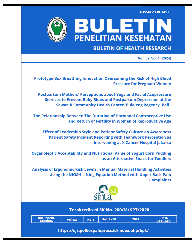

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Water, Hygiene, and Sanitation Risk Factors towards Stunting among Children (0-14 years): A Systematic Literature Review

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ABSTRACT

Background: Stunting remains a major public health problem in low- and middle-income countries and is closely linked to inadequate water, sanitation, and hygiene (WASH) conditions through repeated infections and impaired nutrient absorption. Evidence on the role of WASH across a broader child age range remains limited. This study aimed to systematically review the association between WASH factors and stunting among children aged 0–14 years.
Methods: A systematic literature review was conducted following PRISMA guidelines. Articles published in English between 2013 and 2023 were retrieved from PubMed and Scopus using the keywords "water," "sanitation," "hygiene," "WASH," and "stunting." Observational studies conducted in low- and middle-income countries were included. Two reviewers independently screened titles, abstracts, and full texts.
Results: A total of 83 studies were included, predominantly cross-sectional in design. Most studies were conducted in East Africa and Southeast Asia. Consistent evidence showed that unimproved water sources, lack of water treatment, poor sanitation facilities, open defecation, unsafe disposal of child feces, and inadequate hygiene practices—particularly handwashing—were significantly associated with increased risk of stunting. Improved water access, sanitation infrastructure, and hygiene behaviors were identified as protective factors.
Conclusion: Inadequate WASH conditions are strongly associated with childhood stunting. Integrating WASH interventions, especially sanitation and hygiene improvements, with nutrition programs is essential to reduce stunting and promote healthy child growth in low- and middle-income countries.

INTRODUCTION

An approximate 144 million children across the globe, who are under the age of 5, exhibit stunted growth as a direct consequence of inadequate nutrition, which accounts for approximately 21.3% of the global child population (Waller et al., 2020). From 2000 to 2020, the worldwide rate of stunting declined from around 30.3% to 22%. However, despite this notable decrease, it was estimated that in 2019, 21.3% of children under the age of five globally were still affected by stunting (Janawisuta & Gunawan, 2024).

Childhood stunting continues to pose a major barrier to progress in human development (Nadhiroh et al., 2023; Soofi et al., 2023). Stunting is defined as a condition where a child's height or length is significantly below the expected standard for their age, specifically more than two standard deviations below the World Health Organization's child growth standards (Thahir et al., 2023; Yani et al., 2023). The consequences of stunting are both immediate and long-term, including higher risks of illness and death, impaired physical and cognitive development, increased vulnerability to infections and chronic diseases later in life, and reduced productivity and economic potential (Beal et al., 2018; G. Berhanu et al., 2018). Access to adequate water, sanitation, and hygiene practices is a fundamental human right.

Access to adequate sanitation remains a significant global concern, with 46% of the world's population lacks access to safely managed sanitation. This underscores the complexities involved in formulating and implementing robust public policies aimed at improving sanitation infrastructure, which is essential for ensuring optimal nutritional status among children. (Mudadu Silva et al., 2023). It was found in a recent study, that the occurrence of stunting is associated with environmental sanitation, and personal hygiene (WASH) practices via various mechanisms, including recurrent episodes of diarrhea, pathways of infection, and the presence of environmental enteric dysfunction (Woldesenbet et al., 2023). Access to water is adequately provided for, reasonably priced, and physically obtainable, encompassing secure water of satisfactory quality. Access to sanitation pertains to the accessibility and utilization of facilities or services for the disposal of urine and feces. Hygiene denotes the circumstances and behaviors at the personal or communal level aimed at averting infection through contamination (Gaffan et al., 2023). Epidemiological research utilizing various methodologies was utilized to elucidate the impact of WASH practice on the occurrence, prevention, or mitigation of stunting (S. Das et al., 2021). Recent findings indicate that water, sanitation, and hygiene (WASH) behaviors influence children's nutritional health, particularly their linear growth during early childhood. Poor hygiene, inadequate sanitation, and water contamination have been identified as contributing factors to the ingestion of fecal pathogens, resulting in the development of intestinal infections. These infections have been observed to worsen a child's nutritional status by diminishing their appetite and impeding nutrient absorption, while also increasing nutrient depletion (Rah et al., 2020). The combination of enhanced water, sanitation, and hygiene (WASH) practices with enhanced infant diets is a rational strategy, attributable to the significant impact of WASH on the reduction of morbidity, particularly intestinal infection (Makasi & Humphrey, 2020).

To the best of our knowledge, there is a lack of comprehensive systematic reviews examining the relationship between WASH risk factors and stunting in children. Existing reviews have primarily focused on children under the age of five, with limited studies addressing a broader age range.

Therefore, to fulfill this gap, the aim of this systematic review was to evaluate the WASH risk factors associated with stunting among children agen 0-14 The investigation posits that the absence of availability of water, sanitation, and hygiene (WASH) contributes to a higher prevalence of diarrheal ailments that impede the growth of children. Therefore, research question of this study is "Do WASH (Water, Sanitation, and Hygiene) factors influence the prevalence of stunting among children aged 0-14 years in low- and middle-income countries?"

METHODS

A systematic review of available literature was undertaken to discern the linkages between washing, hygiene, and sanitation practices and the manifestation of chilhood stunting. The ensuing exploration methodology is delineated in the following section.

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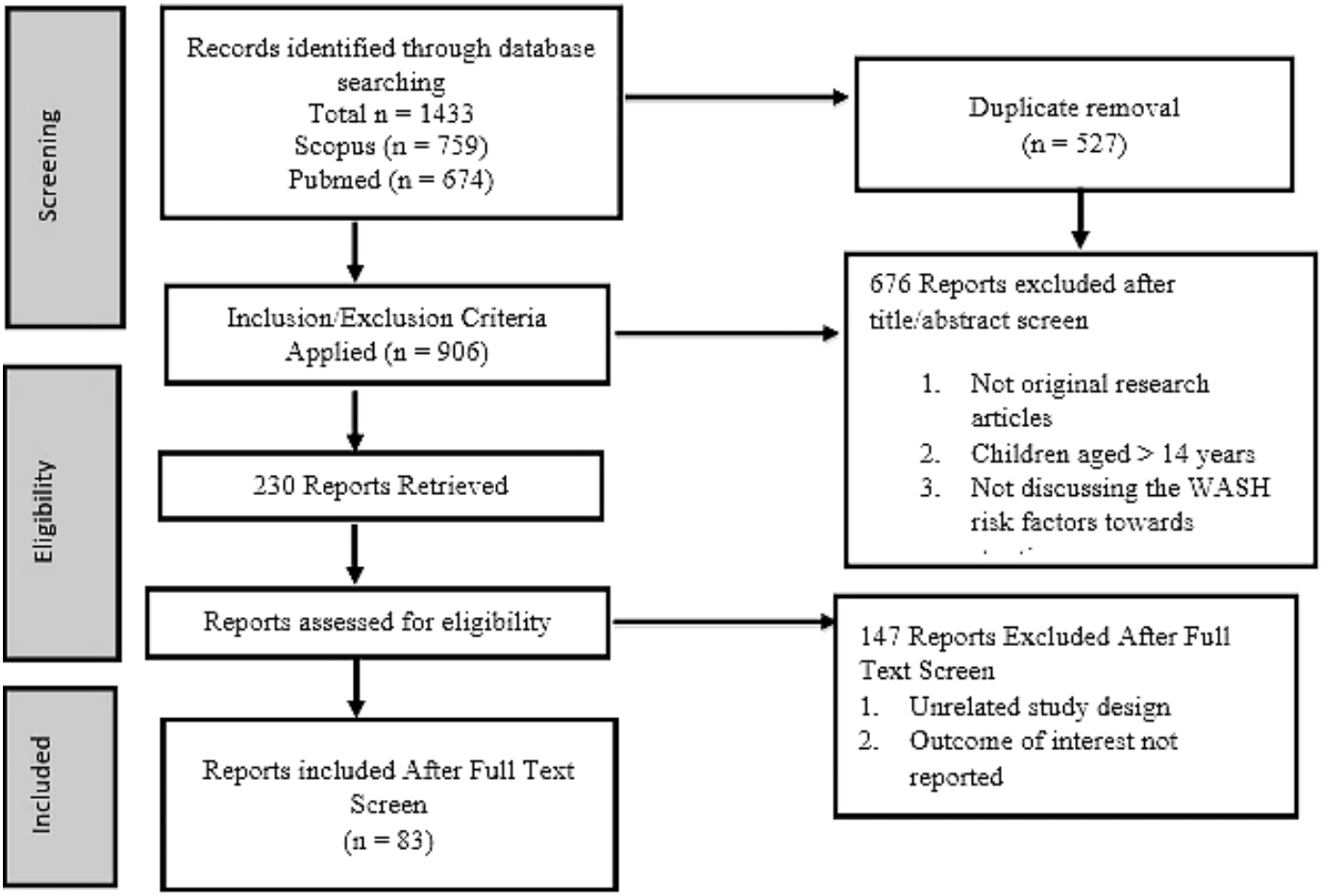

Figure 1. Flow chart illustrating the selection process of documents to be included in this review guided by PRISMA

Search strategy

This study followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines for reporting systematic reviews. A thorough literature search was performed to identify English-language articles published between January 1, 2013, and September 20, 2023, using the PubMed and Scopus databases. The search employed the keywords ("Hygiene" OR "Sanitation" OR "WASH" AND "Stunting"). The Population, Exposure, and Outcome (PEO) elements of the research question are presented in Table 1, serving as the framework for formulating systematic review questions in observational studies. The primary research question posed was: "What WASH-related risk factors are associated with stunting in children?" Titles and abstracts were screened based on the inclusion and exclusion criteria outlined in Table 1, after which the full texts of the eligible articles were retrieved and assessed.

Screening of the articles

The screening of articles was undertaken independently by two reviewers through a systematic, multi-stage process, which included identifying pertinent keywords within both databases, selecting suitable titles and abstracts, and evaluating the availability and relevance of the full texts against the predetermined inclusion criteria. (see Table 1).

Table 1. Describing The Population (P), Exposure (E), Outcome (O) elements of the research question, the inclusion and exclusion criteria

PEO elements of the research question	
PEO elements of the research question	
P – Children aged 0-14 years	
E – WASH risk factors including the availability and accessibility of improved water source, individual hygiene practice, and access to improved sanitation facilities	
O – Stunting. The anthropometric indices measured included height, length, and length- or height-for-age z-scores (HAZ). Stunting, defined as HAZ values more than 2 standard deviations below the International Reference Standard, was used to assess nutritional imbalance. According to WHO and UNICEF, HAZ scores below -2 SDs are considered indicative of stunting	
Inclusion criteria	**Exclusion criteria**
Studies related to the PEO of the research question	Studies unrelated to PEO of the research question
Children aged 0-14 years	Children aged more than 14 years
All descriptive, observational, cohort, cross-sectional, case-control will be included in the review	All review studies, randomised/non-randomised control trials, case reports, case series, letter to the editors will be excluded

Data Selection

The conduct of data extraction has been performed, followed by a comprehensive discussion of any issues that have been observed in the context of each article within the results section. In the case of all articles, a thorough and independent extraction of data has been carried out, encompassing multiple variables of interest. These variables include the year of publication, study design, population, sampling size, geographical location, country, type of study, water, hygiene and sanitation (WASH) components, and findings.

RESULTS

The initial process of conducting a thorough search in the literature resulted in the identification of a total of 1433 citations then reduced to 906 after removing duplicates. Subsequent screening of the title and abstract was carried out to determine their relevance to the research question. As a result of this screening, a total of 676 records were excluded from further consideration. The final systematic review included a total of 83 studies, which were selected based on specific inclusion and exclusion criteria. These studies were published between the years 2013 and 2023.This systematic literature review did not include a formal quality assessment of the studies, which limits the ability to evaluate the methodological rigor and potential biases of the included research. As a result, the findings may be influenced by studies of varying quality, and the strength of the evidence supporting the conclusions cannot be fully determined.

Characteristics of Included Studies

The overview of the investigations encompassed in this review was categorized according to sub-regions (see Table 2). Geographically, studies were conducted in East Africa region (Ethiopia, Uganda, Tanzania, and Rwanda), Middle Africa (Cameroon, Angola and Democratic Republic of Congo), West Africa (Ghana, Guinea, and Benin), South Asia (Pakistan, India, Bangladesh, and Nepal), South-east Asia (Indonesia, Malaysia, Vietnam, Philippines, and Cambodia), South America (Ecuador, Colombia, Brazil, and Peru), remaining studies were based in East Europe (Armenia), Oceania (Vanuatu), and East Asia (China). The studies that were incorporated in the analysis comprised five case-control studies, two prospective cohort studies, and 75 cross-sectional studies. All of these studies were conducted in low- and middle-income countries as per the classifications provided by the World Bank.

Table 2. Summary of the key findings (*n* = 83)

Geographic Region	n	%
Multi region	4	4.82
East Asia	1	1.20
South Asia	18	21.69
South East Asia	20	24.10
East Africa	29	34.94
Middle Africa	3	3.61
West Africa	3	3.61
South America	3	3.61
East Europe	1	1.20
Oceania	1	1.20
Type of Study		
Cross sectional	75	90.36
Case control	6	7.23
Prospective cohort	2	2.41
WASH component		
Water	8	9.64
Hygiene	10	12.05
Sanitation	15	18.07
Water Higiene	5	6.02
Higiene and Sanitation	6	7.23
Water Sanitation	24	28.92
Water Higiene Sanitation	15	18.07

Table 3 presents findings from various cross-sectional studies conducted across multiple geographic regions, focusing on the relationship between Water, Sanitation, and Hygiene (WASH) components and determinants of stunting among children. Most studies are cross-sectional, allowing for the examination of associations at a specific point in time, though some case-control studies are also included. The populations studied range from small samples (around 100) to large cohorts (over 200,000), enhancing the reliability of findings in larger studies. The table categorizes the studies based on specific WASH components—primarily water, sanitation, and hygiene practices—highlighting how access to improved water sources, sanitation facilities, and hygienic practices correlate with reduced stunting risk.

Key determinants of stunting identified include water quality, sanitation access, and hygiene practices (See Table 3). Unimproved drinking water sources significantly increase the odds of stunting, with studies from Ethiopia and other regions showing that treated and safe drinking water is associated with better health outcomes. Access to improved sanitation facilities is crucial, as poor sanitation practices, such as open defecation or using unimproved toilet facilities, correlate with higher odds of stunting. Additionally, handwashing practices before meals and after using the toilet are strongly linked to reduced stunting; poor hygiene practices increase the likelihood of stunting, as indicated by several studies. Statistical findings, such as odds ratios (OR) and confidence intervals (CI), quantify these relationships, with an OR greater than 1 indicating increased risk associated with specific WASH conditions. Variability exists in how these factors influence stunting across different regions, underscoring the need for region-specific interventions. In conclusion, this table underscores the significant impact of WASH components on child health, suggesting that improving water quality, sanitation facilities, and hygiene practices can substantially mitigate the risk of stunting in young children across diverse geographic contexts.

Table 3. A systematic review of stunting determinants for stunting among children

No	Geographic Region	Country	Type of Study	Population	Sample Size	WASH component	Finding (stunting determinants)	Refe-rences
1	East Africa	Ethiopia	Cross-sectional	Children < 5 years and mothers/caregivers	630	Water Hygiene Sanitation	Unimproved drinking water source (OR= 3.854, 95% CI: 2.13, 6.97); Poor hygienic practice of households (OR= 2.434, 95% CI: 1.74, 3.403); unimproved sanitation status OR= 1.712, 95% CI: 1.231, 2.379)	(Ademas et al., 2021)
2	South Asia	India	Cross-sectional	The mother or principal caretaker of children 0–23 months old	2630	Sanitation	No access to improved sanitation (OR= 1.324, 95% CI: 1.182, 2.481)	(Aguayo et al., 2016)
3	South Asia	Pakistan	Cross-sectional	Children 6-59 months	504	Hygiene Sanitation	No practice of handwashing before meals (OR= 1.39, 95% CI: 1.25,1.75); Hand washing without soap after toilet (OR= 3.72, 95% CI: 0.56, 5.66); No access to latrine facilities (OR= 1.45, 95% CI: 1.22, 2.12); Using ponds as a source of water (OR= 1.85, 95% CI: 1.34, 2.56)	(Ahmad et al., 2022)
4	South-east Asia	Indonesia	Cross-sectional	Families with children < 5 years	393	Sanitation	Environmental sanitation of family (OR= 0.254; 95% CI: 0.163, 0.397).	(Ainy et al., 2021)
5	East Africa	Tanzania	Cross-sectional	Children aged 6 to 59 months	204	Water	Functioning water station (OR=0.63, 95% CI: 0.40, 0.98); Improved water source (OR= 0.70, 95% CI: 0.52, 0.93)	(Altare et al., 2016)
6	East Africa	Ethiopia	Cross-sectional	School children, aged 7-14 years	861	Water Hygiene	Using treated drinking water (OR= 0.32, 95% CI: 0.11, 0.97); Not washing hands with soap after use of latrine (OR= 4.30, 95% CI: 1.21, 15.3)	(H. H. Amare & Lindtjorn, 2021a)
7	East Africa	Ethiopia	Cross-sectional	Mother and their children aged 0-59 months	9420	Sanitation	Non-improved toilet (OR= 1.28, 95% CI: 1.07, 1.53)	(Z. Y. Amare et al., 2019)
8	South-east Asia	Indonesia	Cross-sectional	Children aged 25–59 months	123	Water Hygiene	Clean water source (OR= 0.024, 95% CI: 0.01–0.85); Poor hygiene (handwashing) (OR= 2.742, 95% CI: 1.194, 6.293)	(Astuti et al., 2020)
9	Sub-Saharan Africa, Asia, and North Africa	34 low- and middle-income countries	Cross-sectional	Children under five and children under two	202,614 (children < 5 years); 82,949 (children < 2 years)	Sanitation	Disposal of child feces in an improved toilet was associated with an adjusted prevalence ratio (aPR) of 0.90 (95% CI: 0.89–0.92). Among households with access to improved sanitation, practicing proper disposal of child feces was linked to a prevalence ratio (PR) of 0.94 (95% CI: 0.91–0.96).	(Bauza & Guest, 2017)

No	Geographic Region	Country	Type of Study	Population	Sample Size	WASH component	Finding (stunting determinants)	Refe-rences
10	East Africa	Ethiopia	Cross-sectional	Primary school children	341	Hygiene	Washing hands less frequently before eating (OR= 3.96, 95% CI: 2.09, 11.66); Less frequent handwashing practice after defecation (OR= 2.17, 95% CI: 0.070, 4.42)	(Bazie et al., 2021)
11	East Africa	Ethiopia	Cross-sectional	Children under five-mother or caregiver pairs	11023	Water Hygiene Sanitation	Improved WASH facilities (OR = 0.67; 95% CI: 0.45, 0.98)	(Bekele et al., 2020)
12	South-east Asia	Indonesia	Cross-sectional	Mothers of toddlers aged 0-59 months	182	Water Sanitation	Gallon drinking water (OR= 0.42, 95% CI: 0.20, 0.90); Using standard latrines (OR= 0.31, 95% CI: 0.13, 0.75), Wastewater sewerage construction materials from cement (OR= 0.28, 95% CI: 0.09, 0.83 and pipes (OR= 0.23, 95% CI: 0.07, 0.80), Managed solid waste (OR= 0.17: 0.04, 0.69)	(Berawi et al., 2023)
13	East Africa	Ethiopia	Cross-sectional	School-age children from age 5–14 years and their parents or caregiver	606	Sanitation	Absence of latrines (OR= 2.54, 95% CI: 1.71, 3.77)	(A. Berhanu et al., 2022)
14	East Africa	Ethiopia	Cross-sectional	Preschool children aged 24-59 months	1073	Water	The amount of water (<40 litters) for use (OR= 1.58, 95% CI: 1.06, 2.34); Time spent on the water (≥ 30 minutes) (OR= 1.29, 95% CI: 0.84, 1.98)	(G. Berhanu et al., 2018)
15	Sout-east Asia	Philippines	Cross-sectional	Children ages 0-60 months and 61-120 months in households headed by fisherfolks	13,423 children ages 0–60 months; 16,398 school children ages 61–120 months	Sanitation	Water-sealed toilet (OR= 0.55, 95% CI: 0.50, 0.60)	(Capanzana et al., 2018)
16	Sub-Saharan Africa countries	Sub-Saharan Africa countries	Cross-sectional	Caregivers	33,846	Water Sanitation	Improved water source for drinking (OR= 0.99, 95% CI: 0.930, 1.064); Improved sanitation (OR= 0.82, 95% CI: 0.764, 0.885)	(Christian et al., 2023)

No	Geographic Region	Country	Type of Study	Population	Sample Size	WASH component	Finding (stunting determinants)	Refe-rences
17	South Asia	India	Cross-sectional	Children aged 6–59 months	186,875	Water Sanitation	Unsafe disposal of child stool (OR= 1.1, 95% CI: 1.1, 1.2); Unimproved sanitation (OR= 1.1, 95% CI: 1.1, 1.1); Low regional water availability (OR= 1.3, 95% CI: 1.2–1.3)	(M. Das et al., 2022)
18	South Asia and South America	Bangladesh, India, Nepal, and Brazil	Cross-sectional	Children aged 6-59 months	186,875	Water Hygiene Sanitation	Frequent handwashing behavior (OR= 0,52, 95% CI: 0,12, 2,23); Treated with drinking water (OR= 0,48, 95%CI: 0,09, 2,68); Households with a toilet just outside the compound (OR= 0,995, 95% CI: 0,22, 4,48)	(M. V De Vita et al., 2019)
19	East Africa, South Asia, South America, and South-east Asia	Ethiopia, India, Peru, and Vietnam	Prospective cohort	Children 1 year, 5 years, and 8 years	8062	Water Sanitation	Ethiopia: Access to improved water (RR= 0.84, 95% CI: 0.75,0.94); Access to improved toilets (RR= 0.46, 95% CI: 0.36, 0.59); India: Access to improved water (RR= 1.00, 95% CI: 0.85, 1,17); Access to improved toilets (RR= 0.59, 95% CI: 0.49, 0.71); Peru: Access to improved water (RR= 0.74, 95% CI: 0.63, 0.87); Access to improved toilets (RR= 0.62, 95% CI: 0.53, 0.72); Vietnam: Access to improved water (RR= 0.22, 95% CI: 0.11, 0.41); Access to improved toilets (RR= 0.61, 95% CI: 0.50, 0.74)	(Dearden et al., 2017)
20	East Africa	Ethiopia	Cross-sectional	Mother-child (age 6-59 months) pairs	815	Hygiene Sanitation	Not washing hands before food preparation by the mother (OR= 1.46, 95% CI: 1.1, 2.0); Not washing hands after the mother cleans the baby (OR= 1.48, 95% CI: 1.1, 2.1); Managing solid wastes by scattering in the field (OR =1.6, 95% CI: 1.1, 2.1)	(Demilew & Alem, 2019)
21	East Europe	Armenia	Case-control	Children aged 0-59 months	193	Hygiene	Never/rarely using soap forchild's hand washing (OR= 3.61, 95% CI: 1.21,10.71)	(Demirchyan et al., 2016)
22	South-east Asia	Indonesia	Cross-sectional	Toddlers	191	Sanitation Hygiene	Environmental sanitation hygiene(OR= 44.000, 95% CI: 12.233–158.255)	(Fadjriah et al., 2021)
23	South Asia	Bangladesh	Cross-sectional	Ever-married women between the age of 15–49 years	6,341	Sanitation	Unimproved toilet facilities (OR= 1.863, 95% CI: 1.737, 2.010)	(Faisal Ahmed et al., 2021)
24	East Africa	Ethiopia	Cross-sectional	Children < 5 years	8,714	Sanitation	Unimproved toilet facilities (OR= 1.41, 95% CI: 1.18, 1.68)	(Farah et al., 2021)
25	Middle Africa	Angola	Cross-sectional	Children < 5 years	742	Water	Water supply came from the river or lake (PR=1.19, 95% CI, 0.89, 0.59)	(Fernandes et al., 2017)

No	Geographic Region	Country	Type of Study	Population	Sample Size	WASH component	Finding (stunting determinants)	Refe-rences
26	South America	Ecuador	Cross-sectional	Children < 5 years	1618	Sanitation	Improved sanitation (PR 0.86, 95% CI: 0.64, 1.15)	(Fuller et al., 2016)
27	South-east Asia	Indonesia	Cross-sectional	Children aged 6–35 months	1450	Water Sanitation	Improved source of drinking water(OR= 0.91, 95% CI: 0.70, 1.18); Improved sanitation facility(OR= 0.71, 95% CI: 0.51, 0.97)	(Rah et al., 2020)
28	South Asia	India	Cross-sectional	Children 0–23 months	10,364 (NFHS-3); 34,639 (HUNGaMA); 1282 (CNSM)	Sanitation Hygiene	Household access to toilet facility based on three survey data sets (OR=0.84, 95% CI: 0.71, 0.99, OR=0.84, 95% CI: 0.78, 0.91, and OR=0.61, 95% CI: 0.44, 0.85); Practices of washing hands with soap before meals (OR=0.85, 95% CI: 0.76, 0.94) or after defecation (OR=0.86, 95% CI: 0.80, 0.93)	(Rah et al., 2015b)
29	South-east Asia	Malaysia	Cross-sectional	Mothers with children aged 0-59 months	808	Sanitation	Having poor environment and sanitation within the household (OR=1.429, 95% CI: 0.840, 2.432)	(Rahman et al., 2021)
30	East Africa	Ethiopia	Cross-sectional	Households with children < 5 years	1091	Water	Non-piped water source (OR= 1.5, 95% CI: 1.07, 2.00); Untreated drinking water (OR= 1.9, 95% CI: 1.31, 2.85)	(Roba et al., 2021)
31	South Asia	India	Cross-sectional	Children aged 0–59 months	146,521	Water Sanitation	Unsafe water (OR= 1.11, 95% CI: 1.02, 1.26); Improper sanitation (OR= 1.06, 95% CI: 1.03, 1.10);	(Roy et al., 2023)
32	West Africa	Ghana	Cross-sectional	Children aged 6–23 months and their mothers/caregivers	301	Water Hygiene Sanitation	Unimproved source of drinking water (OR= 3.48, 95% CI: 1.32, 9.16); Availability of toilet facility (OR= 0.97, 95% CI: 0.47, 2.02); Improper disposal of child feces (OR= 1·49, 95% CI: 0.74, 3.02); Handwashing with soap (OR= 0.53, 95% CI: 0.07, 4.21); Not havingimproved water + toilet facility + proper child feces disposal (OR= 1.21, 95% CI: 0.55, 2.68)	(Saaka et al., 2021)
33	East Africa	Ethiopia	Cross-sectional	Children aged < 5 years	33,763	Water Sanitation	Open defecation (OR= 2.13, 95% CI: 1.98,2.29); Unimproved toilet (OR=1.61, 95% CI: 1.49,1.74); Unimproved source of drinking water (OR= 1.39, 95 CI: 1.32, 1.46); Unimproved household flooring (OR= 2.82, 95% CI: 2.60, 3.05); More than 30 minutes to get water source (OR= 2.80, 95% CI: 2.53,3.09); Poor drinking water service (OR= 1.42, 95% CI : 1.34, 1.49); Unimproved Water + Unimproved Sanitation (OR= 2.57, 95% CI: 2.36, 2.79)	(Sahiledengle et al., 2022)

No	Geographic Region	Country	Type of Study	Population	Sample Size	WASH component	Finding (stunting determinants)	Refe-rences
34	South Asia	Bangladesh	Cross-sectional	Children	187	Water Sanitation Hygiene	Unimproved toilet type (OR= 2.61, 95% CI: 0.94, 7.25); No treatment of drinking water (OR= 2.50, 95% CI: 1.03, 6.05); Presence of insects/pests in the cookingarea (OR= 2.16, 95% CI: 0.98, 4.78)	(Sanin et al., 2022)
35	East Africa	Ethiopia	Cross-sectional	Children aged 6-23 months with their mothers or caregivers	421	Hygiene	Handwashing without soap or ashes (OR= 2.32, 95% CI: 1.05, 5.11)	(Sewenet et al., 2022)
36	East Africa	Rwanda	Cross-sectional	Children aged < 2 years	5062	Water Sanitation	Improved source of drinking water (PR = 0.80, 95% CI: 0.73, 0.87); Treating their drinking water using adequate methods (PR = 0.88, 95% CI: 0.80, 0.96); Having an improved sanitation facility (PR = 0.90, 95% CI: 0.82, 0.97), Structurally complete sanitation facility (PR = 0.65, 95% CI: 0.50, 0.84), Households practice open defecation (PR = 1.44, 95% CI: 1.21, 1.71).	(Sinharoy et al., 2016)
37	East Africa	Ethiopia	Cross-sectional	School-aged children (6-14 years)	821	Water Sanitation Hygiene	Poor hygiene practice (OR= 1.64, 95% CI: 1.01,2.68); Unimproved water source (OR= 1.76, 95% CI: 1.07,2.91); Untreated water (OR= 1.1, 0.686, 1.79); Unimproved latrine type (OR= 1.72, 95% CI: 1.03, 2.89)	(Sisay et al., 2022)
38	South Asia	Pakistan	Cross-sectional	Children < 5 years	52,602	Water Sanitation	Unimproved drinking water sources (OR= 1.158, 95% CI: 1.062, 1.262); Unimproved sanitation facilities (OR= 1.144, 95% CI: 1.068, 1.226);	(Soofi et al., 2023)
39	South Asia	Pakistan	Cross-sectional	Children < 2 years	984	Sanitation	Poor toilet facility (OR= 2.00, 95% CI: 1.35, 2.72)	(Tariq et al., 2018)
40	East Africa	Uganda	Cross-sectional	Children < 5 years	14,492	Water Hygiene Sanitation	Improved drinking water quality (OR= 0.83, 95% CI: 0.70, 0.99); Improved sanitation facility (OR= 0.64, 95% CI: 0.49, 0.86); Basic hygiene facility (OR= 1.01, 95% CI: 0.83, 1.23)	(Terfa et al., 2022a)
41	South-east Asia	Indonesia	Cross-sectional	Children aged 0-23 months	1366	Water Hygiene Sanitation	Unimproved sanitation (OR= 1.71, 95% CI: 1.37, 2.15); Unsafe disposal of child feces (OR= 1.10, 95% CI: 0.87, 1.40); Not using soap for handwashing (OR= 1.29, 1.00, 1.67); Untreated water (OR= 1.59, 95% CI: 1.08, 2.34); Unimproved water source (OR= 0.86, 95% CI: 0.67 - 1.10)	(Torlesse et al., 2016)
42	South-east Asia	Indonesia	Case-control	Children aged 1-60 months	194	Water Sanitation	Unimproved sanitation (OR= 2.98, 95% CI: 1.62, 5.48); Unimproved water source (OR= 2.71, 95% CI: 1.50, 4.88)	(Wicaksono et al., 2021)
43	South-east Asia	Indonesia	Cross-sectional	Children aged 0-59 months	3887	Sanitation	Good sanitation (OR= 0.77, 95% CI: 0.65, 0.90)	(Widyaningsih et al., 2018)

No	Geographic Region	Country	Type of Study	Population	Sample Size	WASH component	Finding (stunting determinants)	Refe-rences
44	East Africa	Ethiopia	Cross-sectional	Children aged 24 to 59months	415	Hygiene Sanitation	Unimproved toilets (OR= 3.6, 95% CI: 1.43, 9.03); Unsafe child feces disposal (OR= 2.7, 95% CI: 1.6,5.3); No handwashing with soap after defecation (OR= 3.1, 95% CI: 1.3, 8.3); No handwashing before feeding the children (OR=6.2, 95% CI: 2.1, 19.1)	(Woldesenbet et al., 2023)
45	West Africa	Guinea	Cross-sectional	Children 24-59 months	1633	Water Sanitation	Unsafe water source (OR= 1.3, 95% CI: 1.01, 1,7); Appropriate child stool disposal (OR= 1.4, 95% CI: 1.1, 1.8)	(Woodruff et al., 2018)
46	South-east Asia	Indonesia	Cross-sectional	Mothers with infants aged 0–23 months	152	Water Sanitation Hygiene	Unimproved sanitation (OR= 1.26, 95% CI: 0.99, 1.63); Unimproved water source (OR= 0.87, 95% CI: 0.67, 1.10); Not using soap for handwashing (OR= 1.28, 95% CI: 1.00, 1.67); Untreated water (OR= 1.57, 95% CI: 1.08, 2.34)	(Yunitasari et al., 2022)
47	South-east Asia	Indonesia	Case-control	Children aged 6–59 months and their mothers or caregivers	160	Sanitation	Access to sanitation (OR = 6.06, 95% CI: 1.25, 29.35).	(Yushananta & Ahyanti, 2022)
48	West Africa	Benin	Cross-sectional	Children aged 0-5 years	11,253	Water Sanitation Hygiene	Households using surface water were (OR= 1.35, 95% CI:1.15, 1.59); Households practicing open defecation (OR= 1.27, 95% CI: 1.01, 1.59); Households with no hygiene facilities (OR= 1.31, 95% CI: 1.05, 1.63); Households using limited hygiene services (OR= 1.35, 95% CI: 1.10, 1.67)	(Gaffan et al., 2023)
49	South America	Colombia	Cross-sectional	Children aged < 5 years	6963	Water Sanitation	Access to water (PR= 1.15, 95% CI: 0.93, 1.41); Access to sanitation (PR= 0.69, 95% CI: 0.56, 0.84)	(Garcia et al., 2013)
50	East Africa	Ethiopia	Cross-sectional	Children aged < 5 years	394	Hygiene	Presence of washing facilities nearby latrine (OR= 2.363, 95% CI: 1.320,4.229)	(Gebru et al., 2019)
51	East Africa	Ethiopia	Cross-sectional	Children aged 24-59 months and mothers	401	Water Hygiene	Poor handwashing practice (OR= 1.40, 95% CI: 0.83, 2.32); Adequate water (OR= 0.81, 95% Ci: 0.42,1.56);	(Girma et al., 2019)
52	East Africa	Ethiopia	Cross-sectional	Children aged 24-59 months	224	Water Hygiene Sanitation	Open field defecation (OR= 3.0, 95% CI: 1.2, 7.9); E. coli contamination in drinking water (OR= 4.2, 95% CI: 1.1, 15.3); E. coli detected in ready-to-eat food (OR= 1.4; 95% CI: 0.4, 4.5); Animal excreta in the living environment (OR= 3.4, 95% CI: 1.2, 9.9)	(Gizaw et al., 2022)
53	South Asia	Pakistan	Cross-sectional	Children aged < 2 years	10,080	Water Sanitation	Improved source of drinking water (OR= 0.65, 95% CI: 0.55, 0.76); Treat water to make it safer (OR= 0.54, 95% CI:	(Haq & Abbas, 2022a)

No	Geographic Region	Country	Type of Study	Population	Sample Size	WASH component	Finding (stunting determinants)	Refe-rences
							0.39, 0.74); Improved sanitation (OR= 1.14, 95% CI: 1.00–1.29)	
54	South Asia	Bangladesh	Cross-sectional	Children aged 12–23 months	9501	Hygiene Sanitation	No hygienic latrine (OR= 1.20, 95% CI: 1.10 to 1.30); Water and soap available in the handwashing place (OR= 1.19, 95% CI: 1.08 to 1.30)	(Haque et al., 2023)
55	South Asia	Bangladesh	Cross-sectional	Children aged 0-59 months	22,521 and 7993	Hygiene Sanitation	No access to a basic sanitation facility (OR= 1.12, 95%CI: 1.03, 1.22); No access to a handwashing facility (OR= 1.30,95%CI: 1.10, 1.54).	(Hasan et al., 2023a)
56	South-east Asia	Indonesia	Case-control	Children aged 7–24 months	150	Water Hygiene Sanitation	High-risk WASH condition (OR=2.7, 95% CI: 1.379, 5.566)	(Hasanah et al., 2020)
57	East Africa	Tanzania	Cross-sectional	Pupils aged 5-12 years	400	Hygiene	No handwashing practices after visiting the toilet at school (OR= 3.5, 95% CI: 1.62, 7.58); No handwashing practices after visiting the toilet at home (OR= 13.0, 95% CI: 2.73, 6176)	(Hiliza et al., 2020)
58	South America	Brazil	Cross-sectional	Children aged < 5 years	6055	Water Sanitation	Household without piped drinking water (PR= 1.89, 95% CI: 1.20, 2.96); No access to trash collection service (PR= 2.55, 95% CI: 1.59, 4.10)	(Horta et al., 2013)
59	South-east Asia	Vietnam	Cross-sectional	Children < 5 years	938	Water Sanitation	Unprotected drinking water (RR: 1.13, 95% CI: 1.09, 1.17); Having unsanitary latrine (RR= 1.45, 95% CI: 1.29, 1.62)	(Htet et al., 2023)
60	South-east Asia	Cambodia	Cross-sectional	Children < 5 years	10,366	Water Sanitation	Improved drinking water source in the dry season (OR= 1.0341, 95% CI: 0.9318, 1.1476); Improved sanitation facility (OR= 0.8145, 95% CI: 0.6902, 0.9612)	(Ikeda et al., 2013)
61	South Asia	India	Cross-sectional	Children < 5 years	12,925	Hygiene	Poor handwashing practice of mothers (OR= 1.15, 95% CI: 1.06, 1.24)	(Ishwarji et al., 2019)
62	East Africa	Uganda	Cross-sectional	Children aged 6-59 months	640	Sanitation	Disposal of child stool by putting or rinsing in the latrine (OR= 0.41, 95% CI: 0.23, 0.74); Disposal of child stool by throwing in the garbage (OR= 0.29, 95% CI: 0.12, 0.72)	(Kasajja et al., 2022)
63	East Africa	Ethiopia	Cross-sectional	Children < 5 years	1339	Sanitation	No toilet facilities (OR = 1.45, 95% CI: 1.12, 1.87)	(Kebede & Aynalem, 2021)
64	Middle Africa	Democratic Republic of Congo	Cross-sectional	Children < 5 years	8884	Water Sanitation	Access to safe water (OR= 0.89, 95% CI: 0.67, 1.19); Access to hygienic toilet (OR= 0.80, 95% CI: 0.48, 1.31);	(Kismul et al., 2017)

No	Geographic Region	Country	Type of Study	Population	Sample Size	WASH component	Finding (stunting determinants)	Refe-rences
65	South-east Asia	Cambodia	Cross-sectional	Children aged ≤ 2 years	4036	Water Sanitation	Community-level improved sanitation (PR= 0.43, 95% CI: 0.21, 0.88); Community-level open defecation (PR= 2.13, 95% CI; 1.10, 4.11) Household with improved drinking water (PR= 0.80, 95% CI: 0.67, 0.97); Household with adequate disposal of child stools (PR= 0.82, 95% CI: 0.64, 1.03)	(Lai et al., 2022a)
66	South Asia	India	Cross-sectional	Children < 5 years	1194	Water Sanitation	Improved drinking water source (OR= 0.77, 95% CI: 0.58, 1.00); Improved sanitation facility (OR= 0.51, 95% CI: 0.32, 0.83)	(Lee et al., 2021)
67	East Asia	China	Cross-sectional	Children < 5 years	1054	Water Sanitation Hygiene	Improved WASH (RR= 0.85, 95% CI: 0.46, 1.58)	(Lin & Feng, 2023)
68	South Asia	Pakistan	Cross-sectional	Children < 5 years	25,066	Water Sanitation	Improved sanitation facility (OR= 0.87, 95% CI: 0.8,1.0); Improved drinking water facilities (OR= 1.12, 95% CI: 0.8,1.5); Untreated water (OR= 1.25, 95% CI: 1.0,1.6)	(Mahmood et al., 2020)
69	East Africa	Ethiopia	Cross-sectional	Children aged 6–23 months	477	Water	Drinking water from an unsafe source (OR = 4.08, 95% CI: 1.33, 12.54)	(Malako et al., 2019)
70	South Asia	Nepal	Prospective cohort	Children aged 6 months to 10 years	589	Hygiene	Frequent handwashing with soap (OR= 0.75, 95%CI: 0.66, 0.92,	(Meierhofer et al., 2023)
71	South Asia	India	Cross-sectional	Children aged 0 to 12 months	5453	Hygiene	No handwashing practice of the mothers (OR= 1.18, 95% CI: 1.04, 1.34)	(Meshram et al., 2015)
72	South Asia	India	Cross-sectional	Children aged <2 years	6539	Water Sanitation	Safe drinking water (OR= 1.03, 95% CI: 0.88, 1.21); Improved latrine (OR= 0.88, 95% CI: 0.79, 0.98); Hygienic toilet condition (OR= 0.79, 1.02)	(Mistry et al., 2019)
73	East Africa	Tanzania	Cross-sectional	Children aged <5 years	430	Hygiene	Handwashing before food (OR= 0.5403, 95% CI: 0.3042, 0.940)	(Modern et al., 2020)
74	Oceania	Vanuatu	Cross-sectional	Children aged <5 years	320	Water	Household water MPN 10/100 mL (OR= 0.96, 95% CI: 0.49, 1.90); Improved water (OR= 0.61, 95% CI: 0.46, 0.80)	(Morrison et al., 2020)
75	East Africa	Tanzania	Cross-sectional	Children aged 6-59 months	310	Water Hygiene	Use of surface water (OR= 13, 95% CI: 5.8, 30); Consumption of raw cow's milk (OR= 1.8, 95% CI: 1, 3.8)	(Mshida et al., 2018)
76	East Africa	Ethiopia	Cross-sectional	Children aged 6-59 months	8117	Water Sanitation	Unimproved toilet facilities (OR= 1.26, 95% CI: 1.05, 1.54); ≥ 30 minutes to get drinking water (OR= 1.08, 95% CI: 0.94–1.23); Unimproved drinking water (OR= 0.91, 95% CI: 0.80–1.03)	(Muche et al., 2021)

No	Geographic Region	Country	Type of Study	Population	Sample Size	WASH component	Finding (stunting determinants)	Refe-rences
77	East Africa	Uganda	Cross-sectional	Preschool children aged 1–5 years	206	Water	Drinkingunboiled water (PR= 1.21, 95%CI: 1.10, 1.34)	(Mugarura et al., 2021)
78	South-east Asia	Indonesia	Cross-sectional	Young children aged 5 years old and below	8920	Water Sanitation Hygiene	No access to clean water (OR= 1.36, 95% CI: 0.98, 1.89); Having no access to sanitation (OR= 1.27, 95% CI: (1.10–1.46); Lack access to hygiene (OR= 1.52, 95% CI: 1.28–1.80)	(Mulyaningsih et al., 2021)
79	South-east Asia	Malaysia	Cross-sectional	Children aged 2-6 years old	264	Water Hygiene	No presence of piped water (OR= 2.395, 95% CI: 1.047, 5.476); Poor nail cleanliness (OR= 1.956, 95% CI: 1.163, 3.289; Not wearing shoes outside the home (OR= 2.602, 95% CI: 1.453, 4.660); No handwashing using soap (OR= 1.426, 95% CI: 0.805, 2.524)	(Murtaza et al., 2018a)
80	Middle Africa	Cameroon	Cross-sectional	Children aged 6-59 months	321	Water	Unprotected water source (OR= 2.32, 95% CI: 1.30; 4.15)	(Ngassa et al., 2022a)
81	South-east Asia	Indonesia	Case-control	Children aged 1-5 years	51	Water Sanitation Hygiene	No proper sanitation access (OR= 1.979, 95% CI: 0.590, 6.644; No habit of washing hands with soap (OR= 2.222, 95% CI: 0.660, 7.478; Cadmium concentration in clean water source exceeds the quality standard (OR= 3.13, 95% CI: 0.303, 32.314; Arsenic concentration in drinking water source exceeds the quality standard (OR= 3.684, 95% CI: 1.114, 12.250)	(Oginawati et al., 2023)
82	East Africa	Uganda	Cross-sectional	Children aged 6 –59 months	240	Water Sanitation	No drinking water treatment (OR= 2.011, 95% CI: 0.876, 4.618); No latrine ownership (1.510, 95% CI: 0.545–4.182)	(Okidi et al., 2022a)
83	South-east Asia	Indonesia	Case-control	Pre-school children and their caretakers.	228	Water Sanitation	No toilet sewer treatment (OR= 2.06, 95% CI: 0.81–5.19); Drinking from tap water (OR= 2.26, 95% CI: 1.03, 4.93)	(Otsuka et al., 2019)

Water Management Risk Factors Associated with Stunting among Children

An association between the utilization of unimproved sources of drinking water and stunting among children was featured prominently in the previous research (Ademas et al., 2021; Fernandes et al., 2017; Gaffan et al., 2023; Htet et al., 2023; Malako et al., 2019; Mshida et al., 2018; Ngassa et al., 2022b; Roba et al., 2021; Roy et al., 2023; Saaka et al., 2021; Sisay et al., 2022; Soofi et al., 2023; Torlesse et al., 2016; Wicaksono et al., 2021; Woodruff et al., 2018; Yunitasari et al., 2022), which revealed that using surface water such as rivers, ponds and lakes as the water source (Ahmad et al., 2022; Fernandes et al., 2017; Gaffan et al., 2023; Mshida et al., 2018). No treatment of drinking water was identified as the risk factor for stunting among children (Geletaw et al., 2021; Okidi et al., 2022b; Sanin et al., 2022; Sisay et al., 2022; Torlesse et al., 2016; Yunitasari et al., 2022), of which specified households without piped drinking water (Horta et al., 2013; Murtaza et al., 2018a).

On the contrary, treated water has been reported to provide protection against stunting in various prior investigations (H. H. Amare & Lindtjorn, 2021b; M. V De Vita et al., 2019; Haq & Abbas, 2022a; Sinharoy et al., 2016). Previous research has investigated the correlation between enhanced water supply and the occurrence of stunting in the pediatric population. The investigation yielded results indicating that an upgraded water source acts as a protective factor against stunting. (Altare et al., 2016; Astuti et al., 2020; Berawi et al., 2023; Christian et al., 2023; Dearden et al., 2017; Haq & Abbas, 2022a; Ikeda et al., 2013; Kismul et al., 2017; Lai et al., 2022a; Lee et al., 2021; Mistry et al., 2019; Muche et al., 2021; Rah et al., 2020; Sahiledengle et al., 2022; Sinharoy et al., 2016; Terfa et al., 2022a).

Earlier studies have also indicated a correlation between the amount of time spent obtaining a water source exceeding 30 minutes and the occurrence of stunting (G. Berhanu et al., 2018; Muche et al., 2021; Sahiledengle et al., 2022). Additionally, it has been reported that regions with low water availability are associated with stunting (M. Das et al., 2022), while the presence of an adequate quantity of water has been identified as a protective factor against stunting (Girma et al., 2019). Previous investigations have also discovered an association between water contamination and stunting. Contamination of water with heavy metals such as cadmium and arsenic is associated with stunting in children (Oginawati et al., 2023). Additionally, contamination by bacteria such as *E. coli* and others has been linked to an increased risk of stunting (Gizaw et al., 2022; Morrison et al., 2020).

Sanitation Risk Factors Associated with Stunting among Children

The association between unimproved sanitation and stunting has been prominently emphasized in prior research studies. The association between unimproved sanitation and stunting was highly featured in the previous studies (Ademas et al., 2021; Aguayo et al., 2016; Mulyaningsih et al., 2021; Oginawati et al., 2023; Roy et al., 2023; Soofi et al., 2023; Torlesse et al., 2016; Wicaksono et al., 2021; Yunitasari et al., 2022). Conversely, enhanced sanitation practices at both an individual and communal level have been established as a protective factor against stunting(Christian et al., 2023; Fuller et al., 2016; Haq & Abbas, 2022b; Ikeda et al., 2013; Lai et al., 2022b; Mahmood et al., 2020; Rah et al., 2015a; Reese et al., 2019; Terfa et al., 2022b; Widyaningsih et al., 2018).

The unimproved toilet facilities were the aspect of sanitation that received significant attention in relation to stunting, as indicated by various studies (Ahmed et al., 2021; Z. Y. Amare et al., 2019; Farah et al., 2021; Muche et al., 2021; Sahiledengle et al., 2022; Sisay et al., 2022; Tariq et al., 2018; Woldesenbet et al., 2023). Previous research has also highlighted the absence of latrine facilities (Ahmad et al. 2022; Amare et al. 2019; Berhanu et al. 2022; Kebede & Aynalem 2021; Okidi et al. 2022a) and latrine facilities (Ahmad et al., 2022; Z. Y. Amare et al., 2019) and the practice of open defecation at the household (Gaffan et al., 2023; Gizaw et al., 2022; Sinharoy et al., 2016) and community (Lai et al., 2022a) level was identified as risk factor of stunting among children. Additionally, unsafe disposal of child stool (M. Das et al., 2022; Torlesse et al., 2016; Woldesenbet et al., 2023), poor management of solid waste (Demilew & Alem, 2019; Horta et al., 2013) and poor sewer treatment (Otsuka et al., 2019) has been found to be associated with child stunting. Meanwhile,

the presence of improved toilet facilities was identified as a protective factor that reduces the risk of stunting in children (Dearden et al., 2017; Kismul et al., 2017; Mistry et al., 2019; Rah et al., 2015b; Saaka et al., 2021; Sanin et al., 2022), from which specified access to hygienic toilet (Mistry et al., 2019) and water-sealed toilet (Capanzana et al., 2018). Improved child feces disposal (Bauza & Guest, 2017; Lai et al., 2022a), managed solid waste (Berawi et al., 2023; Geletaw et al., 2021), and managed sewerage (Berawi et al., 2023) were also identified as the protective factors against stunting.

Hygiene Risk Factors Associated with Stunting among Children

Poor hygiene practice was identified as a risk factor for stunting in previous findings (Ademas et al., 2021; Astuti et al., 2020; Sisay et al., 2022) with a prominent discussion about poor handwashing practice after the use of toilet (Ahmad et al., 2022; H. H. Amare & Lindtjorn, 2021b; Bazie et al., 2021; Hiliza et al., 2020; Murtaza et al., 2018b; Oginawati et al., 2023; Torlesse et al., 2016; Woldesenbet et al., 2023; Yunitasari et al., 2022) and before meal (Ahmad et al., 2022; Bazie et al., 2021; Woldesenbet et al., 2023). Other hygiene aspects that were discussed as risk factors of stunting were the poor handwashing practice by the mothers (Ishwarji et al., 2019) before food preparation (Demilew & Alem, 2019), before feeding the children (Woldesenbet et al., 2023), after cleaning the babies (Demilew & Alem, 2019), and children handwashing without soap (Demirchyan et al., 2016). Conversely, the practice of washing hands with soap was identified as protective against stunting among children (Meierhofer et al., 2023; Modern et al., 2020; Mulu et al., 2022; Rah et al., 2015b; Saaka et al., 2021; M. V. De Vita et al., 2019), especially before meals (Modern et al., 2020; Mulu et al., 2022; Rah et al., 2015b) and after defecation (Rah et al., 2015b). Other hygiene risk factors that were identified as risk factors of stunting among children were the presence of insects or pests in the cooking area (Sanin et al., 2022), poor nail cleanliness, not wearing shoes outside the house (Murtaza et al., 2018a), and consumption of raw cow's milk (Mshida et al., 2018).

DISCUSSION

The significance of ensuring safe drinking water, sanitation, and hygiene (WASH) has been widely acknowledged in terms of overall public health as well as the well-being of children. Increasing evidence indicates that prolonged exposure to enteric pathogens during early childhood, resulting from inadequate WASH conditions, can significantly impact children's growth and development (Cumming & Cairncross, 2016). This review compiles a comprehensive compilation of WASH risk factors that have been extensively examined in relation to their correlation with childhood stunting. It is evident that there exists an association between childhood stunting and unsafe water sources, inadequate sanitation facilities, and substandard hygiene practices. Our findings demonstrate that the absence of improved sanitation and the consumption of untreated drinking water contribute to the occurrence of childhood stunting.

Multiple studies conducted in low and middle-income countries have suggested that children exposed to contaminated drinking water, insufficient sanitation, and poor hygiene practices face a substantially increased risk of stunted growth. Our findings indicate, similar to previous studies, that the well-being of the environment in which individuals reside is closely associated with the occurrence of child stunting (Vilcins et al., 2018; Yani et al., 2023). Furthermore, a meta-analysis examining the detection of enteropathogens in the environment found associations with child growth faltering, indicating that environmental contamination is a significant pathway for pathogen transmission, which can lead to stunting(Mertens et al., 2024).

Ensuring access to safe drinking water, sanitation, and hygiene (WASH) is crucial for protecting public health, especially in reducing childhood stunting, which impairs growth and development. Numerous studies consistently demonstrate a strong association between childhood stunting and poor WASH conditions, underscoring that unsafe water supplies, insufficient sanitation infrastructure, and inadequate hygiene practices are major contributing factors (Hasan et al.,

2023b).The global burden of disease attributable to unsafe WASH is substantial, with estimates indicating that a significant proportion of diarrhoeal diseases, acute respiratory infections, and undernutrition could be prevented through improved WASH services (Wolf et al., 2023). This is supported by findings that highlight the reduction in disease burden and improvement in child health outcomes when WASH interventions are implemented, as seen in various low- and middle-income settings (Heller & Carneiro, 2023).

Collectively, these findings underscore the need for integrated strategies that combine nutritional interventions with improvements in WASH infrastructure to effectively address childhood stunting and promote healthier environments for children. Strengthening efforts to improve WASH conditions, especially in vulnerable areas, is crucial for achieving meaningful public health outcomes and advancing the health and well-being targets of the Sustainable Development Goals (Dominguez-Salas et al., 2024).The implications derived from our discoveries, as well as those from other studies, collectively underscore the importance of incorporating enhanced nutritional strategies that prioritize the enhancement of hygiene practices, sanitation facilities, and access to portable drinking water.

However, the limitation of this systematic literature review is the absence of a formal quality assessment of the included studies. This limitation may impact the reliability and validity of the findings, as studies with varying levels of methodological rigor and potential biases were not critically appraised. Without evaluating the quality of the studies, it becomes challenging to gauge the strength of the evidence supporting the conclusions, and the results may be influenced by lower-quality studies that could either exaggerate or underestimate the true relationship between the examined factors. Future reviews should incorporate a comprehensive quality assessment to ensure more precise and reliable outcomes.

CONCLUSION

The outcomes of this review have validated that stunting among children is higher in locations that are more susceptible to water, sanitation, and hygiene (WASH) challenges. Moreover, it has been demonstrated that inadequate access to improved sanitation facilities is an integral aspect of the broader WASH framework that is significantly linked to the occurrence of child stunting. Based on our research findings, we propose the inclusion of WASH strategies, particularly sanitation measures, in the design and implementation of interventions that integrate with health promotion policies, to foster healthy early childhood development. Governments and organizations should prioritize enhancing water, sanitation, and hygiene (WASH) infrastructure in low- and middle-income countries to reduce childhood stunting. This includes improving access to clean water, building sanitation facilities, and ensuring the availability of proper waste management systems. Alongside infrastructure improvements, community education on hygiene practices such as handwashing, safe food handling, and the importance of clean water is essential for promoting better health behaviors. Such education empowers individuals to adopt practices that prevent waterborne diseases and malnutrition, both key contributors to stunting. Furthermore, WASH interventions should be integrated with nutrition programs to create a comprehensive approach that addresses both the direct and indirect causes of stunting. Regular monitoring and evaluation are essential for measuring the success of these programs and for adapting interventions to address the specific needs of vulnerable groups. Targeted, localized interventions are needed to achieve long-term, sustainable reductions in stunting and improve child health outcomes. Additionally, we recommend that future studies prioritize the development of methodologies and systems for data collection pertaining to the actual state of sanitation and the nutritional status of children, ensuring that these methods are comprehensive and practical for use in developing nations.

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