





Research Paper

Limited water access is associated with food insecurity and diarrheal episodes among children suffering from moderate acute malnutrition in Far-North Cameroon

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ABSTRACT

To gain further understanding of the interlinkages between poor water access, household food insecurity, and undernutrition among children, this study used a cross-sectional design with 474 female caretakers of children suffering from moderate acute malnutrition (MAM) to explore the relationship between limited access to water and diarrheal diseases among children, aged <5 years, experiencing MAM. The mean age of the caretakers was 28.50 ± 6.88 years and that of their MAM children (sex ratio=0.7) was 17.79 ± 9.59 months. The participants reported spending an average of 19.29 ± 15.69 min for one trip to fetch water. A negative correlation was found between mean time spent fetching drinking water and hygiene and handwashing score ($r = -0.141$, $p = 0.003$). Furthermore, the more severe the food insecurity status of a household, the farther the family member likely had to go to fetch drinking water [$F(2, 444) = 8.64$, $p \leq 0.001$]. Results from binary logistic regression showed that children from households practicing open defecation ($p = 0.008$) and/or having inadequate hygiene practices ($p = 0.004$) had increased odds of developing diarrhea. Therefore, ameliorating water access in households with MAM children could contribute to improvements in hygiene and sanitation attitudes with a subsequent increase in the effectiveness of nutrition interventions aiming at reducing acute malnutrition among children.

Key words: diarrhea, food insecurity, moderate acute malnutrition, WASH, water insecurity

HIGHLIGHTS

- Wasting is a huge public health emergency in sub-Saharan Africa with 6.9% of children aged <5 years being affected.
- The existence of relationships between the different forms of undernutrition and water, sanitation, and hygiene may contribute toward the persistency of children's poor nutritional status.
- Children from households practicing open defecation or with poor hygiene practices have increased odds of having diarrhea.

INTRODUCTION

According to 2019 estimates, 75% of children experiencing wasting live in low- and middle-income countries (UNICEF/WHO/World Bank Group 2020). Wasting defined as a condition whereby a child is too thin for his/her height, is an indicator of acute malnutrition, and is measured using weight-for-height Z-score (WHZ) or mid-upper arm circumference (MUAC). It was estimated that about 47 million children globally are wasted, with approximately 32.7 million moderately wasted and 14.3 million severely wasted (UNICEF/WHO/World Bank Group 2020; UNICEF 2021). Described as a recent rapid weight loss or a failure to gain weight, acute malnutrition mainly occurs due to poor nutrient intake and/or disease. As a

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result, the immunity is weakened and the child presents an increased risk of mortality due to infectious diseases, especially when wasting is severe (WHZ under -3) (UNICEF/WHO/World Bank Group 2020; UNICEF 2021).

The Sustainable Development Goals included a global target of reducing and maintaining childhood wasting to $<5\%$ by 2025 (WHO/UNICEF 2017). In an effort to achieve this goal, it is critical that children diagnosed as wasted receive timely and appropriate life-saving treatment. Additionally, a clear understanding of proximal and distal factors of moderate acute malnutrition (MAM) and interlink between them is of utmost importance to improve and implement successful prevention interventions (Wegner *et al.* 2015). According to the UNICEF conceptual framework of the determinants of child undernutrition, poverty, lack of physical and social capital, and poor access to other resources such as land and technology put families at risk for the following two main things: (1) household food insecurity and (2) unhealthy household environment (UNICEF 2015).

Household food insecurity occurs when access to a sufficient amount of nutritious food is lacking (Food and Agriculture Organization of the United Nations 2019). Moderate to severe levels of food insecurity at the household level have been shown to be significantly associated with wasting among young children in sub-Saharan Africa (Motbainor *et al.* 2015; Abdurahman *et al.* 2016). Unhealthy household environment, including poor sanitary condition, negatively impacts food utilization, defined as the biological availability of the food after it has been consumed (UNICEF 2015; MALED Network Investigators 2017). Because it is the ultimate predictor of food insecurity, poor food utilization will thereby put children at risk for repeated infections, such as diarrhea, causing acute malnutrition, and the resulting inadequate childhood development capacities will extend their negative effects to their older ages (UNICEF 2015; Clark *et al.* 2020). It has been hypothesized that linkages exist between different forms of undernutrition and water, sanitation, and hygiene (WASH) (UNICEF 2021). The lack of sanitation is shown to contribute approximately 10% of the diarrheal diseases worldwide (Mara *et al.* 2010). Recent water insecurity studies have demonstrated that the lack of water could be significantly associated with a reduction of hygiene behaviors at the household level, increasing the risk for diarrheal diseases and thereby acute malnutrition for children (Hadley & Freeman 2016). For instance, in a qualitative study, it was found that the limited availability of water was associated with re-cycling water to wash clothes and floors, and handwashing was often neglected to save water for drinking and cooking purposes (Nounkeu & Dharod 2020). Similarly, a study conducted with 7,209 children in Ethiopia revealed that proper short distance to water source was associated with a lower prevalence rate of acute malnutrition (Van Cooten *et al.* 2019).

Recognizing the importance of water and thereby a clean environment in addressing diarrheal diseases and undernutrition among children, the UN-Water has established time- and distance-related indicators to measure water access at the household level. Water access is considered inadequate if the water-fetching time is >30 min round trip and/or distance to water source is $>1,000$ m (WHO 2021). Nevertheless, it is not clear how these indicators are associated with the risk of infection and the subsequent undernutrition among children. Among the limited literature, it is found that a long distance to the water source is correlated with a low availability of water in the household at any given time (Sorenson *et al.* 2011; Geere & Cortobius 2017; Nounkeu *et al.* 2019). Additionally, in recent studies, it was found that hand hygiene practices were lower among those who had to walk a long distance to fetch water (Sorenson *et al.* 2011; Geere & Cortobius 2017; Nounkeu *et al.* 2019). This study explores the association between limited access to water and diarrheal diseases among children aged <5 years experiencing MAM and living in 14 villages located within the different health areas of the Kaélé Health District in Far-North Cameroon.

Study design

This study took place between January 2020 and August 2020 and was conducted as part of a longitudinal research imbedded in a Food Voucher Project implemented by the Helen Keller International in the Kaélé Health District, Far-North Region of Cameroon. The conceptual framework and description of the implementation standard operation procedures have been presented elsewhere (Helen Keller International 2021). Throughout the Food Voucher Project, children who were screened as potential MAM based on the MUAC measurement using the WHO-colored tapes underwent a confirmation stage at the health center using the MUAC ($115 \text{ mm} \leq \text{MUAC} \leq 125 \text{ mm}$) and/or the WHZ ($-3 < \text{WHZ} < -2$). A total of 724 confirmed MAM children aged between 6 and 53 months were randomly selected in 14 health areas of the Kaélé Health District to be eligible for the study. Adult female caretakers who consented to participate and who were from households with those identified MAM children (index children) were recruited to take part in the study. Throughout the study, the phrase 'index children' was used to define MAM children enrolled in the study along with the caretakers and whose health (occurrence of diarrhea) and demographic (age and gender) information were sought.

Using a door-to-door approach, with the help of community health workers and the list of 724 MAM children retrieved from the health center, enumerators went to houses of eligible caretakers and administered a questionnaire on a one-on-one basis. The survey guide included questions on demographic and socio-economic characteristics, diarrhea incidence among index children, nature of the water sources, time spent to collect one batch of water, and the person responsible for fetching water. To assess hygiene, hand washing, and sanitation practices, the participants were asked how frequently they practiced hand washing at each of five key stages of hygiene, i.e. before cooking, before eating, before feeding a child, after defecation, and after cleaning a child's feces. In addition to that, the survey guide included questions on the availability of facilities near the toilets to wash hands properly, the presence/type of toilets used in the households, and the practice of open defecation. The households' food insecurity status was assessed using the Household Food Insecurity Access Scale (HFIAS) guide published by Coates *et al.* (2007). The households were categorized based on the severity of food insecurity: mild, moderate, or severe.

The data collection for the study was marked by the advent of the COVID-19 pandemics. Hence, in alignment with the Cameroonian government recommendations, specific measures were taken to reduce contamination risks during in-house one-on-one interviews. These included but were not limited to enumerators using hydroalcoholic solution before entering and leaving each home, avoiding contact greeting, consistently wearing facemasks, respecting social distancing, having the caretaker disinfecting their hands with hydroalcoholic solution when arriving to their houses and after the interview, and making sure the caretakers properly wore their facemasks throughout the interview. Moreover, in their efforts to sensitize participants on WASH practices, enumerators emphasized on the importance of functional handwashing points in households.

Data analysis

Descriptive statistics were conducted to assess socio-demographic and socio-economic characteristics of participants, diarrheal incidence, WASH component prevalence, and food insecurity status of households. Continuous data were reported as mean and standard deviation, and categorical data were summarized using percentages. As for the assessment of time spent to fetch drinking water, outliers were identified and excluded from the analysis. Binary logistic regression analysis was used to determine predictors of diarrheal occurrence in MAM children from selected households. Potential predictors included in the model were binary (matrimonial, education, index child gender, household global monthly income, household practicing open defecation, and household water access as defined by the WHO), categorical (caretaker's occupation), and numeric (time spent to fetch drinking water, hygiene, and handwashing score) data with the outcome variable being the occurrence of diarrhea (yes or no). Univariate associations were reported using the odds ratios with 95% confidence intervals. Maximum likelihood estimation was used to assess parameters. Predictors with $p < 0.2$ in the univariate analysis were included in the multivariate analysis. Multivariate associations based on binary logistic regression models were reported using the odds ratios with 95% confidence intervals. The IBM-SPSS 25.0 (IBM Corporation, Armonk, NY, USA) was used for statistical analyses. Statistical significance was set at $p < 0.05$.

IRB clearance

Prior to the beginning of the study, approval was obtained from the Cameroon National Committee of Ethics for Human Research under the number 2020/02/1207/CE/CNERSH/SP.

RESULTS

Socio-demographic characteristics of the participants

A total of 474 female caretakers consented to participate in the study. The mean age of the caretakers was 28.50 ± 6.88 years and the majority of them (70%) were married monogamy (see Table 1). Approximately 40% of participants had the secondary school level of education or more. The majority of women in the study were business owners (45%) or farmers (34%). As for the main source of income of the household, it came from selling harvest products (36%), followed by retail activities (33%), or being involved in occasional jobs (18%) (Table 1). On average, each household had approximately 6.88 ± 3.91 people (Table 1). The mean monthly income for households was 39.06 ± 101.26 USD corresponding to about 19 cents available per family member per day.

Table 1 | Socio-economic and demographic characteristics of participants living in the Kaélé Health District, Far-North Cameroon (*n*=474)

Household characteristics	Mean ± SD (range) n (%)
Caretaker's age (years)	28.50 ± 6.88 (15–62)
Number of people in the household	6.88 ± 3.91 (2–33)
Global monthly income of the household (USD)	39.06 ± 101.26 (0.94–1688.53)
Marital status	
Monogamy	333 (70.25)
Polygamy	111 (23.42)
Single/separated/divorced/widower	30 (06.33)
Level of education of the caretaker	
None	72 (15.19)
Primary education or less	212 (44.73)
Secondary education or more	190 (40.08)
Main occupation of the caretaker	
Agricultural	159 (33.54)
Informal	86 (18.14)
Own business	215 (45.36)
Waged worker	14 (02.95)
Main source of income of the household	
Salaries	46 (09.70)
Selling harvest products	171 (36.08)
Retail	155 (32.70)
Occasional job	83 (17.51)
Other (clothes styling, transportations, selling animal-based products)	19 (04.00)
Household food security status	
Mild food insecurity	82 (17.30)
Moderate food insecurity	283 (59.70)
Severe food insecurity	99 (20.89)
Index child's characteristics	
Child's age (months)	17.79 ± 9.59 (6–50)
Duration of the index child recent illness (days)	6.52 ± 6.47 (1–65)
Gender of the index child	
Female	280 (59.07)
Male	194 (40.93)
The child took part to the first food voucher project	95 (20.04)
The child has recently been sick	237 (50)
The child has diarrhea	124 (26.16)

Water access-related behaviors

Water-fetching source and water quality

Participants used both unimproved (20%) and improved (80%) water sources to collect water they used for drinking. The majority of them (53%) drew water from boreholes and 3% of caretakers were drawing drinking water from rivers. Only

11% of participants reported using water from taps supplied by the national water company (Cameroon Water Utilities Corporation). About half of women stated that they used water treatment methods for the household drinking water (45%) or for the water given to the index child (47%) (see Table 2).

Time spent to collect drinking water

Overall, households spent an average of 19.29 ± 15.69 min to collect drinking water (one round trip to and from the water source and queuing time) (Table 2). Approximately one-quarter (23%) of participants did not meet the WHO threshold of spending ≤ 30 min to draw water, an indicator of good water access.

Persons responsible for water fetching

Women were the main water fetchers in our study. In 96% of households, women were reported to be in charge of water-fetching activities, followed by children <19 years old, who were responsible for water drawing in 33% of households. However, only 7% of households declared that an adult man was the main one taking care of collecting water for the family.

Hygiene, handwashing, and sanitation practices

The mean hygiene and handwashing score at the five key stages of hygiene was 7.32 ± 1.71 and the scores ranged from 3 to 10 (Table 3). Only 7% of households had handwashing facilities nearby their latrines at the moment of the interview. There was a significant positive association between the hygiene and handwashing scores and the global monthly income of the household ($r=0.120$, $p=0.018$). Additionally, there was a negative correlation between mean time spent fetching drinking water and hygiene and handwashing scores ($r=-0.141$, $r=0.003$).

Table 2 | Drinking water access-related behaviors of participants of households located in the Kaélé Health District, Far-North Cameroon ($n=474$)

Variables	<i>n</i> (%) ^a
Types of water sources used for drinking ^b	
Boreholes	249 (52.53)
Protected wells	80 (16.88)
Tap water (Cameroon Water Utilities Corporation)	51 (10.75)
Rivers	12 (02.53)
Unprotected wells	80 (16.88)
Unimproved water sources (rivers, unprotected wells)	92 (19.41)
Improved water sources (boreholes, protected wells, tap)	380 (80.17)
Who takes care of water fetching	
Adult man	31 (6.54)
Adult woman	454 (95.78)
Boy/girl <19 years	158 (33.33)
Drinking water treatment	
Before the household members drink	211 (44.51)
Before the water is given to the index child for drinking	224 (47.26)
Time spent to collect one batch of drinking water ^a	
≤ 30 min (good water access)	309 (77.44)
> 30 min (poor water access)	90 (22.56)
	Mean \pm SD (range)
Time spent to collect water (round trip to the water source+queuing time, in min) ^c	19.29 ± 15.69 (1–60)

^aSample size $n=399$.

^bTwo of the participants used other types of water sources not listed here for drinking.

^c $n=456$, outliers were excluded before conducting the analysis.

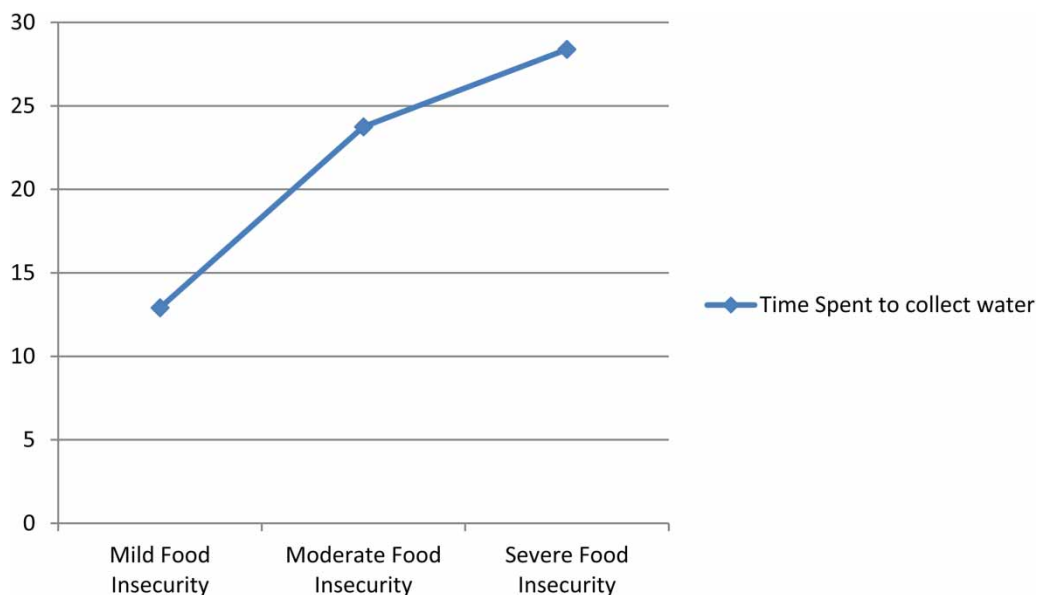
Table 3 | Hygiene, handwashing, and sanitation practices of households located in the Kaélé Health District, Far-North Cameroon ($n=474$)

Variables	<i>n</i> (%)
Availability of toilets facilities	
Households with latrines	375 (79)
Households without latrines	99 (21)
Households practicing open defecation	84 (18)
Types of toilets facilities	
Traditional latrines with planks	360 (75.95)
Traditional latrines with concrete	112 (23.63)
Other (flushing toilets, combination of two or more types)	02 (00.42)
Households with facilities to wash hands nearby latrines	27 (05.70)
	Mean \pm SD (range)
Hygiene and handwashing score	7.32 \pm 1.71 (3–10)

A total of 98 households (21%) did not have latrine facilities. Among them, 86% reported practicing open defecation. For those owning their toilets, it was principally traditional latrines made with planks (76%) or concrete (24%) (Table 3). When assessing associations, households not having latrines spent significantly more time to fetch water on average (no latrines: 23.75 ± 17.12 , with latrines: 18.06 ± 15.00 , $F(1, 453)=9.87$, $p=0.002$) than their counterparts. Similarly, among those practicing open defecation, drinking water collection took more time than for those who did not, and the difference was significant (yes: 25.27 ± 16.95 , no: 18.07 ± 15.16 , $F(1, 454)=13.85$, $p \leq 0.001$).

Household food insecurity status and its relationship with water-fetching time

Almost all the households (98%) in the study experienced some level of food insecurity in the 4 weeks preceding the interview (Table 1). In fact, 17% of households were mildly food insecure, 60% moderately food insecure, and 21% were severely food insecure. When comparing food insecure households using one-way ANOVA statistics, the mean time spent to fetch water was significantly different [$F(2, 444)=8.64$, $p \leq 0.001$] depending on the severity of food insecurity with a dose-response relationship, i.e. the more severe the food insecurity status of a household, the farther the family member likely had to go

**Figure 1** | Household food insecurity status and its relationship with water-fetching time in the Kaélé Health District, Far-North Cameroon ($n=464$).

to fetch for water (mildly food insecure: 12.91 ± 12.02 min, moderately food insecure: 20.59 ± 15.83 min, severely food insecure: 21.10 ± 15.65 min) (Figure 1).

Diarrheal status of the index children and relationship with WASH practices

The mean age of the index children was 17.79 ± 9.59 months. They included 59% of females and 41% of males (Table 1). Among these children, 20% were enrolled as beneficiary of this voucher program for the second time within a 2-year time-frame. Approximately half of the children experienced a sickness in the few days prior to the interview and among about half of them ($n=124$ children), the clinical presentation included diarrhea.

A logistic regression analysis was performed to ascertain the effects of caretakers' matrimonial status, caretakers' education level, index children gender, household global monthly income, and individual WASH components on the likelihood that an index child experienced diarrhea in the 2 weeks preceding the survey at both the univariate and the multivariate levels. All predictors, with $p < 0.2$ using the univariate analysis (Table 4), were included in the multivariate analysis (Table 5).

Table 4 | Risk factors of diarrheal occurrence among MAM children from the Kaélé Health District, Far-North Cameroon ($n=474$) using univariate analysis

Characteristics	OR (95%CI)	p-Value
<i>Socio-demographic and economic</i>		
Matrimonial status		
Married	1.45 (0.58, 3.63)	0.430
Not married ^a	1	
Education level		
Primary education	1.13 (0.74, 1.72)	0.564
Secondary education	1	
Caretakers' occupation		
Agriculture	7.07 (0.90, 55.44)	0.063
Informal	2.11 (0.25, 17.62)	0.491
Own business	4.47 (0.57, 34.95)	0.154
Waged worker	1	
Age	1.00 (0.97, 1.02)	0.667
Index children gender		
Male	1.45 (0.96, 2.18)	0.080
Female	1	
Household global monthly income		
> Poverty threshold	1.52 (0.96, 2.40)	0.074
≤ Poverty threshold (51.81 USD)	1	
<i>WASH indicators</i>		
Time spent to fetch drinking water	1.00 (0.99, 1.01)	0.715
Good water access by WHO		
≤ 30 min	0.96 (0.57, 1.63)	0.883
> 30 min	1	
Hygiene and handwashing score	0.88 (0.78, 0.99)	0.034
Households practicing open defecation		
Yes	1.96 (1.06, 3.63)	0.031
No	1	

^aSingle/separated/widower.

Table 5 | Risk factors of diarrheal occurrence among MAM children from the Kaélé Health District, Far-North Cameroon ($n=474$) using multivariate analysis

Characteristics	aOR (95%CI)	p-Value
<i>Socio-demographic and economic</i>		
Caretakers' occupation		
Agriculture	7.12 (0.89, 57.22)	0.065
Informal	2.50 (0.29, 21.65)	0.407
Own business	4.03 (0.51, 32.25)	0.188
Waged worker	1	
Index children gender		
Male	1.48 (0.96, 2.28)	0.074
Female	1	
Household global monthly income		
> Poverty threshold	1.40 (0.84, 2.33)	0.193
≤ Poverty threshold (51.81 USD)	1	
<i>WASH indicators</i>		
Hygiene and handwashing score	0.84 (0.73, 0.96)	0.008
Households practicing open defecation		
Yes	2.61 (1.36, 5.02)	0.004
No	1	

When determining the relationship between WASH practices and the incidence of diarrhea among MAM children, the results showed that children from households practicing open defecation had increased odds of developing diarrhea ($p=0.008$, Table 5). Additionally, an increase in hygiene and handwashing scores was associated with reduced odds of children manifesting diarrheic symptoms ($p=0.004$).

DISCUSSION AND CONCLUSION

This research assessed the association between water collection time and household food security status as well as attempting to understand the relationship between limited water access and the incidence of diarrheal diseases among children <5 years of age who suffer from MAM. Similar to the WHO and UNICEF Joint Monitoring report, which states that 8 of 10 individuals living in rural areas of the world lack basic access to water (time spent >30 min, use of unimproved water sources) (WHO 2021), the investigation of water access-related behaviors in this study revealed that the use of unimproved water sources such as unprotected wells or rivers was common for both chore and drinking purposes coupled with low utilization of drinking water treatment methods. In addition to that, caretakers had to spend a considerable amount of time every day to provide their households with a sufficient amount of water. In the same order of ideas, Geere & Cortobius (2017), presenting a synopsis of water-fetching-related data collected from households in 23 countries, reported that the mean single trip time to collect water ranged from 10–65 ± 2–13 min in rural areas.

The use of diverse sources for water collection reported in this study was also found in an analysis of Demographic Health Surveys data from 26 countries of sub-Saharan Africa as well as in a study conducted in the West region of Cameroon (Pickering & Davis 2012; Nounkeu & Dharod 2018). However, similar to multiple studies assessing the gender differences in experiencing poor water access (Wutich & Ragsdale 2008; Tsai *et al.* 2016), women shared the heaviest burden of household-level water scarcity, often helped by their children. This time loss endorsed by women on a daily basis will eventually prevent them from efficiently engaging in other activities such as household food production, healthy foods cooking, or caring for/feeding their children. A recent study conducted in rural areas of West Cameroon showed that in order to cope with water scarcity, women frequently had to change their meal plan switching from highly nutritious foods demanding large quantities of water for preparation to less nutrient-dense foods or even snacks, which required less water for cooking (Nounkeu & Dharod 2020).

Limited access to water at the household level was associated with poor hygiene and sanitation practices in this study. Moreover, poor hygiene and hand washing as well as the practice of open defecation in households significantly predicted the occurrence of diarrheal diseases among their MAM children. [Luby et al. \(2011\)](#) described optimal hand washing as the use of water and soap to wash hands at least 10 times per day. This level of hygiene, even though critical to stop the fecal oral transmission and therefore reduce the incidence of diarrhea and subsequent undernutrition among children, is difficult to achieve in a context where households already struggle to have water for drinking.

More than half (58%) of the total diarrhea-related deaths in poor countries are due to inadequate WASH practices ([WHO 2014](#)). In addition to that, 5.6% of deaths among children aged <5 years could have been prevented through improved water access, proper sanitation, and optimal hygiene practices ([WHO 2014](#)). Furthermore, a recent meta-analysis showed that the risk of diarrhea could be largely reduced through the delivery of WASH-related interventions ([Wolf et al. 2018](#)). In our study, good water access measured as reduced time spent to collect water tended to positively impact hygiene and sanitation practices. In fact, researchers have shown that households who had to spend a lot of time to reach a water source tended to have a reduced amount of water available for use at the household level. As a result, caretakers from these affected households developed a sort of hierarchy in tasks to be completed with the available amount of water, an organization that generally sacrificed hygiene and sanitation practices against drinking and cooking ([Pickering & Davis 2012](#); [Geere & Cortobius 2017](#); [Nounkeu & Dharod 2020](#)). Hence, and similar to other findings ([Nounkeu et al. 2019](#)), in this study, inadequate WASH practices such as open defecation or low hygiene and handwashing scores were associated with increased odds of children presenting diarrheic diseases. In fact, three randomized efficacy trials conducted in Bangladesh, Kenya, and Zimbabwe and unprecedented in terms of scale and costs demonstrated no effect of household WASH interventions on stunting among children with mixed effects on the incidence of diarrhea ([Luby et al. 2018](#); [Null et al. 2018](#); [Humphrey et al. 2019](#)). [Pickering et al. \(2019\)](#) in their interpretation paper recommended focusing on interventions that could more effectively reduce fecal contamination in domestic environments. Furthermore, as highlighted in a recent review of integrated WASH and Nutrition interventions, water access represents a key component and should be addressed properly for uptake of hygiene or sanitation practices and optimal caretaking behaviors to be easily achievable by women ([Nounkeu & Dharod 2021](#)).

Not surprisingly, almost all the households in the study were food insecure. This was foreseeable recognizing that all the families selected in the study had one or more MAM children, translating a certain extent of food insecurity and poverty. In fact, a report published in 2016 showed that approximately one-third of the Far-North Region population were estimated food insecure ([OCHA 2016](#)). Especially, according to the 2018 SMART survey report, three of four food insecure people in Cameroon lived in the North and Far-North Regions ([UNICEF 2018](#)) with the latter having the highest prevalence of acute malnutrition (5.2%) at the national level. Even though factors that influence undernutrition among children are multifaceted, the UNICEF conceptual framework for undernutrition has recognized household food insecurity as a critical determinant and key underlying cause of undernutrition ([UNICEF 2015](#)). Furthermore, young children of families are frequently protected toward the effect of food insecurity because, in general, parents display altruism toward their children and exhibit a preferential treatment for younger children over elder ones in food allocation ([Eswaran & Kotwal 2004](#)). About one-quarter of children in this study were involved in this project for the second time, evoking the possibility of relapse in MAM after the intervention. Hence, the identification of a MAM child in a household could actually represent only a 'symptom' of the whole ménage precarious situation.

In a study involving 21 low- and middle-income countries across the world, results showed that reduced time spent on water management led to greater food security ([Brewis et al. 2020](#)). Similarly, in our study, time spent significantly affected the extent of food insecurity with more severe levels among those whose water collection activities took longer. These findings were also supported by another study, showing that a 15-min decrease in one-way walking time to the water source was associated with improved anthropometric indicators of child nutritional status ([Pickering & Davis 2012](#)). Acknowledging these, interventions such as water pump constructions might be highly effective in combination to current strategies aiming to reduce the incidence of MAM among children, since its implementation takes into consideration the big picture of the family's potential distress. Interventions aiming to achieve maternal and child food security are of utmost importance to tackle childhood malnutrition and subsequent intergenerational poverty ([Clark et al. 2020](#)). Additionally, a two-way link has been shown to exist between malnutrition and poverty, leading to a vicious cycle with each fueling the other ([Siddiqui et al. 2020](#)). On the other hand, household food and lack of WASH access can co-occur in multiple pathways and lead to undernutrition aggravating the poverty status of the family ([Workman et al. 2021](#)). Hence, due to the multiplicity of pathways involved when assessing the potential relationship among food insecurity, malnutrition, lack of access to WASH, and poverty,

a syndemic framework to global health interventions was proposed and it integrates the majority of stressors that vulnerable populations generally face (Workman *et al.* 2021).

Some limitations of this study include the use of a cross-sectional design and the fact that the study was conducted only with MAM children, which prevent us establishing cause–effects types of relationships. However, the participants were recruited from 14 health areas of the Kaélé Health District, which can be described as a typical focus of food insecurity, economic water scarcity, and undernutrition in the Far-North Region. Thus, results and conclusions from this study could be used as a basis for policymakers working on reducing acute malnutrition among children in Cameroon. Improving water access in households with MAM children could be of great importance to hope for amelioration in hygiene and sanitation attitudes and therefore increase the effectiveness of nutrition interventions aimed at reducing undernutrition, especially acute malnutrition among children. Research on the impact on providing caretakers with a sufficient amount of clean water in addition to nutritious food items is warranted to establish the critical place this essential nutrient plays in the MAM recovery process.

One-quarter of the MAM children in our sample experienced diarrhea. The occurrence of such a high incidence of diarrhea among children whose body is already weakened by wasting on one hand and poor food utilization resulting from their household food insecurity status on the other hand really jeopardizes the efforts of governments and policymakers to slow down the aggravation of MAM children into severe acute malnutrition (SAM). Besides, diarrhea has been shown to be a major cause that results in complication in children suffering from SAM. To illustrate this, studies conducted in different settings of sub-Saharan Africa revealed that the outbreak of diarrhea led to higher rates of acute malnutrition and mortality among children <5 years (Mach *et al.* 2009; Talbert *et al.* 2012). In fact, because of the structural and immunological changes that occur in the small intestine and are associated with SAM, diarrhea accompanying SAM has been associated with an increased mortality. A recent review aiming at understanding an integrated WASH+nutrition approach and their outcomes concluded that consistent access to sufficient amounts of clean water was critical to expect a fecal-free environment and a decreased rate of diarrhea among children (Nounkeu & Dharod 2021). Especially, recommendations should be made to the Community-Based Management of Acute Malnutrition programs to always include not only soft WASH educational-related components (hygiene and handwashing practices) but also hardware delivery such as boreholes or latrines, in order to hope for the extent of fecal-free environment that should be attained for WASH interventions to have beneficial and significant effects on children’s nutritional status.

AUTHORS’ CONTRIBUTIONS

I.T. conceived and designed the study. F.R.N. and B.U.S.F. monitored data collection. C.D.N. and J.M.D. conducted the literature search. C.D.N., I.T., and B.U.S.F. conducted data analysis. C.D.N. and J.M.D. wrote and finalized the paper. All authors revised the manuscript for intellectual content and approved the final version.

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CONFLICT OF INTEREST

The authors declare no conflict.

DATA AVAILABILITY STATEMENT

Data cannot be made publicly available; readers should contact the corresponding author for details.

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