Radiological Study of Epiphyseal Fusion Process at Lower End Of Femur In Age Group of 12-20 Years

Dr. Patel Dharmesh*, Dr. Raloti Sandip, Dr. Jhaveri Shailesh***, Dr. Vora Dipak****, Dr. Khubchandani Harish*****, Dr. Lad Kamlesh******

*Professor and Head, Department of Forensic Medicine & Toxicology Government Medical College, Bhavnagar, Gujarat **Assistant Professor, *** Associate Professor Department of Forensic Medicine & Toxicology SMIMER Medical College, Surat, Gujarat, **** Assistant Professor Department of Forensic Medicine & Toxicology B. J. Medical College, Ahmedabad, Gujarat, ***** Associate Professor Department of Forensic Medicine & Toxicology GMERS Medical College, Gandhinagar, Gujarat, ****** Tutor, Department of Forensic Medicine & Toxicology GMERS Medical College, Valsad, Gujarat

Abstracts: Introduction: Age estimation in living as well as dead is a prerequisite for personal identification and it is increasingly important in criminal and civil matters. The growth of the human skeleton is of major importance for the aging process as the appearance of ossification centers and union of epiphysis relate to a fairly definite sequence and time table that makes skeletal maturity a reliable age indicator according to sex and ethnical differences[1,2,3,].This present work is carried out to study the epiphyseal fusion of lower end of femur bone in relation to age, sex, physical development, and nutritional status. **Materials and Methods:** The present study was conducted in the Department of Forensic medicine & Toxicology and Department of Radiology at B.J. Medical College & Civil Hospital, Ahmedabad during the year 2010-2012 on 160 subjects, 80 males and 80 femalesfrom the age-group of 12-20 years. **Results: T**he epiphyseal fusion in both male and female at lower end of femur starts by the age of 13-14 years and complete by 17-18 years in male and 16-17 years in females.It is not found any effect of the dietary habit, height, and weight on the timing of epiphyseal fusion of lower end of femur. **Conclusion:** From our study we may conclude that the epiphyseal fusion in both male and female at lower end of femur starts by the same age and completes earlier in females than males.There is no effect of diet, height, and weight on epiphyseal fusion of lower end of femur. [Raloti S NJIRM 2014; 5(6):60-67]

Key Words: Epiphyseal fusion, Lower end of femur, Age estimation, Association

Author for correspondence: Dr. Raloti Sandip, Assistant Professor Department of Forensic Medicine & Toxicology SMIMER Medical College, Surat, Gujarat **Mo:** +919099069806 **Email:** sandip_raloti@yahoo.com

Introduction: Age estimation in living as well as dead is one of the most important tasks for a forensic practitioner[1]. In developing countries like India because of illiteracy, the births are not registered or records of birth are not properly maintained. It is a prerequisite for personal identification and it is increasingly important in criminal and civil matters. In fact, if doubt arises regarding the age of a person in any legal inquiry, forensic age estimation is promptly requested by authorities to ascertain whether the person concerned has reached the age of immutability. Here, age estimation becomes a valuable tool to assist in administration of many civil and criminal procedure codes such as identification, consent, criminal responsibility, clinical examination, and validity of will, attainment of majority, kidnapping or abduction, rape, criminal abortion[2].

There are 3 steps for age estimation

- Physical examination
- Dental examination
- Radiological examination

Radiological examination (skeletal age): The growth of the human skeleton is of major importance for the aging process as the appearance of ossification centers and union of epiphysis relate to a fairly definite sequence and time table that makes skeletal maturity a reliable age indicator according to sex and ethnical differences[1,2,3,].

Various studies have shown that the lower end (epiphysis) of upper and lower end of femur fuses with their respective diaphysis within the age group of 12-20 years. The minor differences in the age of fusion could be due to effects of changes in climate, economic, hereditary, dietetic conditions or involving some unknown factors[5,6] . On the ground of above mentioned reasons it is very essentials to conduct regional work in different states of India, regarding the age of epiphyseal union. The other Indian workers in this field are Hepworth[7] in Punjab, Galstauan[8]in Bangal, Basu and Basu[9] in Bangal, Bajaj, Loomba[10]in Uttar Pradesh, D. R. Kothari[11]in Marwar region of

Rajasthan, Dr. K.A. Shah[12] in Gujarat, Dr. P. R. Patel[13] in Ahmedabad, and Dr. D.S. Patel[14] in Ahmedabad.

This present work is carried out with an attempt to study epiphyseal union in lower end of femur in the age-group of 12-20 years among the people of Ahmedabad, Gujarat region that will help many civil and criminal cases to help in administration of justice.

Materials and Methods: The present study was conducted in the Department of Forensic medicine & Toxicology and Department of Radiology at B.J. Medical College & Civil Hospital, Ahmedabad during the year 2010-2012. The subjects were selected on cross-sectional basis from the students of B.J. Medical College and patients or their relatives at Civil Hospital, original native of Ahmedabad region. Subjects with criteria affecting the growth of bones and epiphyseal fusion like congenital deformities, fracture cases, chronic illness, on steroid therapy etc., were excluded from the study.

A total 160 apparently healthy subjects, 80 males and 80 females, irrespective of caste and religion with known birth-date and from the age-group of 12-20 years were selected for the purpose of the study. The subjects who have completed 12 years of age but not 13 years were grouped in 12-13 years and similarly for other age-groups. Preliminaries of the subjects including sex, age, height, weight, dietary habits were recorded.
Purpose was explained to the subjects and written informed consent was obtained for the digital x-ray. X-ray of both hip joints showing both lower end of femur were taken in antero-posterior view in all 160 subjects. Subjects of either sex were grouped into 8 age-groups from 12 to 20 year with difference of 1 year each year.

Findings of epiphyseal fusion are divided into 4 stages:

- **Non-union**: A dark black radiolucent line seen between the area of diaphysis and epiphysis. This stage labelled as **stage 0.**
- **Beginning of union**: Gap between diaphysis and epiphysis begins to decrease but complete union does not occur. This stage labelled as **stage +.**
- **Recent union**: Union between diaphysis and epiphysis completed but white dense line still visible at diphysio-epiphyseal junction. This stages labelled as **stage ++.**
- **Complete union**: Union between diaphysis and epiphysis completed and no white dense line visible at diphysio-epiphyseal junction. This stage labeled as **stage +++.**

The findings are recorded on a specially designed proforma, tabulated, analyzed and compared with similar studies by different authors.The gender, height, weight and diet of the subject are also included to see their effects on epiphyseal fusion. Variables were evaluated and analyzed statistically. Chi-square (χ^2) test was used to compare variables and tests were considered significant when P-Value < 0.05.

Results: Subjects of either sex (80 male and 80 female) were grouped into 8 age-groups from 12 to 20 year with difference of 1 year each. In our study the subjects for either sex were nearly equally distributed in all 8 age-groups (10 male and 10 female in each age group).

Table 1 exhibits the various degree of epiphyseal fusion in lower end of femur of both sides in male according to age groups.

Table 1: Epiphyeal Fusion in Lower End Of Femur Of Both Sides In Male

Age groups in years	Various degree of epiphyseal fusion in lower end of femur of both side in male (number of cases)								Total cases
	0		+		++		+++		
	R	L	R	L	R	L	R	L	
12-13	10	10	0	0	0	0	0	0	20
13-14	4	4	6	6	0	0	0	0	20
14-15	1	1	7	7	2	2	0	0	20
15-16	0	0	5	5	5	5	0	0	20
16-17	0	0	4	4	5	5	1	1	20
17-18	0	0	0	0	2	2	8	8	20
18-19	0	0	0	0	0	0	10	10	20
19-20	0	0	0	0	0	0	10	10	20
Total	15	15	22	22	14	14	29	29	160

0=Non-union, +=Beginning of union, ++=Recent union, +++=Complete union

From table 1 and on careful observation from Figure 1 & 2, it can be said that the epiphyseal fusion in male at lower end of femur starts by the age of 13-14 years and completes by the age of 17-18 years.

Figure 1: X-Ray Showing Recent Union (++) In Lower End of Femur in 16 Years Male

Figure 2: X-Ray Showing Complete Union (+++) In Lower End of Femur in 18 Years of Male

Table 2: Epiphyseal Fusion in Lower End of Femur of Both Sides in Female

Age groups in	Various degree of epiphyseal fusion in lower end of femur of both side in female (number of cases)								Total cases
years	**0**		**+**		**++**		**+++**		
	R	L	R	L	R	L	R	L	
12-13	10	10	0	0	0	0	0	0	20
13-14	8	8	2	2	0	0	0	0	20
14-15	1	1	7	7	2	2	0	0	20
15-16	0	0	1	1	5	5	4	4	20
16-17	0	0	0	0	2	2	8	8	20
17-18	0	0	0	0	0	0	10	10	20
18-19	0	0	0	0	0	0	10	10	20
19-20	0	0	0	0	0	0	10	10	20
Total	**19**	**19**	**10**	**10**	**9**	**9**	**42**	**42**	**160**

0=Non-union, +=Beginning of union, ++=Recent union, +++=Complete union

Table 2shows the various degree of epiphyseal fusion in lower end of femur of both sides in female according to age groups.

From table 2 and on careful observation from Figure 3 & 4, it can be said that the epiphyseal fusion in female at lower end of femur starts by the age of 13-14 years and completes by the age of 16-17 years.

Fig 3: X-ray showing recent union (++) in lower end of femur in 15 years female

Figure 4: X-ray showing complete union (+++) in lower end of femur in 18 years of female

Table 3 shows that fusion process starts in males at the age of 14-15 years whereas in case of female it starts at the age of 13-14 years, and fusion process complete at the age of 17-18 years in male and 16-17 years in female. Thus from our study, we observe that in head of femur process of fusion starts and completes earlier in females then males.

Table 3: Sex Wise Differences for Epiphyseal Fusion of Lower End of Femur of Both Sides in Either Sex

Age groups in years	Various degree of fusion in lower end of femur of both side in either sex								Total cases
	0		+		++		+++		
	M	F	M	F	M	F	M	F	
12-13	10	10	0	0	0	0	0	0	20
13-14	4	8	6	2	0	0	0	0	20
14-15	1	1	7	7	2	2	0	0	20
15-16	0	0	5	1	5	5	0	4	20
16-17	0	0	4	0	5	2	1	8	20
17-18	0	0	0	0	2	0	8	10	20
18-19	0	0	0	0	0	0	10	10	20
19-20	0	0	0	0	0	0	10	10	20
Total	15	19	22	10	14	9	29	42	160

0=Non-union, +=Beginning of union, ++=Recent union, +++=Complete union

Table 4 shows that the 122 subjects on vegetarian diet and 38 subjects on mixed diet were showing epiphyseal fusion of lower end of femur at various stages. It is observed that the number of cases on mixed diet is very small owing to the dietary habits of the people of Ahmedabad, Gujarat region. Nevertheless, from the available cases, it is not found any effect of the dietary habit on the timing of epiphyseal fusion of lower end of femur.

Table 4: Table Showing Effect of Diet on Epiphyseal Fusion of Lower End of Femur of Both Sides in Either Sex

Age groups in years	SEX	Effect of diet on fusion of lower end of femur of both side in either sex								Total cases
		0		+		++		+++		
		Veg.	Mixed	Veg.	Mixed	Veg.	Mixed	Veg.	Mixed	
12-13	M	7	3	0	0	0	0	0	0	20
	F	8	2	0	0	0	0	0	0	
13-14	M	3	1	4	2	0	0	0	0	20
	F	6	2	2	0	0	0	0	0	
14-15	M	1	0	5	2	2	0	0	0	20
	F	1	0	5	2	1	1	0	0	
15-16	M	0	0	3	2	3	2	0	0	20
	F	0	0	1	0	4	1	3	1	
16-17	M	0	0	2	2	4	1	1	0	20
	F	0	0	0	0	2	0	6	2	
17-18	M	0	0	0	0	2	0	6	2	20
	F	0	0	0	0	0	0	8	2	
18-19	M	0	0	0	0	0	0	7	3	20
	F	0	0	0	0	0	0	9	1	
19-20	M	0	0	0	0	0	0	8	2	20
	F	0	0	0	0	0	0	8	2	
Total		26	8	22	10	18	5	56	15	160

0=Non-union, +=Beginning of union, ++=Recent union, +++=Complete union

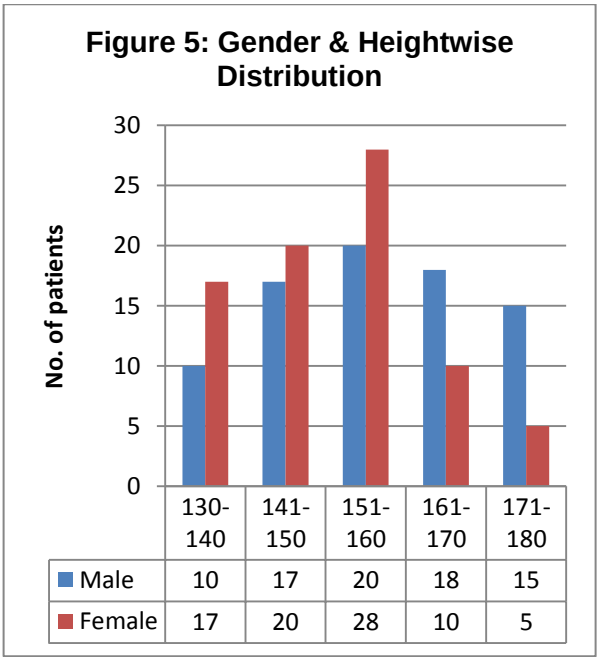
From Table 5 it can be observed that change in height group has no effect on the timing of epiphyseal fusion of lower end of femur. Although the fusion of the epiphysis with respective diaphysis is indicative of completion of the growth of long bones, it is not dependent on height as it is genetically determined.

Table 5: Table Showing Effect of Height on Epiphyseal Fusion of Lower End of Femur in Different Age Groups in Either Sex

AGE IN YEARS AND STAGE OF FUSION		HEIGHT IN CM										TOTAL
		130-140		140-150		150-160		160-170		170-180		
		SEX		SEX		SEX		SEX		SEX		
		M	F	M	F	M	F	M	F	M	F	
12-13	0	2	6	4	2	3	2	1	0	0	0	20
	+	0	0	0	0	0	0	0	0	0	0	0
	++	0	0	0	0	0	0	0	0	0	0	0
	+++	0	0	0	0	0	0	0	0	0	0	0
13-14	0	0	5	1	3	2	0	1	0	0	0	12
	+	3	0	3	0	0	1	0	1	0	0	8
	++	0	0	0	0	0	0	0	0	0	0	0
	+++	0	0	0	0	0	0	0	0	0	0	0
14-15	0	0	1	0	0	0	0	1	0	0	0	2
	+	3	5	2	1	1	1	1	0	0	0	14
	++	2	0	0	0	0	0	0	2	0	0	4
	+++	0	0	0	0	0	0	0	0	0	0	0
15-16	0	0	0	0	0	0	0	0	0	0	0	0
	+	0	0	2	1	3	0	0	0	0	0	6
	++	0	0	0	1	2	4	3	0	0	0	10
	+++	0	0	0	0	0	2	0	2	0	0	4
16-17	0	0	0	0	0	0	0	0	0	0	0	0
	+	0	0	2	0	2	0	0	0	0	0	4
	++	0	0	0	2	2	0	2	0	1	0	7
	+	0	0	0	1	0	3	0	3	1	1	9
	++	0	0	0	0	0	0	0	0	0	0	0
17-18	0	0	0	0	0	0	0	0	0	0	0	0
	+	0	0	0	0	0	0	0	0	0	0	0
	++	0	0	0	0	2	0	0	0	0	0	2
	+++	0	0	2	2	0	6	3	1	3	1	18
18-19	0	0	0	0	0	0	0	0	0	0	0	0
	+	0	0	0	0	0	0	0	0	0	0	0
	++	0	0	0	0	0	0	0	0	0	0	0
	+++	0	0	0	3	1	4	3	1	6	2	20
19-20	0	0	0	0	0	0	0	0	0	0	0	0
	+	0	0	0	0	0	0	0	0	0	0	0
	++	0	0	0	0	0	0	0	0	0	0	0
	+++	0	0	1	4	2	5	3	0	4	1	20
TOTAL		10	17	17	20	20	28	18	10	15	5	160

0=Non-union, +=Beginning of union, ++=Recent union, +++=Complete union

As per the average height of the individuals of Gujarat region and as also seen in the present study described in Figure 5, majority of males and females are in 151-170 cm height group.



s per the average weight of the individuals of Gujarat region and as seen in the present study described in Figure 6, highest numbers of males and females are in 66-70kgweight group.

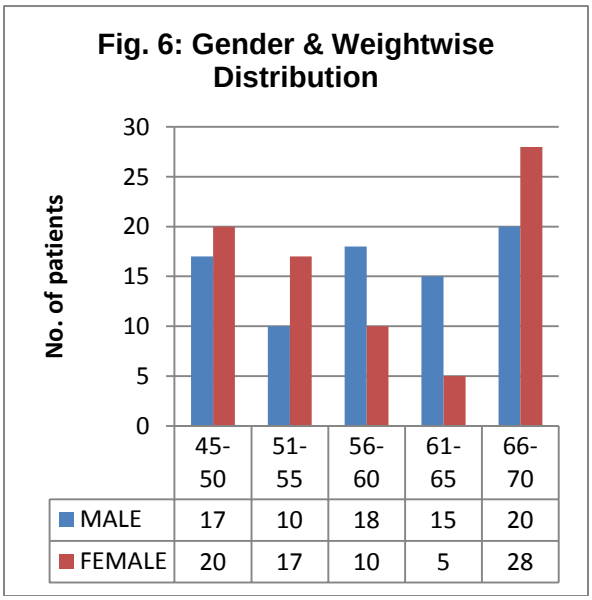


Table 6 shows that in all weight groups the cases are distributed in all four stages of epiphyseal fusion. There is no exact pattern to guide us timing of epiphyseal fusion as it is seen in different age groups. This suggests that with change in weight there is no effect on the timing of epiphyseal fusion of lower end of femur.

Table 6: Table Showing Effect Of Weight On Epiphyseal Fusion Of Lower End Of Femur In Different Age Groups In Either Sex

AGE IN YEARS AND STAGE OF FUSION		WEIGHT IN KG.										TOTAL
		45-50		**51-55**		**56-60**		**61-65**		**66-70**		
		SEX		SEX		SEX		SEX		SEX		
		M	F	M	F	M	F	M	F	M	F	
12-13	**0**	4	2	2	6	1	0	0	0	3	2	**20**
	+	0	0	0	0	0	0	0	0	0	0	**0**
	++	0	0	0	0	0	0	0	0	0	0	**0**
	+++	0	0	0	0	0	0	0	0	0	0	**0**
13-14	**0**	1	3	0	5	1	0	0	0	2	0	**12**
	+	3	0	3	0	0	1	0	0	0	1	**8**
	++	0	0	0	0	0	0	0	0	0	0	**0**
	+++	0	0	0	0	0	0	0	0	0	0	**0**
14-15	**0**	0	0	0	1	1	0	0	0	0	0	**2**
	+	2	1	3	5	1	0	0	0	1	1	**14**
	++	0	0	2	0	0	2	0	0	0	0	**4**
	+++	0	0	0	0	0	0	0	0	0	0	**0**
15-16	**0**	0	0	0	0	0	0	0	0	0	0	**0**
	+	2	1	0	0	0	0	0	0	3	0	**6**
	++	0	1	0	0	3	0	0	0	2	4	**10**
	+++	0	0	0	0	0	2	0	0	0	2	**4**
16-17	**0**	0	0	0	0	0	0	0	0	0	0	**0**
	+	2	0	0	0	0	0	0	0	2	0	**4**
	++	0	2	0	0	2	0	1	0	2	0	**7**
	+++	0	1	0	0	0	3	1	1	0	3	**9**
17-18	**0**	0	0	0	0	0	0	0	0	0	0	**0**
	+	0	0	0	0	0	0	0	0	0	0	**0**
	++	0	0	0	0	0	0	0	0	2	0	**2**
	+++	2	2	0	0	3	1	3	1	0	6	**18**
18-19	**0**	0	0	0	0	0	0	0	0	0	0	**0**
	+	0	0	0	0	0	0	0	0	0	0	**0**
	++	0	0	0	0	0	0	0	0	0	0	**0**
	+++	0	3	0	0	3	1	6	2	1	4	**20**
19-20	**0**	0	0	0	0	0	0	0	0	0	0	**0**
	+	0	0	0	0	0	0	0	0	0	0	**0**
	++	0	0	0	0	0	0	0	0	0	0	**0**
	+++	1	4	0	0	3	0	4	1	2	5	**20**
TOTAL		**17**	**20**	**10**	**17**	**18**	**10**	**15**	**5**	**20**	**28**	**160**

0=Non-union, +=Beginning of union, ++=Recent union, +++=Complete union

Discussion: The demand of forensic age determination in living individuals deals mostly with juvenile or sub adults, as in most countries

legal relevant age limit range between 12 to 20 years. Among the variety of scientific procedure available in age assessment, there is wide agreement about the methods based on sexual, skeletal, and dental maturity. However in age group 12-20years, x-ray of upper and lower end of femur to see epiphyseal fusion is most accurate method.Present work is done to estimate age from fusion of both lower ends of femur.

Ossification of the lower end of femur is of medico-legal importance. Presence of its centre in a newly born child found dead indicates that the child was viable, i.e., it was capable of independent existence. The lower end of femur is the growing end. The lower epiphyseal line passes through the adductor tubercle. The epiphyseal line of the head coincides with the articular margins, except superiorly where a part of non-articular area is included in the epiphysis for passage of blood vessels to the head. In addition, the plane of this epiphysis changes with age from an oblique to more vertical one[15].

Lots of work has been done on age determination from epiphyseal union. Most of them have done so in the second quarter of the present century. The work has been carried out in foreign countries as well as in India. Galstaun's study over Indian population shows that complete fusion of lower end of femur occurs at >18years in male and >17 years in female[8].

For our study, total 160 subjects were taken; subjects of either sex were grouped into 8 age-groups from 12 to 20 year with difference of 1 year each year. Digital x-ray of both knees joint showing both lower end of femur were taken in antero-posterior view in all 160 subjects. Sex, height, weight, diet of each individual were noted and tabulated. All findings were analysed and compared with individual studies.

Our study shows that the epiphyseal fusion in both male and female at lower end of femur starts by the age of 13-14 years and complete by 17-18 years in male and 16-17 years in females.In present study age of epiphyseal fusion in male is 17-18 year, which is nearer to study done by Hepworth(1929), Todd(1930), O'connor JE et al (2008),while study done by Narain and Bajaj (1957), Johnston(1961), Saxena and Vyas (1969), Das gupta et al (1974), Bokaria et al (2009) was 18-19 years which are nearer to present study, while in the study done by Davies and parson(1927), Flecker (1932), age of epiphyseal fusion in lower end of femur was 19 years, which suggest fusion is about 1year late in comparison to present study.

In present study age of epiphyseal fusion in female is 16-17 year, which is similar to study done by bokaria et al(2009) Hepworth(1929) and das gupta et al(1974),while study done, while in the study done by Davies and parson(1927), Stevenson(1924), Todd(1930) and Narain and Bajaj(1957) age of epiphyseal fusion in lower end of femur was 18-19 years, which suggest fusion is about 1-2year late in comparison to present study.
It is observed that the number of cases on mixed diet is very small owing to the dietary habits of the people of Ahmedabad, Gujarat region. Nevertheless, from the available cases, it is not found any effect of the dietary habit on the timing of epiphyseal fusion of lower end of femur.

As per the average height and weight of the individuals of Gujarat region and as also seen in the present study, majority of males and females are in 151-170 cm height group and highest numbers of males and females are in 66-70kgweight group. It is observed that change in height group has no effect on the timing of epiphyseal fusion of lower end of femur. Although the fusion of the epiphysis with respective diaphysis is indicative of completion of the growth of long bones, it is not dependent on height as it is genetically determined.

Conclusion: We may conclude that the epiphyseal fusion in both male and female at lower end of femur starts by the age of 13-14 years and complete by 17-18 years in male and 16-17 years in females.The age for epiphyseal fusion of lower end of femur is bilaterally similar, i.e. it occurs at the same age in both sides.The epiphyseal fusion of lower end of femur occurs earlier by about one year in females as compared to males.There is no effect of diet (whether vegetarian or on mixed diet) on epiphyseal fusion of lower end of

femur.There is no effect of height and weight on epiphyseal fusion of lower end of femur.

References:

1. Reddy K S N.: The essentials of forensic medicine and toxicology 29th edition Hydrabad : K. Saguna Devi 2009 . pp 61-71.
2. Scheuer L , Sue B : Developmental juvenile osteology;Elsevier academic press, 2000
3. Sorg, M.H., Andrew, R.P.,Iscan,M.Y. :Radiographic Aging of the adults. In; Iscan,M.Y.,Ed.,Age markers in the Human Skeleton.Charls C. Thomas, Springfiled , I L.1989 pp.169-193.
4. Schmitt A E Cunna J Pinherio : Forensic Medicine: Anthropology and Complementary Sciences from Recovery to Cause of Death; Humana press 2006: 58-77.
5. Modi, J.P, Medical Jurisprudence and toxicology. Subrahmanyam, B. V.(Ed.),22nd edition 2001, Butterworths.
6. 6. Schmeling A, W. Reisinger, D. Loreck, K. Vendura, W. Markus, G. Geserick. Effects of ethnicity on skeletal maturation: consequences for forensic age estimations Int. J Legal Med. 2000 113 (5) 253-258.
7. Hepworth S.M., Determination of age in Indians from a study of ossification of ossification of the epiphysis of long bonesInd. Med. Gaz. :1939 74, pp. 614–616.
8. Galstaun,G: A study of ossification as observed in Indian subjects, Indian Journal of Medical Research; July 1937 25; 1.
9. 9. Basu,S.K., Basu.S. : Age order of epiphyseal union in Bengali girls in preliminary study. J Ind Med Asso. ; 1938,7:571-578.
10. Loomba S. D.: Age of epiphyseal union at wrist joint in Uttar Pradesh, Journal of Indian Medical AssociationJune 16 1958 30 (12) 389-395.
11. Kothari, D. R.: Age of epiphyseal union at the elbow and wrist joints in Marwar region of Rajasthan, Journal of Indian Medical Association;1974 63: 8, Oct, 16
12. Shah, K.A: A study of fusion of epiphysis of iliac crest in relation to age, sex & physical development in human beings.A thesis for M.D. (Forensic medicine) Gujarat University.
13. 13 Patel, P.R.: A study of fusion of epiphysis of ischial tuberocity in relation with age and physical development in human beings. A thesis for M.D (Forensic medicine) Gujarat University.
14. Patel,D.S. et al: Radiological study of epiphyseal fusion at elbow region in relation to physiological findings in 12-17 years age group. J. Ind.Acad.Forensic Medicine31 (4), 360-367, 2009.
15. Chaurasia B.D.: Human anatomy regional and applied, CBS publishers vol.2, 4th edition(2009), 16-22.

Conflict of interest: None
Funding: None