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The association between acute malnutrition and water, sanitation, and hygiene among children aged 6–59 months in rural Ethiopia

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Abstract

The causes of acute malnutrition—or "wasting"—are complex, and a better understanding of the underlying drivers is necessary in order to design effective interventions. Water, sanitation, and hygiene (WASH) practices may play a fundamental role in acute malnutrition, but more research is needed to confirm this relationship. We investigated the association between WASH practices and acute malnutrition among children 6 to 59 months of age in rural Ethiopia, making use of the Ethiopian Demographic and Health Survey. Descriptive statistics were used to assess the WASH status of all rural children. Bivariate logistic regression analyses were performed to assess associations between nutritional status and WASH. Multivariate logistic regression analyses were used to adjust for confounders. A total of 7,209 children were included in the analysis, of which 867 (12.0%) were acutely malnourished. Proper toilet facilities (AOR = 0.63, 95% CI [0.46, 0.86]) and a water source close to home (AOR = 0.71, 95% CI [0.61, 0.83]) were associated with a lower prevalence of wasting. A safe water source for drinking (COR = 1.03, 95% CI [0.89, 1.19]) and a safe disposal of the child's stool (AOR = 0.97, 95% CI [0.84, 1.13]) were not significantly associated with acute malnutrition. These results suggest that WASH practices are related to acute malnutrition. Future studies—in particular intervention studies—should investigate whether improving WASH practices is effective in reducing malnutrition in infants and young children.

KEYWORDS

acute malnutrition, DHS, Ethiopia, hygiene, sanitation, water

1 | INTRODUCTION

Despite increased attention to nutrition in the last decades, nutritional deficiencies remain a multifaceted problem affecting many infants and young children globally (UNICEF, 2015). Although rates are dropping, acute malnutrition, or "wasting," still threatens the lives of almost 52 million children worldwide, with more than a quarter of these children residing in Africa (UNICEF, WHO, & World Bank Group, 2017).

The causes of undernutrition are multifactorial and interlinked, as depicted by various conceptual frameworks. Examples are UNICEF's widely used conceptual framework, describing the immediate, underlying, and basic causes of malnutrition (UNICEF, 2013) and the food and nutrition security framework, depicting the four "pillars"—food availability, food access, food stability, and food utilization—on which food security and nutrition depend (Gross, Schoeneberger, Pfeifer, & Preuss, 2000).

Water, sanitation, and hygiene (WASH) has been linked to all four "pillars" of the food and nutrition security framework (Cumming & Cairncross, 2016; Pritchard, Ortiz, & Shekar, 2016), as immediate or proximate risk factors, but also as more distant causes. The most direct pathway that links poor WASH to undernutrition is via repeated bouts of diarrhoea (Brown, Cairncross, & Ensink, 2013; Casanovas Mdel et al., 2013). It is now well accepted that diarrhoea can be both a cause and a consequence of malnutrition. It reduces nutrient absorption and can decrease dietary intake, whereas malnutrition can impair barrier protection and immune function, leading to more frequent episodes of diarrhoeal disease (Brown, Cairncross, & Ensink, 2013; Katona & Katona-Apte, 2008; Marshak, Young, Bontrager, & Boyd, 2016). Studies show that poor environmental conditions, lack of availability of safe, accessible drinking water, and poor hygiene and sanitation practices are the principle causes of diarrhoea among children under 5 years of age (Bhutta et al., 2013). However, despite the growing body of research into this topic, WASH remains a low priority in both national and international policies (Bartram & Cairncross, 2010; Cairncross, Bartram, Cumming, & Brocklehurst, 2010).

Research that investigated the role of WASH practices in malnutrition has largely focused on the chronic form of malnutrition, also commonly referred to as "stunting" or low height-for-age (Checkley et al., 2008; Lin et al., 2013; Rah et al., 2015), though the causes and consequences between the acute and chronic form seem to differ (Bergeron & Castleman, 2012). The relationship between wasting and stunting is still poorly understood, and it is often presumed that the factors that drive wasting are the same as those for stunting (Briend, Khara, & Dolan, 2015; Martorell & Young, 2012). Yet, at a cross-sectional level, studies have found little association between wasting and stunting (Frongillo, de Onis, & Hanson, 1997; Richard, Black, & Checkley, 2012; Victora, 1992).

The amount of evidence that has explicitly focused on the association between poor WASH practices and acute malnutrition is limited, and the available evidence is inconclusive. A study determining the factors associated with childhood malnutrition in 36 low- and middle-income countries suggested that the use of pit latrines and flush toilets had significantly positive effect on the weight-for-height z-score (WHZ) (Smith, Ruel, & Ndiaye, 2005). However, a comprehensive review including seven WASH interventions studied the effect of improved water quality, sanitation, and hygiene practices on acute malnutrition in 4,322 children under the age of five and found no such association (Dangour et al., 2013). This was possibly due to poor quality of the WASH interventions. Hence, further evidence is required to identify the linkages between WASH practices and acute malnutrition and to provide a basis for further research.

Therefore, the aim of this study was to assess the relationship between acute malnutrition and WASH practices among children under five. Within this study, national representative data of the 2011 Ethiopian Demographic and Health Survey (EDHS) was used to assess the WASH practices among well-nourished and acutely malnourished children aged 6 to 59 months and to determine the association between these practices and moderate-to-severe wasting in rural Ethiopia.

Key messages

- The prevalence of acute malnutrition was higher among children from households with access to poor toilet facilities and who needed to walk more than 60 min to fetch water.
- Even though water, sanitation, and hygiene appear to be important factors in acute malnutrition, more than half of the rural Ethiopian children made use of an unsafe source for drinking and almost 95% made use of a poor toilet facility.
- Randomized effectiveness trials of WASH improvements are urgently needed to measure the impact of WASH interventions on acute malnutrition at household level.

2 | METHODS

2.1 | Data source

We used data from the EDHS of 2011. The 2011 EDHS was used, as this was the latest, complete DHS in Ethiopia. Details of the survey are described elsewhere (Central Statistical Agency (CSA) and ICF, 2012). Briefly, the EDHS was carried out by the Ethiopian Central Statistical agency and ICF International and provides information on a wide range of socio-demographic and health characteristics such as education, mortality, fertility, childhood illnesses, family planning, nutritional status, breastfeeding, and maternal and child health.

The survey covered all 11 geographic/administrative regions (nine regional states and two city administrations) in Ethiopia using a stratified, two-stage cluster design. In the first stage, each kebele—the lowest administrative unit—was subdivided into census enumeration areas (EAs). After the EAs were selected, a complete listing of households was carried out in each included EA. All conventional households were listed, and a representative sample of 17,817 was selected using computerized spreadsheets (Central Statistical Agency (CSA) and ICF, 2012; ICF international, 2012).

In our analysis, 7,209 households across all regions were selected for inclusion. This comprised all rural households with children aged 6 to 59 months. The study was restricted to rural households, as the prevalence of wasting and poor WASH practices is much higher in rural areas (Smith, Ruel, & Ndiaye, 2005).

2.2 | Data collection

All interviews and anthropometric measurements were conducted at home by 35 field teams who had followed a 1-month training including instructions on interviewing techniques and all field procedures (Central Statistical Agency (CSA) and ICF, 2012).

In addition to the field teams, a quality control team was present in each of the 11 regions, who closely supervised and monitored the team throughout the fieldwork period. To ensure data quality, supervisors periodically returned to a few households that were recently interviewed to do a short reinterview and comparing the list with what was reported by the original interviewer (ICF international, 2012).

Information on the child's age, sex, morbidity in the past weeks, size at birth, and birth order was collected from the mother or caregiver. Mothers were interviewed regarding their age, education, occupation, birth history, disposal of the child's stool, and the husband's background characteristics. Information on household characteristics included the composition, source of drinking water, sanitation facility, and the socio-economic status of the household (Central Statistical Agency (CSA) and ICF, 2012). All interviews were carried out using a pretested, structured questionnaire.

Anthropometric measurements were taken from all children under five following standard procedures (WHO, 2006b). Weight measurements were obtained using lightweight, SECA mother–infant scales with a digital screen. Height measurements were carried out using a measuring board. Children younger than 24 months were measured for height while laying down (Central Statistical Agency (CSA) and ICF, 2012).

2.3 | Outcome variable

The outcome variable of interest in this study was the nutritional status, that is, having acute malnutrition or being well-nourished. A child aged 6 to 59 months with a WHZ below minus two standard deviations (−2 SD) was considered acutely malnourished, as defined by the 2006 WHO growth standards (WHO, 2006b). This comprised both moderate (MAM) and severe acute malnutrition (SAM). Children with a WHZ above −2 were considered to be well-nourished.

2.4 | Exposure variables

The key exposure variables examined were all variables related to WASH. In the analysis, the categories of these variables were classified as improved/unimproved and sanitary/unsanitary according to WHO/UNICEF classification formulated in 2006 (Kleinau et al., 2004; WHO, 2006a). These categories are incorporated in many international survey programmes. The operational definitions are stated in Table 1.

2.5 | Confounders

As it is a well-known fact that child undernutrition is the outcome of multiple factors, several other independent variables were taken into consideration following UNICEF's conceptual framework of malnutrition (UNICEF, 2013) and other relevant literature (Marshak, Young, Bontrager, & Boyd, 2016; Rah et al., 2015; Tette, Sifah, & Nartey, 2015).

The wealth index was created by making five equal groups (five wealth quintiles) calculated from the assets owned by the household using principal component analysis. Details on calculation of the household wealth index are described elsewhere (Central Statistical Agency (CSA) and ICF, 2012). Other possible confounding factors included the child's age and gender, size of the child at birth, the mother's and father's highest level of education, and environmental characteristics of the household.

2.6 | Statistical analysis

To examine the association between WASH practices and the risk of wasting, bivariate logistic regression analyses were conducted for each variable related to water and sanitation individually. Nutritional status, that is, malnourished or well-nourished, was included as the dependent variable. Variables related to WASH were included as the primary independent variables.

The association between acute malnutrition and WASH practices in the bivariate analysis may be distorted by other risk factors associated with both malnutrition and WASH practices (confounding). Variables were included as potential confounders under the assumption that they were (a) associated with the exposure variable (WASH practices); (b) associated with the outcome (nutritional status); and (c) not an intermediate factor between the exposure and the outcome. Association between variables related to WASH and acute malnutrition was assessed separately at each level of a potential confounder (via stratified analysis). Factors were identified as a confounder when they were associated with both the WASH variable and acute malnutrition using the χ^2 test ($P < 0.05$).

The adjusted relationship between acute malnutrition and WASH practices was assessed using multivariate logistic regression analysis for each WASH variable individually, while controlling for all identified confounders. Moreover, as the DHS used a multistage cluster design which deviates from simple random sample, we adjusted for stratification and clustering in the multivariate logistic regression using the complex samples procedure in SPSS. This was done to prevent bias towards oversampled subpopulations. Association between dependent and independent variables was assessed using odds ratio (OR) and corresponding 95% confidence intervals (CIs), with statistical significance defined as $P < 0.05$. All analyses were performed using SPSS version 21.0 (IBM Corp, 2012).

TABLE 1 Operational definitions of improved/unimproved drinking water and toilet facilities, sanitary/unsanitary disposal of child's stool, and safe water management according to WHO/UNICEF guidelines (2006)

Variables		Definition
Drinking water	Improved	Water piped into the residence, a public tab, water from a borehole, water from a protected spring or well, rain water and bottled water.
	Unimproved	Water from unprotected dug wells or springs, water from a vendor or tanker-truck and surface water (including rivers, dams, lakes, ponds, streams, canals and irrigation channels).
Toilet facility	Improved	A pour-flush toilet/latrine, a pit latrine with slab, a ventilated improved latrine (VIP) or a composting toilet. The toilet facility is only classified as improved when it is used only by members of the household.
	Unimproved	No facilities, a pit latrine without slab, a hanging toilet/latrine, a bucket or a toilet/latrine that flushes to elsewhere (in or nearby the household environment).
Disposal of the child's stool	Sanitary	The child uses latrine, the faeces is rinsed into the latrine or the faeces is buried.
	Unsanitary	The faeces is put into a drain or ditch, thrown into the garbage or left in the open.
Safe water management		An improved water source within 30 minutes of reach (includes time travelling both ways, waiting and collecting).

3 | RESULTS

3.1 | Socio-demographic characteristics

Table 2 summarizes the socio-demographic and socio-economic characteristics of all 7,209 children included in the analysis. Both sexes were equally presented, with 50.6% being male and 49.4% being female. The majority (66.6%) of the children was above 25 months of age. In terms of marital status of the parents, 89.1% were married, 4.6% divorced or separated, 2.0% widowed, and the rest were living with partner but not married. The majority (76.5%) of the mothers, and similarly, more than half of the husbands (58.3%) had no previous education. The most common occupation of the husband was farmer (83.9%). The income distribution revealed that the majority belonged to the lowest two wealth quintiles, with only 5.1% in the richest quintile.

3.2 | Characteristics related to WASH

Table 3 shows the characteristics related to WASH of all included households. More than half (56.2%) of the households used an unimproved source of drinking water and only 5.3% made use of an improved toilet facility. Nearly three quarters (70.0%) of the households practiced an unsanitary disposal of the child's stool.

Almost all households (98%) reported their drinking water source location as outside of their premise. Only a quarter (25.2%) of the households had an improved water source within 30 min of reach and thus practiced safe water management.

TABLE 2 Socio-demographic and socio-economic characteristics of all children and their caretakers included in the sample (*n* = 7,209)

Characteristic		Frequency *n* (%)
Sex	Male	3,647 (50.6)
	Female	3,562 (49.4)
Age category	6–12 months	949 (13.2)
	13–24 months	1,460 (20.3)
	≥25 months	4,800 (66.6)
Birth order	1–3	1,308 (18.1)
	≥ 4	5,901 (81.9)
Mother's age	15–24	1,616 (22.4)
	25–34	3,728 (51.7)
	≥ 35	1,865 (25.9)
Mother's education	No education	5,512 (76.5)
	Primary	1,619 (22.5)
	Secondary or above	78 (1.1)
Mother's occupation	No occupation	3,788 (52.5)
	Farmer	1,826 (25.3)
	Sales	963 (13.5)
	Other	551 (7.7)
Husband's education	No education	4,144 (58.3)
	Primary	2,590 (36.4)
	Secondary or above	375 (5.3)
Husband's occupation	Farmer	6,046 (83.9)
	Sales	462 (6.4)
	Other	464 (6.5)
	No occupation	127 (1.8)
Marital status	Married	6,425 (89.1)
	Divorced/separated	331 (4.6)
	Living with partner	307 (4.3)
	Widowed	146 (2.0)
Wealth index	Poorest	2,561 (35.5)
	Poorer	1,584 (22.0)
	Middle	1,379 (19.1)
	Richer	1,319 (18.3)
	Richest	366 (5.1)

TABLE 3 Characteristics related to water, sanitation, and hygiene of all households included in the sample (*n* = 7,209)

Characteristics		Frequency *N* (%)
Water source for drinking	Improved	3,095 (42.9)
	Unimproved	3,977 (56.2)
Toilet facility	Improved	384 (5.3)
	Unimproved	6,825 (94.7)
Disposal of child's stool	Sanitary	2,087 (30.0)
	Unsanitary	4,859 (70.0)
Time to water source	On premise	144 (2.0)
	≤30 min	3,644 (51.5)
	31–60 min	1,585 (22.4)
	≥ 61 min	1,707 (24.1)
Safe water management	Yes	1,817 (25.2)
	No	5,392 (74.8)

3.3 | Malnutrition status

A total of 867 of the 7,209 children (12%) were classified as wasted by WHO standards (WHZ ≤ −2; WHO, 2006b). The rest (88%) was considered to be well-nourished (data not shown). Among boys, the prevalence of wasting was 13.8% and among girls, the prevalence was 10.2% (Table 4). The malnourished group was on average younger than the well-nourished group. More than a quarter (26.4%) of the malnourished children had diarrhoea 2 weeks prior to data collection; this was 15.1% among well-nourished children.

3.4 | Bivariate analyses

Access to an improved toilet facility, a sanitary disposal of the child's stool and a water source within 30 min of reach seemed to be protective factors for acute malnutrition, with odds ratios of 0.52 (95% CI [0.35, 0.77]), 0.78 (95% CI [0.66, 0.92]), and 0.64 (95% CI [0.54, 0.76]), respectively (Table 4). Children who had diarrhoea in the past two weeks were two times more likely to have acute malnutrition (COR = 2.02, 95% CI [1.71, 2.38]). Access to an improved water source for drinking did not predict nutritional status in the bivariate analysis, and this did not change after adjustment for potential confounding factors in the multivariate analysis (data not shown).

Bivariate logistic regression analyses between wasting and socio-economic and demographic variables (potential confounders) showed that the odds of having acute malnutrition were significantly lower among girls (COR = 0.7, 95% CI [0.61, 0.81]) and significantly higher among children below 12 months of age (COR = 1.5, 95% CI [2.10, 3.04]). Furthermore, children in households that belonged to the highest wealth quintile were more likely to be well-nourished (COR = 0.48, 95% CI [0.32, 0.71]).

3.5 | Multivariate analyses

Simple associations between water and sanitation variables and the nutritional status are likely to overstate the association between the former and the latter. To prevent erroneous conclusions, multivariate analyses including potential confounders and adjustment for

TABLE 4 Unadjusted risk of acute malnutrition, bivariate logistic regression analysis (OR, 95% CI)

Characteristic		Nutritional status of child: Malnourished n (%)	Nutritional status of child: Well-nourished n (%)	Crude OR (95% CI)
Water source for drinking	Improved	378 (12.2)	2717 (87.8)	1.03 [0.89, 1.19]
	Unimproved	472 (11.9)	3505 (88.1)	1.0
Toilet facility	Improved	26 (6.8)	358 (93.2)	0.52* [0.35, 0.77]
	Unimproved	841 (12.3)	5984 (87.7)	1.0
Disposal of child's stool	Sanitary	213 (10.2)	1874 (89.8)	0.78* [0.66, 0.92]
	Unsanitary	616 (12.7)	4243 (87.3)	1.0
Time to water source	On premise	17 (11.8)	127 (88.2)	0.7 [0.44, 1.25]
	≤30 min	381 (10.5)	3263 (89.5)	0.64* [0.54, 0.76]
	31–60 min	192 (12.1)	1393 (87.9)	0.76* [0.62, 0.93]
	≥61 min	262 (15.3)	1445 (84.7)	1.0
Diarrhoea in past two weeks	Yes	228 (19.3)	953 (80.7)	2.02* [1.71, 2.38]
	No	637 (10.6)	5378 (89.4)	1.0
Sex of child	Male	505 (13.8)	3142 (86.2)	1.0
	Female	362 (10.2)	3200 (89.8)	0.70* [0.61, 0.81]
Child's age	6–12 months	191 (20.1)	758 (79.9)	1.5* [2.10, 3.04]
	13–24 months	240 (16.4)	1220 (83.6)	1.97* [1.66, 2.33]
	≥25 months	436 (9.1)	4364 (90.9)	1.0
Size of child at birth	Very large	108 (8.8)	1116 (91.2)	0.45* [0.35, 0.57]
	Larger than average	90 (10.1)	804 (89.9)	0.52* [0.40, 0.67]
	Average	290 (10.3)	2515 (89.7)	0.53* [0.45, 0.64]
	Smaller than average	93 (14.0)	572 (86.0)	0.75* [0.58, 0.97]
	Very small	286 (17.8)	1321 (82.2)	1.0
Mother's education	No education	714 (13.0)	4798 (87.0)	1.0
	Primary	145 (9.0)	1474 (91.0)	0.66* [0.55, 0.80]
	Secondary or above	8 (10.3)	79 (89.7)	0.77 [0.37, 1.6]
Father's education	No education	561 (13.5)	3583 (86.5)	1.0
	Primary	261 (10.1)	2329 (89.9)	0.72* [0.61, 0.84]
	Secondary or above	35 (9.3)	340 (90.7)	0.66* [0.46, 0.94]
Wealth index	Poorest	380 (14.8)	2181 (85.2)	1.0
	Poorer	196 (12.4)	1388 (87.6)	0.81* [0.67, 0.98]
	Middle	153 (11.1)	1226 (88.9)	0.72* [0.59, 0.88]
	Richer	110 (8.3)	1209 (91.7)	0.52* [0.42, 0.65]
	Richest	28 (7.7)	338 (92.3)	0.48* [0.32, 0.71]

*Statistically significant association $P < 0.05$.

stratification and clustering were conducted for each WASH variable separately (Table 5).

3.5.1 | Toilet facility

Table 5 shows the results from the multivariate analysis of the toilet facility on nutritional status after adjusting for confounding factors and adjusting for sampling design. Wealth index, time to water source, and the disposal of the child's stool were all associated with the household's use of toilet facility and the nutritional status in the χ^2 test ($P < 0.05$) and were thus included as confounders in model 2.

Once all other factors were controlled for, children in households with access to an improved toilet facility had 37% lower odds of being wasted relative to children in households with access to improved toilet facilities (AOR = 0.63, 95% CI [0.46, 0.86]).

3.5.2 | Time to water source

Even though the association between the time to water source and nutritional status was less prominent compared with the bivariate analysis, it remained significant after controlling for potential confounders and clustering (Table 5). The wealth index, mother's

TABLE 5 Unadjusted (model 1) and adjusted (model 2) odds ratios of all variables related to WASH and nutritional status, adjusted for potential confounders and sampling design

Variable		Model 1 COR (95% CI)	Model 2[a] AOR (95% CI)	*P*-value
Toilet facility	Improved	0.52 [0.35, 0.77]	0.63 [0.46, 0.86]	0.00*
	Unimproved	1.0	1.0	
Time to water source	On premise	0.74 [0.44, 1.25]	0.82 [0.61, 1.11]	0.19
	≤30 min	0.76 [0.54, 0.76]	0.71 [0.61, 0.83]	0.00*
	31–60 min	0.76 [0.62, 0.93]	0.81 [0.67, 0.97]	0.02*
	≥61 min	1.0	1.0	
Disposal of child's stool	Sanitary	0.78 [0.66, 0.92]	0.97 [0.84, 1.13]	0.73
	Unsanitary	1.0	1.0	

[a]Factors adjusted for in model 2 are stated in the text.

*Statistically significant association $P < 0.05$.

education, and the type of toilet facility were all associated with both the distance to the water source and the nutritional status in the χ^2 test ($P < 0.05$) and were included as potential confounders in model 2.

The multivariate analysis showed that children from households that had a water source within 30 min of reach or a water source within 60 min of reach were all less likely to be wasted compared with children from households who needed more than 60 min to fetch water, with odds ratios of 0.71 (95% CI [0.61, 0.83]) and 0.81 (95% CI [0.67, 0.97]), respectively.

3.5.3 | Disposal of the child's stool

Wealth index, mother's highest level of education, father's highest level of education, and the type of toilet facility were included as confounders in the multivariate analysis, as these were significantly associated with the disposal of the child's stool and the nutritional status in the χ^2 test ($P < 0.05$).

In the bivariate analysis, disposal of the child's stool was independently associated with the nutritional status (COR = 0.78, 95% CI [0.66, 0.92]). However, after all factors were controlled for and after adjusting for the sampling design, the significant association disappeared (AOR = 0.97, 95% CI [0.84, 1.13]).

4 | DISCUSSION

We attempted to analyse the impact of access to basic environmental services—such as water and sanitation—on the prevalence of acute malnutrition, using national representative data of the EDHS. A total of 7,209 children under five were included in the analysis, of which 12% was wasted. More than half of the households of the included children made use of an unimproved source for drinking and for almost all households, this water source was outside their premise. Safe water management was practiced by a quarter of the households. Only 5.3% of the households had access to an improved toilet facility that was used only by members of one household.

It was expected that all variables related to water and sanitation would be associated with moderate-to-severe wasting. Analysis showed that access to a toilet facility, disposal of the child's stool, and the time to the water source were all individually associated with acute malnutrition among children under five. Although several variables lost their significance in the multivariate analyses, having access to an unimproved toilet facility and living far from a water source were predictors of wasting also after adjusting for other factors. Interestingly, the water source for drinking did not predict nutritional status.

Overall, the results showing the inverse association between acute malnutrition and household access to a toilet facility tend to confirm the findings of other studies carried out in Ethiopia (Patricia, 2005) and other parts of the world (Esrey, 1996; Smith, Ruel, & Ndiaye, 2005). Data collected in the late 1990s from eight countries in sub-Saharan Africa found that optimal sanitation versus no sanitation was associated with higher WHZ (Esrey, 1996). Also, the use of pit latrines and flush toilets had significantly positive effect on WHZ in 36 low- and middle-income countries (Smith, Ruel, & Ndiaye, 2005). It is stated previously that good sanitation prevents contamination of the environment by excreta and prevents the transmission of pathogens from faeces of an infected person to a new host and, thus, avoids diarrhoea and nutritional problems (Brown, Cairncross, & Ensink, 2013). The relationship between diarrhoea and wasting is already widely accepted (Brown, Cairncross, & Ensink, 2013; Rodriguez, Cervantes, & Ortiz, 2011; Schaible & Kaufmann, 2007) and was reaffirmed in our current study.

Although an association between wasting and improved water source was expected, no such relationship was found in this analysis. A possible explanation is that even improved water sources may be subject to faecal contamination in Ethiopia. There is evidence from many low- and middle-income countries that improved water sources are often contaminated with *Escherichia coli* or thermotolerant coliforms (Bain et al., 2014). Furthermore, a systematic meta-analysis of 57 studies showed that microbiological contamination of water between source and point-of-use was widespread (Bain et al., 2014). Taking the water source quality into account, the estimated proportion of the Ethiopian population with access to uncontaminated, safe drinking water would fall by 11% (Bain et al., 2012). The faecal contamination of water sources may lessen the health benefits of water source improvements and may have nullified the effect of having an improved water source in this study.

Remoteness of a water source to the household was shown to be a factor associated with acute malnutrition in this analysis. This is in accordance with previous research (Esrey, 1996; Pickering & Davis, 2012). Close proximity to a water source may allow for more hygienic use of a toilet facility (e.g., pour flushing, cleaning, post-defecation handwashing) and may improve the frequency of hygiene behavior (handwashing). Evidence for this complementary behaviour has been documented previously in Lesotho (Esrey, Habicht, & Casella, 1992) and Burkina Faso (Curtis et al., 1995). Furthermore, a water source far from home leads to increased storage times. Prolonged storage of water may offer increased opportunities for microbial contamination through repeated extraction with dirty utensils and hands (Pickering & Davis, 2012). Besides that, mothers that spend significant time fetching water may have less time to care for their children in ways that affect the nutritional status and for income-generating activities that allow for the purchase of better health care and food (Esrey, 1996; Pickering & Davis, 2012).

This study was not without limitations. One such limitation was that the study made use of secondary data with a predetermined set of variables. This means that measures for some important variables were not available, such as personal hygiene practices. As these variables appear to be important in child health, it is highly recommended that the variables are added in future DHS. This study was restricted to rural households only. This exposes the associations in an area where malnutrition and poor WASH are most evident but also limits the scope to which the results can be generalized to all households. Lastly, due to the cross-sectional nature of the data, a causal relationship between improved WASH practices and a reduced likelihood of wasting could not be determined.

The association between WASH practices and wasting was assessed using a multivariate model to adjust for potential confounders. Adjusting for confounding factors is crucial, as the crude exposure-outcome association will probably be a biased estimate of the true association without proper adjustment (Lee, 2014). However, including too many confounders in a model could distort the relationship and create over-adjustment bias (Schisterman, Cole, & Platt, 2009). As there are many ways to identify confounders, one must be careful in what variables to include in the multivariate model. In this analysis, diarrhoea—considered to be an intermediate factor between WASH practices and nutritional status—was not included in the multivariate analysis as the intermediate factor probably would have biased the result towards null (Schisterman, Cole, & Platt, 2009). Nevertheless, this analysis may have missed some other confounding factors, what could have led to an overestimated association between WASH practices and acute malnutrition.

Despite above limitations, a clear association between acute malnutrition and both use of toilet facility and the time needed to fetch water was found. Assessing the association between WASH and childhood wasting using large, national representative survey data is a critical step in strengthening the evidence base on the underlying determinants of childhood wasting, especially because most studies have been focused on the chronic form of malnutrition. Clean water and sanitation are supposed to be important factors in preventing malnutrition, but they remain subordinate in the prevention and treatment of malnutrition. Although great strides have been made, it is estimated that 663 million people still lack improved drinking water sources and 2.4 billion people still live without access to basic sanitation (WHO & Unicef, 2015). Even though improved water sources did not came forward as a protective factor for wasting in this analysis, it could still be important in the prevention of wasting. So, in order to decrease the burden of undernutrition in young children and infants, WASH components should become a crucial element in nutrition programmes.

This study reaffirmed the link between WASH and wasting and provides a basis for further studies. Yet additional research is required and should focus on randomized effectiveness trials of WASH improvements acting especially at household level, which include childhood wasting as outcome variable. So far, the evidence on the effectiveness of WASH interventions has been limited and of low quality (Dangour et al., 2013). This is crucial, as nutrition outcomes for infants and young children requires a framework that is broader than nutrition-specific interventions alone.

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CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

CONTRIBUTIONS

MHC analysed the data, did the interpretations, and wrote the first draft of the manuscript. SMB and MS contributed to the interpretations and writing and SG provided the data and critically revised the manuscript. All authors contributed to and approved the final version of the manuscript.

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