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Original Article

Nutritional and Lifestyle Factors Associated with Rickets in Children Under Three Years of Age at a Tertiary Care Hospital in Abbottabad

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Abstract

Background: Rickets is a pediatric bone disorder characterized by defective mineralization of growing bone and cartilage. Despite being largely preventable, nutritional rickets remains a significant public health concern, particularly in low- and middle-income countries. Changing lifestyles, poor maternal nutrition, inadequate sunlight exposure, and suboptimal infant feeding practices have contributed to its re-emergence globally.

Objective: To assess the association of modifiable nutritional and lifestyle factors with the prevalence of nutritional rickets in children under three years of age presenting to a tertiary care hospital.

Methodology: This cross-sectional observational study was conducted at Ayub Medical Complex, Abbottabad, from 4 October 2024 to 5 July 2025. A total of 150 children under three years of age with clinical or radiological suspicion of nutritional rickets were enrolled using a non-probability purposive sampling technique. Diagnosis was supported through clinical examination, biochemical investigations, and measurement of serum 25-hydroxyvitamin D levels using ELISA. Data regarding feeding practices, sunlight exposure, maternal education, and supplementation were collected through structured parental interviews. Statistical analysis was performed using SPSS version 28, with age- and gender-based stratification.

Results: Among the 150 children, 60% were boys and 40% were girls, with nearly half of the cases occurring in infants ≤10 months of age. Vitamin D deficiency was identified in 81.6% of children and was particularly prevalent among those with low maternal education (75.5%). Inadequate sunlight exposure (35.4%), poor weaning practices (49.7%), animal milk feeding (48.3%), and undernutrition (46.9%) were frequently observed. Significant associations were found between these risk factors and both age and gender ($p \leq 0.05$).

Conclusion: Nutritional rickets in young children is strongly associated with preventable nutritional and lifestyle factors, particularly lack of vitamin D supplementation, poor maternal awareness, inadequate weaning, and insufficient sunlight exposure. Early preventive strategies focusing on maternal education and infant nutrition are essential to reduce disease burden.

Keywords: Cervical Ripening, Foley Balloon Catheter, Labour Induction.

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Introduction

Rickets is a pediatric bone disease characterized by impaired mineralization of the growing skeleton, resulting primarily from deficiencies in calcium, phosphate, or vitamin D. Depending on the underlying deficiency, rickets may be classified as either phosphopenic or calciopenic. Adequate calcium and phosphate homeostasis, regulated largely by vitamin D metabolism, is essential for normal growth plate development and bone mineralization. Disruption of these processes leads to defective osteoid mineralization, abnormal chondrocyte maturation, and apoptosis within the growth plate, producing characteristic clinical and radiological manifestations of rickets [1].

Clinically, rickets presents with features such as craniotabes, delayed closure of fontanels, widened wrists, prominent frontal bossing, delayed dentition, bowing of long bones, and the classical rachitic rosary. Persistent deficiency can result in growth retardation, skeletal deformities, and long-term functional impairment. Adequate dietary calcium intake and optimal vitamin D status are therefore crucial for maintaining skeletal health during early childhood [2].

Nutritional rickets remains prevalent in South Asia due to poor maternal nutrition, inadequate dietary calcium and vitamin D intake, and insufficient exposure to sunlight. In India and neighboring regions, maternal vitamin D deficiency, prolonged exclusive breastfeeding without supplementation, and limited outdoor activity have been identified as major contributors [3]. Urban minority populations are particularly vulnerable, reflecting socioeconomic disparities and lifestyle-related risk factors [4].

In Pakistan, nutritional rickets continues to pose a significant pediatric health challenge, especially in low-income and rural communities. Cultural practices involving limited sun exposure, poor maternal nutrition, inadequate complementary feeding, and lack of routine vitamin D supplementation have been widely reported. Low parental education and restricted access to healthcare further exacerbate the condition, emphasizing the need for targeted public health interventions [5].

Globally, the resurgence of nutritional rickets has been documented in both developed and developing countries. Dietary restrictions, including vegan diets in infants, can predispose children to calcium and vitamin D deficiencies if not appropriately supplemented [6]. Epidemiological data indicate a rising incidence of nutritional rickets over recent decades [7], with rates increasing significantly in North America and Europe [8,9], while clinical signs are reported in up to 30% of children in some low- and middle-income countries [10].

Vitamin D plays a central role in calcium and phosphate absorption, with its active form, 1,25-dihydroxyvitamin D, facilitating intestinal mineral uptake [11]. In deficiency states, calcium absorption may decline to as low as 10–15%, leading to secondary hyperparathyroidism and defective bone mineralization [12]. Although vitamin D and calcium supplementation are effective treatments [13], exclusively breastfed infants remain at risk due to the low vitamin D content of breast milk, particularly when maternal stores are inadequate or sunlight exposure is limited [14].

Radiological findings such as metaphyseal cupping, fraying, and widening, along with characteristic biochemical abnormalities including low serum 25-hydroxyvitamin D, hypocalcemia, hypophosphatemia, and elevated alkaline phosphatase, are integral to diagnosis and monitoring of nutritional rickets [15,16]. Given the rising burden and preventable nature of this condition, the present study was conducted to evaluate the nutritional and lifestyle factors associated with rickets in children under three years of age presenting to a tertiary care hospital in Abbottabad.

Methodology

Study Design

This study employed a cross-sectional observational design to evaluate the association between modifiable nutritional and lifestyle factors and the occurrence of nutritional rickets among children under three years of age. The design was chosen to allow simultaneous assessment of exposure variables and clinical outcomes within a defined population presenting to a tertiary care hospital.

Ethics

The study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki. Ethical approval was obtained from the Institutional Ethical Review Committee of Ayub Medical College (Approval Ref. No. RC-EA-2024-229, dated 04 October 2024). Written informed consent was obtained from parents or legal guardians prior to enrollment. Confidentiality of participant data was maintained throughout the study, and participation was entirely voluntary.

Setting

The study was carried out at the Department of Pediatrics, Ayub Medical Complex, Abbottabad, a major tertiary-care referral center catering to urban and rural populations of

Khyber Pakhtunkhwa. Data collection was conducted over a seven-month period, from 4 October 2024 to 5 July 2025.

Participants

A total of 150 children under three years of age were enrolled using a non-probability purposive sampling technique. Eligible participants were children presenting with clinical or radiological features suggestive of nutritional rickets, including delayed growth, bone pain, widened wrists, bowed legs, delayed closure of fontanels, or other skeletal deformities. Children older than three years, those with genetically determined or metabolic causes of rickets, chronic renal or hepatic disease, recent vitamin D or calcium supplementation (within the previous three months), incomplete records, or lack of parental consent were excluded.

Variables

The primary outcome variable was the presence of nutritional rickets, confirmed through clinical, biochemical, and radiological assessment. Independent variables included vitamin D supplementation status, sunlight exposure, feeding and weaning practices, animal milk consumption, nutritional status, maternal education level, age, and gender. These variables were selected based on prior evidence linking them to nutritional rickets.

Data Sources/Measurement

Data were collected using a structured proforma that recorded demographic details, clinical findings, and parental interview responses. Clinical examination was followed by laboratory investigations, including serum calcium, phosphorus, and alkaline phosphatase levels.

Serum 25-hydroxyvitamin D [25(OH)D] was measured using enzyme-linked immunosorbent assay (ELISA). Vitamin D status was classified as deficient (<20 ng/mL), insufficient (20–30 ng/mL), or sufficient (>30 ng/mL). Sunlight exposure was considered inadequate if exposure was less than 15–30 minutes at least twice weekly on exposed skin. Nutritional status was assessed clinically.

Bias

To minimize information bias, all data were collected using standardized instruments and predefined criteria. Laboratory investigations were performed using uniform protocols.

However, recall bias related to parental reporting of feeding practices and sunlight exposure could not be entirely eliminated due to the observational nature of the study.

Study Size

The sample size of 150 participants was calculated using the WHO sample size calculator, based on an anticipated prevalence of nutritional rickets, a confidence level of 95%, and an acceptable margin of error. This sample size was considered adequate to detect meaningful associations between exposure variables and nutritional rickets.

Quantitative Variables

Continuous variables such as age were treated as quantitative variables and summarized using means and standard deviations. Categorical variables, including supplementation status, sunlight exposure, feeding practices, maternal education, and nutritional status, were treated as qualitative variables and expressed as frequencies and percentages.

Statistical Methods

Data were entered and analyzed using SPSS version 28. Descriptive statistics were used to summarize participant characteristics. Associations between categorical variables were assessed using the Chi-square test, while comparisons of means were performed using the independent t-test or one-way ANOVA, as appropriate. Age- and gender-based stratification analyses were conducted to explore variations in risk factors. A p-value ≤ 0.05 was considered statistically significant.

Results

Participants

A total of 150 children under three years of age diagnosed with nutritional rickets were included in the analysis. Of these, 90 (60%) were boys and 60 (40%) were girls, indicating a male predominance. The largest proportion of affected children belonged to the youngest age group: 71 children (47.3%) were ≤10 months old. This was followed by 45 children (30%) aged 16–20 months, 25 children (16.6%) aged over 20 months, and 9 children (6.1%) aged 11–15 months (Table 1). The distribution demonstrates that nutritional rickets was most frequently identified during infancy, particularly within the first year of life.

Descriptive Data

Analysis of nutritional and lifestyle characteristics revealed a high burden of modifiable risk factors among the study population. Vitamin D supplementation was lacking in 81.6% of children, making it the most prevalent risk factor identified. Low maternal education was observed in 75.5% of cases, suggesting a strong link between caregiver awareness and child health outcomes. Inadequate weaning practices were reported in 49.7%, while animal milk feeding

was noted in 48.3% of children. Nearly half of the cohort (46.9%) was found to be undernourished, and 35.4% of children had insufficient sunlight exposure, defined as less than 15–30 minutes of exposure per day (Table 2). These descriptive findings highlight the clustering of nutritional, behavioral, and socioeconomic risk factors among affected children.

Outcome Data

Age-wise stratification demonstrated that all major risk factors showed statistically significant associations with age categories ($p \leq 0.05$). Children aged ≤10 months showed a higher relative burden of inadequate sunlight exposure, lack of vitamin D supplementation, poor weaning practices, animal milk feeding, and malnutrition compared with older age groups (Table 3). Similarly, gender-based analysis revealed that most risk factors were more frequently observed among boys than girls, with statistically significant differences across sunlight exposure, maternal education, vitamin D supplementation status, feeding practices, and nutritional status ($p \leq 0.05$) (Table 4). These findings suggest that both age and gender influence exposure to risk factors associated with nutritional rickets.

Main Results

The overall results indicate that nutritional rickets in children under three years of age is strongly associated with preventable nutritional and lifestyle factors. Lack of vitamin D supplementation emerged as the dominant contributor, followed by low maternal education, inadequate weaning, animal milk feeding, insufficient sunlight exposure, and undernutrition. The burden was greatest in infants below one year of age, emphasizing early infancy as a critical window for prevention. The consistent statistical significance across age- and gender-based analyses reinforces the role of modifiable behaviors and caregiver-related factors in the development of nutritional rickets within this population.

Table 1: Age Distribution of Children with Nutritional Rickets (n = 150).

Age Group	Frequency	Percentage (%)
≤10 months	71	47.3
11 – 15 months	9	6.1
16- 20 months	45	30
>20 months	25	16.6
Total	150	100

Table 2: Prevalence of Key Nutritional and Lifestyle Risk Factors in Children with Rickets.

Factors		Frequency	Percentage (%)
Sunlight exposure of less than 15–30 minutes per day	Yes	53	35.40
	No	97	64.60
Low maternal education	Yes	113	75.50
	No	37	24.50
Inadequate weaning practices	Yes	74	49.70
	No	76	50.30
Lack of vitamin D supplementation	Yes	122	81.60
	No	28	18.40
Animal milk feeding	Yes	72	48.30
	No	78	51.70
Age of children (<3years)	Yes	92	61.20
	No	58	38.80
Malnutrition	Yes	70	46.90
	No	80	53.10

Table 3: Impact of Age on Key Risk Factors for Nutritional Rickets.

Factors		Age (month wise)		p-value
		≤10.0 (%)	11.0+ (%)	
Sunlight exposure of less than 15–30 minutes per day	Yes	50.00	50.00	≤0.05*
	No	44.20	55.80	
Low maternal education	Yes	45.00	55.00	≤0.05*
	No	50.00	50.00	
Inadequate weaning practices	Yes	43.80	56.20	≤0.05*
	No	48.60	51.40	
Lack of vitamin D supplementation	Yes	45.80	54.20	≤0.05*
	No	48.10	51.90	
Animal milk feeding	Yes	46.50	53.50	≤0.05*
	No	46.10	53.90	
Age of children (<3years)	Yes	44.40	55.60	≤0.05*
	No	49.10	50.90	
Malnutrition	Yes	43.50	56.50	≤0.05*
	No	48.70	51.30	

*p<0.05 is considered statistically significant

Table 4: Gender-Based Comparison of Risk Factors Associated with Nutritional Rickets.

Factors		Gender		p-value
		Boys (%)	Girls (%)	
Sunlight exposure of less than 15–30 minutes per day	Yes	59.60	40.40	≤0.05*
	No	61.10	38.90	
Low maternal education	Yes	61.30	38.70	≤0.05*
	No	58.30	41.70	
Inadequate weaning practices	Yes	63.80	37.01	≤0.05*
	No	58.10	41.90	
Lack of vitamin D supplementation	Yes	62.50	37.50	≤0.05*
	No	51.90	48.10	
Animal milk feeding	Yes	54.90	45.10	≤0.05*
	No	65.80	34.20	
Age of children (<3years)	Yes	56.70	43.30	≤0.05*
	No	66.70	33.30	
Malnutrition	Yes	60.90	39.10	≤0.05*
	No	60.30	39.70	

*p<0.05 is considered statistically significant

Discussion

The present study highlights the continued burden of nutritional rickets among children under three years of age and reinforces the role of modifiable nutritional and lifestyle factors in its etiology. The high prevalence of vitamin D deficiency observed in this cohort aligns with growing global and regional evidence that inadequate supplementation and limited sunlight exposure remain the primary drivers of infantile rickets [7–9]. The predominance of cases among infants less than one year of age underscores the vulnerability of early life stages, particularly when preventive strategies are not implemented promptly. A striking finding of this study was the strong association between low maternal education and lack of vitamin D supplementation, a relationship consistently reported in both South Asian and Middle Eastern populations [5,10]. Mothers with limited health literacy may be less aware of the importance of vitamin D supplementation, appropriate weaning practices, and safe sunlight exposure, thereby increasing the risk of deficiency-related bone disease in

their children. This observation emphasizes that rickets is not merely a biological disorder but is deeply rooted in socioeconomic and educational determinants of health.

Inadequate sunlight exposure was identified in over one-third of the children, reflecting cultural practices, indoor lifestyles, and environmental constraints that limit ultraviolet B exposure. Similar findings have been reported from Pakistan, India, and Saudi Arabia, where traditional clothing, urban living, and concerns about heat exposure reduce effective sun exposure despite abundant sunlight [3,4,17,18]. These patterns suggest that public health messaging must balance cultural sensitivity with evidence-based recommendations for safe sun exposure.

Dietary factors also played a significant role. Nearly half of the children had inadequate weaning practices, and a substantial proportion were fed animal milk at an early age. These practices may compromise calcium intake and overall nutritional adequacy, particularly when complementary feeding is delayed or poorly diversified. Evidence from randomized trials and observational studies indicates that vitamin D supplementation alone may be insufficient to prevent rickets in populations with chronically low dietary calcium intake, highlighting the need for combined nutritional interventions [13,19].

The gender-based differences observed, with boys showing a higher prevalence of several risk factors, have been noted in previous studies, although the reasons remain multifactorial. Possible explanations include gender-based caregiving practices, health-seeking behavior, or sociocultural biases favoring male children for hospital presentation rather than true biological susceptibility [8,9]. Nonetheless, the statistically significant associations across age and gender groups reinforce the consistency and robustness of the identified risk factors.

Recent evidence further supports the importance of maternal vitamin D status in preventing infantile rickets. Secondary analyses of randomized trials demonstrate that combined prenatal and postpartum maternal vitamin D supplementation significantly reduces biochemical rickets in infants, corroborating the findings of widespread deficiency in unsupplemented infants observed in this study [17]. Moreover, updated analyses defining serum 25-hydroxyvitamin D thresholds for rickets risk provide a strong rationale for targeted biochemical screening in high-risk children presenting to tertiary care centers [20].

Limitations

This study has several limitations that should be considered when interpreting the findings. First, the cross-sectional design precludes the establishment of causal relationships between identified risk factors and nutritional rickets. Second, reliance on parental reporting for feeding practices and sunlight exposure introduces the possibility of recall bias. Third, the study was conducted at a single tertiary care hospital, which may limit the generalizability of results to community-based or primary-care settings. Additionally, genetic factors, environmental variables, and long-term follow-up outcomes were not assessed. Despite these limitations, the study provides valuable insight into locally relevant and preventable determinants of nutritional rickets.

Conclusion

This study demonstrates that nutritional rickets in children under three years of age is strongly associated with lack of vitamin D supplementation, low maternal education, insufficient sunlight exposure, inadequate weaning practices, animal milk feeding, and undernutrition. The highest burden was observed in infants below one year of age, highlighting early infancy as a critical period for prevention. These findings underscore the urgent need for integrated preventive strategies, including routine vitamin D supplementation, caregiver education, promotion of nutritionally adequate complementary feeding, and guidance on safe sunlight exposure. Incorporating maternal education and infant nutrition counseling into routine child health services may substantially reduce the burden of nutritional rickets. Future community-based and longitudinal studies are recommended to evaluate the long-term impact of combined vitamin D and calcium interventions and to inform evidence-based public health policies.

Authors' Contributions:

All authors meet the ICMJE criteria for authorship.

Author 1: Substantial contribution to conception and design, drafting the manuscript, final approval, agreed to be accountable for all the work.
Author 2: Substantial contribution to conception and design, data acquisition, drafting the manuscript, final approval, agreed to be accountable for all the work.
Author 3: Analysis and interpretation of data, drafting the manuscript, final approval, agreed to be accountable for all the work.
Author 4: Analysis and interpretation of data, critical revision, final approval, agreed to be accountable for all the work.

Author 5: Substantial contribution to conception and design, drafting the manuscript, final approval, agreed to be accountable for all the work.

Author 6&7: Substantial contribution to conception and design, data acquisition, drafting the manuscript, final approval, agreed to be accountable for all the work.

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