

Radiological Assessment of Hand Skeleton Ossification in Children under Protein Energy Malnutrition (PEM)

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ABSTRACT

Introduction: Protein energy malnutrition (PEM) in childhood leads to a skeletal undergrowth that cannot be rectified during later stages of life, therefore it may lead to an increase risk of osteoporotic fractures.

Aim: This study designed to assess the radiological assessment of skeletal changes in children with malnutrition.

Materials and Methods: A total one hundred cases between age group 0-12 years reporting to paediatric department were recruited and cases with skeletal and ossification anomalies were excluded. The grading for the malnutrition cases was done according to the recommendation of the Indian Academy of Paediatrics Nutrition sub-committee. The plain skiagrams of the wrist, with hand (AP view) and knees (AP view) were taken.

Results: The capitata and hamate were having least affected centres in the hand skeleton. The most severely affected centres were the epiphysis of the metacarpals. In group 1 & 2, the skeletal age was highly lagged behind the chronological age at 6-7 years in low income (24 months) and middle income (27 months) groups. Whereas in Grade 3 and 4, it was seen in 33.3% cases of both sexes and in 100% cases at the age of three years.

Conclusion: Malnutrition plays a crucial role in determination of mortality rate in <5 year children. There is a variation between skeletal age and chronological age in children with malnutrition. Ossification centres appear earlier in females compared to that of the males. Adequate supply of calories, protein, mineral and vitamin D is a prerequisite for the attainment of peak bone mass.

Keywords: Carpal bones, Marasmus, Metacarpal bones, Ossification

INTRODUCTION

Protein energy malnutrition (PEM) can cease the growth at the end of long bones. PEM is a major cause of infant morbidity and mortality among children of India and developing countries [1] and leads to difficulties of physical and mental growth in survived cases [2]. Almost 6000 children with <5 years die every day in India and most of these deaths are due to low birth weight, pre-term birth, lack of Vit-A, Iron, calcium, iodine, zinc, infections like pneumonia and diarrhoea [3]. Reduction of cortical bone mass and osteoporosis could result from increased sub periosteal deposition of poorly mineralized bone and greater endosteal resorption of bone [4-7].

Marasmus and Kwashiorkor are two extreme forms of malnutrition. The age, acuteness, time span of deprivation and its linked symptoms determines the clinical manifestation of malnutrition [8]. The present study utilises skeletal growth and maturation rate as criterion for assessment of the effect of PEM on child growth. With the literature support, the present study was designed for radiological assessment appearance

of ossification centres of carpals, metacarpals, lower end of radius and ulna in PEM children of different grades.

MATERIALS AND METHODS

The present cross sectional study was conducted in Department of Radiology, MNR Medical College and Hospital Sangareddy during April 2016 to January 2018. Children between age group 0-12 years reporting to paediatric department were included in the study. Cases with skeletal and ossification anomalies, endocrine disorders, cardio vascular disorders and chronic drug intake were excluded from the study. A total 100 children with protein energy malnutrition were recruited. The study sample size was considered based on the prevalence of PEM children attending to the paediatrics department. Children between age group 0-12 years belong to all socioeconomic groups and urban and rural areas were included.

Informed consent was obtained from the parents to examine the children and study protocol was approved by institutional ethics committee. All children were subjected to general and systemic, clinical examination. The grading of PEM is done according to weight for age as per ICDS programme [9].

Grade	Percentage
Grade 1	71 – 80%
Grade 2	61 – 70%
Grade 3	51 – 60%
Grade 4	Less than 50%

The plain skiagrams of the wrist, with hand (AP view) and knees (AP view) were taken. The nature of the two hands or knees was chosen for the study in asymmetrical cases. The films were processed under standard time and reviewed over good homogenous illuminating box and were also scrutinised for the structural anomalies. Radiographs of wrist are used to detect epiphyseal, non-epiphyseal anomalies, delayed appearance of secondary ossification centres and growth arrest. Extracted data was tabulated and percentages were calculated by using Microsoft excel office sheet.

RESULTS

A total 100 PEM children were recruited between age group 0-12 years. Majority cases were belonged to 0-3 years (44%) followed by 3-6 years (29%), 6-9 years (16%) and 9-12 years (11%). Among the cases, 29% had grade 2 malnutrition, 26%

Age (In Yrs.)	Total cases		Grades			
	Number	Percentage	1	2	3	4
0-3	44	44%	7	14	10	13
3-6	29	29%	6	7	8	8
6-9	16	16%	4	5	4	3
9-12	11	11%	2	3	4	2
Total	100	100%	19	29	26	26

[Table/Fig-1]: Age wise and Grade wise distribution of PEM cases.

Age group (Years)	Low income group			Middle income group		
	Skeletal age (months)	Chrono logical age (months)	Age lag (months)	Skeletal age (months)	Chrono logical age (months)	Age lag (months)
0-1	-	-	-	-	-	-
1-2	13	17	4	9	15	5
2-3	16	29	13	18	29	10
3-4	24	38	14	34	46	5
4-5	31	54	23	-	-	-
5-6	-	-	-	42	68	23
6-7	52	76	24	49	76	27
7-8	70	88	18	-	-	-
8-9	79	99	20	81	107	26
9-10	-	-	-	-	-	-
10-11	98	113	15	-	-	-
11-12	-	-	-	-	-	-

[Table/Fig-2]: Comparison of skeletal age with chronological age in various socio-economic groups of grade 1 & 2 PEM cases.

cases had grade 3 or 4 malnutrition and 19% had grade 1 malnutrition [Table/Fig-1].

In group 1 & 2, the skeletal age was highly lagged behind the chronological age of 6-7 years in low (24 months) and middle income (27 months) groups and it was less at 1-2 years age in both groups (4 months in low income & 5 months in middle income groups) [Table/Fig-2]. Whereas, in group 3 & 4, age lag was high at 5-6 years (43 months), followed by 7-8 years (38 months) and least at 1-2 years (11 months) in low income group [Table/Fig-3].

Capitate and hamate were ossified in 100% females and 66.6% males of Grade 1 & 2 at 2 years age. Whereas in grade 3 & 4, it was seen in 33.3% cases of both sexes and in 100% cases at the age of 3 years. In this study capitate and hamate are less affected by malnourishment (Table 4 & 5). None of the cases had trapezium, trapezoid till 6-7 years and No cases had scaphoid, lunate till 3-4 years in group 1 & 2. In group 3 and 4 had no scaphoid till 5-6 years and trapezium and trapezoid till 3-4 years. Radial epiphysis was appeared at 2 years of age in all groups. The radial epiphysis was the most stable centre, most frequently being the closest to the mean skeletal age [Table/Fig-4,5]. This study results showing radial ossification was delayed and not correlating with other studies.

Second and third metacarpal bones were present in 25% of cases in group 1 & 2 at 2 years age. Whereas in group 3 & 4, 2nd metacarpal was present in 25% cases and 4th metacarpal was seen in 50% cases at 2 years. First metacarpal was present in 100% cases at 3 years age in group 3 & 4 cases. 4th metacarpal was seen in 66.6% cases at 5-6 years age in group 1 & 2 [Table/Fig-6,7].

Age group (In Years)	Low income group			Middle Income Group		
	Skeletal age (months)	Chrono logical age (months)	Age lag (months)	Skeletal age (months)	Chrono logical age (months)	Age lag (months)
0-1	0	-	-	-	-	-
1-2	6	17	11	-	-	-
2-3	10	29	19	13	29	16
3-4	12	41	29	20	39	19
4-5	20	51	31	-	-	-
5-6	24	67	43	-	-	-
6-7	50	78	28	-	-	-
7-8	54	92	38	-	-	-
8-9	69	98	29	-	-	-
9-10	-	-	-	81	108	27
10-11	-	-	-	104	124	20
11-12	114	135	21	-	-	-

[Table/Fig-3]: Comparison of skeletal age with chronological age in various socio-economic groups of grade 3 & 4 PEM cases.

Carpal Centres	Sex	Age (In years)											
		0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12
No. of cases	F	-	5	6	2	2	2	1	3	1	-	-	-
	M	-	4	6	1	3	3	1	2	1	-	-	-
Scaphoid	F	-	-	-	-	100	-	-	100	100	-	-	-
	M	-	-	-	-	50	50	-	100	100	-	-	-
Lunate	F	-	-	-	-	100	-	-	-	100	-	-	-
	M	-	-	-	-	50	100	-	100	100	-	-	-
Triquetral	F	-	-	66.6	66.6	100	-	-	-	100	-	-	-
	M	-	-	33.3	50	50	100	-	100	100	-	-	-
Trapezium	F	-	-	-	-	-	-	-	-	100	-	-	-
	M	-	-	-	-	-	-	-	33.3	100	-	-	-
Trapezoid	F	-	-	-	-	-	-	-	66.6	100	-	-	-
	M	-	-	-	-	-	-	-	100	100	-	-	-
Capitate	F	-	100	100	100	100	-	-	100	100	-	-	-
	M	-	66.6	100	100	100	100	-	100	100	-	-	-
Hamate	F	-	100	100	100	100	-	-	-	100	-	-	-
	M	-	66.6	100	100	100	100	-	100	100	-	-	-
Ulnar epi	F	-	-	-	-	-	-	-	33.3	100	-	-	-
	M	-	-	-	-	-	-	-	33.3	100	-	-	-
Radial epi	F	-	50	50	100	100	100	-	-	100	-	-	-
	M	-	66.5	50	50	100	100	-	100	100	-	-	-

[Table/Fig-4]: Percentage of cases showing ossification of carpal centres at different ages in children with grade 1 & 2 Marasmus.

Carpal Centres	Sex	Age (In years)											
		0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12
No. of cases	F	-	6	5	6	1	1	1	1	1	-	2	-
	M	-	7	5	2	4	1	2	1	1	1	1	2
Scaphoid	F	-	-	-	-	-	-	100	100	-	-	-	-
	M	-	-	-	-	-	-	-	100	100	100	100	100
Lunate	F	-	-	-	50	-	66.6	100	100	100	-	10	-
	M	-	-	-	-	33.3	50	-	-	100	-	100	100
Triquetral	F	-	33.3	50	50	-	-	100	100	-	-	100	-
	M	-	-	50	66.6	66.6	100	-	-	100	100	100	100
Trapezium	F	-	-	-	-	-	66.6	-	100	100	-	-	-
	M	-	-	-	-	33.3	-	66.6	-	100	-	100	100
Trapezoid	F	-	-	-	-	-	-	-	100	-	-	-	-
	M	-	-	-	-	33.3	-	66.6	100	100	100	100	100
Capitate	F	-	-	100	100	-	-	100	100	-	-	-	-
	M	-	33.3	100	100	100	100	-	-	100	-	100	100
Hamate	F	-	-	100	100	-	-	100	100	-	-	-	-
	M	-	33.3	100	100	100	100	-	-	100	-	100	100
Ulnar epi	F	-	-	-	-	-	50	-	100	-	-	-	-
	M	-	-	-	-	-	-	-	-	100	-	100	100
Radial epi	F	-	-	50	50	-	-	100	100	-	-	-	-
	M	-	33.3	40	66.6	66.6	100	100	-	100	-	100	100

[Table/Fig-5]: Percentage of cases showing ossification of carpal centres at different ages in children with grade 3 & 4 Marasmus.

Meta-carpals	Sex	Age (In years)											
		0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12
	F	-	5	6	2	2	2	1	3	1	-	-	-
	M	-	4	6	1	3	3	1	2	1	-	-	-
1 st	F	-	-	50	100	100	-	50	-	100	-	-	-
	M	-	-	80	100	100	100	-	100	100	-	-	-
2 nd	F	-	50	50	100	100	-	-	80	100	-	-	-
	M	-	25	25	100	100	100	100	100	100	-	-	-
3 rd	F	-	-	50	100	100	100	-	-	100	-	-	-
	M	-	25	25	100	50	100	-	100	100	-	-	-
4 th	F	-	-	50	100	100	66.6	-	100	100	-	-	-
	M	-	-	-	100	50	100	-	100	100	-	-	-
5 th	F	-	-	100	100	50	-	-	100	100	-	-	-
	M	-	-	100	100	50	-	-	100	100	-	-	-

[Table/Fig-6]: Percentage of cases showing ossification of metacarpal epiphysis at different ages in children with grade 1 & 2 PEM.

Metacarpals	Sex	Age (In years)											
		0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12
	F	-	6	5	6	1	1	1	1	1	-	2	-
	M	-	7	5	2	4	1	2	1	1	1	1	2
1 st	F	-	-	100	-	-	-	100	100	-	-	100	-
	M	-	-	100	-	-	100	-	-	100	-	100	100
2 nd	F	-	25	50	50	50	-	100	100	100	-	100	-
	M	-	25	25	33.3	100	100	100	100	100	100	100	100
3 rd	F	-	-	50	50	-	100	100	100	-	-	-	-
	M	-	-	25	33.3	50	-	100	-	100	-	100	100
4 th	F	-	50	50	66.6	-	-	100	100	-	-	-	-
	M	-	-	-	33.3	50	-	-	-	100	100	100	100
5 th	F	-	-	50	-	-	-	100	100	100	-	100	-
	M	-	-	50	-	50	-	100	100	100	-	100	100

[Table/Fig-7]: Percentage of cases showing ossification of metacarpal epiphysis at different ages in children with grade 3 & 4 PEM.

DISCUSSION

Skeletal development is always dissimilar in children belongs to various ethnics, food habits, physiologic factors, socioeconomic status and living conditions [9]. Malnutrition is one of the factor affecting the skeletal growth in children and was evidenced in literature from western countries [10, 11]. In India, due to malnutrition, more than six thousand children die every day [12]. Socioeconomic status plays a key role to supply sufficient nutrition to a person. Poor economic status leads to insufficient supplementation of nutrition which has direct or indirect impact on developmental retardation of skeletal system. This study assessed appearance of ossification centres in hand skeleton radiologically.

During the first three years of life, the bone age of boys in the upper income group was higher than that of girls, thereafter they lag behind the girls. In India, upper income group boys of 4-8years are behind the standards of the Grenich & pyle atlas by 2 years. Whereas girls closely follow the American standards except for lag between the ages of 3-5years [13]. Majority studies concluded that ossification centres appear earlier in females compared to that of the males, which is also observed in this study.

Studies by Saxena et al., found 100% presence of capitate and hamate at 2 years of age [16]. Capitate and hamate were present in 100% cases of grade 1 & 2 and 33.3% of cases of grade 3 & 4 at 2 years of age. Ashutosh Srivastav et al., in his study stated that ossification center for capitate and hamate appeared at 6-12 months. Whereas according to Datta Banik et al., and Saxena et al., it was appeared between 1-2yrs. Findings of this study is correlating with the findings of Datta Banik et al., and Saxena et al [13-15]. Study by Gnanavel et al., stated that ossification centers for capitate and hamate was appeared between 6-12 months in grade 1&2 children and ossification was delayed by 1 year in grade 3&4 children, whereas no change in control group children [16].

Study by Gnanavel et al., showed ossification centre was appeared in 28% male and 25% female between 1.1-2 years and become 100% at 4.1-5 years age in grade 1. In grade 2, 50% male and 50% female at 4.1-5 years age, in grade 3, 50% female and 66% male between 4.1-5 years and 100% at 5.1-6 years age, in grade 4, ossification centre was appeared in 100% cases of both sex between 5.1-6 years age [16]. Ossification centre for triquetral in grade 1 & 2 were present in 50% of cases in the age group of 3-4 years, while in grade 3 & 4 it was present in 66.6% cases. Grade 1 & 2 malnutrition group showed the presence of triquetral in 100% of females and 50% of males in the age group 4-5 years, whereas in group 3 & 4 it was 66.6% in males.

Centres for trapezium and trapezoid appeared in 33% female and 25% male between 4.1-5 years of grade 1. In grade 2 ossification centres was appeared 50% in male and 50% in female between age group 5.1-6 years. Whereas in Grade 3&4, ossification centres was not appeared [16]. In present study, ossification centres for trapezium and trapezoid was appeared at age group 6-7.3 years [Table/Fig-8,9]. Saxena et al., in his study stated,



[Table/Fig-8]: Boy with 7.2 years showing development of scaphoid and trapezium bone.

ossification centres for scaphoid appeared age group between 9-10 years in grade 1, 2, 3 & 4 PEM [15]. Ossification centres for scaphoid appeared in 28% male and 50% female between age group 5.1-6 years in grade 1 children. No appearance of ossification centres in grade 2, 3 & 4 PEM children [16].



[Table/Fig-9]: Girl with 7.2 years showing development of scaphoid and trapezium bone.

CONCLUSION

Good nutrition is important for bone health as it is for general health. Radiological estimation of accurate age of children is often difficult task but it can be assessed by the development of ossification centres. In PEM, development of bone is almost ceased and developed bone were utilized for protein. In this study, development of ossification centres in carpal and metacarpal bones was delayed. There is an impact of age, socioeconomic status and ethnicity on developmental delay. This study focused on impact of age, socioeconomic status on ossification in malnutrition but evaluation is needed to assess the impact of racial, genetic, environmental factors on ossification of bony centres in malnutrition.

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