# The Effect of Improved Sanitation on Linear Growth Amongst Children Living in Developing Countries: a Systematic Review

***Elton Chavura, MSc***
***Wales Singini, Prof.***
***Russel Chidya, Ph.D***
Mzuzu University, Faculty of Environmental Science, Mzuzu, Malawi
***Balwani Chingatichifwe Mbakaya, Associate. Prof***
University of Livingstonia, Department of Public Health, Malawi

Doi:10.19044/esipreprint.7.2022.p474

Approved: 19 July 2022
Posted: 21 July 2022



*Cite As:*
Chavura E., Singini W., Chidya R., Mbakaya B.C. (2022). *The Effect of Improved Sanitation on Linear Growth Amongst Children Living in Developing Countries: a Systematic Review.* ESI Preprints. https://doi.org/10.19044/esipreprint.7.2022.p474

## Abstract

Constant exposure to poor sanitation contribute to the environmental enteric dysfunction-a disorder that is frequently implicated as a cause of linear growth failure. We aimed to evaluate the efficacy of water, sanitation, and hygiene (WaSH) interventions on linear growth amongst children aged 0-24 months. We reviewed fourteen studies retrieved from AMED, CINAHL, DOAJ, PubMed, PsycINFO, Google Scholar, and EMBASE databases following guidelines developed by PROSPERO and COCHRANE. The screening process was summarized using a PRISMA flow diagram, and the methodologies were critically appraised by a Mixed Method Appraisal Tool. No difference was seen in mean height for age Z-score (0.01, 95% CI-0.16 to 0.18) between children who received WaSH interventions and those who did not. Only 5 studies reported a significant association between WaSH and child linear growth ($P < 0.001$). All combination intervention studies include in this review did not establish any significant benefit of WaSH and nutrition integration. Although robust sanitation coverage could be an important component amongst proven interventions to stimulate linear growth, stunted growth is embedded within myriad determinants beyond improved sanitation. More research is needed to quantify the complementary effect of WaSH and nutrition co-programming. This systematic review was registered in the PROSPERO database with registration number CRD42022322462.

**Keywords:** Systematic review, WaSH, Linear Growth, and Environmental Enteric Dysfunction

## Introduction

Most countries are ill-prepared to meet the global target to reduce stunted growth among under-five children by 40% by 2025 (Goal 2: Target 2.2) as current investment efforts are insufficient to drive progress to achieve the set goal (Shekar et al., 2017). Fortunately, there is a growing body of evidence that indicates that WaSH could be critical in addressing children's nutritional deficits, including stunting, which is considered the main indicator of chronic malnutrition. At the direct, biological level, soil-transmitted helminths, repeated diarrheal episodes, and environmental enteric dysfunction (EED) are thought to be pathway linkages between WaSH and linear growth failure. Prolonged exposure to fecal pathogens increases vulnerability to enteric infections that contribute to environmental enteric EED (Chandna et al., 2020), a postulated condition characterized by malabsorption, villas atrophy, crypt hyperplasia, T-cell infiltration, and inflammation of the jejunum. EED is known to reduce oral vaccine efficacy and gut absorption and is implicated as a cause of stunting, an irreversible and easy-to-measure manifestation of early childhood developmental deficit (Budge et al., 2019). Stunting affects 165 million children globally (Keusch et al., 2013), the vast majority of whom live in sub-Saharan Africa (Bethany et al., 2018). Height-for-age is a measure of height compared to the height of children of the same age and sex from a reference population (Reese et al., 2021). It is an indicator of chronic malnutrition, which is used to identify stunted growth. A stunted child has a height-for-age z score below 2 standard deviations (SD) below the WHO Child Growth Standards median.

We hypothesized that if linear growth failure is multifaceted, observance to WaSH practices alone may not reduce the odds of stunting. The question that this systematic review tries to resolve is "What is the effect of improved water supply and sanitation on linear growth among children aged 0-59 months?" The key outcome of the review was "LAZ -2 SD" at 59 months. Additional outcomes were "underweight" (weight-for-age) and "wasting" (weight-for-height), based on the WHO 2006 Child Growth Standard.

## Methods

To improve the clarity of reporting, we summarized the article screening process using an evidence-based minimum set of items. As propagated by Moher et al., (2009), the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram is designed to enhance transparent reporting and justification for every action taken by systematic reviewers. A Mixed Method Appraisal Tool (MMAT) was used to critically appraise the methodological quality of all the selected studies.

### *Inclusion criteria*

We considered all studies regardless of their design: studies involving children with stunted growth, environmental enteric dysfunction, and studies on water supply, sanitation, and child health.

### *Exclusion criteria*

All reviews, communications, perspectives, and articles from developed countries were automatically excluded.

### *Information source /search strategy*

Research articles were retrieved from DOAJ, PubMed, PsycINFO, CINAHL, Google Scholar, AMED, and EMBASE databases using appropriate keywords to search and retrieve articles. The search period was set from the period starting from January 2012 to December 2021, covering a period of 9 years. The following search terms were used; sanitation OR improved water supply AND/OR WaSH AND/OR stunting, AND/OR linear growth, AND/OR environmental enteric dysfunction. An effort was made to manually extract both published and unpublished interventional studies and hand search key journals.

**Table 1:** Search strategy

| Databases | Search | Search word/terms | esults |
|---|---|---|---|
| **PubMed** | Title and abstract | sanitation OR improved water supply AND/OR WaSH AND/OR stunting, AND/OR linear growth, AND/OR environmental enteric dysfunction | |
| **EMBASE** | Title, abstract and full article | sanitation OR improved water supply AND/OR WaSH AND/OR stunting, AND/OR linear growth, AND/OR environmental enteric dysfunction | |

| | | | |
|---|---|---|---|
| **PsycINFO** | Title, abstract and full article | sanitation OR improved water supply AND/OR WaSH AND/OR stunting, AND/OR linear growth, AND/OR environmental enteric dysfunction | |
| **AMED** | Title and abstract | sanitation OR improved water supply AND/OR WaSH AND/OR stunting, AND/OR linear growth, AND/OR environmental enteric dysfunction | |
| **CINAHL** | Title and abstract | sanitation OR improved water supply AND/OR WaSH AND/OR stunting, AND/OR linear growth, AND/OR environmental enteric dysfunction | |
| **DOAJ** | Title, abstract and full article | sanitation OR improved water supply AND/OR WaSH AND/OR stunting, AND/OR linear growth, AND/OR environmental enteric dysfunction | |
| **Google Scholar** | Title, abstract and full article | sanitation OR improved water supply AND/OR WaSH AND/OR stunting, AND/OR linear growth, AND/OR environmental enteric dysfunction | 0 |
| **Reference search from other sources** | Title, abstract and full article | | |
| | | **Total Result Search** | **4** |

### *Selection of studies*

Identified articles were imported to Mendeley desktop window before they could be reviewed against the set inclusion criteria.

### *Data collection process*

Using the non-automated data extraction method, we collected data on outcomes of interest for each participant in the same manner, using a well-defined instrument. In this manner, information from multiple studies that have investigated the same thing was gathered. Potential studies were identified and assessed for eligibility by two authors, and where discordant opinions arose, the third author resolved the tie. All relevant information was extracted from each study, summarized, and documented. The data extraction table details the following information: author, year of study, type of participants, age, setting, country, sample size, study design, and methods, study purpose/objectives, study outcomes, and results.

***Search outcome***

An initial database search located 2103 articles. A total of 441 articles were left after the removal of duplicates. The remaining articles were further filtered, and 427 articles were excluded because of age bracket (256), inappropriate outcome measures (150), and studies from developed countries (21). The remaining 14 articles were selected for the final review (see Figure 2).

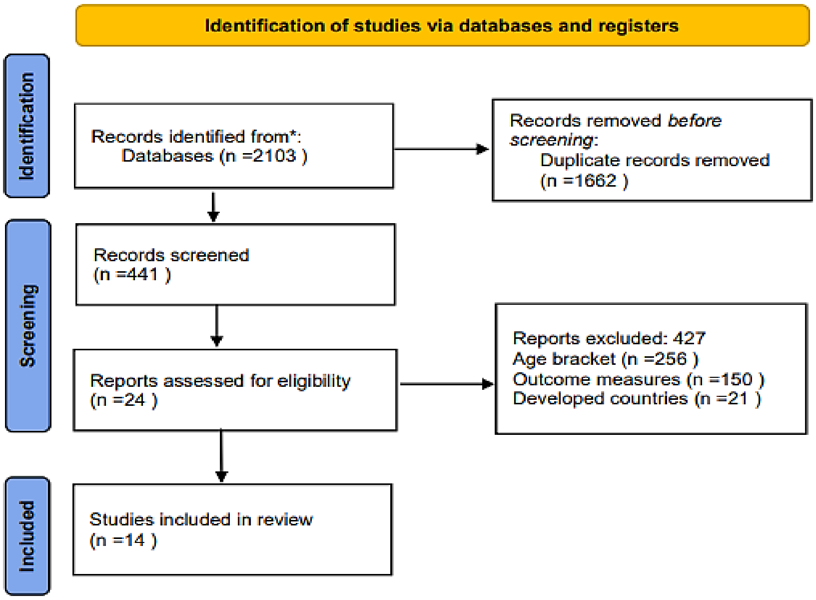


**Figure 2:** The PRISMA Flow Diagram

We reviewed studies that reported integrated WaSH and nutrition as long as the design and methodology were able to clearly separate and allow individual evaluation of the combined interventions. A total of fourteen studies were selected and are summarized in Table 2 below.

**Table 2:** Summary of studies

| Author & year | Population | | | | Sample size | Study design & methods | Objectives/aims | | |
|---|---|---|---|---|---|---|---|---|---|
| | Participant | Age | Setting | Country | | | Study purpose/ Objective | Outcomes | Results |
| **Saaka et al.,2021** | Children | 6-23 months | Households | Ghana | 301 | Randomized controlled trial | To assess tge effect of complementary feeding and poor WaSH practices on child growth | The WaSH intervention (alone or combined with IYCF) only offered marginal protection against stunting | Poor sanitation and hygiene practices, were not associated with the risks of stunting. Poor complementary feeding practice was significantly associated with stunted growth. |
| **Humphrey et al., 2019** | Children from HIV negative mothers | 0-18 months | Households | Zimbabwe | 3686 | Cluster Randomized controlled trial | To test the independent and combined effects of improved WaSH and improved IYCF on stunting | No effect of WaSH on linear growth as both treatment and experimental groups were the same | The IYCF intervention was more efficacious in increasing mean length-for-age Z scores among boys (0·24 [95% CI 0·14 to 0·34]) than among girls (0·07 [95% CI –0·04 to 0·17]). |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Hill et al.,2020** | Children | 0-36 months | Households | South Africa | 404 | Randomized controlled trial | To determine whether the use of Point-of-Use Water Treatment technologies can improve child growth. | No differences were observed in HAZ, WAZ, or WHZ among children in the intervention groups | The prevalence of diarrhea in the combined intervention group was 1.05 times (95% CI: 0.73, 1.50) the prevalence in the combined control group. |
| **Walles et al., 2017** | HIV exposed uninfected HIV unexposed infants | 0-12 months | Households | Ethiopia | 302 | cross-sectional study | To determine the impact of exposure to maternal HIV infection in relation to socio-economic factors | Availability of running water did not matter as it did not affect linear growth | Unavailability of running water was associated with reduced risk for stunting (AOR 0.57; 95% CI 0.35–0.94; p = 0.026) |
| **Null et al., 2018** | Children | 0-24 months | Households | Kenya | 6659 | Block Randomized controlled trial | To assess whether WaSH and nutrition interventions reduced diarrhoea or growth faltering | No effect of any interventions on linear growth | Children in the combined WaSH and nutrition group were not significantly taller than children in the nutrition group (mean difference 0·04 [95% CI –0·11 to 0·19] |
| **Sofeu et al., 2019** | HIV exposed uninfected infants HIV infected infants HIV | 0-59 months | Household | Cameroon | 611 | Randomized controlled trial | To determine the risk of HIV-related growth retardation during early childhood | No significant effect on linear growth was observed | Although not statistical significant, the presence of water supply at home was a protective factor of stunting (aHR: 0.8, 95%CI: 0.6–1.0). |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | unexposed uninfected infants | | | | | | | | |
| **Prendergast et al 2018** | HIV exposed children and Children whose HIV status is unknown | ≤18 months | Household | Zimbabwe | 668 | Cluster Randomized controlled trial | To evaluate the efficacy of both WaSH and improved complementary feeding on child stunting | WaSH intervention had no effect on linear growth<br><br>The IYCF intervention increased height | No difference in mean height for age Z-score (0.01, 95% CI-0.16 to 0.18) between WaSH and non-WaSH group.<br>IYCF increased mean length for age Z score by 0·26 (95% CI 0·09–0·43; p=0·003) |
| **Christian et al.,2020** | Children | 6–23 months | Household | Malawi | 2453 | quasi-experimental study design | To perform an impact evaluation of the program using a neighboring district as comparison. | No reduction in stunting prevalence was observed. | No differences in mean length-for-age z-score or prevalence of stunting were found at endline. |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Fenn et al., 2012** | Children | 6-36 months | Household | Ethiopia | 3758 | Cluster Randomized controlled trial | To determine which interventions can reduce stunting in a food-insecure population in Ethiopia | WaSH significantly increased linear growth. | WaSH increased mean height-for-age Z-score (+0.33, P= 0.02), with a 12.1% decrease in the prevalence of stunting, compared with the baseline group. |
| **George et al., 2020** | children | 6–36 months | Households | Bangladesh | 2626 | Cluster-randomized Controlled Trial | To determine the effect of a WaSH Mobile Health Program on Diarrhea and Child Growth in Bangladesh | WaSH resulted in significantly improved linear growth in the intervention group compared with a comparison group | Children were less likely to be stunted in both the mHealth with 2 home visits arm (33% vs 45%; OR, 0.55 [95% CI: .31–.97]) and the mHealth with no home visits arm (32% vs 45%; OR, 0.54 [95% CI: .31–.96]) |
| **Deichsel et al., 2019** | HIV-exposed infants | 0-12 months | Households | Kenya | 372 | Longitudinal cohort study | To determine early life household, maternal, and infant factors associated with linear growth from birth to 12 months of life. | household sanitation had sustained effects on linear growth trajectory, but LAZ varied according to toilet type | Socio-economic status and sanitation were associated with change in LAZ. Infants in homes with pit latrines (p = .010), shared toilet (p = .032), or crowding (p = .005) experienced a greater deterioration of LAZ despite having similar LAZ at birth |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Head et al.,2019** | Children | 0-59 months | Households | Ethiopia | 1007 | cross-sectional matched control evaluation | To compare the prevalence of stunting, wasting, underweight and two-week history of acute respiratory infection (ARI) in children 0-59 months | Lack of significant association between WaSH or WaSH and nutrition interventions and mean WHZ or WAZ | Odds of stunting in the integrated group was 50% lower than children in the comparison group (OR: 0.50, 95% CI: 0.26, 0.97). |
| **Bekele et al.,2020** | Children | 0-59 months | Households | Ethiopia | 11023 | observational study | To determine the effect of access to water, sanitation and handwashing facilities on child growth indicators | WaSH led to significant effect on linear growth And other growth measures | WaSH group had 29% lower odds of linear growth failure (adjusted odds ratio (AOR) = 0.71; 95% CI: 0.51–0.99) compared with others. |
| **Torlesseet al.,2016** | Children | 0-23 months | Households | Indonesia | 1366 | Cross sectional survey | To establish determinants of stunting in Indonesian children | WaSH resulted to significant increase in linear growth | The prevalence of stunting and severe stunting was 28.4 % and 6.7 %, respectively.<br><br>Odds on child stunting was over three times higher if the household used unimproved latrine |

### *Data synthesis*

The authors provide a narrative synthesis of the findings from the included studies. Emphasis was on the *length-for-age* Z-score (LAZ). A subset analysis was categorized based on the set study outcomes, thus; underweight (weight-for-age) and wasting (weight-for-height). A narrative synthesis was conducted based on the content analysis of the included articles.

## Results

### Quality appraisal

The methodological quality of included studies was critically appraised using the Mixed Method Appraisal Tool (MMAT). Based on the (MMAT), twelve studies scored 100%; all of which were randomized controlled trials (George et al., 2020; Bekele et al., 2020; Christian et al 2020; Hill et al.,2020; Sofeu et al., 2019; Deischel et al., 2019; Prendergast et al., 2018; Humphrey et al., 2018; Null et al 2018; Walles et al., 2017; Torlesse et al.,2016; Fenn et al.,2012). The remaining two studies (Saaka et al 2021; Head et al., 2019) scored 80% and 60%, respectively. Between these, one study (Head et al., 2019) had no baseline assessment to appreciate changes attributable to the study. Sample selection and design were not clear in the other study (Saaka et al., 2021), and the author did not come clear on how to deal with confounders. Nonetheless, all the fourteen studies were categorized as high quality after meeting almost all core criteria for their study design. The overall quality cut-off point was set at 60%. With an average score of 96% across the included articles, the studies are categorized as very high quality. Therefore, the finding from our systematic review can be relied upon to inform policy, practice, education, and research.

**Table 3:** Mixed Method Appraisal Tool (MMAT)

| Name of study/ author | Type of study | Methodological quality criteria | Y/N | Comment | Score |
|---|---|---|---|---|---|
| **Prendergast et al 2018**<br>Independent and combined effects of improved water, sanitation, and hygiene, and improved complementary feeding, on stunting and anaemia among HIV-exposed children in rural Zimbabwe | Cluster Randomized controlled trial | 2.1.Appropriate randomization?<br>2.2. Comparability of groups at baseline<br>2.3. Completeness of outcome data<br>2.4. Blinding of outcome assessors to the intervention<br>2.5 Participants adherence to the assigned intervention | Y<br>Y | | 100% |
| **Humphrey et al., 2018**<br>Independent and combined effects of improved water, sanitation, and hygiene, and improved complementary feeding, on child stunting and anaemia in rural Zimbabwe | Cluster Randomized controlled trial | 2.1.Appropriate randomization?<br>2.2. Comparability of groups at baseline<br>2.3. Completeness of outcome data<br>2.4. Blinding of outcome assessors to the intervention<br>2.5 Participants adherence to the assigned intervention | Y<br>Y | | 100% |
| **Null et al 2018**<br>Effects of water quality, sanitation, handwashing, and nutritional interventions on diarrhoea and child growth in rural Kenya | Cluster Randomized controlled trial | 2.1.Appropriate randomization?<br>2.2. Comparability of groups at baseline<br>2.3. Completeness of outcome data<br>2.4. Blinding of outcome assessors to the intervention<br>2.5 Participants adherence to the assigned intervention | Y<br>Y | | 100% |
| **Head et al., 2019**<br>Integration of WaSH and nutrition programming is associated with lower prevalence of child and fever in Oromia, Ethiopia | Randomized controlled trial | 2.1.Appropriate randomization?<br>2.2. Comparability of groups at baseline<br>2.3. Completeness of outcome data | Y<br>Y | | 100% |

| | | | | | |
|---|---|---|---|---|---|
| | | 2.4. Blinding of outcome assessors to the intervention | | | |
| | | 2.5 Participants adherence to the assigned intervention | | | |
| **Saaka et al 2021**<br>Independent and joint contribution of inappropriate complementary feeding and poor WaSH practices to stunte child growth | Quantitative Non randomized study | 3.1. Participants' representativeness | Y | Sample selection and design not clear The author has not come clear how to deal with confounders. For a cross-sectional study the cause effect relationship cannot be properly established because of the lack of a temporal sequence | 60% |
| | | 3.2. Appropriateness of measurements with regard to the outcome and intervention | | | |
| | | 3.3.Completeness of outcome data | Y | | |
| | | 3.4. Accounting for confounders in the design and analysis | | | |
| | | 3.5. During the study period, isAdministering of the intervention administered during the study period | | | |
| **Christian et al 2020**<br>Impact Evaluation of a Comprehensive Nutrition Program for Reducing Stunting in Children Aged 6–23 Months in Rural Malawi | Quasi experimental study | 2.1.Appropriate randomization? | Y | | 100% |
| | | 2.2. Comparability of groups at baseline | | | |
| | | 2.3. Completeness of outcome data | Y | | |
| | | 2.4. Blinding of outcome assessors to the intervention | | | |
| | | 2.5 Participants adherence to the assigned intervention | | | |
| **Hill et al.,2020**<br>Impact of Low-Cost Point-of-Use Water Treatment Technologies on Enteric Infections and Growth among Children in Limpopo, South Africa | | 2.1.Appropriate randomization? | Y | | 100% |
| | | 2.2. Comparability of groups at baseline | | | |
| | | 2.3. Completeness of outcome data | Y | | |
| | | 2.4. Blinding of outcome assessors to the intervention | | | |
| | | 2.5 Participants adherence to the assigned intervention | | | |

| | | | | |
|---|---|---|---|---|
| **Walles et al., 2017**<br>Growth pattern in Ethiopian infants – the impact of exposure to maternal HIV infection in relation to socio-economic factors | Quantitative non randomized (Cross sectional study) | 3.1. Participants' representativeness<br>3.2.Appropriateness of measurements with regard to the outcome and intervention<br>3.3.Completeness of outcome data<br>3.4. Accounting for confounders in the design and analysis<br>3.5. During the study period, isAdministering of the intervention administered during the study period | Y<br>Y | 100% |
| **Sofeu et al.,2019**<br>Early treated HIV-infected children remain at risk of growth retardation during the first five years of life: Results from the ANRSPEDIACAM cohort in Cameroon | Quantitative non randomized (Cohort study) | 3.1. Participants' representativeness<br>3.2.Appropriateness of measurements with regard to the outcome and intervention<br>3.3.Completeness of outcome data<br>3.4. Accounting for confounders in the design and analysis<br>3.5. During the study period, isAdministering of the intervention administered during the study period | Y<br>Y | 100% |
| **Fenn et al.,2012**<br>An evaluation of an operations research project to reduce childhood stunting in a food-insecure area in Ethiopia | Quantitative non randomized | 3.1. Participants' representativeness<br>3.2.Appropriateness of measurements with regard to the outcome and intervention<br>3.3.Completeness of outcome data<br>3.4. Accounting for confounders in the design and analysis | Y<br>Y | 100% |

| | | | | |
|---|---|---|---|---|
| | | 3.5. During the study period, isAdministering of the intervention administered during the study period | | |
| **George et al.,2020** Effects of a Water, Sanitation, and Hygiene Mobile Health Program on Diarrhea and Child Growth in Bangladesh | Block randomised controlled design | 2.1.Appropriate randomization? 2.2. Comparability of groups at baseline 2.3. Completeness of outcome data 2.4. Blinding of outcome assessors to the intervention 2.5 Participants adherence to the assigned intervention | Y Y | 100% |
| **Deischel et al.,2019** Birth size and early pneumonia predict linear growth among HIV-exposed uninfected infants | Quantitative non randomized (Cohort study) | 3.1. Participants' representativeness 3.2.Appropriateness of measurements with regard to the outcome and intervention 3.3.Completeness of outcome data 3.4. Accounting for confounders in the design and analysis 3.5. During the study period, isAdministering of the intervention administered during the study period | Y Y | 100% |
| **Bekele et al.,2020** The effect of access to WaSH on child growth indicators: Evidence from the Ethiopia Demographic and Health Survey 2016 | Quantitative non randomized (Cross sectional study) | 3.1. Participants' representativeness 3.2.Appropriateness of measurements with regard to the outcome and intervention 3.3.Completeness of outcome data 3.4. Accounting for confounders in the design and analysis | Y Y | 100% |

| | | | | |
|---|---|---|---|---|
| | | 3.5. During the study period, isAdministering of the intervention administered during the study period | | |
| **Torlesse et al.,2016** Determinants of stunting in Indonesian children: evidence from a cross-sectional survey indicate a prominent role for WaSH sector in stunting reduction | Randomised controlled trial | 2.1.Appropriate randomization?<br>2.2. Comparability of groups at baseline<br>2.3. Completeness of outcome data<br>2.4. Blinding of outcome assessors to the intervention<br>2.5 Participants adherence to the assigned intervention | Y<br><br><br>Y | 100% |

## Study characteristics

Fourteen studies fulfilled the eligibility criteria. These studies were conducted in Ethiopia (George et al., 2020; Bekele et al., 2020; Head et al., 2019; Walles et al., 2017; Fenn et al.,2012); Bangladesh (George et al., 2020); Malawi (Christian et al., 2020; Cameroon (Sofeu et al., 2019); Zimbabwe (Prendergast et al., 2018; Humphrey et al., 2019); South Africa (Hill et al., 2020); Ghana ( Saaka et al., 2021) and Indonesia (Torlesse et al., 2016).

Seven studies were RCT (Hill et al., 2020; George et al., 2020; Head et al., 2019; Humphrey et al., 2019; Prendergast et al., 2018; Null et al., 2018; Torlessee et al., 2016). Two studies were cross sectional (Bekele et al.,2020; Walles et al., 2017). The other two were quantitative non-randomized (Saaka et al., 2021; Fenn et al., 2012). One study was quasi-experimental (Christian et al., 2020), another was a longitudinal cohort (Sofeu et al.,2019) and the last one was an observational study (Deischel et al.,2019).

The age range of selected participants were 0-35 months (1 study), 0-36 months (1 study), 0-36 months (1 study), 6-23 months (2 studies), 0-12 months (2 studies), 0-24 months (1 study), 0-59 months (3 studies), 0-18 months (2 studies) and 0-35 months (1 study).

Participants' characteristics were as follows: HIV-exposed uninfected infants (Deischel et al., 2019; Sofeu et al., 2019; Prendergast et al., 2018; Walles et al., 2017); HIV-infected infants (Sofeu et al., 2019), HIV-unexposed uninfected infants (Humphrey et al., 2019; Sofeu et al., 2019; Walles et al., 2017). All other studies (Saaka et al., 2021; Hill et al., 2020; Christian et al., 2020; George et al., 2020; Bekele et al., 2020; Head et al., 2019; Null et al., 2018; Torlessee et al., 2016; Fenn et al., 2012) did not ascertain their participants' HIV infection status.

## Summary of the findings

Studies included in this review was analyzed based on the following outcomes- length-for-age z score (primary outcome) and underweight (weight-for-age) and wasting (weight-for-height), based on the WHO 2006 Child Growth Standard. All fourteen studies reported length-for-age as their primary outcome. A child was considered stunted if they had a height-for-age z-score below 2 standard deviations compared with the WHO Child Growth Standards median of the same age and sex.

Different sample sizes were used in the studies, ranging from 301 to 11023. All the articles managed to statistically present the findings and clearly indicated whether the results were statistically significant or not using either P-values or confidence intervals. Unimproved latrines and untreated drinking water were associated with increased odds of stunting compared with improved conditions (Bekele et al., 2020; Torlessee et al., 2016). Household sanitation had an effect on linear growth but LAZ varied according to toilet type (Deischel et al.,2019). Shared toilets had a higher Median IQR 339(91%); than pit latrines 193(52%) and flush toilets 179(48%). Upward movement on the sanitation ladder was associated with increasingly higher LAZ scores (Deischel et al.,2019; Head et al.,2019). While Walles et al., (2017), found that unavailability of running water was associated with a reduced risk for stunting (AOR 0.57; 95% CI 0.35–0.94; P=0.026), George et al., 2020) in their study found that clean water sources resulted in a reduction of diarrhea and significantly improved linear growth (33% vs 45%; OR, 0.55 [95% CI: .31–.97]. Household drinking water quality did not translate to significant improvements in child growth (Hill et al., 2020) as there were no observable significant differences in LAZ, WAZ, or WHZ. In another study (Sofeu et al., 2019), although statistically insignificant, the presence of water supply at home was a protective factor.

All combination studies included in this review did not establish any significant benefit of WaSH and nutrition/IYCF integration. For the combined interventions, the WaSH intervention had no additional effect on the mean infant length-for-age z score compared with the non-WASH group (Humphrey et al., 2019). While the IYCF component increased the mean length for age z score by 0·26 (95% CI 0·09–0·43; P=0·003), no difference was seen in mean height for age z-score (0.01, 95% CI-0.16 to 0.18) at 18 months between children who received WaSH and those who did not in Zimbabwe (Prendergast et al., 2018). A study that employed a similar methodological approach in Kenya (Null et al., 2018) found that combined interventions led to marginal growth benefits which were not statistically significant (mean difference 0·04 [95% CI –0·11 to 0·19]. In a Ghanaian study (Saaka et al., 2021), the WaSH intervention (alone or combined with IYCF) only offered marginal protection against stunting. A similar combination study in Malawi (Christian et al., 2020) reported no differences in mean length-for-age z-score or prevalence of stunting was not lower at endline. However, mean weight, weight-for-length z-score, and mid-upper arm circumference were higher at endline by 150 g, ($P < 0.05$). 0.22, ($P < 0.05$) and 0.19 cm, ($P < 0.05$) respectively compared with the comparison district.

**WaSH indicators and length for age**

Poor sanitation and hygiene comprised the use of unimproved household toilet facilities, washing hands without soap, and improper disposal of child feces and how these variables were associated with the risks of stunting among children. All the included studies reported the primary outcome (LAZ). In this review, we noted different cut-off points for determining to stunt as these were entirely based on individual and specific study focus. In all combination studies included in this review, the WaSH intervention had no additional effect on the mean infant length-for-age z score compared with the non-WaSH group (Saaka et al., 2021; Christian et al., 2020; Humphrey et al., 2019; Prendergast et al., 2018; Null et al., 2018). Additionally, few other non-combination studies (Hill et al., 2020; Walles et al., 2017) found no meaningful impact of WaSH on linear growth.

## WaSH indicators and secondary outcomes

This systematic review sought to establish the effect of improved water supply and sanitation on linear growth. Additional outcomes were underweight (weight-for-age) and wasting (weight-for-height). Most of the included studies had a different focus and reported on outcomes that are not aligned with our interests e.g. fever, head circumference, diarrhea, mid-upper arm circumference (MUAC), or anemia. Overall, the quality of evidence of the remaining studies examining underweight (weight-for-age) and wasting (weight-for-height) was determined to be poor due to the lack of some essential data elements and the limited number of studies reporting weight-for-age and weight-for-height as outcomes. Other relevant data on secondary outcomes are reported in other sections and are not separated from the primary outcome.

## Discussion

There is discordant evidence on the effect of WaSH on linear growth. While other studies suggest that linear growth is significantly linked to poor sanitation, some have reported no association. Discordant opinions emanated from contextual factors, or study settings, sample size, methodological limitations, population characteristics, and in some cases bias towards funding authority and consequent failure to limit the same. It is also worth noting that different disciplines have different error tolerance thresholds, hence the variation of results from similar studies conducted by different researchers.

In this systematic review, we collated the current state of knowledge and the uncertainty about inconsistent outcomes. We critically appraised, summarized, and attempted to reconcile the published evidence on the effect of improved sanitation on stunting. All the included studies reported linear growth as a primary outcome and must have been explicitly defined within the manuscript or abstract. We reviewed the evidence on the effect of WaSH interventions on nutritional outcomes. We also reviewed studies that reported integrated WaSH and nutrition as long as the design and methodology were able to separate and allow individual evaluation of the combined interventions.

While improved sanitation interventions are critical in eliminating microbes from the child's surroundings, intervention studies were usually time-bound, hence subject to poor compliance and limited exposure making it unlikely to stimulate linear growth. Regardless of the child's HIV status, WaSH interventions provided no special benefit to improve linear growth in settings with a high prevalence of stunting and poor sanitary conditions. Arguably, the fecal-oral transmission of these pathogens might have occurred through other environmental pathways which may not have been fully addressed by elementary WaSH interventions.

Overall, access to improved sanitation had less significant protection against stunting in the majority of included cases. Five studies reported significant improvements in linear growth (George et al., 2020; Bekele et al., 2020; Deischel et al., 2019; Torlessee et al., 2016; Fenn et al., 2012); marginal protection (Saaka et al., 2021; Sofeu et al., 2019); no protection (Christian et al., 2020; Head et al., 2019; Null et al., 2018; Prendergast et al., 2018; Humphrey et al., 2019; Walles et al., 2017; Hill et al., 2020).

While protective, combined-treatment groups produced statistically significant but inconsistent, outcomes. Consistent with the available evidence, neither intervention on its own may be sufficient to measurably improve linear growth without firm logical contradictions. As we are unable to rule out residual correlations between unobservable household characteristics and our primary outcome; we might underestimate the effects of improved water supply and sanitation. However, as we earlier hypothesized, linear growth failure is multifaceted, and observance of WaSH practices alone may not reduce the odds of stunting.

## Implications of the study findings for practice, research, and policy

Attributable causes of child undernutrition are household food insecurity, inadequate maternal and child care and feeding practices, poor WaSH, and lack of health services. The study findings indicate the problem of stunting is complex and multifaceted- prompting a need for an integrated response. Stakeholders must therefore engage in a multisectoral dialogue and explore multifaceted approaches *to end all forms of malnutrition, including achieving, by 2025, the internationally agreed targets on stunting and wasting in children under 5 years of age* (SDG 2). Accordingly, there is a need to set up policies and develop measurable and integrated indicators, strategies, sectoral plans, and technical guidelines for integrated services that are carefully guided by research.

## Conclusion

Water supply and sanitation are critical for health. Emerging evidence indicates a close relationship between stunting and poor WaSH.

Since the causes of undernutrition are multifaceted, the contribution of specific WaSH conditions to rates of childhood undernutrition warrants further study.

**Availability of data and material**

The data and materials used in this systematic review are available from the corresponding author on request.

**Competing interests**

The authors declare no competing interests.

**References:**


1. Shekar, M., Kakietek, J., Eberwein, J.D. and Walters, D., 2017. An investment framework for nutrition: reaching the global targets for stunting, anemia, breastfeeding, and wasting. World Bank Publications.
2. Chandna J, Ntozini R, Evans C, et al. Effects of improved complementary feeding and improved water,sanitation and hygiene on early child development among HIV-exposed children: substudy of a cluster randomised trial in rural Zimbabwe. BMJ Global Health 2020;5:e001718. doi:10.1136/ bmjgh-2019-001718.
3. Budge, S., Parker, A.H., Hutchings, P.T. and Garbutt, C., 2019. Environmental enteric dysfunction and child stunting. Nutrition reviews, 77(4), pp.240-253.
4. Keusch, G.T., Rosenberg, I.H., Denno, D.M., Duggan, C., Guerrant, R.L., Lavery, J.V., Tarr, P.I., Ward, H.D., Black, R.E., Nataro, J.P. and Ryan, E.T., 2013. Implications of acquired environmental enteric dysfunction for growth and stunting in infants and children living in low-and middle-income countries. Food and nutrition bulletin, 34(3), pp.357-364.
5. Berhanu, G., Mekonnen, S. and Sisay, M., 2018. Prevalence of stunting and associated factors among preschool children: a community based comparative cross sectional study in Ethiopia. BMC nutrition, 4(1), pp.1-15.
6. Reese, Heather, Parimita Routray, Belen Torondel, Sheela S. Sinharoy, Samir Mishra, Matthew C. Freeman, Howard H. Chang, and Thomas Clasen. "Assessing longer-term effectiveness of a combined household-level piped water and sanitation intervention on child diarrhoea, acute respiratory infection, soil-transmitted helminth infection and nutritional status: a matched cohort study in rural Odisha, India." International journal of epidemiology 48, no. 6 (2019): 1757-1767.

7. Moher D, Liberati A, Tetzlaff J, Altman DG GP. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med. 2009;6(7).
8. Hong GN, Pluye P, Fàbregues S, Bartlett G, Boardman F, Cargo M, Dagenais P, Gagnon M, Griffiths F, Nicolau B, O'cathain A, Rousseau M & VI. MIXED METHODS APPRAISAL TOOL (MMAT) VERSION 2018 User guide. Registration of Copyright (#1148552),. Canadian Intellectual Property Office, Industry Canada. 2018.
9. Bekele, T., Rahman, B. and Rawstorne, P., 2020. The effect of access to water, sanitation and handwashing facilities on child growth indicators: evidence from the Ethiopia demographic and health survey 2016. PLoS One, 15(9), p.e0239313.
10. Walles, J., Balcha, T.T., Winqvist, N. and Björkman, P., 2017. Growth pattern in Ethiopian infants–the impact of exposure to maternal HIV infection in relation to socio-economic factors. Global health action, 10(1), p.1296726.
11. Fenn, B., Bulti, A.T., Nduna, T., Duffield, A. and Watson, F., 2012. An evaluation of an operations research project to reduce childhood stunting in a food-insecure area in Ethiopia. Public health nutrition, 15(9), pp.1746-1754.
12. JR, H. and Freeman, M.C., 2019. Integration of water, sanitation and hygiene and nutrition programming is associated with lower prevalence of Child stunting and fever in Oromia, Ethiopia. African Journal of Food, Agriculture, Nutrition & Development, 19(4).
13. Null, C., Stewart, C.P., Pickering, A.J., Dentz, H.N., Arnold, B.F., Arnold, C.D., Benjamin-Chung, J., Clasen, T., Dewey, K.G., Fernald, L.C. and Hubbard, A.E., 2018. Effects of water quality, sanitation, handwashing, and nutritional interventions on diarrhoea and child growth in rural Kenya: a cluster-randomised controlled trial. The Lancet Global Health, 6(3), pp.e316-e329.
14. Deichsel, E.L., Pavlinac, P.B., Richardson, B.A., Mbori-Ngacha, D., Walson, J.L., McGrath, C.J., Farquhar, C., Bosire, R., Maleche-Obimbo, E. and John-Stewart, G.C., 2019. Birth size and early pneumonia predict linear growth among HIV-exposed uninfected infants. Maternal & Child Nutrition, 15(4), p.e12861.
15. George, C.M., Monira, S., Zohura, F., Thomas, E.D., Hasan, M.T., Parvin, T., Hasan, K., Rashid, M.U., Papri, N., Islam, A. and Rahman, Z., 2021. Effects of a water, sanitation, and hygiene mobile health program on diarrhea and child growth in Bangladesh: a cluster-randomized controlled trial of the cholera hospital-based

intervention for 7 days (CHoBI7) mobile health program. Clinical Infectious Diseases, 73(9), pp.e2560-e2568.
16. Christian, P., Hurley, K.M., Phuka, J., Kang, Y., Ruel-Bergeron, J., Buckland, A.J., Mitra, M., Wu, L., Klemm, R. and West Jr, K.P., 2020. Impact evaluation of a comprehensive nutrition program for reducing stunting in children aged 6–23 months in rural Malawi. The Journal of Nutrition, 150(11), pp.3024-3032.
17. Sofeu, C.L., Tejiokem, M.C., Penda, C.I., Protopopescu, C., Ateba Ndongo, F., Tetang Ndiang, S., Guemkam, G., Warszawski, J., Faye, A., Giorgi, R. and ANRS-PEDIACAM study group, 2019. Early treated HIV-infected children remain at risk of growth retardation during the first five years of life: results from the ANRS-PEDIACAM cohort in Cameroon. PLoS One, 14(7), p.e0219960.
18. Prendergast, A.J., Chasekwa, B., Evans, C., Mutasa, K., Mbuya, M.N., Stoltzfus, R.J., Smith, L.E., Major, F.D., Tavengwa, N.V., Mutasa, B. and Mangwadu, G.T., 2019. Independent and combined effects of improved water, sanitation, and hygiene, and improved complementary feeding, on stunting and anemia among HIV-Exposed children in rural Zimbabwe: a cluster randomized controlled trial. The lancet child and adolescent health, 3(2), pp.77-90.
19. Humphrey, J.H., Mbuya, M.N., Ntozini, R., Moulton, L.H., Stoltzfus, R.J., Tavengwa, N.V., Mutasa, K., Majo, F., Mutasa, B., Mangwadu, G. and Chasokela, C.M., 2019. Independent and combined effects of improved water, sanitation, and hygiene, and improved complementary feeding, on child stunting and anaemia in rural Zimbabwe: a cluster-randomised trial. The Lancet Global Health, 7(1), pp.e132-e147.
20. Hill, C.L., McCain, K., Nyathi, M.E., Edokpayi, J.N., Kahler, D.M., Operario, D.J., Taylor, D.D., Wright, N.C., Smith, J.A., Guerrant, R.L. and Samie, A., 2020. Impact of low-cost point-of-use water treatment technologies on enteric infections and growth among children in Limpopo, South Africa. The American journal of tropical medicine and hygiene, 103(4), p.1405.
21. Saaka, M., Saapiire, F.N. and Dogoli, R.N., 2021. Independent and joint contribution of inappropriate complementary feeding and poor water, sanitation and hygiene (WASH) practices to stunted child growth. Journal of Nutritional Science, 10.
22. Torlesse, H., Cronin, A.A., Sebayang, S.K. and Nandy, R., 2016. Determinants of stunting in Indonesian children: evidence from a cross-sectional survey indicate a prominent role for the water, sanitation and hygiene sector in stunting reduction. BMC public health, 16(1), pp.1-11.

23. Simiyu, S.N., Kweyu, R.M., Antwi-Agyei, P. and Adjei, K.A., 2020. Barriers and opportunities for cleanliness of shared sanitation facilities in low-income settlements in Kenya. BMC Public Health, 20(1), pp.1-12.
24. Evans, E.E. and Siedner, M.J., 2017. Tropical Parasitic Infections in Individuals Infected With HIV. Current tropical medicine reports, 4(4), pp.268-280.
25. Waddington, H. and Snilstveit, B., 2009. Effectiveness and sustainability of water, sanitation, and hygiene interventions in combating diarrhoea. Journal of development effectiveness, 1(3), pp.295-335.
26. Luby, S.P., Rahman, M., Arnold, B.F., Unicomb, L., Ashraf, S., Winch, P.J., Stewart, C.P., Begum, F., Hussain, F., Benjamin-Chung, J. and Leontsini, E., 2018. Effects of water quality, sanitation, handwashing, and nutritional interventions on diarrhoea and child growth in rural Bangladesh: a cluster randomised controlled trial. The Lancet Global Health, 6(3), pp.e302-e315.
27. Watanabe, K. and Petri Jr, W.A., 2016. Environmental enteropathy: elusive but significant subclinical abnormalities in developing countries. EBioMedicine, 10, pp.25-32.