

Radiographic Evaluation of Nutritional Rickets in Children: A Cross-Sectional Study

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Abstract

Introduction: Rickets is a pediatric condition characterized by defective mineralization of growing bones, leading to structural deformities, bone pain, and delayed developmental milestones. The purpose of the study was to assess radiographic features of nutritional rickets in children.

Materials and Methods: This cross-sectional study at the Department of Radiology and Imaging, Bangladesh Shishu Hospital & Institute, Bangladesh (January–December 2023) included 45 children with nutritional rickets. Demographics, clinical features, wrist and knee radiographs (graded by Thacher score), and laboratory tests (calcium, phosphate, ALP, vitamin D) were recorded. Data were analyzed using descriptive statistics, with continuous variables as mean \pm SD and categorical variables as frequencies and percentages.

Results: Among 45 children with nutritional rickets, most were 1–3 years old (22, 48.9%) with slight male predominance (26, 57.8%). Common findings included wrist widening (34, 75.6%), leg bowing (28, 62.2%), wrist cupping (32, 71.1%), knee metaphyseal cupping (30, 66.7%), and bilateral involvement (wrist 41, 91.1%; knee 38, 84.4%). Moderate rickets predominated (23, 51.1%; Thacher 6.8 ± 2.1). Biochemical abnormalities were frequent: hypocalcemia (26, 65.0%), low phosphate (23, 57.5%), elevated ALP (31, 77.5%), and vitamin D deficiency (31, 77.5%).

Conclusion: Radiographic assessment, alongside clinical and biochemical evaluation, is essential for identifying and grading skeletal changes in pediatric nutritional rickets.

Keywords: Radiography, Nutritional Rickets, Pediatrics

1. INTRODUCTION

Rickets is characterized by deformities of the bones resulting from defective mineralization in actively growing skeletal tissue [1]. This condition primarily affects children and is associated with structural bone abnormalities, bone pain, convulsions, and delays in developmental milestones [2]. Nutritional rickets remains prevalent in numerous developing nations and has also been observed with increasing frequency in developed countries [3–5]. Modern lifestyles often limit adequate sunlight exposure, which is necessary for cutaneous vitamin D synthesis, contributing to the rising incidence of this condition. Globally, vitamin D (cholecalciferol) deficiency is a major contributing factor to nutritional rickets and is recognized as one of the leading pediatric disorders [6, 7]. Despite advances in healthcare,

its prevalence continues to be a significant concern even in industrialized regions [8, 9].

If left unaddressed, children with rickets are at increased risk of fractures. Severe or prolonged disease may result in permanent skeletal deformities. Critically low levels of calcium in the blood can precipitate muscle cramps, convulsions, and respiratory complications. Affected children often display pallor, irritability, difficulty sleeping, and excessive sweating [10]. Additional clinical manifestations include flaring of the lower anterior thoracic wall, prominence of the costochondral junction (rachitic rosary), and frontal bossing. As children begin to bear weight during ambulation, deformities such as genu valgum or genu varum may develop. Malnutrition contributing to muscular wasting and heightened susceptibility to infections represents other systemic consequences of rickets [11].

Among pediatric populations, rickets is the most frequent clinical manifestation of vitamin D deficiency [12]. Sunlight remains the primary source of vitamin D, yet rickets is frequently diagnosed even in regions with ample sunlight. Radiographic evaluation of the wrists and knees is a crucial component in the assessment of metaphyseal abnormalities in children with nutritional rickets, including cupping, fraying, splaying, and widening of the growth plates. These imaging findings not only assist in confirming the diagnosis but also allow grading of disease severity using the Thacher scoring system [13]. Bilateral involvement of the wrists and knees, along with deformities such as genu varum and genu valgum, are typical radiographic features seen in pediatric rickets [14].

Despite the established clinical and radiographic features of nutritional rickets, there remains limited recent data on the precise pattern and severity of metaphyseal changes in pediatric populations, particularly in regions with abundant sunlight where rickets prevalence is still unexpectedly high. Moreover, variations in the frequency and severity of wrist and knee deformities, as well as their correlation with biochemical parameters, have not been comprehensively documented in many local settings. This gap in knowledge hinders timely diagnosis, appropriate grading of disease severity, and effective monitoring of treatment outcomes. Therefore, the purpose of the study is to assess radiographic features of nutritional rickets in children.

2. OBJECTIVE

- To assess radiographic features of nutritional rickets in children.

3. METHODOLOGY & MATERIALS

This cross-sectional study was conducted at the Department of Radiology and Imaging, Bangladesh Shishu Hospital & Institute, Bangladesh, from January 2023 to December 2023. A total of 45 children diagnosed with nutritional rickets were included, selected based

on predefined inclusion and exclusion criteria. Data on demographic characteristics, clinical features, radiographic findings, and biochemical parameters were collected to evaluate the radiographic features and severity of nutritional rickets in this pediatric population.

3.1. Inclusion Criteria

- Children presenting with clinical signs suggestive of rickets:
- Skeletal deformities (e.g., wrist widening, bowing of legs)
- Growth disturbances (e.g., growth retardation, failure to thrive)

3.2. Exclusion Criteria

- Children with congenital skeletal abnormalities
- Children with chronic systemic illnesses affecting bone metabolism
- Children who had received prior treatment for rickets

Demographic data, including age and sex, were recorded for all participants, followed by a detailed clinical examination to identify characteristic features of rickets such as wrist widening, bowing of legs, rachitic rosary, delayed milestones, growth retardation, failure to thrive, and pathological fractures. Radiographs of the wrists and knees were obtained to assess metaphyseal changes, including cupping, fraying, splaying, and growth plate widening, with bilateral involvement noted. Radiographic severity was graded using the Thacher scoring system as mild, moderate, or severe. Laboratory investigations were performed in 40 children to measure serum calcium, phosphate, alkaline phosphatase (ALP), and 25-hydroxyvitamin D levels, with biochemical abnormalities defined according to standard reference ranges and vitamin D deficiency considered at <20 ng/mL. Data were analyzed using descriptive statistics, with continuous variables expressed as mean ± standard deviation (SD) and categorical variables presented as frequencies and percentages.

4. RESULTS

Table 1. Demographic Characteristics of the Study Population (n = 45)

Variable	Frequency (n)	Percentage (%)
Age (years)	1-3	48.9
	4-5	28.9
	>5	22.2
	Mean age (years)	3.6 ± 1.7
Sex	Male	57.8
	Female	42.2
	Male : Female ratio	1.37 : 1

Table 1 summarizes the age and sex distribution of the children included in the study. The majority of participants were aged between 1 and 3 years. A slight male predominance was

observed, with a male-to-female ratio of 1.37:1. The mean age of the study population was 3.6 ± 1.7 years.

Table 2. *Clinical Features of the Study Population (n = 45)*

Clinical Feature	Frequency (n)	Percentage (%)
Wrist widening	34	75.6
Bowing of legs (genu varum/valgum)	28	62.2
Rachitic rosary	21	46.7
Delayed milestones	18	40.0
Growth retardation	15	33.3
Failure to thrive	9	20.0
Pathological fractures	2	4.4

Wrist widening was the most common clinical feature, observed in 34 children (75.6%), followed by bowing of the legs in 28 (62.2%). Rachitic rosary was present in 21 patients (46.7%), while delayed developmental

milestones were noted in 18 (40.0%). Growth retardation and failure to thrive were identified in 15 (33.3%) and 9 children (20.0%), respectively. Pathological fractures were the least frequent finding, occurring in only 2 patients (4.4%).

Table 3. *Radiographic Findings in Wrist X-rays of the Study Population (n = 45)*

Radiographic Feature	Frequency (n)	Percentage (%)
Cupping	32	71.1
Fraying	29	64.4
Splaying	25	55.6
Widened growth plate	27	60.0
Bilateral involvement	41	91.1

Metaphyseal cupping was the most frequent radiographic finding, observed in 32 children (71.1%), followed by fraying in 29 (64.4%) and widening of the growth plate in 27 (60.0%).

Splaying of the metaphysis was noted in 25 patients (55.6%). The majority of children demonstrated bilateral wrist involvement, seen in 41 cases (91.1%).

Table 4. *Radiographic Findings in Knee X-rays of the Study Population (n = 45)*

Feature	Frequency (n)	Percentage (%)
Metaphyseal cupping	30	66.7
Genu varum deformity	22	48.9
Genu valgum deformity	6	13.3
Bilateral knee involvement	38	84.4

Metaphyseal cupping of the knee was observed in 30 children (66.7%). Genu varum deformity was present in 22 patients (48.9%), while genu

valgum deformity was noted in 6 (13.3%). Bilateral knee involvement was common, occurring in 38 children (84.4%).

Table 5. *Radiographic Severity of Nutritional Rickets Based on Thacher Score (n = 45)*

Severity Category	Frequency (n)	Percentage (%)
Mild rickets	12	26.7
Moderate rickets	23	51.1
Severe rickets	10	22.2
Mean Thacher score	6.8 ± 2.1	

Based on radiographic severity scoring, moderate rickets was the most common category, affecting 23 children (51.1%). Mild rickets was observed in 12 patients (26.7%), while severe rickets was

identified in 10 patients (22.2%). The mean Thacher score of the study population was 6.8 ± 2.1 .

Table 6. Biochemical Parameters of the Study Population (n = 40)

Parameter	Mean ± SD	Abnormal (n)	Abnormal (%)
Serum calcium (mg/dL)	7.6 ± 0.8	26	65.0
Serum phosphate (mg/dL)	3.2 ± 0.6	23	57.5
ALP (IU/L)	820 ± 210	31	77.5
Vitamin D < 20 ng/mL		31	77.5

Hypocalcemia was observed in 26 children (65.0%), while low serum phosphate levels were present in 23 (57.5%). Elevated alkaline phosphatase (ALP) levels were the most common biochemical abnormality, identified in 31 patients (77.5%). Vitamin D deficiency, defined as serum 25-hydroxyvitamin D levels below 20 ng/mL, was also detected in 31 children (77.5%).

5. DISCUSSION

Nutritional rickets is a prevalent pediatric condition that can result in significant skeletal deformities and functional impairment if not identified and managed promptly. Radiographic evaluation of the wrists and knees serves as a critical tool for assessing the extent of metaphyseal abnormalities and grading disease severity. The findings of this study demonstrate that characteristic radiographic changes, including metaphyseal cupping, fraying, splaying, and growth plate widening, are commonly observed in children with nutritional rickets, often with bilateral involvement. These results highlight the clinical importance of early radiographic assessment to confirm diagnosis, determine severity, and guide appropriate management to prevent long-term skeletal deformities.

The demographic characteristics observed in the present study are consistent with patterns reported in earlier studies on nutritional rickets in children. Nearly half of the affected children in our cohort belonged to the 1–3-year age group, with a mean age of 3.6 ± 1.7 years, underscoring early childhood as the most vulnerable period for the development of nutritional rickets. This age distribution is comparable to the findings of Ejaz et al.[15], who reported a mean age of approximately 2.1 years with the highest proportion of cases occurring between 1 and 3 years, indicating a similar early age of presentation. In addition, a slight male predominance was observed in the current study, with males constituting 57.8% of cases and a male-to-female ratio of 1.37:1, which aligns with the observations of Mumtaz et al.[16], who reported a higher prevalence of rickets among male children. Although variations in sex

distribution have been documented across different populations, these findings collectively suggest that nutritional rickets predominantly affects young children, with a tendency toward male predominance, thereby supporting the representativeness and external validity of the demographic profile of the present study.

The clinical features observed in the present study demonstrate a pattern consistent with previously reported manifestations of nutritional rickets, with skeletal abnormalities predominating. Wrist widening was the most frequent finding, present in 34 children (75.6%), followed by bowing of the legs in 28 (62.2%) and rachitic rosary in 21 (46.7%), indicating advanced skeletal involvement at presentation. These findings are comparable to those reported by Reddy et al.[17], who identified rachitic rosary, thickened epiphyses, and limb deformities as prominent clinical signs among children with rickets, reflecting a similar pattern of skeletal changes. In comparison, Anant et al.[18] reported lower frequencies of wrist widening (approximately 48%), bowing of the legs (31%), and rachitic rosary (21%), suggesting that children in the present study may have presented with more pronounced clinical disease. Additionally, delayed developmental milestones were observed in 18 children (40.0%), while growth retardation and failure to thrive were noted in 15 (33.3%) and 9 (20.0%) patients, respectively, underscoring the systemic impact of prolonged nutritional deficiency. Pathological fractures were uncommon, occurring in only 2 children (4.4%), indicating that most patients presented with progressive deformities rather than acute skeletal complications. Overall, the clinical profile of this cohort aligns well with existing literature and supports the characteristic presentation of nutritional rickets in children.

The radiographic findings of the wrist in the present study demonstrate classical metaphyseal changes characteristic of nutritional rickets. Metaphyseal cupping was observed in 32 children (71.1%), fraying in 29 (64.4%), splaying in 25 (55.6%), and widening of the growth plate in 27 (60.0%), with bilateral wrist involvement noted in 41 patients (91.1%), reflecting the

systemic nature of the disease. These findings are comparable to those reported by Sethi et al.[19], who documented a very high prevalence of wrist abnormalities, including cupping in 100%, splaying in 98.7%, fraying in 96.3%, and epiphyseal widening in 87.5% of children with rickets, confirming that these radiographic features are consistently observed in affected populations. In addition, Anant et al.[18] reported metaphyseal cupping and fraying in approximately 74% of cases and growth plate widening in 55%, which closely parallels the frequencies observed in the present study. The slightly lower prevalence of radiographic abnormalities in our cohort may reflect earlier detection or variations in disease severity at presentation. Overall, the radiographic wrist findings in this study align well with previously published literature and underscore the diagnostic value of wrist X-rays in the evaluation of nutritional rickets in children.

The radiographic evaluation of the knee in the present study demonstrates characteristic lower-limb deformities associated with nutritional rickets. Metaphyseal cupping was observed in 30 children (66.7%), genu varum deformity in 22 (48.9%), genu valgum in 6 (13.3%), and bilateral knee involvement in 38 patients (84.4%), highlighting the systemic skeletal impact of the disease. These findings are comparable to those reported by Chabra et al.[20], who observed bilateral genu valgus in 54.54% and bilateral genu varum in 25.92% of children with rickets, confirming that coronal plane knee deformities are common manifestations of the disease. Similarly, Ahmed et al.[21] reported a high proportion of genu varum (75%) and a smaller proportion of genu valgum (25%) among rural Bangladeshi children with active rickets, supporting the frequent occurrence of knee deformities in pediatric rickets. The slightly lower prevalence of genu varum and valgum in the present cohort may reflect earlier detection or differences in disease severity at presentation. Overall, the radiographic knee findings in this study align closely with previous literature, reinforcing the importance of knee X-rays in the assessment of structural abnormalities in children with nutritional rickets.

The radiographic severity of nutritional rickets in the present study, assessed using the Thacher scoring system, demonstrates that the majority of children had moderate involvement, with 23 patients (51.1%) classified as moderate, 12 (26.7%) as mild, and 10 (22.2%) as severe, yielding a mean Thacher score of 6.8 ± 2.1 . These

findings align with the validation study by Thacher et al.[22], who demonstrated that higher scores on the 10-point radiographic scale reliably reflect more extensive metaphyseal abnormalities in both wrist and knee radiographs, supporting the use of this scoring system for grading disease severity. Similarly, Chatterjee et al.[23] reported that initial Thacher scores in children with active rickets correlated with biochemical markers, such as elevated alkaline phosphatase, and that severity categories—mild, moderate, and severe—provided a practical framework for assessing disease burden and monitoring treatment response. The distribution observed in the present cohort, with over half of the children showing moderate radiographic severity, is consistent with these studies and highlights the utility of Thacher scoring in quantifying structural changes and guiding clinical evaluation in pediatric nutritional rickets.

The biochemical profile of children in the present study demonstrates classical metabolic disturbances associated with nutritional rickets. Serum calcium was low in 26 children (65.0%) with a mean of 7.6 ± 0.8 mg/dL, while serum phosphate was abnormal in 23 patients (57.5%) with a mean of 3.2 ± 0.6 mg/dL, reflecting impaired mineralization commonly observed in rickets. Alkaline phosphatase (ALP) was markedly elevated in 31 children (77.5%) with a mean value of 820 ± 210 IU/L, and 31 children (77.5%) had vitamin D levels below 20 ng/mL, consistent with vitamin D deficiency as a primary etiological factor. These findings are comparable to those reported by Chanchlani et al.[24], who described low serum calcium and phosphate along with elevated ALP as well-recognized laboratory features supporting the diagnosis of nutritional rickets. Similarly, Dabas et al.[25] observed that children with vitamin D deficiency rickets commonly exhibited elevated ALP and low or low-normal serum calcium and phosphate, reflecting the metabolic adaptations secondary to defective bone mineralization. The frequencies of abnormal biochemical parameters in the present cohort closely align with these studies, reinforcing the typical laboratory profile seen in pediatric nutritional rickets and supporting the use of these parameters for diagnosis and disease monitoring.

6. LIMITATIONS OF THE STUDY

This study had some limitations:

- The study population was relatively small, limiting generalizability.
- The sample was not randomly selected.

- The study's limited geographic scope may introduce sample bias, potentially affecting the broader applicability of the findings.

7. CONCLUSION

Nutritional rickets is a metabolic bone disorder caused by vitamin D deficiency, leading to impaired mineralization and characteristic skeletal deformities in children. In this study, the condition predominantly affected young children, with a slight male predominance. Clinically, skeletal deformities such as wrist widening and leg bowing were common, while radiographic evaluation revealed characteristic metaphyseal changes in the wrists and knees with frequent bilateral involvement. Moderate rickets was the most frequent severity category based on Thacher scores. Biochemically, hypocalcemia, low phosphate, elevated alkaline phosphatase, and vitamin D deficiency were prevalent, reflecting the systemic impact of vitamin D deficiency on bone metabolism. Overall, these findings underscore the utility of radiographic assessment in identifying characteristic skeletal changes and grading severity, supporting the clinical and biochemical evaluation of pediatric nutritional rickets.

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