





## 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  $28.50 \pm 6.88$  years and that of their MAM children (sex ratio=0.7) was  $17.79 \pm 9.59$  months. The participants reported spending an average of  $19.29 \pm 15.69$  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  $28.50 \pm 6.88$  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  $6.88 \pm 3.91$  people (Table 1). The mean monthly income for households was  $39.06 \pm 101.26$  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 $\pm$ SD (range)             |
|---|-----------------------------------|
| Caretaker's age (years)   | 28.50 $\pm$ 6.88 (15–62)          |
| Number of people in the household                                       | 6.88 $\pm$ 3.91 (2–33)            |
| Global monthly income of the household (USD)                            | 39.06 $\pm$ 101.26 (0.94–1688.53) |
|   | <b>n (%)</b>                      |
| <hr/>   |                                   |
| 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 $\pm$ 9.59 (6–50)           |
| Duration of the index child recent illness (days)                       | 6.52 $\pm$ 6.47 (1–65)            |
|   | <b>n (%)</b>                      |
| <hr/>   |                                   |
| 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  $19.29 \pm 15.69$  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  $\leq 30$  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  $7.32 \pm 1.71$  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> (%) <sup>a</sup>               |
|--|---|
| Types of water sources used for drinking <sup>b</sup>  |   |
| 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 <sup>a</sup>                                 |   |
| $\leq 30$ min (good water access)  | 309 (77.44)                             |
| $> 30$ min (poor water access)   | 90 (22.56)                              |
|  | <b>Mean <math>\pm</math> SD (range)</b> |
| Time spent to collect water (round trip to the water source+queuing time, in min) <sup>c</sup> | $19.29 \pm 15.69$ (1–60)                |

<sup>a</sup>Sample size  $n=399$ .

<sup>b</sup>Two of the participants used other types of water sources not listed here for drinking.

<sup>c</sup> $n=456$ , outliers were excluded before conducting the analysis.

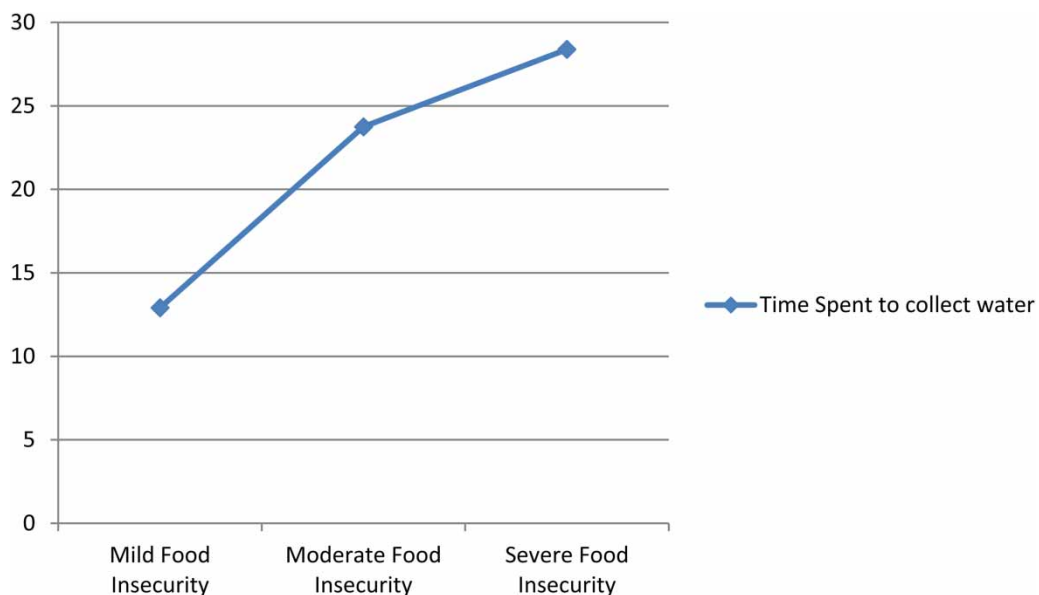
**Table 3** | Hygiene, handwashing, and sanitation practices of households located in the Kaélé Health District, Far-North Cameroon ( $n=474$ )

| 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)                              |
|  | <b>Mean <math>\pm</math> SD (range)</b> |
| 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:  $23.75 \pm 17.12$ , with latrines:  $18.06 \pm 15.00$ ,  $F(1, 453)=9.87$ ,  $p=0.002$ ) 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:  $25.27 \pm 16.95$ , no:  $18.07 \pm 15.16$ ,  $F(1, 454)=13.85$ ,  $p \leq 0.001$ ).

#### 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:  $12.91 \pm 12.02$  min, moderately food insecure:  $20.59 \pm 15.83$  min, severely food insecure:  $21.10 \pm 15.65$  min) (Figure 1).

### Diarrheal status of the index children and relationship with WASH practices

The mean age of the index children was  $17.79 \pm 9.59$  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 <sup>a</sup>              | 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                  |         |

<sup>a</sup>Single/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.

## REFERENCES

Abdurahman, A. A., Mirzaei, K., Dorosty, A. R., Rahimiforoushani, A. & Kedir, H. 2016 Household food insecurity may predict underweight and wasting among children aged 24–59 months. *Ecology of Food and Nutrition* 55 (5), 456–472.

- Brewis, A., Workman, C., Wutich, A., Jepson, W. & Young, S. 2020 Household water insecurity is strongly associated with food insecurity: evidence from 27 sites in low- and middle-income countries. *American Journal of Human Biology* **32** (1), e23309.
- Clark, H., Coll-Seck, A. M., Banerjee, A., Peterson, S., Dalglis, S. L., Ameratunga, S., Balabanova, D., Bhan, M. K., Bhutta, Z. A., Borrazzo, J. & Claeson, M. 2020 A future for the world's children? A WHO–UNICEF–Lancet commission. *The Lancet Global Health* **395** (10224), 605–658.
- Coates, J., Swindale, A. & Bilinsky, P. 2007 Household food insecurity access scale (HFIAS) for measurement of food access: indicator guide: version 3: (576842013–001). *American Psychological Association*. <https://doi.org/10.1037/e576842013-001>.
- Eswaran, M. & Kotwal, A. 2004 A theory of gender differences in parental altruism. *Canadian Journal of Economics/Revue Canadienne D'économique* **37** (4), 918–950.
- Food and Agriculture Organization of the United Nations 2019 *The State of Food Security and Nutrition in the World: Safeguarding Against Economic Slowdowns and Downturns*. Available from: <http://www.fao.org/3/ca5162en/ca5162en.pdf>.
- Geere, J. A. & Cortobius, M. 2017 Who carries the weight of water? Fetching water in rural and urban areas and the implications for water security. *Water Alternatives* **10** (2), 513–540.
- Hadley, C. & Freeman, M. C. 2016 Assessing reliability, change after intervention, and performance of a water insecurity scale in rural Ethiopia. *Food Security* **8** (4), 855–864.
- Helen Keller International 2021 *Baseline Report Grant 720FDA19GR00137 – Prevention and Management of Acute Malnutrition in Cameroon's Far North Region – Sector 1*. Available from: [https://pdf.usaid.gov/pdf\\_docs/PA00WGHR.pdf](https://pdf.usaid.gov/pdf_docs/PA00WGHR.pdf).
- Humphrey, E. H., Mbuya, M. N. N., Ntozini, R., Moulton, L. H., Stoltzfus, R. J., Tavengwa, N. V., Mutasa, K., Majo, F., Mutasa, B., Mangwadu, G., Chasokela, C. M., Smith, L. E., Tielsch, J. M., Jones, A. D., Manges, A. R., Maluccio, J. A. & Prendergast, A. J. & Sanitation Hygiene Infant Nutrition Efficacy (SHINE) Trial Team 2019 Independent and combined effects of improved water, sanitation, and hygiene, and improved complementary feeding, on child stunting and anaemia in rural Zimbabwe: a cluster-randomised trial. *The Lancet Global Health* **7**, e132–e147.
- Luby, S. P., Halder, A. K., Huda, T., Unicomb, L. & Johnston, R. B. 2011 The effect of handwashing at recommended times with water alone and with soap on child diarrhea in rural Bangladesh: an observational study. *PLoS Medicine* **8** (6), e1001052.
- Luby, S. P., Rahman, M., Arnold, B. F., Unicomb, L., Ashraf, S., Winch, P. J., Stewart, C. P., Begum, F., Hussain, F., Benjamin-Chung, J. & Leontsini, E. 2018 Effects of water quality, sanitation, handwashing, and nutritional interventions on diarrhoea and child growth in rural Bangladesh: a cluster randomised controlled trial. *The Lancet Global Health* **6**, e302–e315.
- Mach, O., Lu, L., Creek, T., Bowen, A., Arvelo, W., Smit, M., Masunge, J., Brennan, M. & Handzel, T. 2009 Population-based study of a widespread outbreak of diarrhea associated with increased mortality and malnutrition in Botswana, January–March, 2006. *The American Journal of Tropical Medicine and Hygiene* **80** (5), 812–818.
- MAL-ED Network Investigators 2017 Relationship between growth and illness, enteropathogens and dietary intakes in the first 2 years of life: findings from the MAL-ED birth cohort study. *BMJ Global Health* **2** (4), e000370.
- Mara, D., Lane, J., Scott, B. & Trouba, D. 2010 Sanitation and health. *PLoS Medicine* **7** (11), e1000363.
- Motbainor, A., Worku, A. & Kumie, A. 2015 Stunting is associated with food diversity while wasting with food insecurity among underfive children in East and West Gojjam Zones of Amhara Region, Ethiopia. *PLoS ONE* **10** (8), e0133542.
- Nounkeu, C. D. & Dharod, J. M. 2018 Water insecurity among rural households of West Cameroon: lessons learned from the field. *Journal of Water, Sanitation and Hygiene for Development* **8** (3), 585–594.
- Nounkeu, C. D. & Dharod, J. M. 2020 A qualitative examination of water access and related coping behaviors to understand its link to food insecurity among rural households in the West Region in Cameroon. *International Journal of Environmental Research and Public Health* **17** (13), 4848.
- Nounkeu, C. D. & Dharod, J. M. 2021 Integrated approach in addressing undernutrition in developing countries: a scoping review of integrated water access, sanitation, and hygiene (WASH)+ nutrition interventions. *Current Developments in Nutrition* **5** (7), nzab087.
- Nounkeu, C. D., Kamgno, J. & Dharod, J. M. 2019 Assessment of the relationship between water insecurity, hygiene practices, and incidence of diarrhea among children from rural households of the Menoua Division, West Cameroon. *Journal of Public Health in Africa* **10** (1), 951.
- Null, C., Stewart, C. P., Pickering, A. J., Dentz, H. N., Arnold, B. F., Arnold, C. D., Benjamin-Chung, J., Clasen, T., Dewey, K. G., Fernald, L. C. H. & Hubbard, A. E. 2018 Effects of water quality, sanitation, handwashing, and nutritional interventions on diarrhoea and child growth in rural Kenya: a cluster-randomised controlled trial. *The Lancet Global Health* **6**, e316–e329.
- Pickering, A. J. & Davis, J. 2012 Freshwater availability and water fetching distance affect child health in sub-Saharan Africa. *Environmental Science & Technology* **46** (4), 2391–2397.
- Pickering, A. J., Null, C., Winch, P. J., Mangwadu, G., Arnold, B. F., Prendergast, A. J., Njenga, S. M., Rahman, M., Ntozini, R., Benjamin-Chung, J. & Stewart, C. P. 2019 The WASH benefits and SHINE trials: interpretation of WASH intervention effects on linear growth and diarrhoea. *The Lancet Global Health* **7** (8), e1139–e1146.
- Siddiqui, F., Salam, R. A., Lassi, Z. S. & Das, J. K. 2020 The intertwined relationship between malnutrition and poverty. *Frontiers in Public Health* **8**, 453.
- Sorenson, S. B., Morssink, C. & Campos, P. A. 2011 Safe access to safe water in low income countries: water fetching in current times. *Social Science & Medicine* **72** (9), 1522–1526.

- Talbert, A., Thuo, N., Karisa, J., Chesaro, C., Ohuma, E., Ignas, J., Berkley, J. A., Toromo, C., Atkinson, S. & Maitland, K. 2012 Diarrhoea complicating severe acute malnutrition in Kenyan children: a prospective descriptive study of risk factors and outcome. *PLoS One* **7** (6), e38321.
- Tsai, A. C., Kakuhikire, B., Mushavi, R., Vořechovská, D., Perkins, J. M., McDonough, A. Q. & Bangsberg, D. R. 2016 Population-based study of intra-household gender differences in water insecurity: reliability and validity of a survey instrument for use in rural Uganda. *Journal of Water and Health* **14** (2), 280–292.
- UNICEF 2015 UNICEF's approach to scaling up nutrition for mothers and their children Discussion paper. Programme Division. Available from: [https://www.unicef.org/nutrition/files/Unicef\\_Nutrition\\_Strategy.pdf](https://www.unicef.org/nutrition/files/Unicef_Nutrition_Strategy.pdf).
- UNICEF 2018 SMART Nutritional and Retrospective Mortality Survey among Women, Adolescents and Children in Cameroon (East, Adamawa, North and Far North). Available from: [https://www.humanitarianresponse.info/sites/www.humanitarianresponse.info/files/assessments/rapport\\_smartcmr\\_2018\\_vf.pdf](https://www.humanitarianresponse.info/sites/www.humanitarianresponse.info/files/assessments/rapport_smartcmr_2018_vf.pdf).
- UNICEF 2021 Malnutrition in Children. UNICEF Data. Available from: <https://data.unicef.org/topic/nutrition/malnutrition/>.
- UNICEF, WHO, World Bank Group 2020 Levels and Trends in Child Malnutrition. Available from: <https://www.who.int/publications/item/jme-2020-edition>.
- United Nations Office for the Coordination of Humanitarian Affairs (OCHA) 2016 Cameroon: Food Insecurity in the Far North. Available from: <https://reliefweb.int/report/cameroon/cameroon-food-insecurity-far-north>.
- Van Cooten, M. H., Bilal, S. M., Gebremedhin, S. & Spigt, M. 2019 The association between acute malnutrition and water, sanitation, and hygiene among children aged 6–59 months in rural Ethiopia. *Maternal & Child Nutrition* **15** (1), e12631.
- Wegner, C. W., Loechl, C. & Mokhtar, N. 2015 Moderate acute malnutrition: uncovering the known and unknown for more effective prevention and treatment. *Food and Nutrition Bulletin* **36** (1\_suppl1), S3–S8.
- WHO 2014 Preventing Diarrhoea Through Better Water, Sanitation and Hygiene: Exposures and Impacts in Low- and Middle-Income Countries. Available from: [http://apps.who.int/iris/bitstream/handle/10665/150112/9789241564823\\_eng.pdf?sequence=1](http://apps.who.int/iris/bitstream/handle/10665/150112/9789241564823_eng.pdf?sequence=1).
- WHO/UNICEF 2017 The Extension of the 2025 Maternal, Infant and Young Child Nutrition Targets to 2030. Available from: <https://www.who.int/nutrition/global-target-2025/discussion-paper-extension-targets-2030.pdf>.
- Wolf, J., Hunter, P. R., Freeman, M. C., Cumming, O., Clasen, T., Bartram, J., Higgins, J. P., Johnston, R., Medlicott, K., Boisson, S. & Prüss-Ustün, A. 2018 Impact of drinking water, sanitation and handwashing with soap on childhood diarrhoeal disease: updated meta-analysis and meta-regression. *Tropical Medicine & International Health* **23** (5), 508–525.
- Workman, C. L., Brewis, A., Wutich, A., Young, S., Stoler, J. & Kearns, J. 2021 Understanding biopsychosocial health outcomes of syndemic water and food insecurity: applications for global health. *The American Journal of Tropical Medicine and Hygiene* **104** (1), 8–11.
- World Health Organization 2021 Progress on Household Drinking Water, Sanitation and Hygiene 2000–2020: Five Years Into the SDGs. Available from: <https://data.unicef.org/wp-content/uploads/2021/06/JMP-2021-progress-report.pdf>.
- Wutich, A. & Ragsdale, K. 2008 Water insecurity and emotional distress: coping with supply, access, and seasonal variability of water in a Bolivian squatter settlement. *Social Science & Medicine* **67** (12), 2116–2125.

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