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REVIEW ARTICLE

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Water, sanitation and hygiene interventions and the prevention and treatment of childhood acute malnutrition: A systematic review

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Abstract

Undernutrition is more prevalent among children living in unsanitary environments with inadequate water, sanitation and hygiene (WASH). Despite good evidence for the effect of WASH on multiple infectious diseases, evidence for the effect of WASH interventions on childhood undernutrition is less well established, particularly for acute malnutrition. To assess the effectiveness of WASH interventions in preventing and treating acute childhood malnutrition, we performed electronic searches to identify relevant studies published between 1 January 2000 and 13 May 2019. We included studies assessing the effect of WASH on prevention and treatment of acute malnutrition in children under 5 years of age. Data were extracted by two independent reviewers. We included 26 articles of 599 identified references with a total of 43,083 participants. Twenty-five studies reported on the effect of WASH on prevention, and two studies reported its effect on treatment of acute malnutrition. Current evidence does not show consistent associations of WASH conditions and interventions with prevention of acute malnutrition or with the improvement of its treatment outcomes. Only two high-quality randomized controlled trials (RCTs) demonstrated that improved water quality during severe acute malnutrition treatment improved recovery outcomes but did not prevent relapse. Many of the interventions consisted of a package of WASH services, making impossible to attribute the effect to one specific component. This highlights the need for high-quality, rigorous intervention studies assessing the effects of WASH interventions specifically designed to prevent acute malnutrition or improve its treatment.

KEYWORDS

acute malnutrition, prevention, sanitation and hygiene, treatment, water

1 | INTRODUCTION

Malnutrition remains a major global health challenge, with an estimated 149 million children suffering stunting and almost 50 million acute malnutrition in 2019 (Independent Expert Group of the Global Nutrition Report, 2020; United Nations Children's Fund [UNICEF] et al., 2020). Acute malnutrition in young children is defined as weight-for-height z-score (WHZ) < −2 SD or having a mid-upper arm circumference (MUAC) < 12.5 cm and/or the presence of bilateral pitting oedema. It includes severe acute malnutrition (SAM) defined as WHZ < −3 or MUAC < 115 mm, or the presence of bilateral pitting oedema, or both (WHO & UNICEF, 2009), and moderate acute malnutrition (MAM) defined as WHZ between −2 and −3 or MUAC between 115 and <125 mm (WHO, 2012). Both forms of acute malnutrition have considerable short- and long-term health and development consequences. The risk of all-cause mortality in children younger than 5 years is approximately 11 times higher for SAM children and three times higher for those with MAM compared with children with WHZ > −1 SD (Black et al., 2008; Schwinger et al., 2019). Acute malnutrition may account for over one-third of children deaths and 11% of the total global disease burden (Black et al., 2008). Despite the significant progress made since 1990 on reducing stunting, progress on reducing wasting in the same period is more modest (Annan et al., 2014).

Key messages

- The evidence was mixed with studies of generally low quality and high risk of bias.
- Among all WASH interventions reviewed, only household water treatment, alone or combined with other WASH interventions, showed an effect on improving recovery when implemented during outpatient treatment for severe acute malnutrition as assessed in two high-quality studies. However, it did not prevent relapse post-discharge.
- Further research assessing the effect of community-led WASH interventions on acute malnutrition compared to household-level interventions is needed.
- Higher quality and adequately powered intervention studies are needed to assess the effects of WASH interventions on both the prevention and treatment of acute malnutrition since current evidence does not show consistent protective associations.

The immediate causes of malnutrition are inadequate dietary intake and disease; however, the underlying determinants are complex, spanning from food insecurity, poor care practices, unsanitary living environments and/or poor access to healthcare (Dangour et al., 2013; Prüss-Üstün et al., 2016).

Undernutrition is more prevalent among populations living in unsanitary environments with inadequate WASH, accounting for the 16% of undernutrition burden (Prüss-Ustün et al., 2014; 2016). In theory, WASH can influence main drivers of individual nutritional status, including the food intake and general health status considered as immediate causes, and the physical environment deemed as an indirect cause (Dangour et al., 2013; Prüss-Üstün et al., 2016). In this regard, efforts have been made to better understand the causal links between poor WASH and malnutrition producing evidence to support the implementation of interventions improving the nutritional status of children (Dangour et al., 2013; Gera et al., 2018; Gizaw & Worku, 2019; Pickering et al., 2019).

The hypothesized causal pathways between poor WASH and child undernutrition include both biological mechanisms (direct pathways) and social and economic determinants (indirect pathways). Repeated diarrhoea episodes, helminth infections and environmental enteric dysfunction (EED) are the three main proposed biological mechanisms linking WASH to undernutrition (Cumming & Cairncross, 2016). Enteric infections can result in negative changes to gut structure and/or function even in the absence of diarrhoea having an impact on child's nutrition and development (Petri et al., 2008). The link between diarrhoeal diseases and undernutrition is described as cyclical, whereby diarrhoea increases the loss of nutrients and water in the body, leading to undernutrition, and conversely, undernutrition compromises the immune system, leaving the child more susceptible to diarrhoeal diseases (Crane et al., 2015).

Diarrhoeal diseases, helminth infections and EED are hypothesized to be caused by unsanitary living conditions, unsafe drinking water, inadequate sanitation and poor hygiene. The burden of diarrhoeal diseases from inadequate WASH in children under 5 years old has been estimated in over 300,000 deaths (Prüss-Ustün et al., 2014). Therefore, access to adequate WASH services can help to prevent a large number of infectious diseases, including a broad range of enteric infections (Budge et al., 2019; Crane et al., 2015; Wolf et al., 2018). Indeed, the highest prevalence of helminth infections and undernutrition is often present in the same geographic areas where WASH is also scarce or inadequate (Ziegelbauer et al., 2012). Indirect pathways of WASH impact on undernutrition concern the time and financial costs to the household in ensuring safe WASH (Budge et al., 2019; Cumming & Cairncross, 2016). It also refers to a broader socio-economic environment, including water affordability, available sanitation and hygiene services, education and poverty (Cumming & Cairncross, 2016; Dangour et al., 2013; Guerrant et al., 2008).

Most interventions to address acute malnutrition are food based; however, the nutrition community has increased its focus on nutrition-sensitive programming. This approach goes beyond food provision and nutrition counselling, aiming to address the underlying causes of undernutrition, including poor WASH (Black et al., 2013).

Most of the current evidence of WASH interventions focus on its impacts on diarrhoea and other infectious diseases. Furthermore, most of the evidence regarding the effect of WASH on children nutritional status is focused on stunting, whereas evidence on its effects on acute malnutrition is still scarce even though this condition entails more serious consequences for children's health, also increasing the risk of children to become stunted (Independent Expert Group of the Global Nutrition Report, 2020). Several reviews and pooled analyses documented on the drivers of stunting and the impact of WASH interventions on child linear growth and stunting (Dangour et al., 2013; Gera et al., 2018; Gizaw & Worku, 2019; Kwami et al., 2019), yet no current reviews focus on the documentation of the effect of WASH interventions on acute malnutrition. This lack of evidence can lead to misguided decisions, especially when neglecting that both acute malnutrition and stunting can often occur in the same individual and are present in the same populations (Briend & Berkley, 2016; Independent Expert Group of the Global Nutrition Report, 2020).

At a policy level, there have been many initiatives that were developed to better integrate WASH and nutrition activities, such as 'nutrition-sensitive WASH' interventions (Black et al., 2013). Nevertheless, there is still a lack of policies and operational guidance on whether and how to include WASH interventions as part of the child acute malnutrition prevention and treatment strategies.

Therefore, the aim of this systematic review is to assess the effects of WASH conditions and interventions in preventing and treating acute childhood malnutrition and to summarize the best available evidence to support policy and operational guidelines.

2 | METHODS

2.1 | Study selection

Screened studies were included based on the following criteria: (1) articles written in English dated after 1 January 2000 until 13 May 2019, (2) study design (individual and cluster-randomized controlled trials [RCT/cRCT], quasi-experimental studies, case–control studies and cohort studies), (3) the study population included children below 5 years of age and (4) study assessing WASH conditions or interventions alone and/or WASH interventions combined with other non-WASH interventions.

Our aim in restricting the dates of inclusion was to include recent studies providing a useful summary of evidence only on currently implemented interventions, which could guide programmatic actions of WASH and nutrition operational and humanitarian actors promoting evidence-based practices. This dates restriction also intended to only include intervention and observational studies that were more likely to comply with CONSORT and STROBE guidelines, respectively. There were no parameters around location or whether the context was considered a humanitarian emergency or development setting.

2.2 | WASH conditions and types of interventions

WASH conditions and WASH interventions as included in this review are defined in line with previous Cochrane reviews (Dangour et al., 2013) and WHO technical reports (Prüss-Üstün et al., 2016; WHO, 2019). Based on these definitions, We considered five categories of WASH conditions and interventions: (1) *microbiological water quality* (improved microbiological quality of drinking water or any intervention aimed to improve its microbiological quality, including any water treatment methods and sources of water), (2) *water supply* (improved access to water, improved sources of water or any intervention aimed to improve the amount of water available to a household or individual and providing continuous access to water sources), (3) *sanitation* (current sanitation conditions or any intervention aimed to provide and/or promote sanitation, i.e. enhance access to improved sanitary facilities [flush toilet, piped sewer system, septic tank, flush/pour flush to pit latrine, ventilated improved pit latrine or pit latrine with slab] or use of sanitation facilities and proper disposal of child faeces), (4) *hygiene* (any current hygiene practices or any implemented intervention related to the improved or increased adoption of practices of handwashing with soap, safe storage of water, food and utensils and hygienic preparation of foods) and (5) *environmental hygiene* (any existing practices or any implemented intervention aimed to improve vector control [e.g. water resource management and breeding areas for mosquitos] and reduce the risk of contamination by the immediate environment [e.g. faecal contamination of living and playing space for children]).

2.3 | Outcomes

In this review, acute malnutrition is inclusive of both SAM and MAM and defined as WHZ < −2 SD or MUAC < 12.5 cm and/or the presence of bilateral pitting oedema (WHO & UNICEF, 2009). Only studies that used definitions of acute malnutrition by anthropometric measurements based upon the National Center for Health Statistics (NCHS) child growth references (Kuczmarski et al., 2002), the World Health Organization (WHO) child growth standards (World Health Organization (WHO), 2006) and/or MUAC were included.

The primary outcomes of interest for this review were (1) rates of acute malnutrition, (2) rates of SAM, (3) rates of MAM, (4) rates of wasting (considering wasting as synonym of acute malnutrition), (5) mean WHZ and/or (6) mean MUAC. Because the available literature on the associations between WASH and acute malnutrition is limited, we also considered the average child WHZ and MUAC as a preliminary step to improving acute malnutrition rates.

Prevention outcomes were assessed based on changes in the anthropometric measures of samples composed of children under 5 with various nutritional status. Treatment outcomes were reported based on terms referring to the next indicators: (1) recovery rates, (2) relapse rates, (3) discharge rates and/or (4) time to recovery of acute malnourished children being treated.

2.4 | Search strategy

This review consisted of a computerized search of PubMed. Reference lists of relevant reviews were used to identify literature possibly missed in the primary search. The systematic search strategy was built with researchers and technical and operational experts in the fields of WASH and nutrition. The search strategy included a combination of terms characterizing the impact of widely used WASH indicators and interventions on child acute malnutrition. The following search terms were used: child*, infant*, 'acute malnutrition', 'acutely malnourished', 'severe acute malnutrition', 'severely malnourished', 'severely wasted', 'moderate acute malnutrition', 'moderately malnourished', 'moderately wasted', 'wasted', 'wasting', 'outpatient therapeutic feeding', 'outpatient therapeutic program', 'stabilization center', 'nutrition rehabilitation unit', 'inpatient therapeutic feeding', 'supplementary feeding', 'community-based management of acute malnutrition', 'CMAM', 'weight-for-height', 'weight for height', 'mid-upper arm circumference', 'MUAC', 'kwashiorkor', 'marasmus', 'water', 'sanitation', 'sanitary', 'hygiene', 'hygienic', 'WASH', handwash*, 'soap', 'community led total sanitation', 'CLTS', 'vector control', 'waste', 'feces', 'faeces', 'toilet', 'open defecation', 'WiN Kit', 'latrine', 'chlorine', 'chlorination', 'aquatabs', 'babywash', 'potty' and 'potties'. The search strategy was applied on 13 May 2019 to access the Medline database.

2.5 | Screening process and data extraction

Screening of titles and abstracts identified was performed by a single reviewer (HS). After removing duplicates, full-text versions of the remaining articles were reviewed to determine eligibility for inclusion according to the inclusion/exclusion criteria by two reviewers independently (ARPH, HS). These two reviewers (ARPH, HS) independently assessed the eligibility of the studies, extracted relevant data and assessed the risk of bias for all included studies; the two authors did not perform this assessment and data extraction in parallel but successively. Articles were excluded if the study did not match our search criteria in terms of population, intervention or outcomes and/or if they had other type of study design. Any disagreement regarding the criteria was resolved between the two reviewers.

Studies were assessed following the GRADE guidelines for rating the quality of evidence (Guyatt et al., 2011), and the significance of evidence was adjusted accordingly. We assessed the quality of each study independently, first by the quality of study design according to the GRADE guidelines (Balshem et al., 2011): (1) high quality (++++) (RCT and cRCT), (2) moderate quality (+++) (quasi-experimental studies) and (3) low quality (++) (prospective cohort and case–control study). Studies were then further assessed for additional biases (such as potential confounding, lack of an adequate control or comparison group and inadequate statistical power) We performed an additional evaluation of non-intervention studies according to the Newcastle–Ottawa Scale (NOS) (Wells et al., 2019), and the results are shown in Annex S1.

The overall body of evidence relating to the associations of each WASH condition or intervention with acute malnutrition was assessed based on the Cochrane GRADE approach (Schünemann et al., 2013) and the EPC Approach for Grading Strength of Evidence (Berkman et al., 2013), and results are shown in Table 1. In doing so, we considered the size of the body of evidence (number of studies), the quality of evidence (quality of studies including potential biases) and consistency of evidence (number of studies pointing to similar conclusions). These criteria were used to grade the strength of the body of evidence regarding each category of WASH conditions/interventions according to the next classification: insufficient, low, moderate and high.

2.6 | Ethical considerations

This study synthesize data from already published studies, therefore ethical approval is not required.

3 | RESULTS

The search strategy identified 591 articles, and a further eight studies were identified through the screening of systematic reviews' references lists. After deduplication and screening, 48 full-text articles were reviewed, and a further 22 were excluded after full-text assessment. The review process is presented in the PRISMA flow diagram Figure 1.

The remaining 26 articles included and their characteristics and quality scores are shown in Table 2. Results of the Cochrane assessment of the risk of bias for intervention studies (Higgins et al., 2008), which included eight cRCTs and one RCT, are presented in Table 3. Non-intervention studies included seven case–control studies, five prospective cohort studies, one cross-sectional cohort, two quasi-experimental studies, one observational retrospective study and one panel data secondary analysis. The 26 studies included 43,083 participants, ranging from 88 to 8246 participants. All studies were performed in low- and middle-income countries according to the World Bank categories (12 in Asia, 11 in Africa, 2 in America and 1 was multi-country), 10 in urban settings and 19 in a rural context (Annex S2). Out of the 26 studies, only six described the context of populations in more detail, which mainly consisted of vulnerable populations with economies based on subsistence farming and livestock rearing. Other contextual characteristics such as the food security situation and migratory flows were not described (Annex S2).

Out of the 26 studies, eight intervention studies reported on the effect of WASH interventions on prevention of acute malnutrition, and 17 observational studies reported on the associations of WASH conditions with prevention of acute malnutrition. Only two RCTs describing the effect of WASH interventions on the treatment of acute malnutrition were identified. Fourteen studies reported mean WHZ as an outcome, nine measured wasting according to the WHZ, six measured SAM according to WHZ, four reported on the mean MUAC, two reported on wasting based on MUAC, and one measured SAM according to MUAC. Annexes S3 and S4 indicate the outcome

TABLE 1 Evaluation of the strength of evidence on approaches for managing child acute malnutrition: Prevention and treatment

WASH conditions/interventions	Study design: no. studies (*N*)	Strength of evidence‡
Drinking water access and availability		
Distance to water point <30 min; access to 15 L/person/day; fetching drinking water daily	Observational: 3 (1030)	Insufficient
Water quality		
Water for drinking is treated	RCT: 7 (22,445)	Moderate (regarding associations with prevention of wasting)
	Observational: 5 (3476)	Moderate (regarding associations with treatment of wasting)
Presence of *Escherichia coli* at point of use; turbidity < 5 NTU; type of water source	RCT: 1 (315) Observational: 5 (1465)	Low
Safe water storage		
Water is correctly stored (clean and covered container)	RCT: 4 (15,715) Observational: 1 (411)	Moderate
Handwashing		
Knowledge or practice of proper handwashing behaviours	RCT: 1 (315) Observational: 4 (1833)	Low
Observation of soap at a handwashing station; observation of soap use during a handwashing demonstration	RCT: 2 (404) Observational: 3 (1810)	Low
Provision of soap	RCT: 3 (6971)	Low
Food hygiene		
Provision of a cup with handle for child to drink; use of utensils, monthly hygiene expenses	RCT: 1 (1603) Observational: 2 (1530)	Insufficient
Hygiene promotion and community mobilization activities		
Provision of individual and/or group hygiene sensitization sessions; provision of hygiene promotional material	RCT: 6 (11,973) Observational: 1 (280)	Low
Environmental hygiene and vector control		
Absence of animal and human faeces around children playing/waiting areas; provision of safe child play space	RCT: 1 (5280)	Insufficient
Access to sanitation		
Access to or presence of HH latrine	Observational: 5 (2302)	Insufficient
Presence of HH hygienic toilets or 'improved latrine'	RCT: 5 (19,480) Observational: 7 (10,872)	Moderate
Presence of potties for small children	RCT: 2 (13,797)	Low
Absence of open defaecation	No studies found	Insufficient
Sanitation practices		
Safe disposal of child faeces	Observational: 2 (627)	Insufficient

Notes: The strength of evidence derived from each study was evaluated based on the Cochrane GRADE approach (Schünemann et al., 2013). This was done first by the quality of study design: (1) high quality (++++) (randomized controlled trial and cluster-randomized controlled trial), (2) moderate quality (+++) (quasi-experimental [non-randomized controlled trial] and controlled before and after intervention study) and (3) low quality (++) (controlled or uncontrolled prospective cohort and case–control study). Studies were further assessed for additional biases (such as potential confounding, lack of an adequate control or comparison group and inadequate statistical power), and the strength of the body of evidence was adjusted accordingly, following the Evidence-based Practice Center (EPC) Grading Guidelines (Berkman et al., 2013).

Abbreviations: HH, household; no. studies (*N*), number of studies and their entire-sample size; NTU, nephelometric turbidity unit.

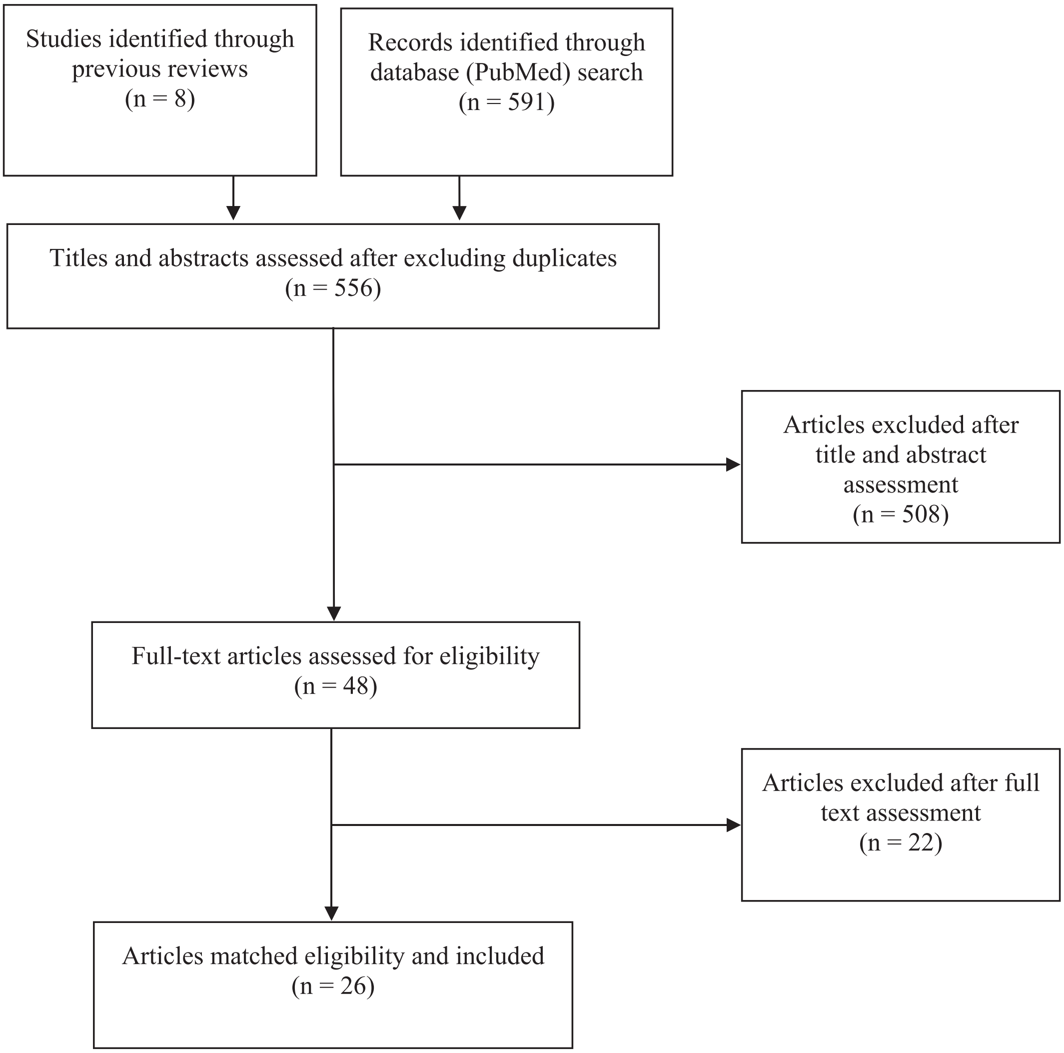

FIGURE 1 PRISMA flow chart of literature search

measures used in each study and provide a detailed description of the assessed WASH interventions and conditions.

3.1 | Effect of WASH on preventing acute malnutrition

Table 4 shows the results of the 25 studies measuring the associations of WASH on preventing acute malnutrition. The results are inconsistent, and the quality of studies varied. Several studies were conducted to examine associations between WASH conditions and acute malnutrition and the effect of WASH interventions on preventing this condition; however, results are mixed, and the evidence relies mostly on low- to moderate-quality observational studies (Ambadekar & Zodpey, 2017; Ayana et al., 2015; Buttenheim, 2008; Chisti et al., 2007; Dodos et al., 2018; Fikree et al., 2000; George et al., 2016; Iannotti et al., 2009; Langford et al., 2011; Lin et al., 2013; Munirul Islam et al., 2018; Nabwera et al., 2018; Stobaugh et al., 2018; Tomedi et al., 2012).

Among the few high-quality intervention studies, most found no effect of WASH interventions on preventing acute malnutrition (Humphrey et al., 2018; Luby et al., 2018; Null et al., 2018; Patil et al., 2014).

3.1.1 | Effect of quality and management of water on preventing acute malnutrition

Current evidence is mixed and weak regarding the association of water quality and acute malnutrition.

Access to water

Only one high-quality RCT (du Preez et al., 2011) and four low-quality non-intervention studies (Arnold et al., 2009; Ayana et al., 2015; Dodos et al., 2018; Nabwera et al., 2018) have examined the association between access to drinking water and acute malnutrition, founding no association with preventing acute malnutrition.

TABLE 2 Summary of the 26 studies included in this review that studied the effect of WASH on child acute malnutrition

First author (year)	Study setting	Outcome measures	Study design	Total *N*	Quality score
Altmann et al. (2018)	Chad	SAM (WHZ ≤ 3 SD)	cRCT	1603	++++
Ambadekar and Zodpey (2017)	India	SAM (WHZ ≤ 3 SD)	Case–control	737	+++
Arnold et al. (2009)	Guatemala	Mean WHZ Mean MUAC	Quasi-experimental	929	++
Ayana et al. (2015)	Ethiopia	Wasting (MUAC < 12.5 cm)	Case–control	339	++
Buttenheim (2008)	Bangladesh	Mean WHZ	Quasi-experimental	153	++
Chisti et al. (2007)	Bangladesh	SAM (WHZ ≤ 3 SD)	Case–control	6881	++
De Vita et al. (2019)	Kenya	Wasting (WHZ ≤ 2 SD)	Case–control	1119	++
Dodos et al. (2018)	Chad	SAM (WHZ ≤ 3 SD)	Case–control	411	++
Doocy et al. (2018)	Pakistan	SAM (MUAC < 11.5 cm)	cRCT	901	++++
du Preez et al. (2011)	Kenya	Median WHZ	RCT	1089	++++
Fikree et al. (2000)	Pakistan	Wasting (WHZ ≤ 2 SD)	Prospective cohort	565	++
George et al. (2016)	Bangladesh	Wasting (WHZ ≤ 2 SD) mean WHZ	Prospective cohort	216	++
Headey and Palloni (2019)	Multi-country	Wasting (WHZ ≤ 2 SD)	Panel data secondary analysis	1612	++
Humphrey (2018)	Zimbabwe	Wasting (WHZ ≤ 2 SD) mean WHZ mean MUAC	cRCT	5280	++++
Iannotti et al. (2009)	Peru	Mean WHZ	Prospective cohort	232	++
Langford et al. (2011)	Nepal	Mean WHZ	Quasi-experimental	88	+++
Lin et al. (2013)	Bangladesh	Wasting (WHZ ≤ 2 SD) mean WHZ	Case–control	119	++
Luby et al. (2018)	Bangladesh	Wasting (WHZ ≤ 2 SD) mean WHZ	cRCT	5551	++++
Munirul Islam et al. (2018)	Bangladesh	SAM (WHZ ≤ 3 SD)	Prospective cohort	154	++
Nabwera et al. (2018)	Gambia	SAM (WHZ ≤ 3 SD)	Case–control	280	++
Null et al. (2018)	Kenya	Wasting (WHZ ≤ 2 SD) mean WHZ	cRCT	8246	++++
Patil et al. (2014)	India	Mean WHZ mean MUAC	cRCT	5209	++++
Seetha et al. (2018)	Malawi	Mean WHZ mean MUAC	cRCT	179	++++
Stobaugh et al. (2018)	Malawi	Wasting (MUAC < 12.5 cm)	Prospective cohort nested within cRCT	315	++++
Tomedi et al. (2012)	Kenya	Wasting (WHZ ≤ 2 SD) mean WHZ	Quasi-experimental	276	++++
Zhang et al. (2013)	China	Mean WHZ	cRCT	599	++++

Abbreviations: cRCT, cluster-randomized controlled trial; LMIC, low- and middle-income countries; MUAC: mid-upper arm circumference; SAM, severe acute malnutrition; WHZ, weight-for-height z-score.

Quality of water and water treatment

Two high-quality studies (du Preez et al., 2011; Stobaugh et al., 2018) and six low-quality studies (Arnold et al., 2009; Dodos et al., 2018; Fikree et al., 2000; George et al., 2016; Lin et al., 2013; Munirul Islam et al., 2018) consistently demonstrated no association between measured water quality and prevention of acute malnutrition or improved WHZ.

One moderate-quality (Ambadekar & Zodpey, 2017) and one low-quality case–control study (Nabwera et al., 2018) found associations between water treatment and preventing SAM (improvements of anthropometric measures and reduction of acute malnutrition prevalence). However, two high-quality cRCTs (Luby et al., 2018; Null et al., 2018) and three non-intervention studies (De Vita et al., 2019; Dodos et al., 2018; Stobaugh et al., 2018) did not find any association of water treatment with improving WHZ or preventing acute malnutrition.

3.1.2 | Water storage

Evidence on safe water storage was limited. Most studies found no association between correctly stored water and prevention of acute malnutrition (Dodos et al., 2018; Luby et al., 2018; Null et al., 2018), except for one high-quality prospective cohort study (Stobaugh et al., 2018).

TABLE 3 Cochrane risk of bias assessment for the intervention studies included in this systematic review

Study	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)
Altmann et al. (2018)	Low	High	High	High	Low	Low
Doocy et al. (2018)	High	High	High	High	Low	Low
du Preez et al. (2011)	Low	Low	High	High	Low	Low
Humphrey (2018)	Low	Low	High	High	Low	Low
Luby et al. (2018)	Low	Low	High	High	Low	Low
Null et al. (2018)	Low	Low	High	High	Low	Low
Patil et al. (2014)	Low	Low	High	High	Low	Low
Seetha et al. (2018)	Low	Low	High	High	Low	Low
Zhang et al. (2013)	Unclear	Unclear	High	High	Low	Low

3.1.3 | Effect of hygiene on preventing acute malnutrition

Food hygiene

Two case–control studies examined the link between food hygiene and acute malnutrition, finding neither an association between monthly hygiene expenses and prevention of SAM (Dodos et al., 2018) nor between the use of utensils and prevention of acute malnutrition (De Vita et al., 2019).

Hygiene promotion and community mobilization activities

Most studies, ranging from low to high quality, did not show an effect of hygiene sensitization sessions and promotional material on improving WHZ (Langford et al., 2011) or preventing acute malnutrition (Luby et al., 2018; Nabwera et al., 2018). Three high-quality studies demonstrated an effect of group hygiene sensitization sessions on improving WHZ (Seetha et al., 2018; Tomedi et al., 2012; Zhang et al., 2013). Yet, in two of these studies (Tomedi et al., 2012; Zhang et al., 2013), the sessions were in combination with the provision of food, preventing the ability to attribute the effect to the hygiene sessions alone.

Handwashing

Compared with other hygiene interventions, the effect of handwashing interventions alone have been evaluated in a larger number of studies; however, findings regarding the association between handwashing and acute malnutrition was mixed and weak. Whereas one case–control study demonstrated an association with preventing SAM (Ayana et al., 2015), four other non-intervention studies ranging in quality found no association between handwashing and acute malnutrition prevention (Arnold et al., 2009; Dodos et al., 2018; Munirul Islam et al., 2018; Stobaugh et al., 2018).

The effect of the use of soap during handwashing have been examined only in few non-intervention studies, which found no association with prevention of acute malnutrition (De Vita et al., 2019; Stobaugh et al., 2018) or SAM (Dodos et al., 2018; Nabwera et al., 2018). Additionally, soap provision was examined in one moderate-quality quasi-experimental study (Langford et al., 2011), showing no association between soap provision and improved WHZ.

3.1.4 | Effect of sanitation on preventing acute malnutrition

Safe disposal of faeces

Two non-intervention studies found a positive association between access to household latrines and preventing acute malnutrition (Ayana et al., 2015) and SAM (Dodos et al., 2018), whereas three other found no association with preventing SAM (Nabwera et al., 2018), wasting (De Vita et al., 2019) or improving WHZ (Buttenheim, 2008). One low-quality quasi-experimental study found an association between the percentage of community using a latrine and improved child WHZ (Buttenheim, 2008), indicating the potential importance of community-level sanitation over household-level sanitation. Two high-quality cRCTs (Luby et al., 2018; Null et al., 2018), two moderate-quality non-intervention studies (Ambadekar & Zodpey, 2017; Langford et al., 2011) and six low-quality non-intervention studies (Buttenheim, 2008; Chisti et al., 2007; De Vita et al., 2019; George et al., 2016; Headey & Palloni, 2019; Munirul Islam et al., 2018) consistently demonstrated no association between the presence of an improved latrine at the household and prevention of acute malnutrition or improvement of WHZ.

Only two studies have examined the effect of the presence of small potties for children on acute malnutrition outcomes. As part of these two high-quality cRCTs, the provision of small potties for children was part of a larger WASH services package (provision of chlorine, water container with lid, messaging on use of latrine and

TABLE 4 Results of studies describing the effect of WASH interventions on prevention of acute malnutrition

First author, (year)	Context	Objective	Measured in	Time of measurement	Statistical analysis	Measure of association	Results	95% CI/SE	*P*-value
Altmann et al. (2018)	Rural	Effectiveness of a household WASH package on the performance of an outpatient therapeutic feeding programme (OTP) for SAM	SAM (WHZ < −3)	2 months post-recovery	Pearson chi square	Difference in number of relapses across the intervention and control groups.	Intervention group: Relapse at 2 months: $n = 105$ (17.6%) Control group: Relapse at 2 months: $n = 91$ (18.0%)	[−7.2; 6.4][a]	0.911
				6 months post-recovery			Intervention group: Relapse at 6 months: $n = 10$ (2.6%) Control group: Relapse at 6 months: $n = 10$ (3.6%)	[−4.0; 2.0] †	0.532
Ambadekar and Zodpey (2017)	Rural	Identify risk factors of severe acute malnutrition (SAM) in children under 5 years of age	SAM (WHZ < −3)	At inclusion	Binary logistic regression	OR	Not using any method of water purification in household: OR = 3.2	[2; 5.1][a]	NR
							Availability of latrine in household: OR = 0.9	[0.4; 2.1][a]	
							Non-utilization of latrine by parents: OR = 3.9	[1.7; 9][a]	
							Utilization of latrine by children: OR = 0.4	[0.2; 0.9][a]	
							Child hand cleanliness after defaecation-not cleaning hand with soap and water: OR = 2.3	[1.6; 3.2][a]	
Arnold et al. (2009)	Rural	Evaluate behavioural and health impacts of a 3-year pre-existing non-randomized intervention	Mean WHZ	At inclusion	NR	Difference in means (intervention group vs control group)	Mean WHZ after 3-year intervention: MD = −0.066	[−0.248; 0.124][a]	
			Mean MUAC				Mean MUAC after 3-year intervention: MD = −0.014	[−0.166; 0.145][a]	

(Continues)

TABLE 4 (Continued)

First author, (year)	Context	Objective	Measured in	Time of measurement	Statistical analysis	Measure of association	Results	95% CI/SE	*P*-value
		combining household water treatment and handwashing campaign							
Ayana et al. (2015)	Rural	Determinants of acute malnutrition among children aged 6–59 months in the study area	Wasting (MUAC < 12.5 cm)	NR	Logistic regression	Adjusted odds ratio (AOR)	Handwashing habit of mothers (WASH less frequently): AOR = 14.39	[7.33; 28.22][a]	<0.001
							Absence of latrine: AOR = 2.99	[1.23; 7.06][a]	<0.05
Buttenheim (2008)	Urban	Effect of improved sanitation on child nutritional status	Mean WHZ	NR	Fixed-effects regression model	Regression coefficient	Household uses improved latrine: β = 0.217 (0.85) ‡	NR	NS
							Community mean of improved latrine use: β = 0.012 (2.23) ‡		≤0.05
							Mother washes hands with soap or ash: β = 0.362 (1.84) ‡		≤0.1
Chisti et al. (2007)	Urban	Identify clinical and nutritional features, and complications among severely malnourished children under 5 years of age	SAM (WHZ < −3)	Existing databases of Dhaka hospital	Logistic regression	OR	Use of unsanitary toilet: OR = 2.0	[1.8; 2.3][a]	0.001
De Vita et al. (2019)	Urban	Explore the relationship between infections and nutritional status and the related association with hygienic conditions as risk of infection	Wasting (WHZ < −2)	NR	Logistic regression	OR	Presence of diarrhoea in the last 2 weeks: AOR = 14.94	[0.02; 11,770.03][a]	0.42
							Utensils for feeding the baby washed separately: AOR = 0.23	[0.00; 47.35][a]	0.59

TABLE 4 (Continued)

First author, (year)	Context	Objective	Measured in	Time of measurement	Statistical analysis	Measure of association	Results	95% CI/SE	*P*-value
Dodos et al. (2018)	Rural	Investigate individual and household risk factors for SAM	SAM (WHZ < −3)	NR	Logistic regression	OR	Handwashing behaviour score: COR = 0.8	[0.6; 1.0][a]	
							Not washing hands after defaecation/ using toilet: AOR = 1.9	[1.2; 3.1][a]	0.009
							Absence of toilet in the household: AOR = 1.9	[1.1; 3.6][a]	0.046
							Destination of child's faeces, outside the house: COR = 1.9	[1.0; 3.8][a]	
							Monthly hygiene expenses <2000 FCFA: COR = 2.0	[1.2; 3.4][a]	
du Preez et al. (2011)	Urban and rural	Investigate the effect of solar disinfection (SODIS) of drinking water on the incidence of diarrhoea, and anthropometric measurements	Median WHZ	Visit 1 (July 2008), Visit 2 (October 2008), Visit 3 (January 2009)	Fractional polynomial quantile regression	NR	NR		0.351
Fikree et al. (2000)	Urban	Assess risk factors for wasting and stunting at the ages of 6, 12 and 24 months	Wasting (WHZ < −2)	At the ages of 6, 12 and 24 months	Logistic regression	OR	Water supply, not piped (6 months of age): AOR = 0.45	NR	NS
							Water supply, not piped (12 months of age): AOR = 0.52		≤0.01
							Water supply, not piped (24 months of age): AOR = 0.68		≤0.05
George et al. (2016)	Rural	Investigate the relationship between unsafe child faeces disposal,	Wasting (WHZ < −2)	NR	Logistic regression	OR	Observed unsafe child faeces disposal: OR = inf[c]	[0.14; inf][a]	
			Mean WHZ			Coefficient β		[−0.98; −0.06][a]	<0.05

(Continues)

TABLE 4 (Continued)

First author, (year)	Context	Objective	Measured in	Time of measurement	Statistical analysis	Measure of association	Results	95% CI/SE	*P*-value
		environmental enteropathy and impaired growth			Linear regression		Observed unsafe child faeces disposal (change in WHZ): $\beta = -0.52$		
Headey and Palloni (2019)	Urban and rural	Examination of whether long-term changes in water and sanitation predict improvements in child nutrition	Wasting (WHZ < −2)	NR	Fixed-effects regression model	Regression coefficient	Sanitation: $\beta = 0.025$ Improved water sources: $\beta = 0.012$	NR	0.322 0.473
Humphrey (2018)	Rural	Assessment of the independent and combined effects of improved WASH and improved IYCF on stunting and anaemia	Wasting (WHZ < −2) Mean WHZ Mean MUAC	At birth and 1, 3, 6, 12 and 18 months postnatal	Multivariable regression model	Adjusted RR compared to non-intervention group	Impact of WASH interventions on wasting: Adjusted RR = 0.88 Impact of WASH interventions on stunting: Adjusted RR = 0.99	[0.55; 1.27][a] [0.90; 1.09][a]	0.571 0.818
Iannotti et al. (2009)	Urban	Comprehensive evaluation of the multidimensional factors determining anthropometric child outcomes	Mean WHZ	At birth, then monthly until the age of 12 months	Linear regression	Regression coefficient	Sanitation and hygiene coefficients were not significant, detailed results are not reported	NR	NR
Langford et al. (2011)	Urban	Assess the impact of a hand-washing intervention on growth and biomarkers of child health	Mean WHZ	Baseline and monthly	Time series linear regression	Coefficient β	Hand-washing intervention (WHZ control group compared with intervention) Coeff. $\beta = 0.241$	[−0.097; 0.579][a]	0.162
Lin et al. (2013)	Rural	Assessment of the relationship of environmental enteropathy and child growth with different levels of household environmental cleanliness	Wasting (WHZ < −2) Mean WHZ	At the inclusion and three years later (years 2007 and 2010).	Linear regression	Regression coefficient	Proportion of WHZ ≤ 2: $r = 0.10$ Mean WHZ: $r = -0.19$	[−0.03; 0.23][a] [−0.61; 0.24][a]	NR

TABLE 4 (Continued)

First author, (year)	Context	Objective	Measured in	Time of measurement	Statistical analysis	Measure of association	Results	95% CI/SE	*P*-value
Luby et al. (2018)	Rural	Assessment of whether water quality, sanitation, and handwashing interventions alone or combined with nutrition interventions reduce diarrhoea or growth faltering	Wasting (WHZ < −2) Mean WHZ	At the inclusion and 1 and 2 years later	t test	Difference in means (vs. control group at 2-year follow-up)	WHZ score mean difference:		NR
							Water = −0.04	[−0.14; 0.05][a]	
							Sanitation = 0.01	[−0.09; 0.11][a]	
							Handwashing = 0.00	[−0.11; 0.12][a]	
							Water, sanitation and handwashing = 0.00	[−0.10; 0.11][a]	
							Nutrition = 0.15	[0.04; 0.26][a]	
							Water, sanitation, handwashing and nutrition = 0.09	[0.00; 0.18][a]	
						Difference in proportion (vs. control group at 2-year follow-up)	Difference in proportion of children wasted:		
							Water = 1.8	[−1.4 to 5.0][a]	
							Sanitation = 0.9	[−2.3; 4.0][a]	
							Handwashing = 0.1	[−3.1; 3.2][a]	
							Water, sanitation and handwashing = 1.4	[−1.8; 4.6][a]	
							Nutrition = −1.6	[−4.5; 1.3][a]	
							Water, sanitation, handwashing and nutrition = −1.7	[−4.7; 1.2][a]	
Munirul Islam et al. (2018)	Urban	Identification of risk factors associated with SAM in children under 6 months of age	SAM (WHZ < −3)	At the inclusion	Pearson chi-square	Difference in proportion	Source of drinking water—stand pipe: SAM = 2 (3%) Non-SAM = 0 (0%) Source of drinking water—tube well: SAM = 75 (97%) Non-SAM = 77 (100%)	NR	0.50
							Types of toilet facility—flush to septic tank/flush to pit latrine/ ventilated		0.68

(Continues)

TABLE 4 (Continued)

First author, (year)	Context	Objective	Measured in	Time of measurement	Statistical analysis	Measure of association	Results	95% CI/SE	*P*-value
							improved pit latrine: SAM = 10 (13%) Non-SAM = 15 (20%) Types of toilet facility—pit latrine with slab: SAM = 65 (84%) Non-SAM = 58 (75%) Types of toilet facility—pit latrine without slab/open pit: SAM = 2 (3%) Non-SAM = 4 (5%)		
Nabwera et al. (2018)	Rural	Identification and quantification of the risk factors associated with severe wasting in children between 0 and 12 months of age	SAM (WHZ < −3)	At birth and 1, 8, 12, 16, 24, 40 and 52 weeks after	Conditional logistic regression	AOR	Water treatment = 0.31 No water treatment = 1.00	[0.09; 1.04][a]	0.06
							Drinking water for household fetched daily = 0.88 Drinking water for household not fetched daily = 1.00	[0.64; 1.21][a]	0.44
Null et al. (2018)	Rural	Assess whether water, sanitation, handwashing and nutrition interventions reduced diarrhoea or growth faltering	Wasting (WHZ < −2) Mean WHZ	1 and 2 years after intervention delivery	Paired *t*-tests	Difference in means (vs active control group at 2-year follow-up)	WHZ score mean difference:		NR
							Water = 0.04	[−0.06; 0.13][a]	
							Sanitation = −0.05	[−0.14; 0.05][a]	
							Handwashing = −0.02	[−0.11; 0.06][a]	
							Water, sanitation and handwashing = −0.02	[−0.10; 0.07][a]	
							Nutrition = 0.04	[−0.05; 0.14] [†] [0.00; 0.19][a]	

TABLE 4 (Continued)

First author, (year)	Context	Objective	Measured in	Time of measurement	Statistical analysis	Measure of association	Results	95% CI/SE	*P*-value
							Water, sanitation, handwashing and nutrition = 0.09		
						Difference in proportion (vs active control group at 2-year follow-up)	Difference in proportion of children wasted:		
							Water = −0.2	[−1.3; 0.8][a]	
							Sanitation = 1.1	[−0.3; 2.4][a]	
							Handwashing = −0.5	[−1.5; 0.4][a]	
							Water, sanitation and handwashing = 0.2	[−0.9; 1.2][a]	
							Nutrition = −0.3	[−1.3; 0.8][a]	
							Water, sanitation, handwashing and nutrition = −0.1	[−1.2; 1.0][a]	
Patil et al. (2014)	Rural	To measure the effect of the TSC implemented with capacity building support from the World Bank's water and sanitation programme on availability of individual household latrines, defaecation behaviours and child health	Mean WHZ	At enrolment with a follow-up	Linear regression	Difference in means	WHZ score mean difference (ITT adjusted) = 0.029	[−0.142; 0.199][a]	NR
			Mean MUAC	Up 2 years later		(Compared with control group)	MUAC mean difference (ITT adjusted) = −0.022	[−0.167; 0.123][a]	
Seetha et al. (2018)	Rural	To assess the impacts of training on nutrition, hygiene and food safety by the CORE on child undernutrition	Mean WHZ Mean MUAC	Day 0, 7, 14, and 21.	Logistic regression	Difference in difference estimation (DID)	DID day 21 OLS robust WHZ = 0·84	0.014[b]	<0.01
							DID day 21 OLS robust MUAC = 1.94	0.253[b]	NS
Stobaugh et al. (2018)	Rural	To identify household factors that may be associated with sustained recovery from malnutrition	Wasting (MUAC < 12.5 cm)	At enrolment and 1, 3, 6 and 12 months after	Multivariate logistic regression	AOR	Factors associated with sustained recovery for 12 months:		

(Continues)

TABLE 4 (Continued)

First author, (year)	Context	Objective	Measured in	Time of measurement	Statistical analysis	Measure of association	Results	95% CI/SE	*P*-value
							Use of improved source for drinking water: AOR = 1.45	[0.66; 3.18][a]	
							All water storage containers have lids: AOR = 1.79	[1.20; 2.68][a]	0.004
							Use of improved sanitation facility: AOR = 1.46	[0.95; 2.26][a]	0.083
							Use of soap or ash during hand-washing demonstration: AOR = 0.84	[0.29; 2.37][a]	0.736
Tomedi et al. (2012)	Rural	To establish the operational feasibility and effectiveness of using locally available foods to prevent malnutrition and improve child growth	Mean WHZ Wasting prevalence (WHZ < −2)	At enrolment and at the end of the study (during the course of the study for the intervention group)	Multivariate mixed-effects model. *T*-test	Difference in means (intervention vs. non-intervention group). Difference in proportions	Adjusted difference in WHZ mean = 1.19	0.13[b]	<0.001
							Difference in malnutrition prevalence:		
							Prevalence intervention group = 0.0%	[0.0; 2.8][a]	<0.001
							Prevalence non-intervention group = 8.9%	[4.3; 13.4][a]	
Zhang et al. (2013)	Rural	Assess the effectiveness of an educational intervention on caregivers' feeding practices and children's growth	Mean WHZ	At inclusion (2–4 months old) and at the age of 6, 9, 12, 15 and 18 months	Multivariate *t*-square test	Difference in means	Intervention group at 18 months t-square = 11.933	NR	0.008

Abbreviations: AOR, adjusted odds ratio; COR, crude odds ratio; DID, difference-in-difference estimations; FCFA, Central African Financial Cooperation franc; ITT, intention to treat; IYCF, infant and young child feeding; MD, mean difference; NR, not reported; NS, non-significant; OLS, ordinary least squares; OR, odds ratio; MUAC, mid-upper arm circumference; OTP, outpatient therapeutic programme; RR, relative risk; SAM, severe acute malnutrition; TSC, India's Total Sanitation Campaign; WASH, water, sanitation and hygiene; WHZ, weight-for-height *z*-score.

[a]Confidence interval.

[b]Standard error.

[c]Infinity.

disposal of child faeces, latrine, messaging on handwashing, soap, handwashing stations, child potties and food supplements). No effect was demonstrated on preventing acute malnutrition (Luby et al., 2018; Null et al., 2018).

Absence of open defaecation

Whereas no studies exploring the relationship between the absence of open defaecation and child acute malnutrition were found, two low-quality non-intervention studies showed mixed results regarding the association between safe disposal of child faeces and prevention of wasting (Dodos et al., 2018; George et al., 2016).

3.1.5 | Effect of combined WASH interventions on preventing acute malnutrition

Among the included intervention studies, four consisted in the provision of WASH packages including various interventions (Altmann et al., 2018; Humphrey et al., 2018; Seetha et al., 2018; Zhang et al., 2013). These studies solely measured the effect of the complete WASH package; therefore, positive or negative effects could not be attributed to each component individually.

Interventions clusters in the cRCT carried out by Altmann et al. received household WASH kits containing a safe drinking water storage container with a lid, water disinfection consumables, bars of soap for handwashing, a plastic cup with handle for children and a laminated leaflet with pictures representing the main hygiene messages; promotion sessions on the kit use were also delivered. Results shown that the distribution of the WASH kits during SAM treatment did not prevent relapse post-discharge (Altmann et al., 2018).

The intervention carried out by Humphrey et al. consisted in the construction of ventilated improved pit latrines and two handwashing stations per household and the provision of information regarding appropriate WASH practices. Chlorine tablets for water treatment, soap and a plastic mat and play yard were also delivered. The implementation of these household-level WASH interventions had no effect on preventing acute malnutrition (Humphrey et al., 2018).

Two cRCTs (Seetha et al., 2018; Zhang et al., 2013) consisted in delivering training sessions and individual counselling for good hygiene practices and proper food handling. Results in both studies shown significant improvements in WHZ. Furthermore, one of these studies shown that the magnitude of WHZ improvements increases along with the duration of the intervention (Seetha et al., 2018).

In addition to the assessment of WASH single components, two high-quality cRCTs (Luby et al., 2018; Null et al., 2018) assessed in two of their groups the effect of a combined WASH intervention (water, sanitation and handwashing) and a combined WASH and nutrition intervention (water, sanitation, handwashing and nutrition) on the mean WHZ and the proportion of wasted children.

After 2 years of intervention, results of Luby et al. showed no differences in the WHZ scores of children in the group receiving the combined water, sanitation and handwashing intervention compared with the control group. The group receiving the combined water, sanitation, handwashing and nutrition intervention showed higher WHZ scores [mean difference 0.09, confidence interval (CI) 95% (0.00; 0.18)] and a lower proportion of wasted children [−1.7, CI 95% (−4.7; 1.2)] compared with the control group; however, these effects can be considered as uncertain.

Similarly, the cRCT performed by Null et al. showed that children in the group receiving the water, sanitation, handwashing and nutrition intervention had higher WHZ scores than children in the control group after a 2-year follow-up [mean difference 0.09, CI 95% (0.00; 0.19)]. Nevertheless, the children in the group receiving the water, sanitation and handwashing intervention showed lower WHZ scores than those in the control group [mean difference −0.02, CI 95% (−0.10; 0.07)]. The proportion of wasted children in the group receiving the WASH and nutrition combined intervention was slightly lower than in the control group [−0.1, CI 95% (−1.2; 1.0)].

3.2 | Effect of WASH on the treatment of acute malnutrition

Only two studies examined the effect of WASH on the treatment of acute malnutrition (Altmann et al., 2018; Doocy et al., 2018), and their results are shown in Table 5. One of these two high-quality cRCTs demonstrated that the provision of water treatment supplies in addition to SAM treatment improved recovery outcomes based on the same anthropometric indicator used for the admission, MUAC or WHZ. Differences in recovery rates between the intervention groups were not statistically significant, indicating that water treatment was equally effective in improving recovery regardless of the type of water treatment intervention implemented (Doocy et al., 2018).

The cRCT carried out by Altmann et al. reported that the provision of a WASH package (including drinking water, a fitted lid container; chlorine tablets, a cup with a handle, handwashing soap and a leaflet with hygiene messages) had an effect reducing by 4.4 days the time to recovery from SAM [−8.6;−0.2]. However, this study did not separately evaluate the effect of each WASH component; therefore, the positive effects could not be attributed to one specific item within the package (Altmann et al., 2018).

4 | DISCUSSION

4.1 | Main findings

Our findings demonstrate that the current literature does not show consistent associations of WASH conditions and interventions with improvements in prevention of acute malnutrition or its treatment outcomes. Yet, limited evidence resulting from two high-quality cRCTs shows consistent improvements in SAM treatment outcomes as results of water treatment in addition to SAM treatment; however, these interventions showed no effect on reducing relapse rates following recovery from acute malnutrition.

TABLE 5 Results of studies describing the effect of WASH interventions on the treatment of child acute malnutrition

First author, (year)	Context	Outcome	Measured in	Time of measurement	Statistical analysis	Measure of association	Results	95% CI, SE	P-value
Altmann et al. (2018)	Rural	Effectiveness of a household WASH package on the performance of an OTP for SAM	SAM (WHZ ≤ 3)	6-month post-recovery	Pearson chi square t-test	Difference in means	Intervention group: TTR in days: 51.7 ± 1.5 Control group: TTR in days: 56.1 ± 1.5	[−8.6; −0.2][a]	0.038
Doocy et al. (2018)	Urban and rural	Effectiveness of point-of-use water treatment in improving treatment of children affected by SAM	SAM (MUAC < 11.5 cm)	Upon exit or after 120 d of enrolment	Logistic regression	AOR (odds of recovery compared with the control group)	Aquatabs: AOR = 2.5	[1.7; 3.9][a] 0.6[b]	<0.001
							Ceramic filter: AOR = 1.9	[1.2; 2.9][a] 0.4[b]	0.001
							P&G PoW: AOR = 1.9	[1.2; 2.8][a] 0.4[b]	<0.001
							Protected water source: AOR = 2.3	[1.5; 3.5][a] 0.5[b]	<0.001

Abbreviations: AOR, adjusted odds ratio; MUAC, mid-upper arm circumference; OTP, outpatient therapeutic programme; SAM, severe acute malnutrition; TTR, time to recovery (in days); WASH, water, sanitation and hygiene; WHZ, weight-for-height z-score.
[a]Confidence interval.
[b]Standard error.

RCTs testing the effectiveness of WASH interventions on acute malnutrition outcomes are limited. Many WASH interventions trials collected child anthropometric data, yet effects on acute malnutrition were not analysed (whereas other conditions, such as stunting or underweight, were presented).

The greatest lack of evidence identified concerned the WASH conditions and interventions on 'hygiene' and 'environmental hygiene', specifically regarding conditions and interventions related to handwashing and food hygiene for which only few low-quality studies were found. Based on the current state of the evidence, a consistent conclusion regarding associations between WASH conditions and interventions with acute malnutrition has not been demonstrated. A low-quality study indicating the importance of community-level interventions over household-level interventions (Buttenheim, 2008) might point to the conclusion that individual approaches are not sufficient to address the direct and the underlying causes of acute malnutrition; hence, comprehensive community-level approaches should be largely considered along with the performance of high-quality studies evaluating their effects.

4.2 | Interpretation of results

Standard outpatient treatment for acute childhood malnutrition concerns the provision of specially formulated therapeutic and supplementary foods in outpatient therapeutic and supplementary feeding programmes (Black et al., 2016), but there is growing evidence for WASH interventions' applicability in preventing and treating undernutrition, including water treatment supplies and counselling for improved water quality. However, the potential scaling up of such interventions might be hampered by cost and logistic implications.

Despite most of the current evidence regarding the effects of WASH interventions on child undernutrition focuses on stunting, recent systematic reviews and meta-analyses point out an overall lack of evidence regarding the effects of WASH interventions on children nutritional outcomes (Dangour et al., 2013; Gizaw & Worku, 2019). Authors agree on the need for more robust intervention studies in order to consolidate evidence on the individual and combined effects of WASH interventions on childhood undernutrition and on their applicability to synergize the positive effects of nutritional and other programmatic interventions (Bekele et al., 2020; Gera et al., 2018).

Gizaw and Worku (2019) point out that the current evidence of the effects of WASH on children nutritional status seems to be conflicting. Nevertheless, the results of the present review linking water treatment with prevention of SAM and improved recovery rates during SAM treatment seem to be consistent with the results of other systematic reviews (Dangour et al., 2013; Gera et al., 2018; Ngure et al., 2014), which observed slight but consistent associations of improved water supply and quality with better growth outcomes.

So far, no or little effects of WASH on child growth outcomes have been observed (Dangour et al., 2013; Gera et al., 2018). Furthermore, described effects are heterogeneous according to the types of interventions and the age of children (Bekele et al., 2020; Gizaw &

Worku, 2019). Available evidence suggest that combined WASH interventions have a greater effect on growth outcomes when compared with single interventions (Bekele et al., 2020; Gera et al., 2018; Gizaw & Worku, 2019; Ngure et al., 2014); it also has shown that effects of WASH are greater among children under 2 (Gizaw & Worku, 2019). Despite the need of more intervention studies evaluating the individual and combined effects of each WASH component, these findings highlight the need for early and comprehensive targeted WASH interventions in order to improve child growth outcomes.

Overall, it is unclear whether the lack of evidence to support the theoretical causal pathways between WASH exposure and nutrition outcomes translates to an incorrect hypothesized causal chain between poor WASH and child acute malnutrition due to confounding factors and the multicausality of acute malnutrition. What is certain is that there is a lack of high-quality intervention studies from which we can more confidently draw conclusions regarding the effects of individual or combined WASH interventions on childhood acute malnutrition and better clarify which WASH interventions are most effective in improving acute malnutrition outcomes. Such studies are also needed to prove which causal pathways are the most significant contributors in acute malnutrition.

Understanding the causal pathways between WASH and child acute malnutrition is important in order to develop appropriate interventions that target specific potential underlying WASH-related causes of acute malnutrition. These causal chains can then be linked to create a theory of change, guiding how programmes might intervene to change the trajectory of child nutrition outcomes. As WASH interventions aim to prevent the transmission of harmful pathogens from the environment to humans, it is important to understand that not all WASH interventions will disrupt the transmission of all pathogens. A better understanding of diarrhoeal disease aetiologies in target populations may be useful to determine which harmful pathogens are particularly present in the context of implementation informing more effective strategies and determining which interventions are best suited to stop transmission.

It is important to consider that the WASH sector includes a wide variety of interventions that aim to address distinct (albeit still related) issues. Therefore, to tailor the WASH interventions to the specific needs of the target population, extensive context analyses are necessary before designing the interventions. In some highly contaminated environments, many basic WASH interventions may be insufficient to reduce exposure to harmful pathogens and thereby influence risk of acute malnutrition. Consequently, many hypothesize that community-led sanitation interventions may show more promise than individual and household interventions as shown by their greater effects on improving linear growth and child health (Buttenheim, 2008; Humphrey et al., 2018). Therefore, the assessment of the effects of community-level interventions compared with household-level interventions should be also considered for further research. In many contexts throughout low- and middle-income countries, communal living is quite pervasive. Therefore, in order to truly reduce the exposure to harmful pathogens, the environment both within and beyond the household must be targeted.

4.3 | Strengths and limitations

To our knowledge, this review is the first attempt to specifically assess the effect of WASH conditions and interventions on both prevention and treatment of acute malnutrition. The strength of our study include the use of relevant operational WASH conditions and nutrition indicators selected by field actors. The search strategy was systematic and used rigorous eligibility and quality assessment criteria for the studies.

Limitations of our review include not conducting a meta-analysis due to the scarcity of evidence and the wide heterogeneity of WASH interventions, which hampers comparability across studies. In addition, for feasibility reasons, the results of the RCTs could not be analysed and presented according to the compliance, uptake, duration and intensity of the interventions presented. Grouping and comparability of studies according to relapse rates as an indicator of secondary prevention were not possible due to a current lack of a standardized definition of relapse. Finally, many of the intervention arms in WASH-related trials consisted of packages of WASH-related services, making impossible to define which effects were caused by which components of the intervention package.

4.4 | Operational recommendations

Although limited to two RCTs, the current literature suggest that WASH interventions focusing on water quality treatment, either alone or combined with other WASH interventions, may support SAM recovery when they are integrated specifically as part of community or outpatient-based treatment of SAM. Results so far are consistent, but further research is needed to conclude on this plausible effect.

Despite better nutrition outcomes through WASH community-level interventions have been described in some studies, evidence on the effects of household-level interventions and comprehensive community-level approaches is still scarce with studies of generally low quality. Therefore, more operational research integrated by high-quality intervention studies should be carried out to assess the acceptability, feasibility and cost-effectiveness of WASH household-level and community-led approaches, placing emphasis on intervention sustainability and long-term recovery of children with acute malnutrition. This will allow to properly document and further support evidence on the effectiveness of different approaches for implementing WASH interventions in nutrition and health programming.

5 | CONCLUSION

The evidence base for the effect of WASH conditions and interventions on acute childhood malnutrition is weak and depends largely on observational studies with high risk of bias. Although WASH interventions can plausibly reduce the risk of acute malnutrition and there is some evidence that improvements in household water quality improves SAM recovery, there is a need for more rigorous intervention studies to assess the effect of different WASH interventions on the prevention and treatment of acute malnutrition, particularly in high burden populations. Beyond epidemiological assessment of the impact on acute malnutrition, more research is also needed to assess the feasibility and cost of adding WASH interventions to the current standard of care for acute childhood malnutrition.

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CONFLICTS OF INTEREST

All authors declare that they have no conflict of interest.

CONTRIBUTIONS

SS and DSND conceived the research project and coordinated the contributors. HS, AA, DP, JL, SS and DSND developed the search strategy. ARPH and HS searched the databases. AR.PH, H. S, S. S and DS.N'D participated in the study selection. ARPH and HS performed the data extraction and interpretation. ARPH, HS, OC, SS and DSND interpreted the findings. ARPH and HS wrote the first draft of the results and revised subsequent drafts. ARPH prepared the manuscript and DSND revised every version of the manuscript. OC, AA, DP, JL and SS contributed to the revision of the manuscript.

DATA AVAILABILITY STATEMENT

As this article is a systematic review, the data that support the findings are articles published in academic journals that are already in the public domain. Therefore, data sharing is not applicable to this article as no new data were created or analysed.

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SUPPORTING INFORMATION

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