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REVIEW ARTICLE

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Sunlight Exposure and the Risk of Nutritional Rickets in Children: A Systematic Review

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ABSTRACT

Insufficient sunlight exposure significantly contributes to the development of nutritional rickets, highlighting the critical importance of sunlight in maintaining optimal bone health and preventing this debilitating condition. Nutritional rickets, a preventable skeletal disorder, has significant implications for child health and development, particularly where there is limited sunlight exposure. Adequate sunlight exposure, especially in the form of ultraviolet B (UVB) radiation, is essential for synthesizing and maintaining optimal vitamin D levels, which play a key role in preventing nutritional rickets. This systematic review aims to comprehensively analyze the relationship between inadequate sunlight exposure and the development of nutritional rickets among children. By identifying the precise levels of sunlight exposure needed for healthy development and the factors contributing to inadequate exposure, the review could inform effective preventive strategies. Literature was searched through Google scholar, PubMed (Medline), Cochrane and Elsever using the following key terms; Nutritional rickets, Sunlight exposure and vitamin D deficiency. Only peer-reviewed articles and research theses were included. Additionally, only literature reporting on nutritional rickets as a result of inadequate sunlight exposure practices were included. A total of 9 papers were included in the review. Findings such as Limited Sunlight Exposure with factors such as closed housing environments, urbanization, and cultural practices contributing to this phenomenon, Misconceptions and Fear regarding potential harms associated with sunlight exposure, such as skin cancer, sterility, and blindness, Disparities in Knowledge and Practices about sunlight exposure, Environmental Influences such as housing conditions and access to outdoor spaces significantly influence sunlight exposure opportunities for children. Interventions aimed at enhancing sunlight accessibility and creating sun-safe environments are crucial for optimizing exposure and preventing rickets. Comprehensive strategies are necessary to address the complexities surrounding sunlight exposure practices, including education, cultural sensitivity, policy reforms, and environmental modifications. Integrating these interventions is essential for promoting optimal sunlight exposure and improving child health outcomes.

Keywords: *Nutritional Rickets, Sunlight exposure, Vitamin D deficiency*

INTRODUCTION

Nutritional rickets remain prevalent in developing countries of the world and rank among the 5 most common diseases in children (Mogire et al., 2020). According to Chanchlani (2020), nutritional rickets is the most prevalent non-communicable disease affecting children worldwide. Rickets is a condition that affects the bones and is defined by abnormal levels of serum phosphate (Pi) and calcium (Ca). A calcium, phosphate, or vitamin D deficiency causes the condition, leading to skeletal abnormalities and decreased bone mineralization (Carboo et al., 2023). Among children, nutritional rickets can lead to skeletal deformities, growth retardation, and impaired physical development (Pettifor, 2004). In order to promote calcium and phosphorus absorption, which strengthens bones and teeth, vitamin D is crucial (Carboo et al., 2023).

In Europe and the USA, rickets was believed to affect between 75 and 98 percent of children in the 1920s and 1930s (World Health Organisation, 2019). The highest prevalence of nutritional rickets is notably concentrated in children from the Middle East, Africa, and South Asia (Thacher et al., 2016). As vitamin D food fortification programs were implemented, nutritional rickets almost disappeared in affluent nations. After implementing clean-air laws and nutritional supplements, the incidence of rickets in public decreased in many wealthy industrialized nations. However, certain reports have shown resurgence in various nations during the previous 10 to 20 years (Ross et al., 2020, WHO, 2019). This is most likely caused by various factors, including fewer hours spent outside generally and reduced sun exposure from sunscreen products. Also, it is believed that increasing population migration, particularly rural-to-urban migration (WHO, 2019).

The regional and national landscape presents significant disparities, as evidenced by varying prevalence rates of rickets in diverse contexts. While few African nations have reported epidemic trends of rickets (WHO, 2019), it remains a prevalent issue in sub-Saharan African countries. For instance, in Ethiopia, it affects a substantial portion of the pediatric population, with a reported prevalence rate of 7.8%. Similarly, in Kenya, available data highlight a notable prevalence of rickets, with 57% affecting males and 43% affecting females (Edwards et al., 2014).

Notably, at Murang'a hospital, a study conducted in 2014 found the prevalence of rickets to be 2% (Ngugi et al., 2018). Hospital records from three different counties further underscore the varying prevalence rates: Nairobi reported 4.02%, Central reported 1%, and the Western area only reported one incidence of rickets (Karuri et al., 2017). According to Roth et al. (2018), any prevalence of rickets in children exceeding 1% necessitates a comprehensive assessment of the incidence and burden of vitamin D deficiency through targeted public health strategies.

Nutritional rickets may be prevented by obtaining enough vitamin D, which can be acquired through food and sunlight. The main function of active vitamin D is to promote intestinal absorption of calcium and phosphate and, jointly with other hormones, to stimulate their renal reabsorption. Vitamin D also helps to maintain plasma calcium and phosphate at adequate levels to promote bone mineralization. At the same time, vitamin D can help restore serum calcium and phosphate levels when they are low, by stimulating bone resorption in conjunction with Parathyroid hormone (WHO, 2019). Contrary to its importance in maintaining optimal bone health and preventing nutritional rickets, vitamin D inadequacy in the body can arise due to insufficient sunlight exposure.

Recently, there has been considerable epidemiological interest in the exposure to ultraviolet radiation (UVR) due to its dual impact, encompassing both advantageous and harmful effects. Overexposure to UVR is linked to conditions such as skin cancer, sunburn, premature skin aging, cataracts, and compromised immune function. Adequate sunlight exposure, especially in the form of ultraviolet B (UVB) radiation, is essential for synthesizing and maintaining optimal vitamin D levels, which play a key role in preventing rickets (WHO, 2009). About 80–90% of the body's vitamin D originates internally (cholecalciferol or vitamin D3) and is produced through the skin's exposure to sunlight; whereas, a much smaller portion comes from the diet, either as cholecalciferol from animal products or ergocalciferol, or vitamin D2 from plants, fungi, or yeast synthesis. Both forms are inactive biologically and require a dual hydroxylation process (hepatic and renal) for activation. Exposure to type B ultraviolet radiation prompts the internal production of cholecalciferol from epidermal dehydrocholesterol (provitamin D3), converting it into precholecalciferol (previtamin D3), a compound that is unstable thermodynamically and quickly converts into cholecalciferol due to body temperature (Durá-Travé & Gallinas-Victoriano, 2023, Pettifor et al., 2018).

While vitamin D supplementation and dietary interventions have been recommended to prevent rickets, the significance of sunlight exposure as a primary source of vitamin D remains paramount (Wagner & Greer, 2008). Achieving such levels of vitamin D synthesis involves considering various factors. These factors include the duration of time spent outdoors, the level of skin pigmentation (Melanin) levels are greater in darker skin, which may significantly reduce the skin's ability to synthesize

vitamin D when exposed to sunshine (Antonucci et al., 2018). Other factors to consider are seasonal variations, cloud cover, air pollution levels, the amount of exposed skin, and the degree of protection against ultraviolet B (UVB) radiation, which includes clothing and sunscreen usage. Geographic location, cultural practices, and lifestyle behaviors may limit sunlight exposure in certain populations, exacerbating the risk of vitamin D deficiency and subsequent development of nutritional rickets (Thacher & Fischer, 2013, Kimlin & Schallhorn, 2014). For optimal vitamin D production, it is recommended to regularly expose unprotected skin (without sunscreen or clothing coverage) to available UVB radiation (Nimitphong & Holick, 2013).

Housing conditions, including access to sunlight and ventilation, can influence the indoor environment and affect exposure to natural light (Theuri et al., 2017). Living in poorly ventilated or dark rooms may reduce vitamin D synthesis and increase rickets risk (Gedamu & Tafere, 2019). Low-resource housing can limit natural light and ventilation, lowering sunlight exposure and raising the risk of rickets. Settings where residents have limited access to natural sunlight due to architectural features, and overcrowded living conditions, have been reported in Kenya, suggesting the potential influence on sunlight exposure and rickets risk (Wangari & Were, 2013). Thus, understanding the contribution of inadequate sunlight exposure to the prevalence of nutritional rickets among children is imperative for developing targeted preventive strategies and public health interventions.

METHODOLOGY

The review adhered to the PRISMA guideline (Vrabel, 2015) throughout its execution.

Eligibility Criteria

Various eligibility criteria were taken into account for the selection of systematic review articles. All included articles met the following criteria:

i. Publication date was post-2018;
ii. Topics encompassed sunlight exposure practices and nutritional rickets;
iii. Articles were published in the English language.
iv. Published in peer reviewed journals.

This study considered all observational studies, such as cross-sectional, case-control, and cohort studies, focusing on maternal practices related to sunlight exposure of their children.

Information Sources

Three medical databases were searched for articles that meet the set criteria. They include PubMed, Cochran and Elsever. The databases were accessed between 20th February 2024 and 20th April 2024.

Search Criteria

Relevant medical subject headings were used to search for articles in the selected databases using google scholar as search engine. This included the following sunlight exposure, nutritional rickets, Vitamin D deficiency.

Selection of Studies

The study selection process was guided by several considerations, including the following:

Conflict of Interest, Author Affiliation, Research Design, Publication Date, Journal Type, Language and Threshold Criteria

Upon retrieval, articles were imported into Zotero Desktop, reference manager software, to facilitate the removal of duplicate studies.

For the synthesis of results from the selected articles, the following data items were considered:

i. Study Title
ii. Research Design and Implementation
iii. Study Objectives
iv. Results
v. Discussion
vi. Search outcomes

Out of the initial pool of 40 articles identified through electronic search, 11 were eliminated because of duplication, leaving 29 unique articles for further assessment. Following a comprehensive evaluation such as research objectives, methodological rigor, validity and reliability, scope and depth of content, the potential for publication bias, and 19 of these articles were fully accessed and scrutinized for their suitability. After consideration of the above data items, 9 articles were found to meet the predetermined eligibility criteria and were consequently incorporated into the final systematic review.

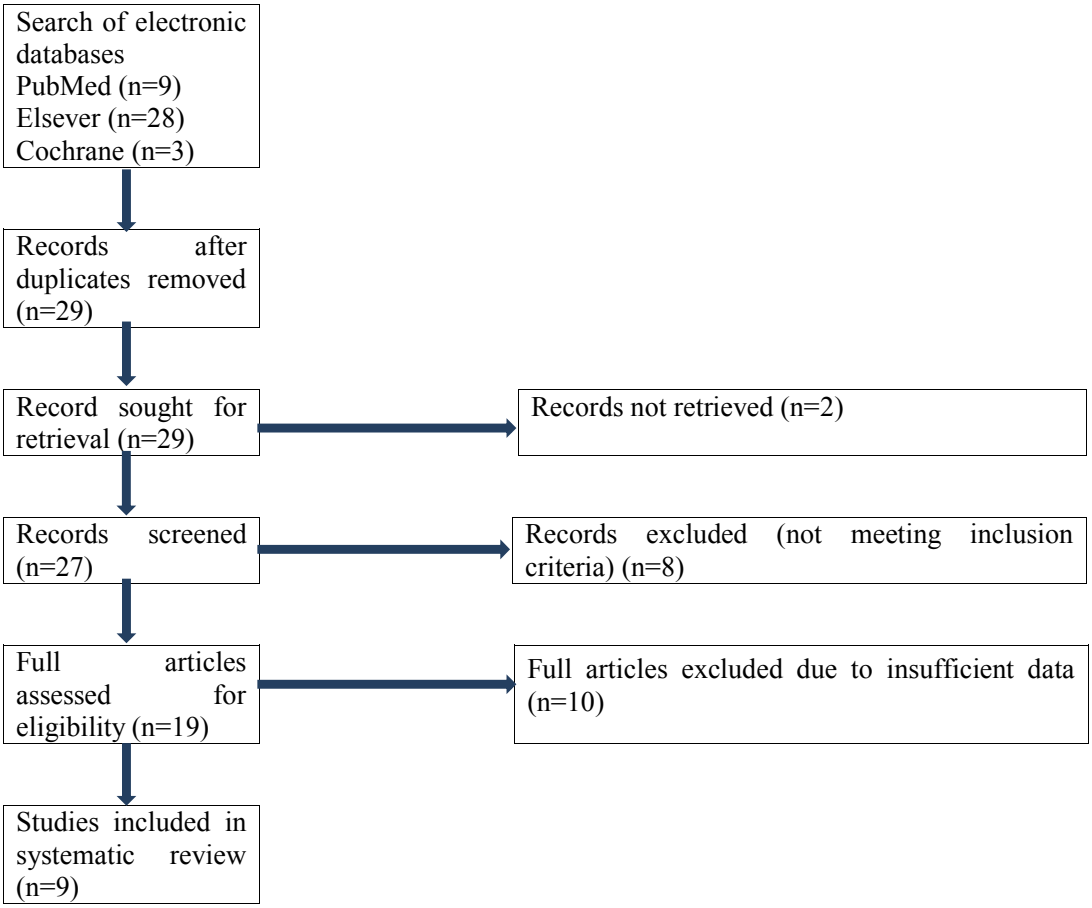

Fig.1. Article selection criteria

TABLE 1:
REVIEW RESULTS

SNO	AUTHOR	TITLE	METHODOLOGY	KEY RESULTS
1	(Teklehaimanot et al., 2021)	Assessment of Practice and Factors associated with Sunlight Exposure of Infants among Mothers in Debre Berhan Town, North Shewa Zone, Amhara Region, Ethiopia	• community-based cross-sectional study • simple random sampling and systematic sampling techniques used • sample size of 530 mother-infant pair who are below 1 year • structured and semi-structured questionnaire were used • Logistic regression analysis used	• 525 (99.1%) respondents intentionally expose their infants to direct sunlight • 450(85.7%) respondents start to expose their infants before they are 15 days old • 322(60.8%) mothers expose infants to sunlight daily with509 (96%) expose in the morning before 10.00am and 188 (35.5%) mothers expose their infants for a duration of 10-15minutes • 290 (54.7%) mothers expose infants with only putting diaper or naked • 306 (57.7&%) of respondents did not apply any lubricant/ body lotion during sunning of their infants

SNO	AUTHOR	TITLE	METHODOLOGY	KEY RESULTS
2	(Micheni, 2020)	Rickets In Children Aged 6-59 Months At Mbagathi Hospital Nairobi County, Kenya	• Hospital based retrospective case-control study • Sample of 157 mother-child pair 6-59 months • Structured and semi structured questionnaires • Multistage sampling technique was used to select the sample • Chi-Square test analysis used	• Those who sunbathed their children were 47.2% against those who did not 52.8% with a P-value 0.000 • Positioning during sunlight exposure » Direct sunlight 80% P-Value 0.000 » Under shade 20% • Children who attended daycare where there is house congestion with inaccessibility to sun were 43.4% with a P-value of 0.037
3	(Muchuka, 2018)	Factors contributing to rickets among children under five years: case study of Ishiara and Embu hospitals, Embu County	• Used a controlled case study design • Children under 5 years • Sample of 178 (89 cases and 89 control) • Purposive and systematic random sampling procedures were used • Questionnaires used • Logistic regression analysis	• Those who sunbathed were 83.1% of which ; • fully undressed 6.7% OR-0.571 » Panty only 11.2% OR-0.740 » Pant and vest 34.8% OR-0.523 » Fully dressed 30.3% OR-1.604 • Length of time basked » <15 minutes – 14.6% odd ratio of 1.2 » None 16.9% OR 8.8 » >15-30 minutes - 30.3% odd of 0.9 » >30 minutes – 38.2% odd ratio of 0.5
4	(Mumtaz et al., 2023)	Risk Factors of Nutritional Rickets among Children Under five Years of Age	• descriptive cross-sectional study • convenient sampling technique • self-structured questionnaire • 132 diagnosed cases between 1 and 5 years only • Analysis done through SPSS	• Sunlight light exposure » Yes (44) 33.33% » No (88) 66.67% • Duration of sunlight exposure » Less than 10 minutes (76) 57.58% » 10 to 20 minutes (45) 34.10% » Above 20 minutes (11) 8.32% • Dressing during sunlight exposure » Undressed (33) 25.0% » Partially dressed (45) 34.10% » Fully dressed (54) 40.90% • Oil massage during sunlight exposure » Yes (48) 36.37% » No (84) 63.63%

SNO	AUTHOR	TITLE	METHODOLOGY	KEY RESULTS
5	(Ashebir et al., 2022)	Attitudes of mothers attending public hospitals in Addis Ababa, Ethiopia, to neonatal sunlight exposure: a cross- sectional study	• An institution-based cross-sectional study • 420 mothers with neonates were recruited • systematic random sampling method was used • Descriptive and logistic regression analyses used	• Knowledge, fear and practice of neonatal sunlight exposure of the study participant • Those who had information about sunlight exposure under the following category were (388)92.4%: » Physician (173) 44.6% » Midwife/nurse (258) 66.5% » Television/radio (17) 4.4% » Neighbors/elder people (105) 27.1% • Is sunlight exposure beneficial? (n=388) Yes (380) 97.9% » The benefit of sunlight exposure (n=380) » Strengthens bone (252) 66.3% » Strengthens teeth (6) 1.6% » Keeps child warm (73) 11.3% » Produces vitamin D (235) 67.1% » Strengthens body (160) 42.1% • Is sunlight exposure harmful? (n=388) Yes (190) 49.0% • The harmful effect of sunlight exposure (n=190) » Skin cancer (37) 19.5% » Sterility (80) 42.1% » Blindness (104) 54% • A good time to expose neonates (n=388) » Morning (365) 94.1% » Afternoon (13) 3.4% » Evening (66) 17.0% • Mothers fear sunlight exposure Yes* (245) 58.3% • Knowledge » Good knowledge (181) 43.1% » Poor knowledge (239) 56.9% • Practice » Good practice (114) 27.1% » Poor practice(306) 72.9%

SNO	AUTHOR	TITLE	METHODOLOGY	KEY RESULTS
6	(Muzaffar et al., 2018)	Rickets among Saudi Infants in Jeddah, Saudi Arabia	• 169 Infants, aged 4 – 24 months, • Cross sectional study	• Sun exposure » less than 30 min/week (165) 97.6% » More than 30 min/week (4) 2.4% • Housing » Closed flat (162) 95.9% » Open house (7) 4.1% • Skin color » Light (31) 18.3% » Tanned (102) 60.4% » Dark (36) 21.3%
7	(Akram et al., 2022)	Rickets among children ≤ 5 years of age presenting with poor growth visiting a tertiary healthcare facility.	• cross-sectional study was done sample size was 261 children • consecutive sampling	Sun light exposure in minutes per day ≤30 13 (8.84%) 134 (91.16%) – rickets present >30 05 (4.39%) 109 (95.61%) – rickets absent, with a p-value of 0.159 Mean sunlight exposure time was 25.67±11.72 minutes/day
8	(Sisay et al., 2019)	Rickets and Its Associated Factors among Under-Five Children in Selected Public Hospitals in Eastern Ethiopia	• A hospital based cross-sectional study • semi-structured questionnaires used • Logistic regression analysis was used	• Age at first sun exposure (n=556) » First week 61 (11.0%) » Second week 179 (32.2%) » Third week 84 (15.1%) » After one month 232 (41.7%) • Dressing during sun exposure (n=556) » Undressed 173 (31.1%) OR -1 » Partially undressed 277 (49.8%) OR-0.81 » Fully dressed 106 (19.1%) OR-10.36 • Way of sun exposure (n=556) » Open to the sky 295 (53.1%) » Under shade 156 (28.1%) » Inside home 109 (18.9%) • Duration of sun exposure in minutes (n=556) » <10 - 86 (15.5%) » 10-15 - 260 (46.8%) » 15-20 - 169 (30.4%) » >20 - 41 (7.4%) • Common practice during sun exposure (n=556) » Oil massage 348 (62.6%) OR-1 » Breast feeding 72 (12.9%) » Nothing 136 (24.5%) OR-4.94

SNO	AUTHOR	TITLE	METHODOL-OGY	KEY RESULTS
				• Benefits » Strengthen bone (147) 67.4% » Strengthen teeth (7) 3.2% » Keep child warm (30) 13.8% » Produce vitamin D (70) 32.1% » Strengthen body (140) 64.2% • Good time to expose » Morning (218) 99.1% » Afternoon (2) 0.9% • Does sunlight exposure is harmful if not exposed appropriately » Yes (114) 51.4% » No (106) 48.2% • Harms they fear Skin cancer (92) 80.7% » Sterility (1) 0.9% » Blindness (33) 28.9% • Assessing the practice of sunlight exposure • Do you expose your infant to sunlight? » Yes (162) 73.6% » No (58) 26.4% • Age of infant to start sunlight exposure » < 7days (1) 0.6% » 8 -14days (15) 9.3% » >15days (146) 90.1% • How frequently do you expose? » Daily (111) 68.5% » Sometimes (51) 31.5% • Do you expose your infant to sunlight outdoors? » Yes (103) 63.6% » No (59) 36.4% • At what time do you expose? » Morning 8–10 am (151) 93.2% » Mid-day 11 am -1pm (7) 4.3% » Afternoon 2-4pm (4) 2.5% • Condition of clothing during exposure » Unclothed (28) 17.3% » With diaper and eye protection (39) 24.1% » Partially covered (8)2 50.6% » Completely covered (13) 8.0% • How many minutes do you expose your neonate? » <10 minute (26) 16.0% » 15–30 minute (135) 83.3% » >30 minutes (1) 0.6% • Apply lubricant during exposure » Yes (149) 92.0% » No (13) 8.0% • When do you apply? » Before exposure (25) 16.8% » During exposure (25) 16.8% » After exposure(99) 66.4%

SNO	AUTHOR	TITLE	METHODOLOGY	KEY RESULTS
				• What thing do you apply? » Baby Vaseline (86) 57.7% » Baby lotion (31) 20.8% » Butter (32) 21.5% • Fear to expose baby to sunlight (n = 149) » Sickness (66) 44.3% » Evil eye (87) 58.4% » Cold (65) 43.6%
9	(Mengistu et al., 2022)	Factors associated with infants' sunlight exposure among mothers attending the EPI unit of Wolkite University Specialized Hospital	• Institutional-based cross-sectional study design • Sample of 220 mothers • Interviewer-administered questionnaires used • Systematic random sampling technique employed • Multivariate logistic regression analysis used	• Assessing knowledge • Heard about sunlight exposure » Yes (216) 98.2% » No (4) 1.8% • Source of information » Health professionals (155) 70.5% » Media (9) 4.1% » Neighbors (54) 24.5% » Friends (75) 34.1% • Sunlight exposure is beneficial » Yes (218) 99.1% » No (2) 0.9% • Benefits » Strengthen bone (147) 67.4% » Strengthen teeth (7) 3.2% » Keep child warm (30) 13.8% » Produce vitamin D (70) 32.1% » Strengthen body (140) 64.2% • Good time to expose » Morning (218) 99.1% » Afternoon (2) 0.9% • Does sunlight exposure is harmful if not exposed appropriately » Yes (114) 51.4% » No (106) 48.2% • Harms they fear Skin cancer (92) 80.7% » Sterility (1) 0.9% » Blindness (33) 28.9% • Assessing the practice of sunlight exposure • Do you expose your infant to sunlight? » Yes (162) 73.6% » No (58) 26.4% • Age of infant to start sunlight exposure » < 7days (1) 0.6% » 8 -14days (15) 9.3% » >15days (146) 90.1% • How frequently do you expose? » Daily (111) 68.5% » Sometimes (51) 31.5% • Do you expose your infant to sunlight outdoors? » Yes (103) 63.6% » No (59) 36.4%

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				• At what time do you expose? » Morning 8–10 am (151) 93.2% » Mid-day 11 am -1pm (7) 4.3% » Afternoon 2-4pm (4) 2.5% • Condition of clothing during exposure » Unclothed (28) 17.3% » With diaper and eye protection (39) 24.1% » Partially covered (8)2 50.6% » Completely covered (13) 8.0% • How many minutes do you expose your neonate? » <10 minute (26) 16.0% » 15–30 minute (135) 83.3% » >30 minutes (1) 0.6% • Apply lubricant during exposure » Yes (149) 92.0% » No (13) 8.0% • When do you apply? » Before exposure (25) 16.8% » During exposure (25) 16.8% » After exposure(99) 66.4% • What thing do you apply? » Baby Vaseline (86) 57.7% » Baby lotion (31) 20.8% » Butter (32) 21.5% • Fear to expose baby to sunlight (n = 149) » Sickness (66) 44.3% » Evil eye (87) 58.4% » Cold (65) 43.6%

DISCUSSION

Adequate exposure to sunlight, especially ultraviolet B (UVB) radiation, is crucial for synthesizing vitamin D and preventing rickets (WHO, 2009). Sunlight exposure is crucial for vitamin D synthesis, which is vital for calcium absorption and bone health. Without adequate vitamin D, children are at risk of developing rickets, a condition characterized by weakened and deformed bones. The studies reviewed highlight a significant awareness among caregivers about the importance of sunlight exposure but also reveal gaps in practice and knowledge that could lead to insufficient vitamin D levels and increased rickets risk. Teklehaimanot et al. (2021) noted a significant awareness among mothers, with 99.1% intentionally exposing their infants to sunlight. This highlights the importance caregivers place on sunlight exposure for their infants' health. The results from Micheni (2020) provide significant insights into sunlight exposure practices and their potential impact on children's health. According to the study, 47.2% of caregivers reported sunbathing their children, while 52.8% did not, with a highly significant P-value of 0.000. This indicates a strong association between sunbathing practices and children's rickets outcomes, suggesting that sunbathing is a common and possibly beneficial practice. However, Mumtaz et al. (2023) found that only 33.33% of caregivers exposed their children to sunlight, with the majority not utilizing this practice. This suggests a gap in knowledge or practice regarding the importance of sunlight exposure in preventing rickets and ensuring optimal vitamin D levels.

Teklehaimanot et al. (2021) revealed that 85.7% of respondents initiated sunlight exposure for their infants before they reached 15 days old, indicating early recognition among mothers of the benefits of vitamin D. This highlights the proactive approach of caregivers in the study population towards ensuring early sunlight exposure for their infants. Conversely, Sisay et al. (2019) reported that a majority of children had their first sun exposure after one month of age, with only 41.7% experiencing it during this critical period. This suggests that a significant portion of infants in the region studied may not have been exposed to sunlight during the crucial early weeks of life, potentially impacting their vitamin D levels and increasing the risk of rickets. Furthermore, Mengistu

et al. (2022) found that the majority of mothers (73.6%) exposed their infants to sunlight, with most initiating exposure after 15 days of age. This aligns with the findings of Teklehaimanot et al. (2021) and underscores the importance caregivers place on early sunlight exposure for their infants' health and well-being.

Among mothers who exposed their infants to sunlight, Teklehaimanot et al. (2021) reported that 60.8% did so daily, with a significant proportion (96%) opting to expose their infants in the morning before 10:00 am. This aligns with the findings of Ashebir et al. (2022), where the majority of participants (94.1%) believed that morning is a suitable time for neonatal sunlight exposure. However, discrepancies were noted, as some participants also mentioned afternoon and evening as suitable times. According to Akram et al. (2022), the mean sunlight exposure time was calculated to be 25.67±11.72 minutes per day. This relatively low mean sunlight exposure time underscores the importance of assessing and promoting adequate sunlight exposure among children, especially those at risk of rickets due to poor growth. Moreover, Mengistu et al. (2022) found that morning was considered the optimal time for sunlight exposure by the majority (99.1%) of participants. This practice aligns with recommendations for optimal sunlight exposure, as UVB radiation is most intense during the morning hours, facilitating efficient vitamin D synthesis. However, it's important to note that the exact time of morning sunlight exposure was not specified in the study.

In the study by Teklehaimanot et al. (2021), 35.5% of mothers reported exposing their infants for 10-15 minutes, a duration likely sufficient for adequate vitamin D production without increasing sunburn risk. Conversely, Muchuka (2018) found variations in sunlight exposure duration among children, with 38.2% spending over 30 minutes basking, while 14.6% spent less than 15 minutes, potentially insufficient for adequate vitamin D synthesis. Odds ratios provided in Muchuka's study offer insights into rickets likelihood based on factors like clothing practices and exposure duration, indicating that longer exposure durations are associated with a reduced risk of rickets, emphasizing the importance of sufficient sunlight exposure for effective vitamin D synthesis.

Moreover, Mumtaz et al. (2023) reported that 57.58% of children had short sunlight exposure, contrasting with 8.32% receiving longer exposure, potentially contributing to nutritional rickets. Similarly, Muzaffar et al. (2018) found 97.6% of infants had <30 minutes of weekly sun exposure, signifying inadequate exposure despite its vital role in vitamin D synthesis and bone health. Akram et al. (2022) noted 56.3% of children had ≤30 minutes/day sunlight exposure, while 43.7% had >30 minutes, with no statistically significant difference in rickets presence based on exposure duration (p-value = 0.159). The absence of a statistically significant relationship between sunlight exposure duration and rickets prevalence underscores the complexity of the condition's etiology. It suggests that while sunlight exposure is crucial for vitamin D synthesis, which is essential for bone health, other factors may play equally or more significant roles in the development of rickets. These factors could include dietary intake of vitamin D and calcium, genetic predispositions, and underlying health conditions that affect nutrient absorption or metabolism. Sisay et al. (2019) reported 46.8% of children exposed for 10-15 minutes, 30.4% for 15-20 minutes, and 7.4% for over 20 minutes. Longer exposure may enhance vitamin D synthesis further. Lastly, Mengistu et al. (2022) found varying exposure durations, with most infants exposed for 15-30 minutes, reinforcing the importance of tailored sunlight exposure practices to optimize vitamin D levels and mitigate rickets risk.

In the study by Teklehaimanot et al. (2021), more than half of the mothers (54.7%) exposed their infants with only a diaper or naked during sunlight exposure, facilitating maximum skin exposure to sunlight and optimizing vitamin D synthesis. This practice aligns with the findings of Muchuka (2018), which highlight the diversity in clothing practices among caregivers during sunlight exposure of their children. Of the children who were sunbathed, 83.1% experienced various degrees of clothing during exposure. The study found that 6.7% of children were fully undressed during sun exposure, with an odds ratio (OR) of 0.571, indicating a reduced risk of inadequate vitamin D synthesis compared to fully dressed children. Those wearing only a panty, comprising 11.2% of the sample, had an OR of 0.740, also suggesting a lower risk. Children dressed in a pant and vest, representing 34.8%, had an OR of 0.523, showing the lowest risk among the different clothing categories. However, 30.3% of children were fully dressed during sun exposure, with a significantly higher OR of 1.604, indicating an increased likelihood of insufficient vitamin D synthesis. These results underscore the importance of minimal clothing during sunbathing to maximize skin exposure and enhance vitamin D production, thereby reducing the risk of vitamin D deficiency and associated health issues such as rickets.

However, Teklehaimanot et al. (2021) also noted that a significant proportion (30.3%) of respondents fully dressed their children during sunlight exposure, potentially limiting the effectiveness of sunlight exposure in promoting vitamin D synthesis.

Similarly, Mumtaz et al. (2023) reported that a majority of respondents opted for lighter clothing options such as panty only (11.2%) or pant and vest (34.8%), allowing for more skin exposure to sunlight. Promoting lighter clothing options or undressing during sunlight exposure may help maximize vitamin D synthesis, as highlighted by Mumtaz et al. (2023). The findings from Sisay et al. (2019) reveal significant differences in rickets risk based on how children are dressed during sunlight exposure. Among the children studied, those who were undressed during sun exposure (31.1%) served as the reference group with an odds ratio (OR) of 1. Children who were partially undressed (49.8%) had a slightly lower risk of rickets, with an OR of 0.81, indicating a relatively effective practice for vitamin D synthesis. However, children who were fully dressed (19.1%) had a significantly higher risk of developing rickets, with an OR of 10.36. This substantial increase in odds underscores the critical importance of minimizing clothing during sun exposure to enhance skin exposure to UVB rays, thereby promoting adequate vitamin D synthesis and reducing the risk of rickets. Additionally, in the study by Mengistu et al. (2022), practices regarding clothing varied, with a notable proportion (17.3%) leaving infants unclothed during exposure. This practice may contribute to maximizing skin exposure to sunlight and optimizing vitamin D synthesis, reinforcing the importance of tailored clothing practices during sunlight exposure to prevent nutritional rickets.

In the study by Teklehaimanot et al. (2021), a significant proportion of respondents (57.7%) reported not applying any lubricant or body lotion during sunlight exposure, aligning with recommendations to avoid hindering vitamin D synthesis. By refraining from such applications, mothers likely facilitated optimal vitamin D production in their infants. However, a subset of respondents (36.37%) reported conducting oil massages during sunlight exposure, as noted by Mumtaz et al. (2023). While oil massages are a common cultural practice, their use during sunlight exposure may hinder vitamin D synthesis by blocking UVB radiation absorption. Educating caregivers about the potential drawbacks of oil massages could promote more effective prevention strategies for nutritional rickets. Interestingly, Mumtaz et al. (2023) highlighted that the most common practice during sun exposure was oil massage, adopted by a significant majority (62.6%) of children. This practice's widespread adoption is noteworthy as it could potentially affect sunlight absorption and vitamin D synthesis. Moreover, findings from Sisay et al. (2019) highlight the common practices during sun exposure and their association with rickets risk among children. The majority of caregivers (62.6%) practiced oil massage during sun exposure, serving as the reference group with an odds ratio (OR) of 1. Interestingly, the practice of doing nothing during sun exposure (24.5%) was associated with a significantly higher risk of rickets, with an OR of 4.94. This indicates that the absence of any additional practices, such as oil massage, might considerably increase the likelihood of rickets. Although breastfeeding during sun exposure was practiced by 12.9% of caregivers, the study did not provide an odds ratio for this group, leaving its direct impact on rickets risk less clear. Overall, these findings suggest that while oil massage is the most common practice, not engaging in any specific practice during sun exposure might significantly elevate the risk of rickets in children. Additionally, Mengistu et al. (2022) reported that a significant majority (92.0%) applied lubricants during exposure, with baby Vaseline being the most common option.

The findings from Micheni (2020) indicate that among children exposed to sunlight, 80% were positioned directly in the sunlight, while 20% were under shade. This distribution suggests that a majority of caregivers opted for direct sunlight exposure, which is optimal for vitamin D production. However, the 20% of children positioned under shade may have experienced limited sunlight exposure; potentially impacting their vitamin D status and causing rickets. Similarly, Sisay et al. (2019) reported that a majority of children (53.1%) were exposed to sunlight in areas open to the sky, while 28.1% were under shade. This distribution highlights that a significant portion of sun exposure occurs in conditions where direct sunlight is available, essential for effective vitamin D synthesis. Overall, these findings emphasize the importance of ensuring adequate exposure to direct sunlight, as it plays a critical role in promoting vitamin D synthesis and maintaining optimal health. Caregivers should be encouraged to prioritize outdoor activities in areas with direct sunlight to facilitate adequate vitamin D production in children.

Micheni (2020) identified significant barriers to adequate sunlight exposure for children, particularly noting that 43.4% of children attended daycare facilities with house congestion and limited sunlight, with a P-value of 0.037. This highlights the impact of environmental factors such as the physical setup of daycare facilities, play a significant role in children's exposure to sunlight. Additionally, socioeconomic status was a key determinant, as mothers from lower socioeconomic backgrounds reported suboptimal practices due to limited access to outdoor spaces or employment constraints. To address these disparities, targeted interventions are needed to improve access to sunlight-rich environments. Promoting outdoor play areas in daycare facilities and providing support for caregivers can help reduce the risk of vitamin D deficiency and rickets in vulnerable populations.

The studies by Ashebir et al. (2022) and Mengistu et al. (2022) shed light on the knowledge, perceptions, and practices regarding neonatal sunlight exposure among caregivers. Both studies indicate a high level of awareness about sunlight exposure, with the majority of participants having heard about its benefits. Health professionals, particularly midwives/nurses, emerge as crucial sources of information, underlining their role in educating families. Despite the widespread belief in the benefits of sunlight exposure, there exists a notable fear among caregivers, as highlighted by Ashebir et al. (2022). Concerns about potential harms such as skin cancer, sterility, and blindness contribute to this fear, indicating a need for comprehensive education on the risks and benefits. Interestingly, while nearly all participants acknowledge the benefits of sunlight exposure, a significant percentage also believe it could be harmful (Ashebir et al., 2022). This discrepancy between perceived benefits and perceived harms underscores the complexity of caregiver attitudes towards sunlight exposure. Moreover, there is a gap between knowledge and actual practices, as observed by Mengistu et al. (2022). Despite good awareness of the benefits and risks, a considerable proportion of caregivers exhibit poor practices regarding neonatal sunlight exposure. This discordance highlights the need for targeted interventions aimed at bridging the gap between knowledge and behavior.

In the study conducted by Muzaffar et al. (2018), variations in skin color among infants were observed, with 60.4% classified as tanned, 18.3% as light, and 21.3% as dark. While skin color is influenced by multiple factors, including genetics, the high percentage of tanned skin suggests some level of sun exposure among the study population. However, it's crucial to recognize that tanned skin alone does not necessarily indicate adequate sunlight exposure for vitamin D synthesis. Tanning occurs as a result of melanin production in response to UV radiation, which can occur even with minimal sun exposure. Therefore, while tanned skin may suggest some degree of sunlight exposure, it does not guarantee sufficient vitamin D synthesis, especially if exposure duration or intensity is insufficient.

The studies collectively underscore the crucial role of sunlight exposure in preventing nutritional rickets among children. Adequate sunlight exposure is critical for vitamin D synthesis and preventing rickets in infants. Studies highlight significant awareness among caregivers about sunlight's benefits, yet gaps in practice and knowledge persist. Variations in exposure timing, duration, clothing practices, and the application of lubricants impact the effectiveness of vitamin D synthesis. Socioeconomic barriers further limit sunlight access for many children, increasing their risk of vitamin D deficiency and rickets.

To address these issues, public health campaigns should be conducted to educate caregivers about the optimal timing (morning hours), duration (at least 15-30 minutes), and practices (minimal clothing, avoiding lubricants) for effective sunlight exposure. Additionally, healthcare providers should be trained to convey clear and consistent messages about the importance of sunlight exposure for vitamin D synthesis and rickets prevention. Policy and infrastructure improvements are also necessary. Implementing regulations to ensure daycare facilities provide adequate opportunities for outdoor sunlight exposure can help. Community programs should be developed to support caregivers, especially those from lower socioeconomic backgrounds, in accessing safe outdoor spaces for their children.

Further research is needed to understand barriers to optimal sunlight exposure and develop tailored interventions. Regular monitoring of the vitamin D status of infants and children, particularly in high-risk populations, is essential for early detection and intervention for vitamin D deficiency and rickets. By addressing these areas, sunlight exposure practices among caregivers can be improved, reducing the risk of rickets and promoting better overall health for infants and children.

Review limitations

This review focused on papers published in specific databases and retrieved in a period of one month. Consequently, additional or alternative information might be found in studies published in other sources.

Conflict of Interest

Authors declare no conflicts of interest.

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