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RESEARCH ARTICLE

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Assessment of Risk Factors for Nutritional Rickets in Children Aged 6–59 Months at A County Referral Hospital in Kenya

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ABSTRACT

Nutritional rickets remains a major child health challenge in low- and middle-income countries, including Kenya. Beyond undernutrition, socio-demographic disadvantage, inadequate calcium and vitamin D intake, and limited sunlight exposure contribute to its persistence. This study assessed the nutritional status of children aged 6–59 months attending Murang'a County Referral Hospital (MCRH) and examined associated risk factors for nutritional rickets. An analytical cross-sectional study was conducted among 212 children aged 6–59 months visiting MCRH. Anthropometric data were converted to Z-scores using World Health Organization standards for classifying stunting, underweight, and wasting. Clinical and biochemical tests were used to confirmed rickets diagnosis. Data on socio-demographic, dietary, and sunlight exposure was collected using a structured questionnaire. Associations were tested using chi-square and multivariable logistic regression at $p < 0.05$. Of the 212 children, 26 (12.3%) had nutritional rickets. Prevalence was highest among wasted (50.0%), stunted (41.2%), and underweight (40.0%) children, compared to 6.8% of those with normal nutrition. Logistic regression showed that stunting (AOR = 3.00, 95% CI: 1.25–7.20), underweight (AOR = 2.46, 95% CI: 1.10–5.50), and wasting (AOR = 2.72, 95% CI: 1.05–6.99) were independently associated with rickets. Additional predictors included younger age (6–24 months), low maternal education (AOR = 3.32, 95% CI: 1.68–6.56), inadequate calcium intake (AOR = 2.40, 95% CI: 1.78–5.28), inadequate vitamin D intake (AOR = 3.00, 95% CI: 1.45–6.33), low dietary diversity (AOR = 2.23, 95% CI: 1.12–4.44), and limited sunlight exposure (<20 minutes/day) (AOR = 2.59, 95% CI: 1.31–5.11). Nutritional rickets in Murang'a hospital is multifactorial, associated with undernutrition, socio-demographic vulnerabilities, poor dietary intake, and inadequate sunlight exposure. Integrated prevention strategies, including food fortification, vitamin D supplementation, maternal education, and community campaigns on safe sun exposure, are essential to reduce rickets burden among children 6-59 months.

Keywords: Nutritional rickets, stunting, underweight, wasting, malnutrition, children, Kenya

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INTRODUCTION

Nutritional rickets is a re-emerging childhood disease that poses significant risks globally, particularly in low- and middle-income countries. This condition results from deficiencies in essential micronutrients, most prominently vitamin D, calcium, or phosphate, each of which is crucial for proper bone development (Creo et al., 2017). Despite being largely preventable, nutritional rickets continues to impact millions of children aged 6–59 months around the world, especially in areas with limited resources (Munns et al., 2016). In some low-income regions, prevalence estimates can soar to 10–20%, primarily due to inadequate dietary intake, poor nutritional practices, and minimal exposure to fortified foods (Creo et al., 2017; Sempos et al., 2021).

There are two primary types of nutritional rickets identified. Vitamin D–deficiency rickets occurs due to insufficient sunlight exposure or inadequate dietary consumption of vitamin D. In contrast, calcium-deficiency rickets, which is increasingly observed in Africa and South Asia, develops when chronically low dietary calcium intake hampers proper bone mineralization, even when vitamin D levels are adequate (Abebe et al., 2025). It is essential to differentiate between these types to create effective intervention strategies, as their prevention approaches vary. Malnutrition continues to be a significant contributor to the development of rickets. It presents itself through stunting, wasting, underweight, and deficiencies in micronutrients, each of which indicates underlying biological, dietary, and socioeconomic vulnerabilities (Charoenngam et al., 2022). Stunting, which serves as a marker of chronic undernutrition, arises from extended periods of nutrient deprivation and frequent infections (Pettifor et al., 2018), whereas wasting is indicative of acute food shortages (Bhan et al., 2016). These conditions not only impede growth but also heighten children's vulnerability to rickets due to insufficient substrates necessary for bone mineralization.

In sub-Saharan Africa, rickets caused by calcium deficiency is more prevalent than that caused by vitamin D deficiency, primarily because diets are predominantly plant-based, low in dairy products, and seldom fortified (Abebe et al., 2025). Research conducted in Ethiopia, Uganda, and Nigeria has consistently shown that low calcium intake is a primary factor contributing to childhood rickets (Piloya et al., 2018; Sempos et al., 2021). Likewise, investigations from India and Uganda indicate that children who are biologically and environmentally disadvantaged, especially those suffering from malnutrition, are at a heightened risk (Piloya et al., 2018). In Kenya, the persistent dual issues of undernutrition and micronutrient deficiencies are particularly evident among young children. While comprehensive national prevalence data on rickets is limited, studies conducted at hospitals and county levels reveal concerning trends. For instance, at Mbagathi Hospital in Nairobi, 3.4% of children aged 6 to 59 months were diagnosed with nutritional rickets, with acute malnutrition recognized as a significant contributing factor (Wangeci, 2022). Research conducted in informal settlements has further pinpointed inadequate complementary feeding, low vitamin D levels, and insufficient sun exposure as additional factors (Jones et al., 2018). Investigations in Embu, Kiambu, and Nairobi counties suggest that rickets predominantly affects children who have low dietary diversity and restricted access to nutrient-rich foods (Micheni, 2020; Muchuka, 2018; Theuri et al., 2017).

In Murang'a County, anecdotal evidence and hospital records from Murang'a County Referral Hospital (MCRH) indicate an increasing incidence of rickets cases. Nevertheless, there are no published studies that have systematically investigated the connection between nutritional status and rickets in children aged 6–59 months within this context. Given that this age group signifies a crucial phase of rapid growth and increased nutrient needs, it is imperative to explore this relationship locally. Consequently, this study aims to assess the nutritional status of children aged 6–59 months who are attending MCRH, examine its correlation with nutritional rickets and evaluate specified risk factors. By filling this knowledge gap, the study will aid in the formulation of context-specific preventive measures, enhance early detection, and bolster evidence-based policymaking at both the county and national levels in Kenya, as well as in similar African contexts.

METHODS

Study Design and Setting

This analytical cross-sectional study assessed the nutritional status of children aged 6–59 months attending Murang'a County Referral Hospital (MCRH) and examined associated risk factors for nutritional rickets. Murang'a County Referral Hospital, a 250-bed facility situated in central Kenya, serves a predominantly rural population across an area of 2,558.8 km². MCRH was specifically selected due to the rising incidence of pediatric rickets cases and its role as the county's referral center. While hospital-based sampling may introduce selection bias, MCRH gathers cases from various sub-counties, making it an appropriate sentinel site for exploring these associations.

Study Population and Eligibility Criteria

The study targeted children aged 6 to 59 months who were receiving care at Murang'a County Referral Hospital, along with their mothers or primary caregivers. This particular age range was selected due to the increased vulnerability of children in this developmental stage to nutritional rickets, as they have a heightened need for calcium and vitamin D during periods of rapid bone growth. Children were eligible for inclusion in the study if they were aged between 6 and 59 months and had received consent from a parent or guardian to participate. Children were excluded from the study if their caregivers met the inclusion criteria but opted not to provide consent for participation.

Sample Size Determination

The sample size was determined using Cochran's formula (Cochran, 1977), assuming a rickets prevalence of 14.9%. This prevalence estimate (14.9%) was obtained from aggregated records of the MCRH Nutrition Clinic and Occupational Therapy for the years 2021–2022. Utilizing a 95% confidence interval (Z = 1.96) and a 5% margin of error (D = 0.05), the minimum required sample size was calculated to be 193. To accommodate a potential 10% non-response rate, the final sample size was adjusted to 212 children, ensuring sufficient power to identify associations within the study population.

Sampling Procedure

Systematic random sampling was implemented at the Maternal and Child Health (MCH) clinic. With an average daily attendance of approximately 100 children, every second child on the registration list was chosen until the daily target of around 42 participants was achieved. Data collection occurred over one randomly selected week.

Study Variables

The independent variable was the nutritional status (measured through anthropometric assessments), confounder variables were socio-demographic, dietary practices and sunlight exposure practices, while the dependent variable was the presence of rickets, which served as the outcome for children aged 6 to 59 months.

Data Collection

Weight was measured to the nearest 0.1 kg using a calibrated digital scale, and height/length to the nearest 0.1 cm using a stadiometer/infantometer. Two trained nutritionists performed measurements; 10% were repeated to assess inter- and intra-observer reliability. To minimize measurement errors, inter- and intra-observer reliability checks were conducted through repeated measurements on a subset of participants, with discrepancies resolved by consensus. WHO Anthro software was used to generate Z-scores. Children were classified as stunted (HAZ < –2 SD), underweight (WAZ < –2 SD), or wasted (WHZ < –2 SD) per WHO standards. Nutritional rickets was identified through a combination of clinical assessment and biochemical evaluation, in accordance with international guidelines (Munns et al., 2016; WHO, 2022). Clinically, children were assessed for distinctive skeletal characteristics, which included bowed legs or knock knees, widened wrists and ankles, rachitic rosary at the costochondral junctions, frontal bossing, delayed closure of the fontanelle, and spinal deformities such as kyphosis or scoliosis. Biochemical confirmation was achieved through serum analysis conducted at the MCRH diagnostic laboratory, adhering to standardized protocols. The markers evaluated included serum calcium, where hypocalcemia was defined as levels falling below 8.5 mg/dL; serum phosphate, with hypophosphatemia defined as levels under 3.4 mg/dL in children younger than five years; and alkaline phosphatase (ALP), where elevated values exceeding 147 IU/L were deemed abnormal according to age-specific reference ranges. Vitamin D status was assessed using 25-hydroxyvitamin D [25(OH)D], with deficiency defined as concentrations below 20 ng/mL and sufficiency as levels above 50 ng/mL. Additionally, parathyroid hormone (PTH) levels were measured, with values surpassing 65 pg/mL indicating secondary hyperparathyroidism. Children exhibiting abnormal biochemical or clinical findings that suggested non-nutritional causes, such as renal disease, genetic or metabolic bone disorders, and chronic liver disease, were excluded from the study. A definitive diagnosis of nutritional rickets was established when at least one classical clinical sign was present alongside at least one corresponding biochemical abnormality, such as hypocalcemia, hypophosphatemia, elevated ALP, vitamin D deficiency, or increased PTH.

Data Analysis

The data were analyzed utilizing SPSS version 25. Descriptive statistics provided a summary of the demographic, dietary, and exposure characteristics of the study population. The initial assessment of associations between nutritional status and rickets was conducted using Chi-square tests. Subsequently, binary logistic regression was implemented in two phases: Univariate models calculated crude odds ratios (ORs) for each predictor. Multivariable logistic regression models were adjusted for potential confounders, which included: Socio-demographic factors (child's age group, maternal education, household income), Dietary factors (exclusive breastfeeding, adequacy of calcium and vitamin D intake, dietary diversity, supplement/fortified food use), and Sunlight exposure variables (duration, timing, protective practices, clothing). Adjusted odds ratios (AORs) along with 95% confidence intervals (CI) were reported. The threshold for statistical significance was established at $p < 0.05$.

Ethical Considerations

Ethical approval for the study was granted by the Kabarak University Research Ethics Committee (KUREC-010524), and a research license was issued by the National Commission for Science, Technology, and Innovation (NACOSTI/P/24/36453). Furthermore, additional permissions were obtained from the Murang'a County administration, the Ministry of Health, the Ministry of Education, and the superintendent of the Murang'a County Referral Hospital. Written informed consent was acquired from the parents/guardians of all participants after they were provided with comprehensive information regarding the study's objectives, procedures, potential risks, benefits, and confidentiality measures. Participation was completely voluntary, and participants were made aware of their right to withdraw at any point without any impact on their access to healthcare services. Confidentiality was preserved by limiting data usage strictly to the research objectives. Confidentiality was rigorously maintained throughout the research process. Each participant was assigned a unique identification code, and no personal identifiers (such as names or contact details) were used during data entry or analysis. Physical records were securely stored in locked cabinets within protected offices, while electronic data was safeguarded on password-protected computer, with access limited to the core researcher. Files were encrypted, and regular backups were performed on secure servers with restricted access. Data were anonymized prior to analysis, ensuring that individual participants could not be identified in any reports or publications. In compliance with institutional and national regulations, research data will be retained for three years following the conclusion of the study, after which both physical and electronic records will be permanently destroyed.

RESULTS

Socio-demographic Characteristics of Children 6-59 months

The age distribution reveals that the majority of the children, 38.1%, were 6-12 months old, followed by 32.4% who are 13-24 months old, 12.7% who are 25-36 months old, and 16.8% who are 37-59 months old. The distribution of gender is relatively balanced, with a slight majority of 53.3% being male and 46.7% being female (Table 1).

Table 1*:*

Socio-demographic Characteristics of Children 6-59 months Attending MCRH

Characteristics	Category	Frequency (N = 212)	Percentage (%)
Age of child	6-12 months	81	38.1
	13-24 months	69	32.4
	25-36 months	27	12.7
	37-59 months	35	16.8
Gender of child	Male	113	53.3
	Female	99	46.7

Socio-demographic Characteristics of Caregivers of Children 6-59 months

In terms of maternal education, the data indicates that most mothers have at least some levels of education, with the majority, 42.6%, having completed secondary education. A majority (21.3%), attained primary education, while 19.3% have college or university education. Only a small percentage of mothers, 2.9%, have no formal education, and 13.9% did not complete secondary education. Regarding parental occupation, the largest group, 36.5%, consists of casual laborers, followed by 30.3% who are self-employed. Smaller percentages are either housewives (4.5%) or involved in business (4.1%), with 24.6% falling into other occupations. The income distribution reveals that nearly half of the households (45.0%) earn between 0-10,000 Kenya Shillings (Ksh) per month, indicating a larger proportion of low-income households. Additionally, 38.7% earn between 10,001-20,000 Ksh, with a smaller percentage earning between 20,001-30,000 Ksh (10.8%). Only a minimal number of households, 5.5%, earn above 30,000 Ksh per month, with just 5.5% earning more than 30,000 Ksh monthly (Table 2).

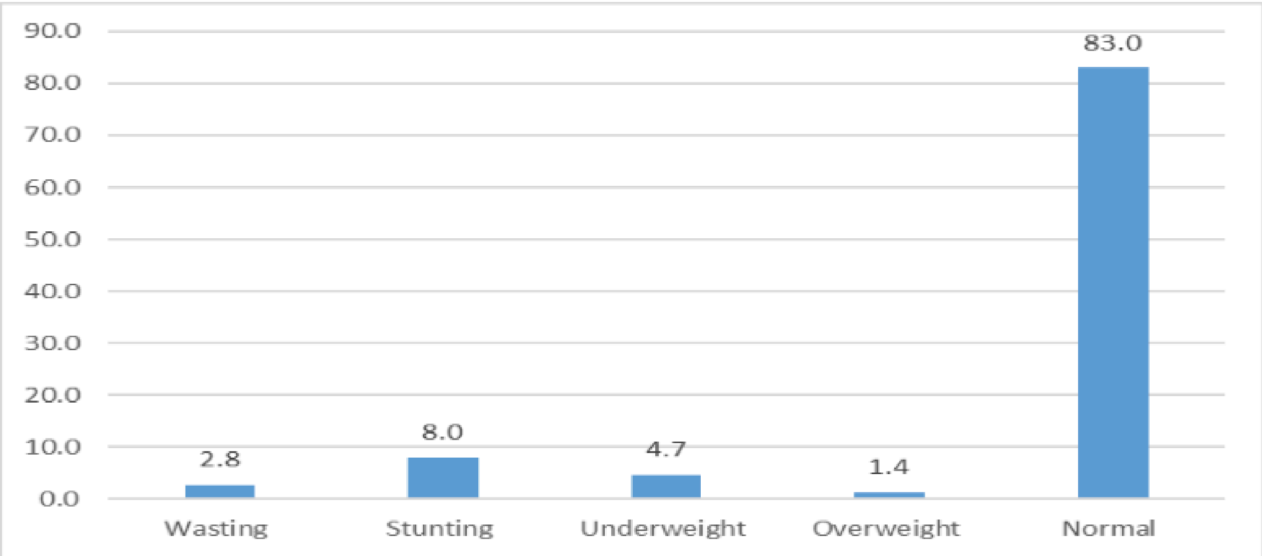
Table 2:
Socio-demographic Characteristics of Caregivers of Children Attending MCRH

Characteristics	Category	Frequency (N = 212)	Percentage (%)
Maternal Education	No formal education	6	2.9
	Primary education	45	21.3
	Incomplete secondary	30	13.9
	Complete Secondary	90	42.6
	College/University	41	19.3
Parental Occupation	Casual labour	77	36.5
	Self-employed	64	30.3
	Housewife	10	4.5
	Business	9	4.1
	Other (Civil service)	52	24.6
Income Range	0-10,000 Ksh	95	45.0
	10,001-20,000 Ksh	82	38.7
	20,001-30,000 Ksh	23	10.8
	>30,00	11	5.65

Nutritional Status of children 6-59 months Attending MCRH

Figure 1 depicts the distribution of nutritional status in children aged 6 to 59 months. A significant majority of these children (83.0%) were found to have a normal nutritional status. Among those experiencing malnutrition, 8.0% were identified as stunted, 4.7% as underweight, and 2.8% as wasted. The category of overweight was the least prevalent, representing only 1.4% of the study population.

Figure 1:
Nutritional Status of Children 6-59 months Attending MCRH

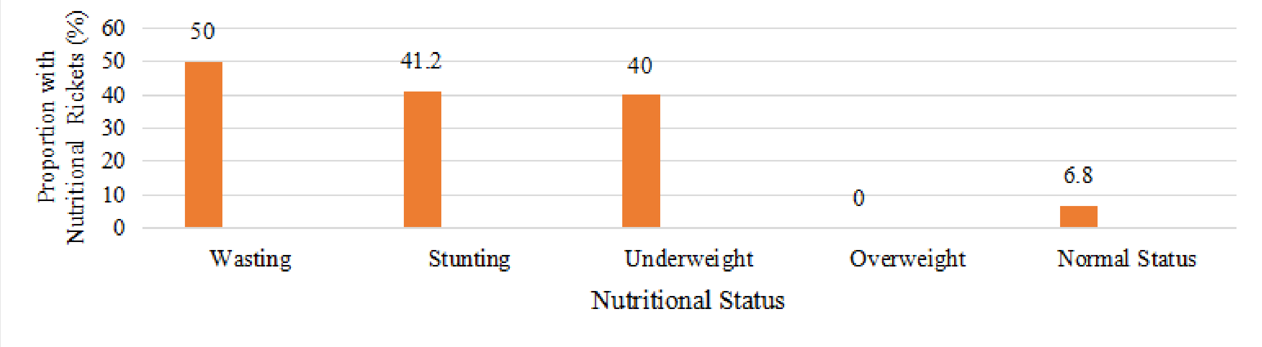


Proportion of children with Nutritional Rickets per category of Nutritional Status

Figure 2 illustrates the prevalence of nutritional rickets among various nutritional status categories. Among the 6 children classified as wasted, 3 (50.0%) were found to have rickets. In a similar vein, of the 17 children identified as stunted, 7 (41.2%) were diagnosed with rickets, while 4 out of 10 children who were underweight (40.0%) were also affected. Conversely, 12 of the 176 children (6.8%) with a normal nutritional status were diagnosed with rickets, and none of the 3 overweight children (0.0%) exhibited the condition. In total, from the 212 children evaluated, 26 (12.3%) were confirmed to have nutritional rickets.

Figure 2:

Proportion of Children with Nutritional Rickets by Nutritional Status



Relationship Between Nutritional Status and Rickets

Logistic regression analysis was conducted to assess the association between nutritional status and the occurrence of nutritional rickets. The findings are detailed in (Table 3). Children experiencing stunting were found to be three times more likely to develop nutritional rickets (OR = 3.00, 95% CI: 1.25–7.20, p = 0.02). Those classified as underweight exhibited 2.46 times greater odds (OR = 2.46, 95% CI: 1.10–5.50, p = 0.03), while wasting was linked to 2.72 times higher odds (OR = 2.72, 95% CI: 1.05–6.99, p = 0.04). Children with a normal nutritional status demonstrated a reduced likelihood of developing rickets, whereas no significant correlation was found between overweight status and the incidence of rickets.

Table 3:

Association Between Nutritional Status of Children 6-59 Months Attending MCRH and Ricket

Nutritional status	OR (95% CI)	p-value
Stunted	3.00 (1.25-7.20)	0.02
Underweight	2.46 (1.10-5.50)	0.03
Wasted	2.72 (1.05-6.99)	0.04
Normal status	Reference	-
Overweight	0.89 (0.34-2.33)	0.76

Association between Socio-Demographic Characteristics of Children 6-59 months and rickets status

As shown in Table 4, socio-demographic characteristics significantly influenced rickets occurrence. Children aged 6–24 months were about twice as likely to develop rickets compared to those 25–59 months (AOR = 2.01, 95% CI: 1.02–4.00, p = 0.04). Low household income (<10,000 KES/month) was marginally associated with rickets (AOR = 1.24, 95% CI: 0.93–1.97, p = 0.04). Maternal education showed the strongest effect: children whose mothers had no formal education had over three times the odds of rickets compared to those with primary education or above (AOR = 3.32, 95% CI: 1.68–6.56, p = 0.01).

Table 4:

Association Between Socio-Demographic Characteristics of Children 6-59 months Attending MCRH and Rickets Status

Socio-demographic Factors	Category	AOR (95%CI)	p-value
Age of the Child	6-12 /13-24 months	2.01(1.02-4.00)	0.04*
	25-36/37-59 months		
Household income	<10,000 (Low)	1.24 (0.93-1.97)	0.04*
	>10,00 (Moderate/high)		
Maternal Education Level	No formal education	3.32 (1.68-6.56)	0.01*
	Primary & above		

Association Between Dietary Practices of Children 6-59 Months and Ricket status

Table 5 shows Exclusive breastfeeding was not significantly associated with rickets (p = 0.20). However, children with inadequate calcium intake were more than twice as likely to have rickets (AOR = 2.40, 95% CI: 1.78–5.28, p = 0.03). Similarly, inadequate vitamin D intake tripled the risk (AOR = 3.00, 95% CI: 1.45–6.33, p = 0.02). Low dietary diversity also increased the odds (AOR = 2.23, 95% CI: 1.12–4.44, p = 0.035). Consumption of fortified foods and supplements did not significantly influence rickets status (p = 0.25).

Table 5:

Association Between Dietary Practices of Children 6-59 Months Attending MCRH and Ricket status

Dietary Practices	Category	B	P-value	OR	95% C.I. for OR
Breast feeding	Practiced EBF	0.50	0.20	1.65	0.85 - 3.19
	No EBF				
Adequacy of dietary Calcium intake	Yes	1.14	0.03	2.4	1.78 - 5.28
	No				
Adequacy of dietary Vitamin D Intake	Yes	1.10	0.02	3.00	1.45 - 6.33
	No				
	Adequate				
Consumption of Supplements or Fortified Foods	Yes	0.40	0.25	1.49	0.76 - 2.94
	No				
Dietary diversity score	Low	0.80	0.035	2.23	1.12 - 4.44
	Moderate /High				

Association Between Sunlight Exposure of Children 6-59 Months and Ricket status

Sunlight exposure variables also showed significant associations with rickets (Table 6). Children exposed to sunlight for less than 20 minutes/day were more than twice as likely to develop rickets (AOR = 2.59, 95% CI: 1.31–5.11, p = 0.01). Non-recommended times of exposure increased the risk (AOR = 1.65, 95% CI: 0.85–3.19, p = 0.02). Protective measures such as clothing coverage during basking doubled the odds of rickets (AOR = 2.01, 95% CI: 0.98–4.12, p = 0.037), and full covering produced a similar effect (AOR = 2.23, 95% CI: 0.98–5.08, p = 0.043).

Table 6:

Association Between Sunlight Exposure of Children 6-59 Months Attending MCRH and Ricket status

Sunlight Exposure	Category	B	P-value	OR	95% C.I. for OR
Duration of exposure to sunlight	<20 mins/day	0.95	0.01	2.59	1.31 - 5.11
	>20 mins/day				
Time of exposure to sunlight	Recommended time	0.50	0.02	1.65	0.85 - 3.19
	Other times				
Practices during basking in the sun	Protective Measures	0.70	0.037	2.01	0.98 - 4.12
	Direct Exposure				
Level of covering while in sunlight	No Covering / Partial Covering	0.80	0.043	2.23	0.98 - 5.08
	Full Covering				

DISCUSSION

This study validates that inadequate nutritional status particularly stunting, underweight, and wasting, is significantly linked to a heightened risk of nutritional rickets. The assessment of nutritional status among children aged 6-59 months at MCRH highlights the prevalence of various forms of malnutrition, including wasting (2.8%), underweight (4.7%), and stunting (8.0%). Comparatively, the reported county-level statistics for these indicators stand at 1.7%, 5.9% and10.0%, respectively (Demographic, 2023). While the figures for stunting and underweight in Murang'a County are slightly different from the hospital findings, the overall trends are comparable, suggesting that malnutrition remains a significant public health concern. Anthropometric measurements, such as weight-for-age, height-for-age, and weight-for-height, serve as critical indicators in assessing malnutrition. Studies by Lala et al. (2022) and WHO (2019) highlight that malnutrition contributes to increased vulnerability to nutritional rickets, particularly in resource-limited settings where food insecurity and micronutrient deficiencies are prevalent. This relationship underscores the need for targeted nutritional interventions to address the risk factors associated with rickets.

Stunting and Nutritional Rickets

Stunting, which is a result of chronic malnutrition, has been identified as a significant predictor of rickets in this research. Children experiencing stunting showed nearly three times the likelihood of developing nutritional rickets. This observation aligns with the findings of (Gentile & Chiarelli, 2021), who reported a high co-occurrence of rickets and stunting within sub-Saharan African populations. Chronic undernutrition disrupts endochondral ossification and the development of bone matrix, thereby compromising skeletal integrity and heightening the risk of deformities (Muchuka, 2018). Additionally, (Hu et al., 2016) highlighted that prolonged socioeconomic disadvantage plays a role in stunting, especially in low-income and rural areas, underscoring the significance of both biological and structural factors.

Underweight and Nutritional Rickets

A low weight-for-age measurement, which indicates both chronic and acute malnutrition, was found to have a significant correlation with rickets in this group. Children classified as underweight frequently lack vital nutrients such as calcium, vitamin D, and phosphorus, all of which are essential for adequate bone mineralization. This conclusion is supported by the research of (Jones et al., 2018), who highlighted that insufficient dietary intake during early childhood raises the risk of metabolic bone disorders. The biochemical relationship between inadequate nutrient intake and skeletal development emphasizes the necessity for comprehensive nutritional programs.

Wasting and Nutritional Rickets

Wasting, which serves as a marker for acute undernutrition, was also significantly associated with nutritional rickets. This correlation is consistent with the guidelines set forth by the World Health Organization (Organization & Fund, 2020), which indicate that acute malnutrition worsens micronutrient deficiencies and accelerates skeletal deterioration. Additionally, Jones et al. (2018) confirmed that children experiencing wasting are more prone to exhibit biochemical indicators of bone demineralization. In areas with high prevalence, wasting is indicative of both food insecurity and inadequate health literacy (Bhan et al., 2016), implying that policy interventions should encompass both health and social protection strategies.

Normal Status and Nutritional Rickets

In the study, it was found that children who had a normal nutritional status were significantly less likely to show signs of nutritional rickets compared to those who were stunted, underweight, or wasted. This suggests that achieving healthy growth levels, in line with WHO standards, acts as a protective factor. This is likely due to an adequate intake of calcium, vitamin D, and protein, all of which are crucial for bone mineralization during early childhood. Similar protective links have been observed in research conducted in Africa. For example, recent studies from the UK and France indicate that nutritional rickets mainly affects undernourished children, while those who are normally nourished are rarely impacted (Flot et al., 2020; Julies et al., 2020). Additionally, a 2023 study from Saudi Arabia confirmed that malnutrition remains a key risk factor for rickets, highlighting the serious effects of chronic undernutrition on its development (Darraj et al., 2023).

However, findings from other regions paint a more complex picture. In Saudi Arabia, for instance, children who are of normal weight or even overweight have been diagnosed with rickets, primarily due to severe vitamin D deficiency linked to limited sun exposure and cultural practices (Darraj et al., 2023). Similarly, in South Asia, rickets can occur in normally nourished children when low dietary calcium is combined with inadequate vitamin D intake (Creo et al., 2017). These comparisons emphasize that while a normal nutritional status may provide some protection in the Kenyan context, rickets is a multifaceted condition. In certain environments, vitamin D deficiency caused by environmental and cultural factors can undermine the benefits of normal growth, leading to cases of rickets even among children who seem well-nourished.

Overweight and Nutritional Rickets

The study found no cases of nutritional rickets among overweight children, suggesting that being overweight might not increase the risk of rickets in this scenario. This is a stark contrast to the higher risk observed in children who are wasted, stunted, or underweight. It seems that adequate or even excessive energy intake in overweight kids could help protect them from rickets by ensuring they get enough macro- and micronutrients, although the overall quality of their diet is still a key factor. That said, evidence from other areas paints a more complex picture. For example, in Saudi Arabia, some overweight children have been diagnosed with rickets, often due to severe vitamin D deficiency linked to limited sun exposure and certain cultural practices (Darraj et al., 2023). Global reviews also show that rickets can occur in overweight or obese children when there's a lack of vitamin D or dietary calcium (Creo et al., 2017). A recent study in Europe reported that children across various BMI categories, including those who are overweight, exhibited symptoms of rickets, underscoring that micronutrient deficiencies play a more significant role than weight status itself (Flot et al., 2020). These findings emphasize that while this study did not associate overweight with rickets, this condition cannot be dismissed in overweight children in other contexts. Excess body fat has been shown to diminish the bioavailability of vitamin D due to its sequestration in adipose tissue, which may elevate the risk of rickets even when dietary intake is adequate.

Socio-Demographic Factors

The study found that children aged 6–24 months were at higher odds of rickets. This period coincides with rapid growth, weaning from breastfeeding, and reliance on complementary foods that may be low in calcium and vitamin D. Younger children are also more vulnerable to infections that exacerbate nutrient depletion. Maternal education emerged as a strong determinant, with children of mothers lacking formal education being more than three times as likely to develop rickets. This aligns with evidence that maternal literacy influences feeding practices, healthcare utilization, and adherence to supplementation programs (Mogire et al., 2020). Low household income also showed a modest but significant association, reflecting the socioeconomic gradient in access to diverse diets and fortified foods.

Dietary Practices

In alignment with earlier studies conducted in Africa, insufficient intake of calcium and vitamin D has been shown to significantly elevate the risk of rickets (Chibuzor et al., 2020). Although vitamin D deficiency is the primary cause of rickets in northern regions, calcium-deficiency rickets is more common in sub-Saharan Africa, where the predominant diets are based on cereals and are low in bioavailable calcium (Jones et al., 2018). This current study corroborates this observation, revealing that inadequate calcium intake increases the risk of rickets twofold. Additionally, insufficient vitamin D intake was found to triple the risk, underscoring the synergistic role of both nutrients in the process of skeletal mineralization. Furthermore, children exhibiting low dietary diversity scores were found to be twice as likely to develop rickets, thereby emphasizing the critical need for balanced complementary feeding and access to fortified food options.

Sunlight Exposure

The significance of sunlight exposure in the prevention of rickets was clear. Children who were exposed to sunlight for less than 20 minutes per day or during non-recommended times exhibited a greater likelihood of developing rickets. Protective measures such as wearing heavy clothing and seeking shade while basking also heightened the risk, likely due to their restriction on the cutaneous production of vitamin D. This observation is consistent with research conducted in Uganda and Ethiopia, where inadequate exposure practices led to vitamin D deficiency, even in regions abundant in sunlight (Creo et al., 2017). These results underscore the paradox that mere availability of sunlight is not enough if cultural practices and childcare norms obstruct adequate exposure.

In summary, the age range of 6-59 months represents a critical developmental period. During this phase, children transition from exclusive breastfeeding to complementary feeding and eventually begin their schooling. Nutritional rickets at this stage can impede motor skills, increase susceptibility to infections, and limit physical activity. The long-term effects may include skeletal deformities, reduced height potential, poor academic performance, and even cognitive delays due to compromised overall health. Therefore, it is essential to implement preventive measures targeting both malnourished and apparently healthy children.

Strengths and limitations

This research provides new evidence as it is the first to investigate the relationship between nutritional status and rickets in Murang'a County. The integration of clinical and biochemical criteria enhanced the accuracy of diagnoses. By adjusting for socio-demographic factors, dietary habits, and sunlight exposure, the validity of the results was improved. Nevertheless, certain limitations must be recognized. Firstly, the hospital-based design may restrict the generalizability to community populations, as children visiting MCRH might represent more severe cases. Secondly, dietary intake was evaluated through caregiver recall, which could be subject to bias. Thirdly, the cross-sectional design prevents causal inference; the identified associations indicate association but do not establish temporality.

Conclusions

This research determined that nutritional rickets impacts 12.3% of children aged 6–59 months who are receiving care at Murang'a County Referral Hospital, with the highest prevalence observed among those who are wasted, stunted, and underweight. The condition is linked to several overlapping determinants: younger age of the child (6–24 months), low levels of maternal education, and low household income as socio-demographic factors; insufficient dietary intake of calcium and vitamin D, along with low dietary diversity as nutritional factors; and limited daily sunlight exposure, inappropriate exposure durations, and covering practices as environmental factors. Collectively, these results indicate that nutritional rickets in Murang'a County cannot be attributed to a singular deficiency but rather emerges from a combination of undernutrition, socio-economic challenges, and inadequate childcare practices. Although the cross-sectional and hospital-based nature of the study restricts causal inference and generalizability, the consistent associations observed across dietary, socio-demographic, and sunlight variables highlight the pressing need for comprehensive preventive measures.

Recommendations

This study recommends:

- Calcium fortification of staple foods such as maize flour.
- Vitamin D supplementation for high-risk children (6–59 months) through routine maternal-child health programs.
- Routine child growth monitoring in clinics, including screening for rickets during under-five visits.
- Community health education campaigns targeting safe sunlight exposure practices and maternal nutrition knowledge.

Recommendations for future research

Future investigations should involve community-based cohorts with larger sample sizes to ascertain the prevalence at the population level. Longitudinal studies are essential to elucidate the causal pathways linking nutritional status and rickets.

Conflict of Interest

The authors declare no conflict of interest.

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