

A Two-year Prospective Study in Western Maharashtra in Relation to Ossification Centers around Wrist Joint for Age Determination using Radiological Examination in Sportspersons

¹Rajesh C Dere, ²Amol R Maiyyar, ³Sachin S Patil, ⁴Ravindra B Deokar, ⁵Hemant G Kukde

ABSTRACT

Introduction: The determination of the age of an individual from the appearance and the fusion of the ossification centers is considered a reasonable scientific method and a well-accepted fact in the field of medical and legal professions. The aims and objectives of the study were scientific estimation of age from the study of appearance and fusion of bone epiphysis of wrist joint.

Materials and methods: The present study was undertaken for the determination of age in 100 sportspersons referred for medical age verification by various sports associations approved by the Sports Authority of India, belonging to different cities of the western part of Maharashtra.

Results: Epiphyseal fusion for lower end of radius was seen in 50% of cases at the age of 18 years in males, while in females, the same was observed in 66.67% of cases at the age of 17 years. The epiphyseal fusion for the lower end of ulna was seen in 50% of cases at the age of 18 years in males, while in females, the same was observed in 66.67% of cases from the age of 17 years onward.

Discussion: In the case of males, the age of fusion of radius and ulna with their shafts corresponds precisely with studies conducted in India with few exceptions. But in the case of females, findings of the current study correlate accurately with most of the studies conducted outside India.

Conclusion: The age of epiphyseal fusion can be useful in detecting sportspersons with forged age certificates in various national and international sports events.

Keywords: Age estimation, Epiphyseal fusion, Wrist joint.

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INTRODUCTION

Determination of the age of an individual from the appearance and the fusion of the ossification centers is considered a reasonable scientific method and a well-accepted fact in the field of medical and legal professions.¹ The bones of human skeletons develop from separate ossification centers. From these centers, ossification progresses till the bone is completely formed. It is therefore, possible to determine the approximate age of an individual by radiological examination of bones till ossification is complete.² The time of appearance of centers of ossification and the process of union of the epiphysis with the diaphysis has a sequence and time period.³ The study of epiphyseal union of bones is considered a reasonable scientific and accepted method for age determination by the law courts all over the world.⁴ Considerable variations occur in this aspect, depending upon race, sex, geographical distribution, nutritional status, physical activity, and hormonal and metabolic disorders. The hand-wrist region has received the greatest attention in the assessment of skeletal maturation.⁵⁻⁷ The present study was conducted to know the radiological appearance and fusion of ossification centers around the wrist joint in sportspersons referred by the Sports Authority of India to this hospital.

AIMS AND OBJECTIVES

- Scientific evaluation of age from the study of appearance and epiphysis union around wrist joint.
- To compare, correlate, and analyze the current study with previous studies.
- To compare and correlate gender-related disparity in the appearance and fusion of epiphysis of bones at elbow joint.

¹Professor, ²Assistant Professor, ³⁻⁵Associate Professor

^{1,3,4}Department of Forensic Medicine and Toxicology, Seth Gordhandas Sunderdas Medical College and King Edward Memorial Hospital, Mumbai, Maharashtra, India

²Department of Forensic Medicine and Toxicology, SMBT Institute of Medical Sciences and Research Centre, Nashik Maharashtra, India

⁵Department of Forensic Medicine and Toxicology, Lokmanya Tilak Municipal Medical College and Hospital, Mumbai Maharashtra, India

Corresponding Author: Sachin S Patil, Associate Professor Department of Forensic Medicine and Toxicology, Seth Gordhandas Sunderdas Medical College and King Edward Memorial Hospital, Mumbai, Maharashtra, India, Phone: +918108609282, e-mail: sachinpatilmdfm@gmail.com

- To know divergence, if any, and exclusion of appearance and fusion of centers of ossification.
- To discuss medicolegal implications in the existing pattern of study with regard to law of the land.

MATERIALS AND METHODS

This prospective study analysis of the relationship between epiphyseal union at the wrist region and chronological age was conducted using radiological examination in a tertiary hospital. The present study was undertaken for the determination of age in 100 sportspersons referred for medical age verification by various sports associations approved by the Sports Authority of India in the state of Maharashtra, belonging to different cities of the western part of the state.

The selection of the subjects was based on the following criteria: those having exact record for date of birth, those between 12 and 20 years as per record, and those having good hygiene and normal physique. Subjects having congenital and acquired anomalies affecting skeletal growth; nutritional and endocrinal deficiencies; subjects who come for age determination, other than sportspersons; pregnant females; and subjects whose date of birth is not known.

Methods

- Institutional ethical committee permission was received after submitting the study project.
- Before the examination of the subject, informed consent was obtained except in cases with age less than 12 years in which case, it was obtained from their parents or guardian.
- Radiological evaluation for union or nonunion of ossification centers around wrist joint was done.
- General and physical examination was conducted in the Department of Forensic Medicine and Toxicology, Lokmanya Tilak Municipal Medical College and Hospital and GH, Sion, Mumbai.
- A master chart was prepared and tabulated after which it was classified, analyzed, and compared.
- Data analysis was done using Statistical Package for the Social Sciences software.
- At the end, conclusions were obtained after comparing with available results of various previous studies.

Procedure

After the acceptance of requisition letter from concerned sports associations, physical examination was done consisting of

- Secondary sexual characters: moustache, beard, pubic hairs, axillary hairs, and voice (for male) and development of breast, pubic hairs, and axillary hairs (for girls).

- Height: Measured by stadiometer in centimeters.
- Weight: Measured in kilograms by a digital weighing machine.
- Chest circumference: Measured in centimeters at the level of nipple.

Similarly, each of these subjects was radiographed for the wrist joint in the Department of Radiology. This includes following radiographs: wrist joint anteroposterior view showing the lower end of radius and ulna, carpal bones, and base of first metacarpal.⁸

After taking radiographs, these were examined at the Department of Forensic Medicine and Toxicology. These images were studied for the appearance and fusion of ossification center. Subsequently, the age of each participant was determined and entered in the master chart. For practical purpose, as taken by Kangne et al,³ stages 1 and 2 were considered not fused while stages 3 and 4 were considered fused.

RESULTS AND OBSERVATIONS

This is an observational study of 100 subjects from various sports associations referred by the Sports Authority of India carried out between 2011 and 2013. Out of them, 62 were males while 38 were females.

Socioeconomic Status

Out of 62 male sportspersons, 53 subjects were of middle class and 9 were of upper class, while in female subjects, 33 subjects were of middle class and 5 were of upper class.

Age

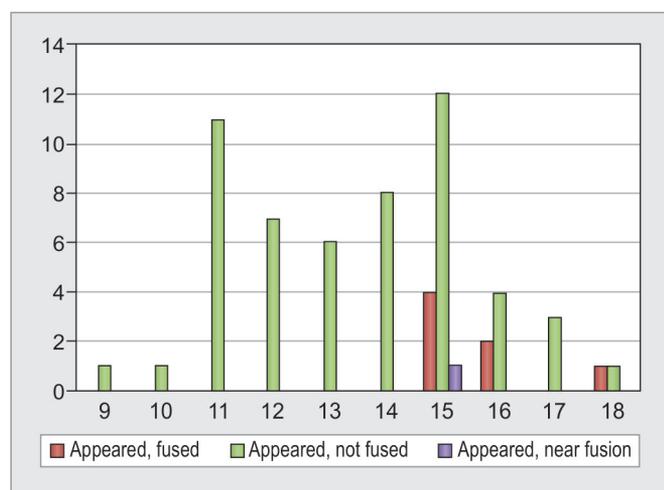
As shown in Table 1, maximum no of male subjects were in the age group of 15 years followed by 11 years, while least in 9 and 10-year groups. Maximum number of female subjects were in the age group of 14 years followed by 11 years, while none were in 09, 16, and 18-year groups.

Table 1: Number of males and females in various age groups

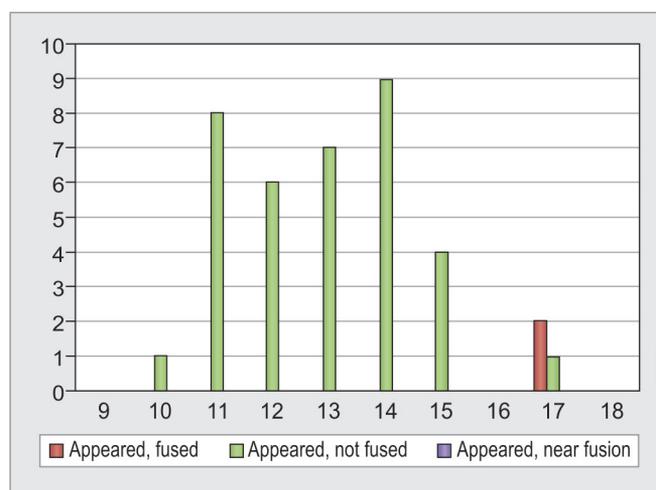
Age in years	Males	Females
9	1	0
10	1	1
11	11	8
12	7	6
13	6	7
14	8	9
15	17	4
16	6	0
17	3	3
18	2	0

Table 2: Fusion of ossification center of lower end of radius with shaft in males and females

Age in years	Males			Females		
	Appeared, fused	Appeared, not fused	Appeared, near fusion	Appeared, fused	Appeared, not fused	Appeared, near fusion
9	0	1 (100%)	0	0	0	0
10	0	1 (100%)	0	0	1 (100%)	0
11	0	11 (100%)	0	0	8 (100%)	0
12	0	7 (100%)	0	0	6 (100%)	0
13	0	6 (100%)	0	0	7 (100%)	0
14	0	8 (100%)	0	0	9 (100%)	0
15	4 (23.52%)	12 (70.59%)	1 (05.89%)	0	4 (100%)	0
16	2 (33.33%)	4 (66.67%)	0	0	0	0
17	0	3 (100%)	0	2 (66.67%)	1 (33.33%)	0
18	1 (50%)	1 (50%)	0	0	0	0



Graph 1: X-ray wrist joint showing the fusion of lower end of radius with shaft in males



Graph 2: X-ray wrist joint showing the fusion of lower end of radius with shaft in females

X-ray Wrist Joint showing Fusion of Ossification Center of Lower End of Radius with Shaft

The ossification center for the lower end of radius was observed in all the cases, while epiphyseal fusion was first seen at the age of 15 years in 23.52% of cases, and in 50% of cases at the age of 18 years in males, while in females, the same was observed in 66.67% of cases at the age of 17 years as shown in Table 2.

The graphical representation is shown in Graphs 1 and 2.

X-ray Wrist Joint showing the Fusion of Ossification Center of Lower End of Ulna with Shaft

The ossification center for the lower end of ulna was observed in all the cases, while epiphyseal fusion was first seen at the age of 15 years in 29.41% of cases, and in 50% of cases at the age of 18 years in males, while in females, the same was observed in 66.67% of cases from the age of 17 years onward as shown in Table 3.

The graphical representation is shown in Graphs 3 and 4.

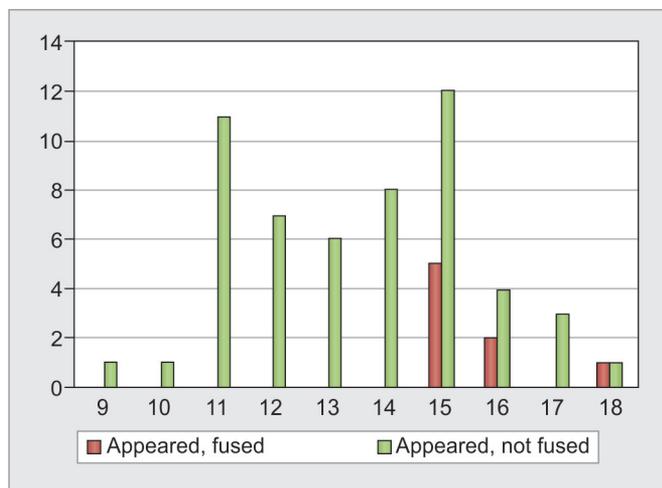
Table 3: Fusion of ossification center of the lower end of ulna with shaft in males and females

Age in years	Males		Females	
	Appeared, fused	Appeared, not fused	Appeared, fused	Appeared, not fused
9	0	1 (100%)	0	0
10	0	1 (100%)	0	1 (100%)
11	0	11 (100%)	0	8 (100%)
12	0	7 (100%)	0	6 (100%)
13	0	6 (100%)	0	7 (100%)
14	0	8 (100%)	0	9 (100%)
15	5 (29.41%)	12 (70.59%)	0	4 (100%)
16	2 (33.33%)	4 (66.67%)	0	0
17	0	3 (100%)	2 (66.67%)	1 (33.33%)
18	1 (50%)	1 (50%)	0	0

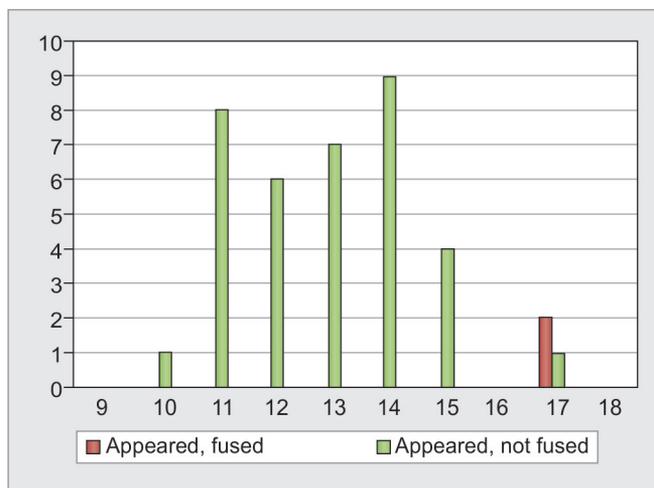
Statistical Analysis

The estimation of age from the study of fusion using bone epiphysis in comparison with gender was analyzed using Mann-Whitney test.

Statistical Test for signed ranks: Mann-Whitney test.



Graph 3: X-ray wrist joint showing the fusion of lower end of ulna with shaft in males



Graph 4: X-ray wrist joint showing the fusion of lower end of ulna with shaft in females

Age at the Fusion of Lower End of Radius with Shaft at Wrist Joint

Hypothesis

H0: The age of fusion of lower end of radius with shaft at wrist joint in males is equal to that in females,

i.e., H0 = The age of fusion of lower end of radius with shaft at wrist joint in males = the age of fusion of wrist joint in females.

H1: The age of fusion of lower end of radius with shaft at wrist joint in males is less than that in females

i.e., H1 = The age of fusion of lower end of radius with shaft at wrist joint in males < the age of fusion of lower end of radius with shaft at wrist joint in females.

H2: The age of fusion of lower end of radius with shaft at wrist joint in males is greater than that in females

i.e., H2 = The age of fusion of lower end of radius with shaft at wrist joint in males > the age of fusion of lower end of radius with shaft at wrist joint in females.

Significant threshold: $p < 0.05$

Conclusion

Since $p = 0.224 > 0.05$ as per Tables 4 and 5, we reject the null hypothesis and alternate hypothesis 1 (H1) and accept alternate hypothesis 2 (H2), i.e., the age fusion of lower end of radius with shaft at wrist joint in males is greater than that in females.

Table 4: Results of statistical tests of age of fusion of lower end of radius with shaft at wrist joint

Gender		n	Mean rank	Sum of ranks
X-ray of lower end of radius with shaft at wrist joint	Female	38	48.16	1830.00
	Male	62	51.94	3220.00
	Total	100		

Table 5: Test statistics of age at fusion of lower end of radius with shaft at wrist joint

	X-ray of lower end of radius wrist joint
Z	-1.216
Asymp. Sig. (2-tailed)	0.224

Age at Fusion of Wrist Joint Lower End of Ulna

Hypothesis

H0: The age of fusion of wrist joint lower end of ulna in males is equal to that in females,

i.e., H0 = The age of fusion of wrist joint lower end of ulna in males = the age of fusion of wrist joint lower end of ulna in females

H1: The age of fusion of wrist joint lower end of ulna in males is less than that in females,

i.e., H1 = The age of fusion of wrist joint lower end of ulna in males < the age of fusion of wrist joint lower end of ulna in females

H2: The age of fusion of wrist joint lower end of ulna in males is greater than that in females,

i.e., H2 = The age of fusion of wrist joint lower end of ulna in males > the age of fusion of wrist joint lower end of ulna in females.

Significant threshold: $p < 0.05$

Conclusion

Since $p = 0.219 > 0.05$ as per Tables 6 and 7, we reject the null hypothesis and alternate hypothesis 1 (H1) and

Table 6. Results of statistical tests of age of fusion of lower end of ulna with shaft at wrist joint

Gender		n	Mean rank	Sum of ranks
X-ray wrist joint lower end of ulna with shaft	Female	38	48.13	1829.00
	Male	62	51.95	3221.00
	Total	100		



Table 7: Test statistics of age at fusion of lower end of ulna with shaft at wrist joint

	<i>X-ray wrist joint lower end of ulna with shaft</i>
Z	-1.230
Asymp. Sig. (2-tailed)	0.219

accept alternate hypothesis 2 (H2), i.e., the age fusion of wrist joint lower end of ulna with shaft in males is greater than that in females.

DISCUSSION

Multiple studies have been performed by various researchers in different parts of the world on the appearance and fusion of various ossification centers of bones for the estimation of age. Appearance and fusion of ossification centers can serve as reliable indicators of age evaluation.

Epiphyseal fusion around wrist joint in the present study has been observed at the age of 18 to 19 years for males, and 17 to 18 years for females.

Comparison of Current Study with Previous Studies in Case of Males (Table 8)

The epiphyseal fusion around wrist joint for lower end of radius with shaft in the present study correlates precisely with the age fusion of ossification centers of radius by Mehta¹¹ (Mumbai), Kothari¹² (Marwar), Pillai¹³ (Chennai), Kadam and Viswanathan¹⁶ (Davangere), Krishnamoorthy et al¹⁷ (Haryana), Leena et al²⁰ (Jodhpur), Das et al²³ (Punjab), and Loder et al³⁰ (America), while it corresponds with the lower limit of age of fusion of epiphysis of study conducted by Banerjee and Agarwal⁴ (Delhi), Breathnach²⁶ (Europe), Gray et al²⁷ (Europe), Pryor²⁹ (America), Sidhom and Derry³¹ (Egypt), and Flecker³³ (Australia). In addition, the age of fusion in the present study is correlated with the upper limit of studies conducted by Bhise et al¹⁰ (Mumbai), Galstaun¹⁴ (Bengal), and Saksena and Vyas²¹ (Punjab). Also, findings obtained in the current study are 1 to 2 years earlier than the studies conducted by Das Gupta et al¹⁹ (Uttar Pradesh), Loobma²² (Uttar Pradesh), Nemade et al²⁴ (Vidarbha), Brash²⁵ (Europe), Paterson²⁸ (English), and Ledger and

Table 8: Comparison of ages (years) of union of epiphyses around wrist joint given by researchers in India and abroad with findings of the current study

Authors	Age of union of epiphyses around wrist joint			
	Males (Years)		Females (Years)	
	Lower end of radius	Lower end of ulna	Lower end of radius	Lower end of ulna
Sangma et al ⁹ (Northeast India)	–	–	18	18
Bhise et al ¹⁰ (Mumbai)	17–18	17–19	16–17	16–17
Mehta ¹¹ (Mumbai)	18–19	18–19	16–17	16–17
Kothari ¹² (Marwar)	18–19	18–19	18–19	18–19
Pillai ¹³ (Chennai)	18	18	18	18
Galstaun ¹⁴ (Bengal)	17–18	18	16.5–17	17
Hepworth ¹⁵ (Punjab)	16–17	16–17	16–17	16–17
Kadam and Viswanathan ¹⁶ (Davangere)	18–19	15–16	–	–
Krishnamoorthy et al ¹⁷ (Haryana)	18–19	17–18	18–19	17–18
Sahni and Jit ¹⁸ (Punjab)	–	–	>16	>16
Das Gupta et al ¹⁹ (Uttar Pradesh)	20–21	20–21	19–20	20–21
Leena et al ²⁰ (Jodhpur)	18–19	19–20	18–19	18–19
Banerjee and Agarwal ⁴ (Delhi)	19–20	19–20	18–19	18–19
Saksena and Vyas ²¹ (Punjab)	<18	<18	–	–
Loobma ²² (Uttar Pradesh)	20–21	20–21	18–19	18–19
Das et al ²³ (Punjab)	>18	>18	–	–
Nemade et al ²⁴ (Vidarbha)	20–21	19–20	19–20	19–20
Brash ²⁵ (Europe)	21	21	19–20	19–20
Breathnach ²⁶ (Europe)	19	19	17	17
Gray et al ²⁷ (Europe)	19	18	17	17
Paterson ²⁸ (English)	21	21	20	20
Pryor ²⁹ (America)	19	19	20	18
Loder et al ³⁰ (America)	>18	18	17	17
Sidhom and Derry ³¹ (Egypt)	19–20	19–20	–	–
Barrett ³² (Burma)	–	–	17	17
Flecker ³³ (Australia)	19	19	18	17.5
Ledger and Wasson ³⁴ (Pakistan)	>20	18–19	18–19	16–17
Present study (Western Maharashtra)	18–19	18–19	17–18	17–18

Wasson³⁴ (Pakistan). In addition, findings of the present study are 1 to 2 years late as compared with the findings obtained by studies of Hepworth¹⁵ (Punjab).

Similarly, the age of fusion of epiphysis of lower end of ulna in the current study corresponds accurately with the studies done by Mehta¹¹ (Mumbai), Bhise et al¹⁰ (Mumbai), Galstaun¹⁴ (Bengal), Kothari¹² (Marwar), Pillai¹³ (Chennai), Das et al²³ (Punjab) and Loder et al³⁰ (American), and Ledger and Wasson³⁴ (Pakistan), while it corresponds with the lower limit of age of fusion of epiphysis of the study conducted by Leena et al²⁰ (Jodhpur), Banerjee and Agarwal⁴ (Delhi), Nemade et al²⁴ (Vidarbha), Breathnach²⁶ (Europe), Pryor²⁹ (America), Sidhom and Derry³¹ (Egypt), and Flecker³³ (Australia). In addition, the age of fusion in the present study is correlated with the upper limit of studies conducted by Krishnamoorthy et al¹⁷ (Haryana) and Saksena and Vyas²¹ (Punjab). Also, findings obtained in the current study are 1 to 2 years earlier than the studies conducted by Das Gupta et al¹⁹ (Uttar Pradesh), Loobma²² (Uttar Pradesh), Brash²⁵ (Europe), and Paterson²⁸ (English). In addition, findings of present study are 1 to 2 years late as compared with the findings obtained by studies of Hepworth¹⁵ (Punjab) and 2 to 3 years late as compared with the findings obtained by studies of Kadam and Viswanathan¹⁶ (Davangere).

Comparison of the Present Study with Other Studies in Females (Table 8)

The age of union of ossification centers of wrist joint for lower end of radius in the present study corresponds unerringly with the age of fusion found by studies of Breathnach²⁶ (Europe), Gray et al²⁷ (Europe), Loder et al³⁰ (America), and Barrett³² (Burma), while findings of this study correspond with the lower limit of age of fusion of epiphysis of the study conducted Sangma et al⁹ (northeast India), Kothari¹² (Marwar), Pillai¹³ (Chennai), Krishnamoorthy et al¹⁷ (Haryana), Leena et al²⁰ (Jodhpur), Banerjee and Agarwal⁴ (Delhi), Loobma²² (Uttar Pradesh), Flecker³³ (Australia), and Ledger and Wasson³⁴ (Pakistan). In addition, the age of fusion in the present study corresponds with the upper limit of studies conducted by Bhise et al¹⁰ (Mumbai), Mehta¹¹ (Mumbai), Galstaun¹⁴ (Bengal), Hepworth¹⁵ (Punjab), and Sahni and Jit¹⁸ (Punjab). Also, findings in the present study are 1 to 2 years earlier than the studies conducted by Das Gupta et al¹⁹ (Uttar Pradesh), Nemade et al²⁵ (Vidarbha), Brash²⁵ (Europe), Pryor²⁹ (America), and Paterson²⁸ (English).

Similarly, the age of epiphyseal fusion of lower end of ulna in current study matches perfectly with the studies done by Galstaun¹⁴ (Bengal), Krishnamoorthy et al¹⁷ (Haryana), Breathnach²⁶ (Europe), Loder et al³⁰ (America), Gray et al²⁷ (Europe), Barrett³² (Burma), and

Flecker³³ (Australia), while it correlates with the lower limit of age of fusion of epiphysis of the study conducted by Sangma et al⁹ (northeast India), Kothari¹² (Marwar), Pillai¹³ (Chennai), Leena et al²⁰ (Jodhpur), Banerjee and Agarwal⁴ (Delhi), Loobma²² (Uttar Pradesh), and Pryor²⁹ (America). In addition, the age of fusion in the present study is correlated with the upper limit of studies conducted by Mehta¹¹ (Mumbai), Bhise et al¹⁰ (Mumbai), Hepworth¹⁵ (Punjab), Sahni and Jit¹⁸ (Punjab), and Ledger and Wasson³⁴ (Pakistan). Also, findings obtained in the current study are 1 to 2 years earlier than the studies conducted by Das Gupta et al¹⁹ (Uttar Pradesh), Nemade et al²⁴ (Vidarbha), Brash²⁵ (Europe), and Paterson²⁸ (English).

Thus, inference can be dawn that in the case of males, the age of fusion of radius and ulna with their shafts corresponds precisely with studies conducted in India with few exceptions. The age of fusion in males is earlier as compared with the studies conducted outside India with the exception of studies done by Das Gupta et al¹⁹ (Uttar Pradesh) and Nemade et al²⁴ (Vidarbha).

But in the case of females, findings of the current study correlate accurately with most of the studies conducted outside India. While the age of fusion in females is also earlier as compared with the studies conducted outside India, with the exception of studies done by Das Gupta et al¹⁹ (Uttar Pradesh) and Nemade et al²⁴ (Vidarbha).

Disparity in the results of the present study with other study findings can be owing to variations in nutrition, geographical factors, genetic factors, socioeconomic status, etc. Correlation also goes well in the case of males with the study done by Mehta HS¹¹ (Mumbai), Kothari¹² (Marwar), Pillai¹³ (Chennai), and Das et al²³ (Punjab), while in females, with the studies conducted by Frazer²⁷ (Europe), Gray et al²⁷ (Europe) and Barrett³² (Burma). Results of the present study coincide precisely with studies conducted by Loder et al³⁰ (America) in both males and females. Thus, it can be concluded that geographical variations are not the only criteria for age of fusion of ossification centers. As the current study was conducted on sportspersons only, findings can be confirmed by conducting the study on common public so that these can become the benchmark for this part of India.

CONCLUSION

Fusion of epiphysis of all ossification centers in females occurs 1 to 2 years earlier compared with males, which coincides with the findings of former studies. The age of epiphyseal fusion can be useful in detecting sportsperson with forged age certificates in various national and international sports events. This study can serve as a yardstick for age verification for sportspersons competing in various sport events from western Maharashtra.

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