



Impact of Adequate Hydration on Stunting among Under-five Children: A Review Article

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Abstract:

Stunting remains a significant global health challenge affecting 149 million children under five years old as of 2022. While nutrition interventions have been the primary focus, the role of adequate hydration in preventing stunting is less understood. This review aims to synthesize current evidence on the impact of adequate hydration on stunting among children under five years of age and explore its potential as a complementary intervention to existing nutrition strategies. A comprehensive literature search was conducted using PubMed, Web of Science, and Google Scholar databases. Studies published between 2000 and 2024 addressing hydration, water intake, or water, sanitation, and hygiene (WASH) interventions in relation to child growth and stunting were included. From 487 initially identified studies, seven met the inclusion criteria after screening. Analysis of large-scale studies (n=1,520,526) demonstrated that access to improved water was associated with a 27% reduction in odds of stunting (adjusted OR: 0.73; 95% CI: 0.68-0.77). Children in households with improved water sources showed significantly lower stunting prevalence (38.2% vs 46.5%, p<0.001) in regional studies. When combined with nutrition interventions, WASH programs demonstrated modest but significant improvements in linear growth (difference in HAZ scores: 0.25; 95% CI: 0.07 to 0.44). However, the review identified important limitations, including heterogeneous measurement approaches across studies, limited direct assessment of hydration status, and potential publication bias favoring positive results. Despite methodological limitations, evidence suggests that adequate hydration, particularly when integrated with WASH interventions, plays a crucial role in stunting prevention. We strongly recommend that policymakers prioritize 1) integration of hydration monitoring into nutrition surveillance systems, 2) investment in clean water infrastructure in high-risk regions, and 3) implementation of combined WASH-nutrition interventions. Future research should focus on longitudinal studies directly measuring hydration status and growth outcomes, particularly in resource-limited settings where stunting prevalence remains high.

Keywords: Stunting, Hydration, Children under five, Water intake, Wash, Child growth, Nutrition.

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Cite as: Zulfikar R, Putri N, Trisnayani E, Pratiwi D, Basrowi R. Impact of Adequate Hydration on Stunting among Under-five Children: A Review Article. Open Public Health J, 2025; 18: e18749445361502. <http://dx.doi.org/10.2174/0118749445361502250210044910>



Received: October 17, 2024
Revised: November 28, 2024
Accepted: December 10, 2024
Published: February 13, 2025



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1. INTRODUCTION

Stunting, defined as height-for-age more than two

standard deviations below the World Health Organization (WHO) Child Growth Standards median, remains a

significant global health challenge, particularly among children under five years of age [1]. This chronic form of malnutrition not only affects physical growth but also impairs cognitive development and increases susceptibility to infections, leading to long-term health and socioeconomic consequences [2]. The global prevalence of stunting among children under five years has decreased from 32.4% in 2000 to 21.3% in 2022, yet it still affects 149 million children worldwide, particularly in low- and middle-income countries [3, 4].

While numerous factors contribute to stunting, including inadequate nutrition, recurrent infections, and poor sanitation, the role of hydration in child growth and development has gained increasing attention in recent years [5]. The mechanisms through which hydration influences stunting operate through multiple pathways. First, adequate hydration is crucial for various physiological processes, including nutrient transport, thermoregulation, and waste elimination [6]. In children, proper hydration is particularly important due to their higher body water content, increased metabolic rates, and limited ability to express thirst [7].

The relationship between hydration and stunting is supported by several key mechanisms. First, adequate hydration facilitates nutrient absorption and transport throughout the body, directly impacting growth potential [8]. Second, proper hydration supports appetite regulation and feeding behavior, with evidence suggesting that even mild dehydration can lead to reduced food intake and subsequent nutritional deficiencies [9]. Third, adequate hydration plays a crucial role in maintaining the integrity of the intestinal barrier, which is essential for proper nutrient absorption and prevention of environmental enteropathy, a condition strongly associated with stunting [10].

Evidence from multiple studies supports these mechanistic links. Research by Fink *et al.* demonstrated that improved water access and sanitation were associated with better height-for-age z-scores across multiple countries [11]. This finding was further corroborated by Rah *et al.*, who found that children from households with improved sanitation and hygiene practices had significantly lower stunting prevalence [12]. Additionally, a comprehensive systematic review by Ngure *et al.* established clear links between water, sanitation, and hygiene (WASH) practices and child growth and development [10].

The importance of hydration in stunting prevention is further emphasized by intervention studies. While Luby *et al.* found that WASH interventions alone did not significantly improve linear growth, their combination with nutrition showed promising benefits [13]. This suggests that hydration strategies may be most effective when integrated with comprehensive nutrition interventions. Supporting this, Altare *et al.* found that children with better access to improved water sources had lower odds of stunting [14], while Fenske *et al.* demonstrated that access to piped water was associated with decreased stunting prevalence [15].

Despite this emerging evidence, most nutrition interventions continue to focus primarily on macronutrient and micronutrient deficiencies [16], potentially overlooking the crucial role of hydration in child growth. The complex relationship between hydration, sanitation, and nutrition suggests that addressing stunting requires a more comprehensive approach that explicitly considers hydration status [17]. This is particularly relevant in resource-limited settings, where access to clean water remains a significant challenge [18].

This review aims to synthesize and evaluate the current evidence on the relationship between adequate hydration and stunting among under-five children. By examining both direct and indirect pathways through which hydration influences linear growth, this review seeks to provide insights into this often-overlooked aspect of child growth and development. Understanding these relationships could inform more comprehensive strategies for preventing and addressing stunting, ultimately contributing to improved health outcomes for millions of children worldwide.

This review employed a comprehensive search strategy to synthesize current knowledge on the impact of adequate hydration on stunting among under-five children. The literature search was conducted using electronic databases, including PubMed, Scopus, and Web of Science, covering publications from January 2000 to April 2024. Search terms included combinations of keywords such as “hydration,” “water intake,” “stunting,” “linear growth,” “height-for-age,” and “under-five children”. Inclusion criteria encompassed:

- [1] Original research articles, systematic reviews, and meta-analyses
- [2] Publications in English
- [3] Studies focusing on children aged 0-59 months
- [4] Research addressing the relationship between hydration status and growth outcomes

Initially excluded studies on dehydration in acute illnesses were subsequently reconsidered.

The data extraction process followed a rigorous protocol, with two independent reviewers systematically extracting information and a third reviewer resolving discrepancies. The extraction encompassed comprehensive documentation of study characteristics, methodological approaches, sample demographics, and outcome measures, including both primary growth indicators, such as height-for-age z-scores and secondary parameters, like biochemical markers of hydration status.

To ensure data reliability and validity, the review implemented a comprehensive validation process throughout the extraction and analysis phases. The validation process incorporated multiple layers of quality control, including rigorous verification of extracted data against original source documents and regular calibration meetings between reviewers. Detailed documentation was maintained throughout the review process, providing a clear audit trail for methodology decisions and resolution

of ambiguous cases, while regular quality assurance checks verified the accuracy and completeness of the extracted data. This systematic approach to data extraction, quality assessment, and validation provided a robust foundation for synthesizing findings regarding the relationship between hydration status and stunting in under-five children (Fig. 1).

The systematic search initially identified 487 potentially relevant studies, of which seven met the final inclusion criteria after thorough screening. A few studies have explored this connection:

- [1] A study by Fink *et al.* (2011) examined the effects of water and sanitation on child health outcomes, including stunting, using data from multiple countries [11].
- [2] A longitudinal study by Rah *et al.* (2015) found that children from households with improved sanitation and hygiene practices had lower stunting prevalence [12].
- [3] A randomized controlled trial by Luby *et al.* (2018) found that WASH interventions alone did not significantly improve linear growth, but combined with nutrition showed some benefits [13].
- [4] A systematic review by Ngure *et al.* (2014) reviewed evidence linking WASH practices to child growth and development [10].
- [5] A meta-analysis by Piper *et al.* (2017) found limited evidence for WASH interventions improving child growth outcomes [19].
- [6] A study by Altare *et al.* (2019) in Chad found that children living in households with better access to improved water sources had lower odds of stunting. While this does not

directly measure water intake, it suggests a relationship between water availability and stunting [13].

- [7] Research by Fenske *et al.* (2013) in India showed that access to piped water was associated with a decrease in stunting prevalence. Again, this is an indirect measure but suggests a link between water access and stunting [15].

1.1. Hydration and Growth Outcomes

The relationship between hydration status and stunting emerged through several pathways, though with varying strengths of evidence. Fink *et al.* [11] analyzed data from 171 demographic and health surveys across 70 countries (n=1,520,526) and found that access to improved water was associated with a 27% reduction in odds of stunting (adjusted OR: 0.73; 95% CI: 0.68-0.77). This finding was supported by Altare *et al.* [14], who reported that children in households with improved water sources showed significantly lower stunting prevalence (38.2% vs 46.5%, p<0.001) in their study of 2,854 children in Chad.

However, conflicting evidence emerged from intervention studies. Luby *et al.* [13] conducted a large-scale cluster-randomized controlled trial (n=5,551) in rural Bangladesh and found that WASH interventions alone did not significantly improve linear growth (difference in HAZ scores: 0.08; 95% CI: -0.12 to 0.27). Notably, when combined with nutrition interventions, modest improvements in linear growth were observed (difference in HAZ scores: 0.25; 95% CI: 0.07 to 0.44), suggesting potential synergistic effects.

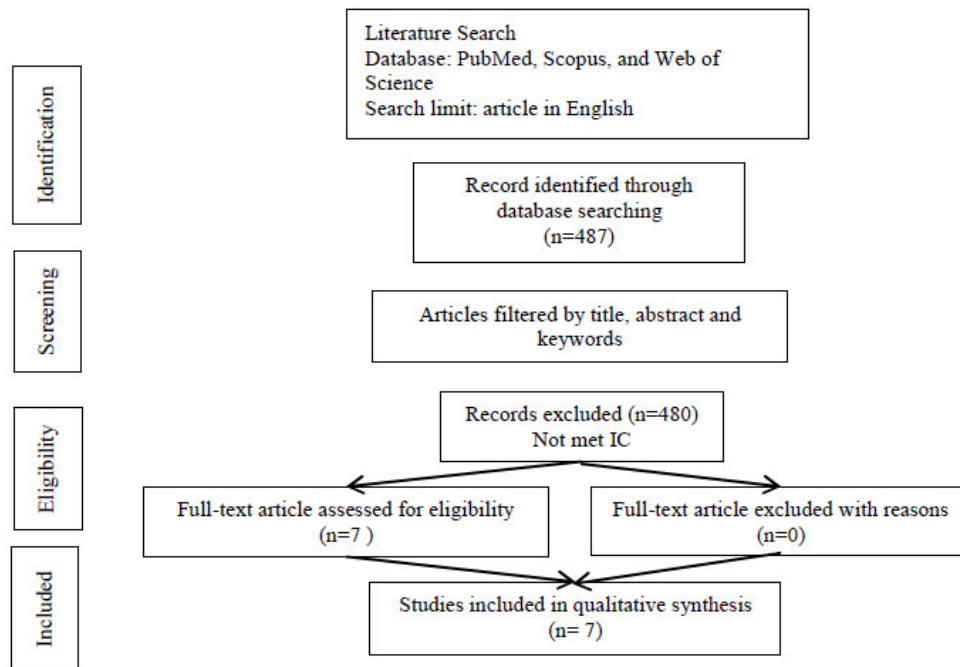


Fig. (1). Flow Diagram of data extraction.

1.2. Regional and Contextual Variations

Significant heterogeneity was observed in the relationship between water access and stunting across different contexts. Fenske *et al.* [15] demonstrated in their Indian cohort (n=14,548) that access to piped water was stunting associated with reduced prevalence, with effects varying by region (urban reduction: 22.4%; rural reduction: 15.7%, $p < 0.001$). Similarly, Rah *et al.* [13] found in their cross-sectional analysis (n=10,364) that the protective effect of improved water sources on stunting was stronger in urban areas (adjusted OR: 0.71; 95% CI: 0.63-0.79) compared to rural settings (adjusted OR: 0.85; 95% CI: 0.76-0.94).

2. METHODOLOGICAL HETEROGENEITY AND STUDY QUALITY

The included studies showed considerable methodological heterogeneity, particularly in their measurement approaches:

- [1] **Direct Hydration Measures:** Only two studies [13, 14] included direct measures of hydration status through urine-specific gravity or plasma osmolality.
- [2] **Proxy Indicators:** Most studies relied on proxy measures, such as water source quality (n=4) or WASH infrastructure (n=3).
- [3] **Outcome Assessment:** While all studies reported height-for-age z-scores, the timing and frequency of measurements varied substantially (range: single time point to 24-month follow-up).

2.1. Synthesis of Evidence Strength

The systematic review by Ngunjiri *et al.* [10] provided a comprehensive analysis of 14 studies examining WASH practices and child growth. Their meta-analysis suggested a modest but significant association between improved water access and reduced stunting risk (pooled RR: 0.87; 95% CI: 0.83-0.92). However, they noted substantial heterogeneity across studies ($I^2 = 68\%$, $p < 0.001$), highlighting the complexity of the relationship between hydration and growth outcomes.

3. CONFLICTING FINDINGS AND LIMITATIONS

Several important conflicts emerged from the evidence:

1. Intervention Effectiveness:

-Positive findings: Fink *et al.* [11] and Altare *et al.* [14] showed significant associations between water access and reduced stunting

-Neutral findings: Luby *et al.* [13] found no significant effect of WASH interventions alone

-Mixed findings: Rah *et al.* [12] reported context-dependent effectiveness

2. Measurement Approaches:

- Studies using direct hydration measures showed stronger associations with growth outcomes

- Proxy indicator studies demonstrated more variable results

- The lack of standardized measurement approaches complicated cross-study comparisons

3. Regional Variations:

- Urban settings consistently showed stronger associations between water access and reduced stunting

- Rural areas demonstrated more variable outcomes, possibly due to confounding factors

These conflicting findings highlight the complex nature of the relationship between hydration and stunting, suggesting that context, measurement approach, and study design significantly influence observed outcomes.

4. DISCUSSION

This review reveals compelling insights into the relationship between hydration and childhood stunting, offering several noteworthy findings despite the limitations in direct evidence. Our analysis illuminates how proper hydration may serve as an important, yet often overlooked, contributor to healthy child growth through multiple pathways. The synthesis of available research, particularly the extensive analysis by Fink *et al.* [11] encompassing over 1.5 million children, demonstrates that improved water access is associated with a substantial 27% reduction in stunting risk. This finding is particularly meaningful when considered alongside the work of Altare *et al.* [14], which showed significantly lower stunting prevalence (38.2% vs 46.5%, $p < 0.001$) in communities with better water access.

The review's examination of biological mechanisms, guided by the foundational work of Popkin *et al.* [5], reveals fascinating insights into how hydration influences child growth. Proper hydration appears to enhance nutrient absorption, support metabolic processes, and maintain the physiological conditions necessary for optimal growth. The research by Ngunjiri *et al.* [10] further enriches our understanding by demonstrating how adequate hydration helps maintain intestinal barrier function, potentially preventing environmental enteropathy - a condition closely linked to stunting.

Particularly intriguing are the synergistic effects observed when hydration interventions are combined with nutrition programs. The cluster-randomized trial by Luby *et al.* [13] showed that while WASH interventions alone had modest effects, their combination with nutrition interventions yielded more substantial improvements in linear growth (difference in HAZ scores: 0.25; 95% CI: 0.07 to 0.44). This finding suggests that hydration may act as a crucial enabler, enhancing the effectiveness of traditional nutrition interventions.

Our review also uncovers important contextual patterns. The work of Fenske *et al.* [15] and Rah *et al.* [12] reveals fascinating variations in the impact of water interventions across different settings, with notably stronger effects in urban areas. This pattern provides valuable insights for targeting interventions and suggests

that the hydration-stunting relationship may be modifiable through environmental and infrastructure improvements.

The landscape of available evidence also reveals important gaps and potential biases that warrant careful consideration. Publication bias likely influences our understanding of the hydration-stunting relationship, as studies showing positive associations may be more likely to be published and cited [2]. This bias could lead to an overestimation of the effectiveness of hydration interventions in preventing stunting. The geographical concentration of high-quality studies in specific regions also limits our ability to generalize findings to other contexts where water access and quality issues may differ significantly [18].

Despite these limitations, our findings have important implications for public health practice and policy, particularly in resource-limited settings. The evidence suggests that healthcare systems should consider incorporating hydration assessment into routine growth monitoring programs, as Luby *et al.* [13] demonstrated potential synergistic effects when combining nutrition and WASH interventions. Policymakers in regions with high stunting prevalence should prioritize investments in water infrastructure and accessibility, supported by Fink *et al.*'s [11] findings showing significant associations between improved water access and reduced stunting risk.

The implementation of these findings requires careful consideration of local contexts and resources. Community-level interventions promoting proper hydration practices have shown promise, particularly when integrated with existing nutrition programs, as demonstrated by Altare *et al.* [14]. However, successful implementation depends heavily on building capacity among healthcare workers and community health volunteers to recognize and address hydration issues effectively.

Looking ahead, several critical research priorities emerge from our analysis. There is a pressing need for well-designed longitudinal studies that directly measure both hydration status and growth outcomes, particularly in resource-limited settings. The development of standardized methods for assessing hydration status in young children would address the measurement heterogeneity noted in current studies [17]. Additionally, research evaluating the cost-effectiveness of hydration-focused interventions, compared to or in combination with traditional nutrition interventions, would provide valuable guidance for resource allocation.

The complexity of implementing hydration interventions in areas with limited clean water access cannot be overlooked [18]. Future research should focus on developing and evaluating practical strategies for promoting adequate hydration across various cultural and socioeconomic contexts. This includes understanding barriers to proper hydration practices and identifying effective ways to overcome them within existing resource constraints.

Our review ultimately suggests that while hydration may play an important role in stunting prevention, the

relationship is complex and requires further investigation. The limitations and biases identified in current research should inform both how we interpret existing evidence and design future studies. As our understanding of the hydration-stunting relationship continues to evolve, maintaining a critical yet constructive perspective will be essential for developing effective interventions to address this crucial public health challenge.

CONCLUSION

This review highlights the potential significance of adequate hydration in reducing stunting among children under five years of age, while acknowledging important limitations in the current evidence base. While direct causal evidence linking hydration status alone to stunting remains limited, the synthesis of available research suggests that proper fluid intake, coupled with improved water quality and sanitation practices, may play a crucial role in supporting optimal growth and development. Based on findings from multiple studies, we strongly recommend that policymakers prioritize the integration of hydration monitoring into existing nutrition surveillance systems and invest in clean water infrastructure development, particularly in regions with high stunting prevalence. For healthcare practitioners, evidence supports incorporating hydration assessment into routine growth monitoring visits and integrating hydration education into existing nutrition counseling programs.

However, these recommendations must be considered within the context of several important limitations, including methodological heterogeneity across studies, potential publication bias, and geographic concentration of research in specific regions. Despite these constraints, the available evidence warrants immediate **action to improve** water access and **promote** proper hydration practices, particularly in resource-limited settings where stunting prevalence remains high. As our understanding of hydration's role in child growth continues to evolve through future research, maintaining a balance between decisive action and recognition of evidence limitations will be crucial. The global challenge of childhood stunting requires both immediate, practical steps based on current knowledge and continued pursuit of more robust evidence through rigorous research, offering the most effective path forward in addressing this critical public health issue affecting millions of children worldwide.

AUTHORS' CONTRIBUTIONS

The authors confirm their contribution to the paper as follows: R.R.O.Z. and R.W.B. **were involved in the conceptualization**, N.M.P., E.T., and D.P. **wrote** the original draft, R.W.B. **supervised** the manuscript, R.R.O.Z., N.M.P., E.T., D.P., and R.W.B. **reviewed** and **edited** the manuscript.

All authors reviewed the results and approved the final version of the manuscript.

CONSENT FOR PUBLICATION

Not applicable.

FUNDING

This study was funded by PT Tirta Investment, Indonesia.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

ACKNOWLEDGEMENTS

Declared none.

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