showed fusion occurred ahead of male subjects.

The appearance of the epiphyseal fusion at the distal end of the tibia and fibula of males began at age 9–17 but showed no fusion. This finding is similar to a study by Crowder and Austin [15] who reported the beginning of the ossification centres at the distal end of the tibia and fibula at age 12–15.

The distal end of the tibia and fibula of males and females showed partial fusion at age 18 and 14 respectively. This may be correlated with hormonal influences on increasing bone shift with puberty as sex hormones, androgens, and estrogen influence bone growth and bone mineral acquisition [16]. This finding was supported by Gupta [17] among Uttar Pradesh, who reported that partial fusion of distal end of tibia and fibula occur at ages 17 and 18 for males and ages 14–16 in females.

This current research indicated that males reached complete epiphyseal fusion at the distal end of the tibia and fibula only at age 19 while the females showed complete fusion from age 15–19. This finding is in conformity with an investigation by Crowder and Austin [15] who reported that all Mexican males showed complete fusion by 19 with no significant variation between ancestral groups, and in females, it occurred at age 16.

Conclusion

From these findings, we therefore conclude that radiographic analysis of bones at the wrist and ankle are a valuable alternative for evaluation of age and will be a useful tool to forensic experts and biological anthropologist.

Declaration of Competing Interest

The authors report no declarations of interest.

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