Chula Med J. January - February 2027;71(1): 45 - 55 **DOI : 10.56808/2673-060X.**

Review article

Prevalence of stunting and environmental determinants among children under 5 years of age: A systematic review and meta-analysis

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Abstract

Background: Stunting remains a major global public health issue, particularly in low- and middle-income countries. It is driven by inadequate nutrition and environmental factors, such as limited access to clean water, sanitation, and hygiene practices.
Objectives: This study aimed to estimate the prevalence of stunting among children under 5 years of age and to assess its correlation with environmental determinants.
Methods: This systematic review and meta-analysis followed PRISMA guidelines. Four international e-databases—Scopus, PubMed, ScienceDirect, and Springer—and reference lists were searched. In total, 20 studies involving 103,313 children met the inclusion criteria. A random-effects model was employed to estimate combined prevalence and associations; the I^2 statistic was used to assess heterogeneity.
Results: Stunting prevalence was 32.9% (95% CI: 28.6–37.8; I^2 = 99.5%). Children from households with inadequate sources of drinking water were at a 1.2-times higher risk of stunting (adjusted odds ratio (AOR) = 1.2; 95% CI: 1.0–1.4; I^2 = 78.5%). Inadequate toilet facilities increased the risk by 1.3 times (AOR = 1.3; 95% CI: 1.0–1.6; I^2 = 86.5%), poor sanitation by 1.2 times (AOR = 1.2; 95% CI: 1.0–1.4; I^2 = 75.0%), and poor handwashing practices by 2.3 times (AOR = 2.3; 95% CI: 1.0–5.5; I^2 = 68.1%).
Conclusion: Stunting prevalence was significantly associated with environmental determinants. Integrating interventions for such factors with nutrition programs is essential to controlling stunting, particularly in rural areas. Policy efforts should prioritize improving access to safe drinking water, providing adequate sanitation facilities, conducting hygiene promotion programs, and community-based nutritional interventions to support child growth and development.

Keywords: Child nutrition, environmental determinants, meta-analysis, stunting, stunting prevalence.

Childhood malnutrition manifests primarily as stunting, wasting, low body weight, and micronutrient deficiencies. [1] It constitutes a major public health issue, particularly in low- and middle-income nations. Stunting is an indicator of chronic undernutrition, defined as the proportion of children whose standard deviation for height-for-age varies < −2 from the median established by the World Health Organization (WHO). [2] Globally, nearly 149 million children under the age of five are stunted, with the highest prevalence in South Asia (34.4%), followed by East and Southern Africa (33.6%), and the lowest in North America (2.6%). [3] Despite its widespread prevalence, stunting most severely impacts children under 2 years of age, as this period is critical for rapid growth and development. [4]

Stunting affects not only physical growth but also has enduring consequences on cognitive development and educational attainment. Stunted children exhibit reduced cognitive abilities compared to their non-

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Received: August 15, 2025
Revised: January 24, 2026
Accepted: February 20, 2026

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stunted peers, potentially impacting future learning outcomes and economic productivity. [5] The economic implications of stunting are substantial; such individuals typically experience delays in school enrolment, attain fewer years of education, and earn lower than their normal counterparts. Stunting influences functional brain connectivity, directly affecting their cognitive ability. [6] Variations in prevalence among developing and advanced countries indicate notable disparities in access to nutrition, healthcare services, and education. The prevalence was notably high at >30.0% in South Asia and Sub-Saharan Africa, in contrast to advanced nations where the average is <5.0% [7]

The initial thousand days of life, encompassing conception to a child's second birthday, represent a crucial phase for implementing nutritional interventions. [8] Malnutrition during this stage can cause irreversible effects on cognitive and physical development, heightened vulnerability to disease, and an increased risk of mortality.[4] Managing stunting during this period presents an optimal opportunity for growth and development, as interventions beyond this timeframe become progressively more challenging. [9] Numerous international initiatives, such as the WHO's objective to decrease stunting prevalence by 40.0% by 2025, highlight the necessity of prioritizing interventions during this period. [10]

Multiple factors contribute to stunting in children, including maternal age, education, and nutritional status; household wealth; child age, gender, and dietary diversity; and frequent illnesses, such as diarrhea and respiratory infections. [11] Environmental factors, including substandard water quality, insufficient sanitation, and inadequate hygiene practices, are prominent contributors to stunting, particularly in low- and middle-income nations. [12] They exacerbate undernutrition and create cyclical health challenges that disproportionately impact vulnerable populations, underscoring the need for integrating environmental management with nutrition strategies. [13]

Although numerous studies on stunting exist, research has concentrated on specific regions, particularly Sub-Saharan Africa and South Asia. [14, 15] However, the global relationship between environmental factors and stunting remains poorly explored, creating an important gap in the literature. This systematic review and meta-analysis fills that gap by examining the relationship between environmental factors and stunting prevalence across different global contexts. Unlike previous studies that often target specific regions or sociodemographic factors, this study integrates findings from multiple regions and settings to provide a holistic understanding of the issue. In addition, this study examines the integration of environmental determinants, such as access to clean water and sanitation and handwashing behavior, which hold great potential in reducing stunting prevalence. [16]

This study is distinct as it used a meta-analysis approach, enabling a comprehensive assessment of the influence of environmental factors on stunting prevalence. It employs a Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)-based approach and analyzes heterogeneity to provide comprehensive knowledge on the correlations among access to clean water, sanitation, handwashing practices, and the prevalence of stunting. [17] These findings potentially provide a foundation for evidence-based policies for public health interventions at the global level, particularly in low-income countries. [18] This study further endorses attainment of the Sustainable Development Goals, namely, objectives 6 and 2, which underscore the significance of access to clean water and the eradication of hunger, including child malnutrition. This study is pertinent to attaining SDG targets by emphasizing how environmental factors, including sanitation, hygiene, and access to clean water, can expedite stunting. [19]

Materials and methods

This review used the PRISMA approach, which includes methods for identifying relevant resources, determining eligibility, defining inclusion and exclusion criteria, and conducting a systematic review, data extraction, and analysis of the available literature. The PRISMA 2020 guidelines were selected because they provide updated, more exhaustive reporting standards for systematic reviews and meta-analyses than the earlier version, PRISMA 2009. PRISMA 2020 introduces new reporting guidelines that include more extensive study identification, selection, scoring, and synthesis. This guide enabled the search for terms relevant to the review and provides advice on aspects that need to be addressed in the report for publication. [20]

Research question formulation

Research questions were developed using PICO, a tool for framing relevant research questions for systematic reviews. The PICO concept incorporates three crucial elements: population or problem, importance, and context. This review focuses on three primary components: children under 5 years old experiencing stunting (Problem), the prevalence of

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stunting and its association with environmental factors (Importance), and a defined geographic location or specific environmental characteristics (Context). The formulation of the research question was guided by the concept: "What evidence exists regarding the relationship between environmental factors and the prevalence of stunting in children under 5 years of age?"

Search strategies

The search strategy included identification, screening, and eligibility processes.

Identification

In the identification stage, synonyms and variations were used to enrich the keywords applied in the search process. A search string was created and generated utilizing Boolean operators and the following keyword searches: "Stunting," "Child stunting," "Determinants of stunting," "Sociodemographic factors," "Socioeconomic status," "Maternal health," "Prenatal care," "Nutrition status," as illustrated in **Supplementary Table S1**. A systematic literature search was conducted across four major databases: Scopus, PubMed, ScienceDirect, and Springer, and 4,384 relevant records were identified; 643 duplicates were removed, leaving 3,741 for title screening. All potential records were then exported from the database and organized in an Excel sheet for title and abstract screening.

Screening

Two authors screened the titles and abstracts based on the questions developed and specific inclusion and exclusion criteria. Inclusion criteria were primary research published in peer-reviewed journals, articles from January 2004 to September 2024, and in English. We excluded systematic reviews, books, conference proceedings, and non-peer-reviewed articles, such as editorials, commentaries, opinions, or short reports. The screening process eliminated 2,954 articles as irrelevant, leaving 787 articles for abstract reading and full-text retrieval for further assessment and eligibility screening.

Eligibility

A total of 219 full-text articles were retrieved, and two authors independently reviewed all for eligibility. All those found to be unrelated to the interest and outcome of interest were excluded, and the reasons were recorded. In total, 185 articles excluded because: 1) they did not use a cross-sectional design (n = 29); 2) they did not include only children aged 0–59 months (n = 43); 3) those that did not report epidemiologic measures such as odds ratio (OR) or adjusted OR (AOR) (n = 38); 4) those conducted on school children (n = 19); and 5) those that did not examine environmental factors (n = 56). The remaining 29 eligible articles were assessed for quality. The PRISMA flowchart **(Figure 1)** summarizes the steps of article screening, from initial identification to eligibility evaluation.

Quality assessment

Article quality was assessed using the Joanna Briggs Institute Critical Appraisal Checklist for Observational Studies. [21] The process involved two independent reviewers, and any disagreements were resolved through discussion. Of the 20 articles evaluated, the majority demonstrated robust methodological quality with a low risk of bias. A total of seven articles (35.0%) met all criteria with a score of 8/8, indicating a very low risk of bias. Meanwhile, nine articles (45.0%) scored 7/8, reflecting a low risk of bias despite some minor weaknesses. The remaining four articles (20.0%) scored 6/8, indicating more significant weaknesses, such as a lack of detailed description of confounding control strategies or potential bias in outcome measurement (**Supplementary Table S2)**.

Data extraction and synthesis

Each author extracted the data independently using a standardized data extraction form and organized it in a Microsoft Excel worksheet. The information collected included: 1) Author/year; 2) Country; 3) Study Design; 4) Sample size; 5) Prevalence; 6) Children's age; 7) Environmental factors (OR, 95% CI); and 8) NOS (**Supplementary Table S3**).

Statistical analysis

The extracted data were exported to STATA software version 17 for analysis. The combined prevalence of stunting in children under 5 years of age and environmental factors was estimated using a *random-effects model* based on the *Der Simonian-Laird weight model.*[22] Heterogeneity between studies was evaluated employing the Cochran's Q test and statistical I^2.[23] Significant heterogeneity was recognized if $I^2 = 99.5$ and $P < 0.001$. Subgroup analyses accounted for random variations in estimates among original studies, focusing on research area, sample size, and place of residence. A sensitivity analysis assessed the impact of an individual study on the aggregated estimates. The influence of small studies was analyzed using graphical approaches (funnel plot) and statistical testing (Egger).[24]

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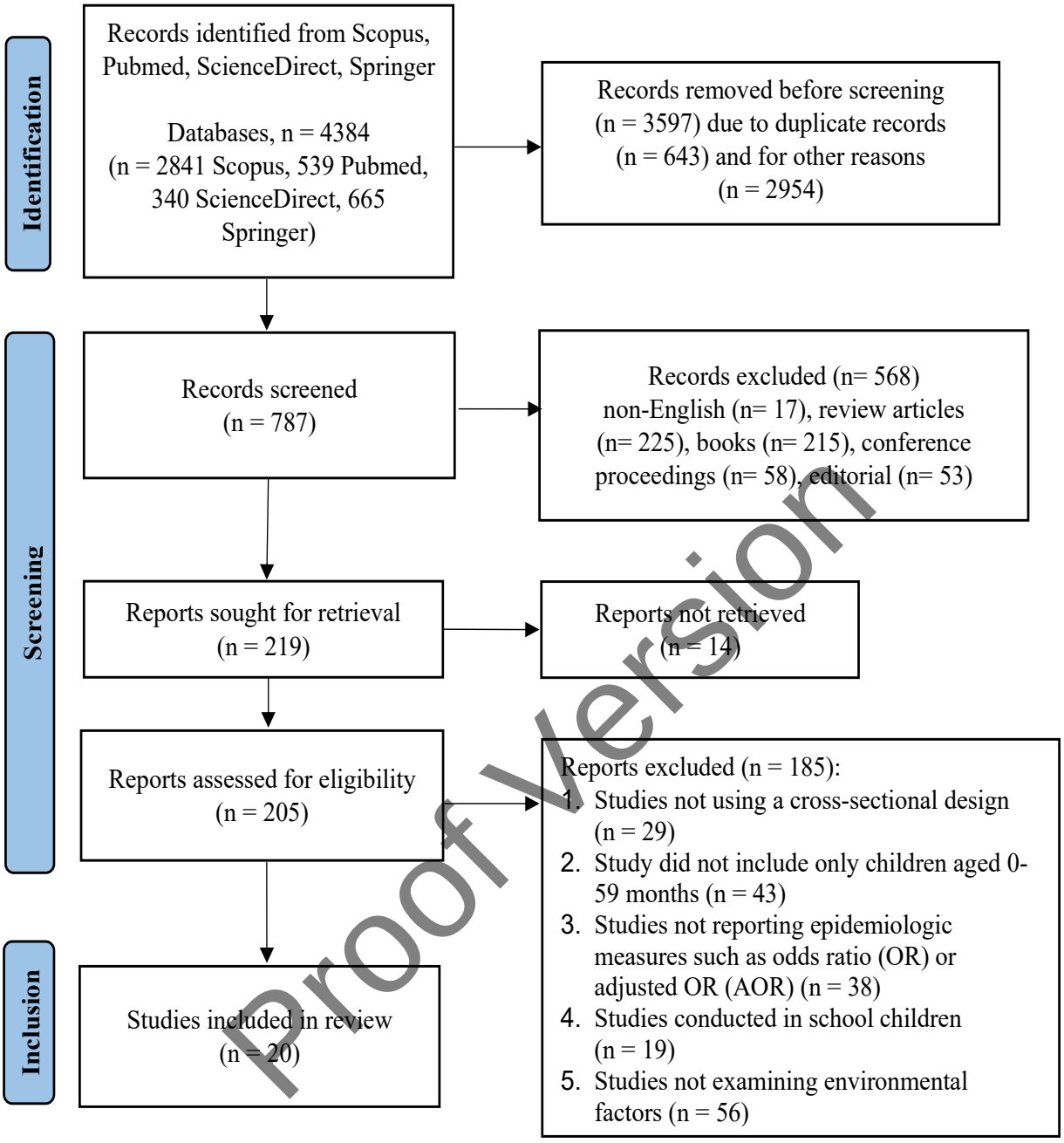

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Figure 1. PRISMA flow diagram of article selection for systematic review and meta-analysis

Results

Characteristics of included studies

This systematic review and meta-analysis included 20 studies from different countries with a total sample size of 103,313 children. The prevalence of stunting ranged from 15.9% in Ghana [25] to 58.1% in Ethiopia.[26] All used a cross-sectional research design and included children under 5 years of age, with some focusing on a narrower age range (such as 0–23 months or 6–59 months). Based on geographical distribution, they were from Africa (Ethiopia [26 – 32], Malawi [33], Zambia [34], Tanzania [35], and Ghana [25]). Asia (Indonesia [36–38], Pakistan [39], Bangladesh [40,41], Nepal [42], Malaysia [43]), and Bhutan [44]. Ethiopia had the largest proportion, while Indonesia and Bangladesh also made significant contributions (**Supplementary Table S3**).

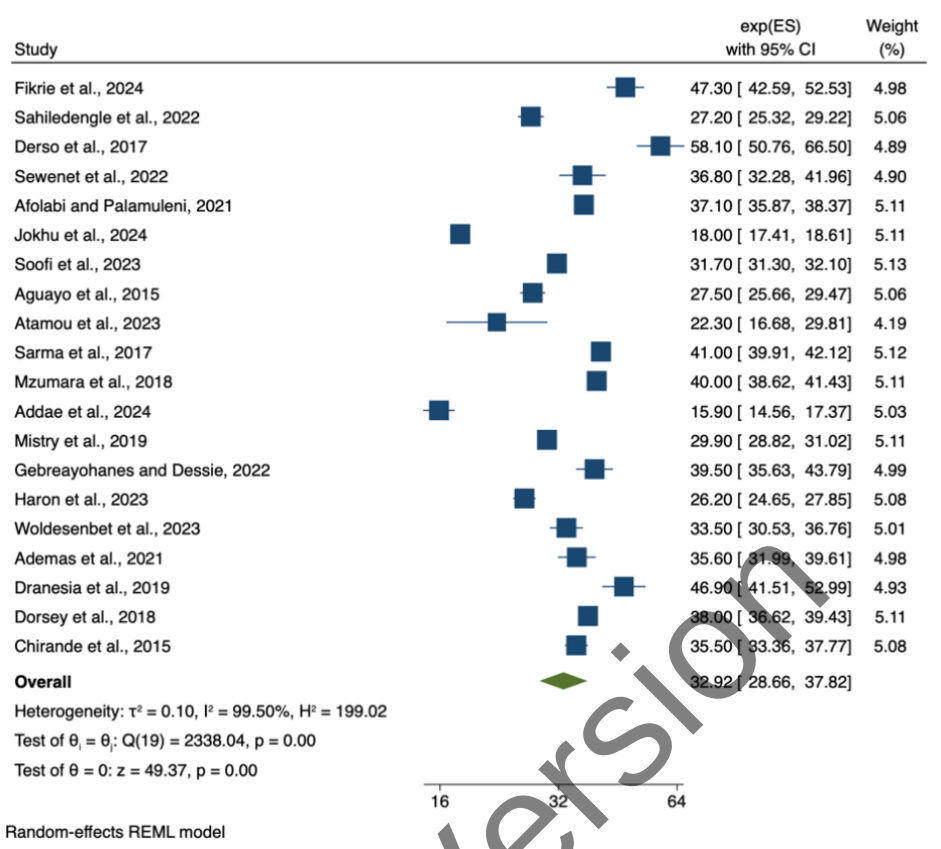

Figure 2. Prevalence of stunting in children under five years old.

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This analysis focused on key environmental variables, namely drinking water sources, types of sanitation facilities, and handwashing with soap practices, as these variables are consistently associated with stunting prevalence in literature. These factors were also reported in each of the included studies (**Supplementary Table S3**), allowing more in-depth analysis to identify prominent associations between environmental determinants and stunting prevalence.

Prevalence of stunting in children under 5 years of age

Stunting prevalence was calculated using a random-effects model. The meta-analysis results showed an overall prevalence of 32.9% (95% CI: 28.6–37.8). The level of heterogeneity was very high with I^2 = 99.5%, τ^2 = 0.10, indicating significant variation between included studies ($P < 0.001$) **(Figure 2)**.

Publication bias

Egger's regression test did not identify any evidence of publication bias among the included studies (B = 0.13, $P = 0.6924$). These results indicated the lack of any marked small-study effect or publication bias.

Handling heterogeneity

The combined estimate utilizing the random-effects model demonstrated considerable heterogeneity. A subgroup study was performed to address this heterogeneity, which was conducted based on region, place of residence, and year of study. By region, prevalence was maximum in Africa (33.3%) and minimum in Asia (30.2%). It was also higher among children living in rural areas (38.6%) than in urban areas (36.0%) or combined urban and rural areas (30.0%). Regarding the year of study, the prevalence was lower in studies conducted after 2020 (29.9%) than in those conducted before 2020 (33.9%) (**Supplementary Table S4**).

Environmental determinants associated with stunting among children under 5 years of age

The study identified associations between drinking water source, type of toilet facility, sanitation, and handwashing with soap practices with stunting (**Table 1**).

Children from households with unimproved drinking water sources were 1.2 times more likely to be stunted than those with access to improved water sources (AOR = 1.2; 95% CI: 1.0–1.4) **(Figure 3A)**.

Table 1. Summary of the effects of environmental determinants associated with stunting among children under five years of age.

Variabel	AOR (95% CI)	Heterogeneity (I^2, *P*-value)	Egger's *P*-value	Total studies
Source of drinking water				
Improved	1			
Unimproved	1.2 (1.0 1.4)	78.5%, < 0.001	0.068	16
Type of toilet facility				
Improved	1			
Unimproved	1.3 (1.0 1.6)	86.5%, < 0.001	0.096	8
Sanitation				
Improved	1			
Unimproved	1.2 (1.0 1.4)	75.0%, < 0.001	0.069	3
Handwashing with soap practice				
Yes	1			
No	2.3 (1.0 5.5)	68.1%, < 0.001	0.015	4

The analysis showed statistically significant heterogeneity (I^2 = 78.5%, $P < 0.001$) and without any significant publication bias (Egger's $P = 0.0680$) among 16 studies. [25 – 28, 30, 32 – 36, 38, 39, 41 – 44] Inadequate toilet facilities were associated with a 1.3-fold increased risk (AOR = 1.3; 95% CI: 1.0–1.6). However, heterogeneity was high and significant (I^2 = 86.5%, $P < 0.001$) **(Figure 3B)**, with no significant publication bias detected (Egger's $P = 0.096$) based on eight studies. [25, 28, 31 - 33, 40, 41, 43]

Children from households with unimproved sanitation systems had a 1.2-fold higher likelihood of stunting than those with improved sanitation (AOR = 1.2; 95% CI: 1.0–1.4). The analysis revealed statistically significant heterogeneity (I^2 = 75.0%, $P <$ 0.001) **(Figure 3C)**. However, no significant publication bias was identified (Egger's $P = 0.069$) among the three reports. [36, 37, 39] Lastly, children in households with poor handwashing practices without soap were 2.3 times more likely to experience stunting than those with proper handwashing practices (AOR = 2.3; 95% CI: 1.0–5.5). The heterogeneity was moderate but statistically significant (I^2 = 68.1%, $P < 0.001$) **(Figure 3D)**, and no publication bias was detected (Egger's $P = 0.015$), based on four studies. [27, 29 – 31] These findings suggest that environmental conditions, particularly access to safe drinking water, adequate sanitation, and proper hygiene practices, play a crucial role in influencing the risk of stunting among children under 5 years of age.

Discussion

Stunting remains a major public health problem worldwide, especially among children under the age of five. [45] In this systematic review and meta-analysis, we aimed to identify the prevalence of stunting and associated environmental factors in such children, with an emphasis on the critical period of the first 1,000 days of life.

It had a prevalence of 32.9% with 95% CI of 28.6%–37.8%. These findings were consistent with similar studies in countries such as Pakistan (40.2%)[46] and Uganda (30.0%) [47] that reported a marked prevalence of stunting in children under 5 years of age. However, it was lower than that from Peru (40.3%) [48], which shows higher rates due to poor socioeconomic and environmental factors. In contrast, the prevalence was higher than in China (8.1%),[49] which has various levels of public health interventions. Research in Ethiopia showed that improved access to clean water and sanitation facilities contributed to a 7.0%–9.0% reduction in the prevalence of stunting among children aged 6–59 months, mainly through reducing open defecation. [29] These differences are likely due to variations in geographical context, sociodemographic characteristics, timing of studies, and sample sizes used. The relationship between environmental determinants and stunting established in this systematic review and meta-analysis is summarized in the graphical abstract.

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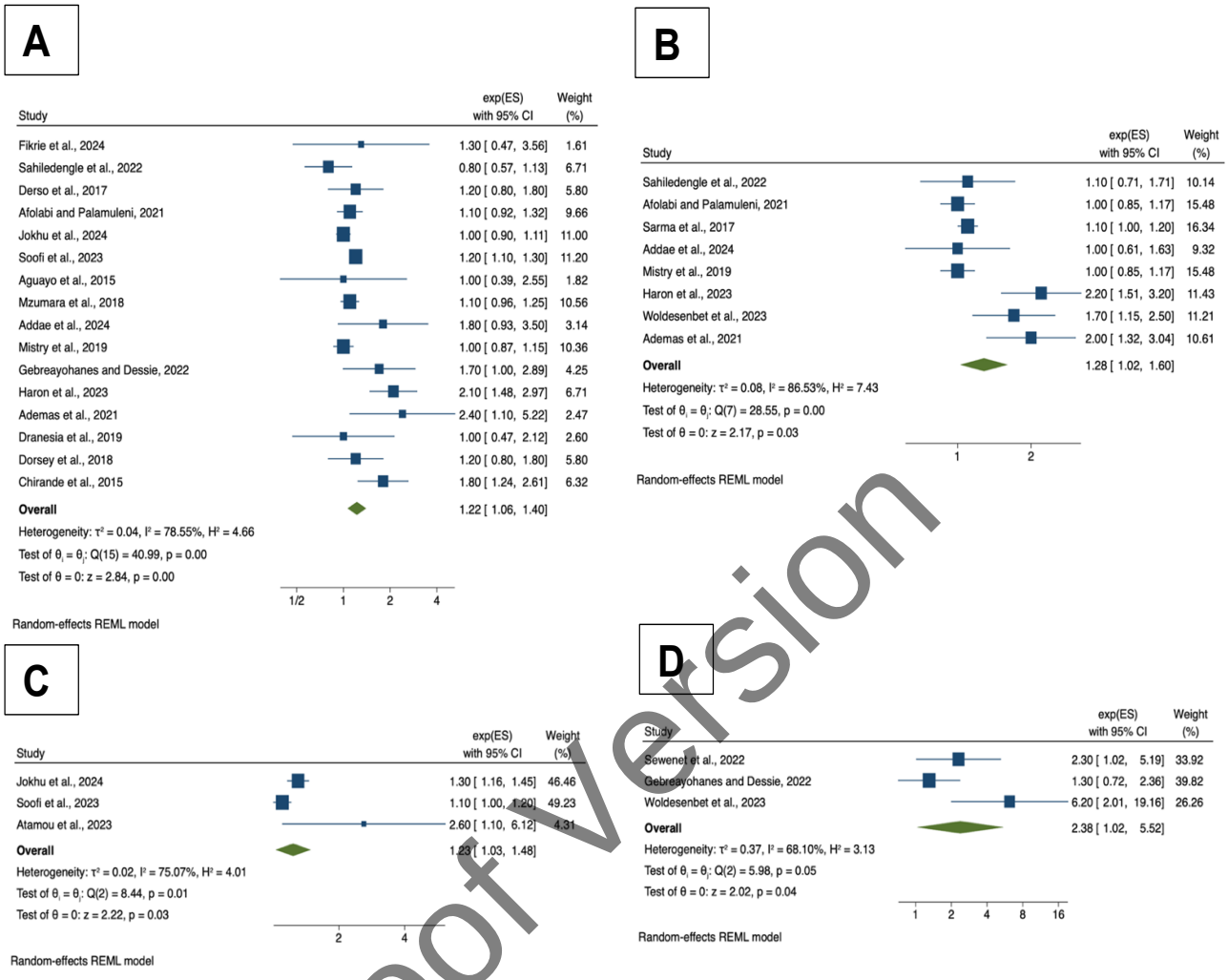

Figure 3. (A) Forest plot showing the association between stunting and source of drinking water, **(B)** stunting and type of toilet facility, **(C)** stunting and sanitation, and **(D)** stunting and handwashing with soap practice.

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Moreover, in low and middle-income nations, children suffer from insufficient quantity, quality, and diversity of food due to limited access and awareness during crucial phases of their growth and development. [21] The results highlight the critical need for interventions grounded in solid evidence, emphasizing not just nutritional aspects but also environmental factors like access to clean water, proper sanitation, and hygiene practices. The combination of environmental and nutritional strategies presents a significant chance to markedly decrease the incidence of stunting and advance international health and nutrition objectives.

Subgroup analysis by region showed that the highest prevalence of stunting was in Africa compared to Asia. Potential influencing factors include variations in time and geographical residence, sample size, study duration, and reduced income levels. [29, 36] However, these differences in prevalence also point to the need for context-based approaches to address the determinants of stunting, such as climatic conditions, availability of health services, and local nutritional customs. Subgroup analysis by place of residence also revealed that the prevalence of stunting was higher in rural areas at 38.6%. This difference was due to limited access to medical services, low maternal education, and inadequate feeding practices in rural areas. In contrast, children in urban areas benefit more from parental job stability, supportive social networks, and better access to health facilities and immunization programs. Higher maternal education in urban areas also increases awareness about the importance of child nutrition.

Community-based studies in Uganda show that education on nutrition, hygiene practices, and stimulation can improve children's cognitive and motor development; however, the impacts on linear growth, such as stunting, still require a more rigorous approach.[50] In this study, random-effects analysis showed that four environmental variables, namely, source of drinking water, type of toilet facility, sanitation, and handwashing with soap practice, were remarkably associated with the prevalence of stunting in children under 5 years old. These results highlight the importance of environment-based interventions in addressing childhood stunting.

Findings from the meta-analysis showed that children with inadequate sources of drinking water were at a 1.2-fold higher risk of stunting than those with access to clean water. Poor environmental conditions, including unsafe drinking water, inadequate sanitation, and poor hygiene practices, may enhance children's exposure to pathogenic microorganisms. Recurrent infections, particularly diarrheal diseases and environmental enteric dysfunction, can impair nutrient absorption and reduce the body's ability to utilize nutrients effectively. Over time, these conditions may contribute to chronic undernutrition and impaired linear growth, ultimately increasing the risk of stunting in young children. This trend indicates that drinking water quality plays a crucial role in determining children's nutritional status. Poor water quality is often associated with an increased prevalence of recurrent diarrhea, leading to nutrient malabsorption and chronic malnutrition in children during critical growth periods.[39] Recent studies have shown that improving access to clean water and sanitation in rural communities can reduce the risk of exposure to pathogenic bacteria by 20.0%–30.0% and gastrointestinal infections that often occur due to consumption of contaminated water. [33]

Inadequate sanitation facilities increased the risk of stunting by 1.3 times. In this analysis, poor toilet facilities were found to exacerbate exposure to pathogens, causing diseases such as chronic diarrhea, impairing the absorption of essential nutrients in children. Research in Indonesia supported these findings, where households without adequate toilets showed a higher prevalence of stunting than those with good sanitation facilities. [43] In Ghana, 45.0% of children in households without toilet facilities were stunted, compared to 25.0% in households with toilets of a good standard. [31] In addition, a global study by the United Nations Children's Fund found that investing in proper sanitation facilities in low-income countries could reduce the prevalence of stunting by 23.0% on average. [36] Therefore, sanitation-based interventions must be prioritized in stunting prevention strategies, especially in rural areas with limited access to infrastructure. [41]

Poor sanitation increases the likelihood of stunted growth by 1.2 times. In this meta-analysis, inadequate household sanitation conditions increased exposure to infectious diseases, resulting in reduced weight and height of children during the early developmental phase. Studies from Bangladesh supported these results, showing that households without proper sanitation have a higher prevalence of stunting than households with good sanitation facilities. [40] In addition, good sanitation not only prevents infections but also increases awareness of the importance of hygiene at the household level, which positively impacts the nutritional status of children.

Handwashing with soap is crucial for infection prevention and enhancing children's nutritional health. Children from households with inadequate handwashing practices are 2.3 times more likely to experience stunting. Research in Ethiopia indicates that maternal handwashing practices substantially reduce the risk of stunting in young children. [27] Such a conclusion is corroborated by international research indicating that teaching on the significance of handwashing with soap, as part of community intervention programs, enhances the overall health and nutritional status of children. These findings highlight the importance of integrating environmental health interventions with nutrition programs to reduce childhood stunting. Public health strategies should prioritize improving access to safe drinking water, expanding sanitation infrastructure, and promoting hygiene education programs, particularly among rural communities where environmental risk factors are more common.

This study has several strengths and limitations. It is one of the first to assess the prevalence of stunting and its environmental determinants among children under 5 years of age across diverse geographical settings, providing valuable insights for determining global public health policy. However, several limitations must be considered. First, the review included only quantitative observational studies published in English, possibly excluding relevant studies in other languages. Second, the high heterogeneity observed may reflect differences in geographical settings, study populations, and measurement methods. Finally, most studies employed cross-sectional designs, which limit the ability to establish causal relationships between environmental determinants and stunting. Therefore, the findings should be interpreted with caution.

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Conclusion

This study indicates a significant prevalence of stunting among children under 5 years of age. Children residing in rural regions were more prone to stunting than their urban counterparts. Environmental factors, including access to safe drinking water, toilet facilities, sanitation conditions, and handwashing practices, significantly influence the risk of stunting. Efforts across multiple avenues are essential to enhance access to clean water, sanitation facilities, and hygiene practices, particularly in rural regions. Public health strategies should prioritize improving access to safe drinking water, expanding sanitation infrastructure, and strengthening hygiene promotion programs in communities at a greater risk of stunting. Programs aimed at enhancing public awareness regarding the significance of nutrition and hygiene are essential.
In addition, interventions during the first 1,000 days of life should include maternal nutrition support, promotion of exclusive breastfeeding, appropriate complementary feeding, and regular monitoring of child growth to prevent long-term growth impairment.

Author contributions

YF contributed substantially to the concept and design of this study, acquiring the data, reviewing the literature, and its analysis and interpretation. DD, FMS, and MKF contributed substantially to acquiring the data. MA and DKN contributed to drafting the manuscript. WW and AS edited the manuscript critically for important intellectual content. All authors approved the final version submitted for publication and take responsibility for statements made in the published article.

Acknowledgements

The authors would like to thank the Universitas Dehasen Bengkulu, College of Health Sciences Bhakti Husada Bengkulu, and Universitas Jenderal Achmad Yani Cimahi for providing support so that this research can be carried out as expected.

Conflicts of interest statement

The authors have declared that no competing interests exist.

Data sharing statement

All data generated or analyzed in the present study are included in the published article. Further details are available for non-commercial purposes from the corresponding author upon reasonable request.

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