Risk factors for diarrhoea and malnutrition among children under the age of 5 years in the Tigray Region of Northern Ethiopia

Araya Gebreyesus Wasihun*, Tsehaye Asmelash Dejene¹,², Mekonen Teferi³, Javier Marugán⁴, Letemichal Negash⁵, Dejen Yemane⁶, Kevin G. McGuigan⁶

¹ College of Health Sciences, Department of Medical Microbiology and Immunology, Mekelle University, Tigray, Ethiopia, ² College of Health Sciences, Department of Medical Microbiology, Axum University, Tigray, Ethiopia, ³ College of Natural and Computational Sciences, Department of Biology, Mekelle University, Tigray, Ethiopia, ⁴ Department of Chemical and Environmental Technology, Universidad Rey Juan Carlos, C/Tulipán s/n, Móstoles, Madrid, Spain, ⁵ College of Health Sciences, School of Public Health, Department of Environmental Health, Mekelle University, Tigray, Ethiopia, ⁶ Department of Physiology and Medical Physics, RCSI, Dublin 2, Ireland

* araya13e25@gmail.com

Abstract

Background

Diarrhoea and malnutrition are the leading cause of morbidity and mortality among children in areas with poor access to clean water, improved sanitation, and with low socioeconomic status. This study was designed to determine the prevalence of diarrhoea, malnutrition and risk factors among children aged 6–59 months in the Tigray Region of Northern Ethiopia.

Methods

A community based cross-sectional study design was conducted from June to August 2017 to assess the magnitude and factors associated with diarrhoea and malnutrition among children. A standardized questionnaire was used to collect data on diarrhoea, environmental, demographic and behavioural factors from 610 mother-child pairs. Anthropometric measurements were collected from the children. SPSS ver.21 statistical software was used for analysis. Factors associated with diarrhoea and nutritional status were identified using bivariate and multivariate logistic regression. A p-value \( \leq 0.05\) was considered statistically significant.

Results

Of the 610 children monitored in this study, the incidence of diarrhoea among 6–59 month-old children in the two weeks preceding the day of the interview day was 27.2% (95% CI: 23.6–31%). Specifically, 35.9%, 9.7%, and 1.8% had 1–2, 3–4 and 5–6 times of diarrhoea episodes in a one year of time, respectively. The prevalence of stunting, underweight, wasting, and acute under-nutrition were 36.1% (95% CI: 31–38.6%), 37% (95% CI: 32–39.6%), 7.9% (95% CI: 5.5–9.7%), and 5.4% (95% CI: 3.8–7.4%), respectively. In a multivariate logistic regression analysis, type of drinking water source \([\text{AOR } = 3.69; 95\% \text{ CI: } 2.03–6.71]\),
mothers not hand washing at critical times [AOR = 15.42; 95% CI: 2.02–117.78], improper solid waste disposal [AOR = 12.81; 95% CI: 2.50–65.62], and child age (36–47 months) [AOR = 2.57; 95% CI: 1.45–4.55] were found to be predictors of diarrhoea. Being within the age range of 12–23 months was a predictor for wasting [AOR = 4.38; 95% CI: 1.61–11.90] and being underweight [AOR = 4.4; 95% CI: 1.7–11.2]. Similarly, the age range of 36–47 months was associated with wasting [AOR = 2.3; 95% CI: 1.45–3.85] and stunting [AOR = 1.7; 95% CI: 1.03–2.67]. Family size (less than 4) [AOR = 0.56; 95% CI: 0.368–0.959] was inversely associated for wasting.

**Conclusions**

Our study revealed that the problem of diarrhoea and malnutrition amongst 6–59 months children in the study area was significant. Access to clean water was the main problem in the study area. Hence, improving access to clean water and providing health education to mothers on personal and environmental hygiene, and proper waste disposal could improve diarrhoea in the study area. Intervention on children’s nutrition should also be implemented to minimize the problem of malnutrition.

**Introduction**

Diarrhoea and malnutrition cause more morbidity and mortality among children under 5 years old worldwide [1]. Among the infectious disease, diarrhoea is the second cause of post-neonatal under 5 year death accounting for 2.5 million each year worldwide, higher than that of AIDS, malaria, and measles combined. This diarrhoeal associated mortality is more concentrated in sub-Saharan African countries (88 per 1000 live births) [2, 3]. Globally, more than 3 million children under the age of 5 years die per year due to malnutrition [4]. Malnourished children are negatively and irreversibly affected in their school performance, physical growth and cognitive development [5].

Malnutrition and diarrhoeal mortality have a bidirectional association [6, 7]. Malnutrition causes immune-deficiency and increased susceptibility to infections such as diarrhoea [8]. Diarrhoea in turn causes malnutrition through reduced food appetite, energy intake, nutrient loss and mal-absorption [9].

Diarrhoea and malnutrition are associated with water, sanitation, and hygiene through different mechanisms. For example, faecal exposure through contaminated water, unimproved sanitation and poor hygiene, leads to diarrhoea which affects physical and mental growth of a child [10–12].

In 2003 the Ethiopian government implemented the Health Extension Program (HEP) as a means of providing comprehensive, equitable and affordable healthcare for the rural population on the basis of promotive, preventive and basic curative services [13]. As a result the 2016 Demographic and Health Survey of Ethiopia (EDHS) report showed an overall decline in the under-five death rate from 166/1000 in 2000 to 67 death/1000 births 2016 [14]. Nevertheless, the national levels of diarrhoea (12%), stunting (38%), wasting (10%), and underweight (24%) reported in the EDHS highlights that malnutrition and diarrhoea still present significant risks for children under five.

In Tigray regional state, the problem of malnutrition is shown by the rates of stunting (39.3%), wasting (11.1%), and underweight (23%), which are all marginally above the national average [14]. Prevalence of diarrhoea among children under 5 years in different regions of
Ethiopia ranges from 18 to 31% [15–21]. Similarly, prevalence of stunting (https://doi.org/10.1186/s12889-015-1370-9 24.9–47.6%), wasting (9–13.4%) and being underweight (14.3–29%) has been reported [22–24]. These studies, however, are focused on either diarrhoea or malnutrition alone, and the association of diarrhoea with malnutrition or vice versa has not being deeply studied. Besides, these studies are done in different regions of the country where socioeconomic, cultural and access to safe water is greatly varied.

There is scant data on prevalence of diarrhoea and malnutrition and risk factors among children aged between six months to fifty nine months in the study area. However, given the poor access to clean water and improved sanitation, low socioeconomic status, and inadequate hygiene, the problem is expected to be high.

Hence, addressing this knowledge gap in the rural community of the study area is reasonable to help policy makers and implementers in order to plan and design proper intervention strategies to prevent diarrhoea and malnutrition associated morbidity and mortality among under five children.

**Materials and methods**

**Study design and study population**

**Study setting.** Tigray is the northernmost of Ethiopia’s federal states located at 12°15’- 4°57’ longitude and 36°27’- 39°59’ latitude with population size of 6,960,003 within an area of 41,409.95 km². The capital city of the State of Tigray is Mekelle, which is located 783 km north of Addis Ababa, the capital of Ethiopia. Based on the 2007 Census conducted by the Central Statistical Agency of Ethiopia (CSA), Mekelle has a total population of 215,914 [25].

This community based cross-sectional study was carried out from June–August 2017 in rural communities surrounding the Mekelle zone, Tigray region, northern Ethiopia. From the total of 32 kebelles (a kebelle is the smallest administrative unit in Ethiopia) found in the surrounding districts, 4 sites were selected using a simple random lottery method. The names of the study sites and their respective GPS are: Serawat 13°29’12.78”N, 39°24’28.10”E, Harena 13°33’0.88”N, 39°32’24.60”E, Maynebri 13°8’12.25”N, 39°29’16.53”E and Tsuwanet 14°0’49.27”N, 39°27’23.39”E. The study area has a semi-arid climate and gets rainfall, mainly from the mid of June to mid of September, and farming is the common means of income among the inhabitants. Likewise, the population typically experience poor sanitation, poor access to safe drinking water, and low socioeconomic status (“Fig 1”).

**Study participants.** The source population was all households with children (paired with their mothers) between the ages of 6–59 months in all the kebelles. To select the study participants, we randomly selected 6–59 months old children (paired with their mothers) who were permanently resident in the districts for at least six months.

**Sample size and sampling technique.** The sample size of the study was determined using a single population proportion formula, considering an estimate of 26.1% expected prevalence of diarrhoea among children younger than 5 years old [26]. Assuming any particular outcome to be within a 5% marginal error and a 95% confidence interval of certainty, the final sample size with a design effect of 2 and a 97% response rate was determined to be 610 mothers/children pair.

We used a multistage stratified sampling technique to identify study participants after the kebelles were stratified. Out of 32 kebelles, 4 were selected by lottery method. In these selected kebelles, 2,674 children who are 6–59 months were identified with their respective households using the registration at health posts and though the Health extension workers (HEW).

We allocated the calculated sample proportionally to the selected kebelles based on the total number of households with 6–59 months children in each kebelle, and study participants were
then identified using simple random sampling of the households. Accordingly, the distribution of households with respect to the kebelles was, 133 from Tsawnet, 142 from Harena, 158 from Serawat, and 177 from Mynebri. In cases where more than one child between 6–59 months of one mother were in the household, the eldest child was included in the study.

Variables

The primary outcome. Diarrhoea among children 6–59 months in the past 14 days. Secondary outcomes were stunting, wasting and being under-weight.

Independent variables. Socio-economic variables: Mother’s and husband’s educational status, family size, family income, sex of child, age of child, number of children 6–59 months.

Environmental and behavioural variables: Use of soap for hand washing, mother’s hand washing at critical times, treatment of drinking water, latrine availability, distance from water source, type of drinking water source, child hand cleanliness, child finger nail status, and method of solid waste disposal of child faeces.

Operational definition.

- Hand washing at all 5 critical times: If a mother/caregiver practiced simple hand washing before eating, before food preparation, before child feeding, after child cleaning and after
latrine visiting, this was considered all practiced, if all five action were done. If not, it was considered as "partially practiced".

- **Proper solid waste disposal**: is a way of disposal of ordinary domestic waste which includes burning, buried in pit or stored in a container, compost, and whereas disposing in open field was considered as improper disposal.

- **Unimproved water source**: when the people use water for drinking from a river, pond, well or unprotected spring.

### Data collection

Data on socioeconomic, environmental, behavioural factors and health related were collected using a structured questionnaire (translated from English and printed in the local Tigrigna language). The data were collected using a face-to-face administrated questionnaire and an observation method by trained data collectors, under the supervision of the investigators. To assess the childhood illness, the mothers were asked whether their children had been affected by diarrhoea in the past two weeks. In addition to this, mothers were also asked the number of diarrhoeal episodes experienced by their children in the last year. Diarrhoea was defined as having three or more loose or watery stool in a 24-hour’s period within the two week period prior to the survey [27]. The collected data were checked for errors and incompleteness on a daily basis. Finally, the data were coded, entered and analyzed using SPSS software, version 21 (Chicago, IL, USA).

### Anthropometric measurement

Height/length and weight measurement of the child were taken by the health extension workers who are already trained by the government and work the health posts. Digital weight scale was used to measure weight of children. Weight was recorded to the nearest 0.1 kg with the child barefoot and wearing light clothing. Children who were unable to stand on the scale, and 6–24 months were weighed with the mother or legal guardian, then the mother/guardian was weighed alone, and the differences were used to obtain the net weight of the children.

The height of the children was measured using a calibrated height measuring board. A child who could not stand erect was measured in supine position. A child who could stand erect and above 24 month was measured standing against a calibrated height measuring board. The height measurement was taken to the nearest 0.1 cm. Mid-Upper Arm Circumference (MUAC) was measured at the mid-point between the tip of the shoulder and the tip of the elbow of the left upper arm using non-stretchable tape to the nearest 1 mm. MUAC below 12.5 cm was considered as indicator of an acute under nutrition.

We used WHO Anthro version 3.2.2 software to convert the anthropometric measures; age, weight, height/length values into Z-scores of the indices; Weight-for-Height (WHZ), Weight-for-Age (WAZ), and Height-for-Age (HAZ) taking gender of the child into consideration using WHO 2006 standards [28]. In all analyses Z-scores $<-6.00$ or $>6.00$ were considered outliers and excluded from the study. Accordingly, HAZ (n = 13), WAZ (n = 1) and WHZ (n = 1) were excluded from the study.

### Statistical analysis

Frequency distributions of socio-demographical and behavioural characteristics of participants were explored. Continuous variables were expressed as mean ± standard error of mean; whereas, categorical variables were expressed as number (percentage, %). Chi-square tests
were used to evaluate the differences in the distribution of categorical variables for study groups. Children who were undernourished with a Z-score value less than or equal to $-2$ S.D. were characterized as stunted (low height/length for-age) (HAZ), wasted (low weight-for-height) (WHZ), and underweight (low Weight for-age) (WAZ), respectively.

Bivariate logistic regression analysis was done to identify factors associated to diarrhoea and under-nutrition. Factors associated with the outcome variables (diarrhoea and under-nutrition) in bivariate analysis at a significance level of 0.25 were identified and exported to multivariable logistic regression analysis. Confidence intervals (CI) of 95% were reported for each odds ratio (OR). All reported p-values were two-tailed, and statistical association was set significant at p-value $\leq 0.05$.

**Ethical considerations**

Ethical clearance was obtained from Mekelle University; College of Health Science Institutional Review Board (IRB) (ERC 0844/2016). The Tigray Regional Health Bureau was an active collaborator in the research project. Written consent was obtained from each mother / guardian of each child. Participants were asked to enroll and were told that they had the right not to respond to questions that they did not want to and could stop at any point in the survey if they wanted. Children with any diarrhoea and acute malnutrition who did not visit health centres during the study period were linked to the nearby health centres by the clinical nurses who were data collectors. Treatment costs for all the diarrhoeic children were covered from the project fund.

**Results**

**Socio-economic and demographic data of the study households**

A total of 610 under-five children/mothers pair participated in the study with a 100% response rate. The majority, 598 (98%) of the interview respondents comprised mothers of the 6–59 months children and the remaining 12(2%) were care-givers older than 18 years. The majority of the mothers (90.4%) were married. Most mothers (79%) had one under-five child. According to the results of the study, 58% mothers and 44.9% of the fathers were illiterate (unable to read or write). Regarding employment status of the mothers and husbands, 92.1% mothers were housewives and 75.6% of the fathers were farmers. The majority of households (76.4%) had more than four members. The majority of households (73.9%) had a family monthly income between 500–2000 Ethiopian Birr ($20–80 USD, Table 1).

**Environmental health conditions the study households**

As to the hand washing habit of mothers at critical times, the majority 93.9% were partially washing at all time. More than half, (60.2%) of the mothers used soap for hand washing. Access to improved waster was only reported among 23% of the households. Regarding proximity of house to main water source, 32% spent 30 minutes, and 33.2% of them travelled a round-trip from 60–120 minutes to fetch water. Household water treatment (any means) was practiced among 150 (24.6%) households. Regarding the latrine availability, 59.7% of the households had their own latrine facilities (Table 2).

**Demographic and health characteristics of the children.** The results of the study showed that 53.4% of the children were male, and the mean age of the children was 35.2 months with S.D. $\pm 14.7$ months. Regarding gastro-intestinal symptoms during the data collection, 22% had some form of GI symptoms, with diarrhoea being the most common. The point prevalence for diarrhoea was 13.1%. Two hundred and nineteen, (35.9%) of the children had diarrhoea
episodes 1–2 times in the previous one year period. Diarrhoea prevalence among children in the two weeks preceding the interview day was 166 (27.2%) (Table 3).

**Prevalence of malnutrition.** Regarding nutritional the status of the children, stunting, underweight, and wasting were seen in 36.1%, 37% and 7.9%, respectively. Prevalence of severe stunting, underweight and wasting among the children were 21.1%, 15.4% and 3.6%, respectively. Middle upper arm circumstance (MUAC) measurement indicated that 5.4% of the children were undernourished (<12.5 cm) ("Fig 2").
Adjusting for other confounding variables, children whose mothers didn’t wash their hands at all the critical times were 15.4 times [AOR = 15.4; 95% CI = 2.02, 117.78] more likely to have diarrhoea compared to those whose mothers did wash at these times. Children who drank from unimproved sources of water were 3.69 times [AOR = 3.69, 95% CI = 2.03, 6.72] more likely to have diarrhoea compared to those using improved water sources. The odds of a child contracting diarrhoea were 12.8 times higher [AOR = 12.81; 95% CI = 2.50, 65.62] among the households who disposed of their solid waste improperly comparing those who dispose properly.

Table 2. Environmental characteristics of households in Tigray region, Northern Ethiopia (June-August, 2017).

| Variables                                      | Frequency | %  |
|------------------------------------------------|-----------|----|
| Mother’s hand washing at all 5 critical times  |           |    |
| All practiced                                  | 37        | 6.1|
| Partially practiced                            | 573       | 93.9|
| Cleaning materials used to wash hands          |           |    |
| Water only                                      | 243       | 39.8|
| Water and soap                                 | 367       | 60.2|
| Habit of eating vegetable and fruits (N = 578)  |           |    |
| Never                                          | 106       | 17.4|
| Some times                                     | 472       | 77.4|
| Always                                         | 32        | 5.2 |
| Source of drinking water of the family         |           |    |
| Protected                                      | 140       | 23  |
| Unprotected                                    | 470       | 77  |
| Time taken to fetch water (in minutes)         |           |    |
| <30                                            | 195       | 32.0|
| 30–59                                          | 213       | 34.9|
| 60–120                                         | 202       | 33.2|
| Use of household water treatment               |           |    |
| Yes                                            | 150       | 24.6|
| No                                             | 460       | 75.4|
| Means of in-house water treatment used (N = 150)|           |    |
| Boiling                                        | 69        | 11.3|
| Chlorination                                   | 73        | 12.0|
| Filtration                                     | 8         | 1.3 |
| Habit of mother washing with soap before child feeding |    |    |
| Never                                          | 80        | 13.1|
| Some times                                     | 344       | 56.4|
| Always                                         | 186       | 30.5|
| Presence of domestic animals in house           |           |    |
| Yes                                            | 486       | 79.7|
| No                                             | 124       | 20.3|
| Latrine availability                            |           |    |
| Pit latrine with slab                           | 161       | 26.4|
| Pit latrine without slab (open pit)             | 203       | 33.3|
| Open defecations                                | 246       | 40.3|
| Solid waste disposal                            |           |    |
| Proper                                         | 317       | 52  |
| Improper                                       | 293       | 48  |

https://doi.org/10.1371/journal.pone.0207743.t002
Table 3. Health and demographic related Characteristics of 6–59 months children in Tigray region, Northern Ethiopia (June- August, 2017).

| Variables                                      | Frequency | %   |
|------------------------------------------------|-----------|-----|
| Gender of the child                            |           |     |
| Male                                           | 326       | 53.4|
| Female                                         | 284       | 46.6|
| Age of the infant (months)                      |           |     |
| 6–11                                           | 32        | 5.2 |
| 12–23                                          | 108       | 17.7|
| 24–35                                          | 160       | 26.2|
| 36–47                                          | 149       | 24.4|
| 48–59                                          | 161       | 26.4|
| Habit of eating vegetable and fruits (N = 578)  |           |     |
| Never                                          | 93        | 16.1|
| Some times                                     | 454       | 78.6|
| Always                                         | 31        | 5.3 |
| Habit of child playing in soil (N = 578)        |           |     |
| Never                                          | 10        | 1.7 |
| Some times                                     | 127       | 22  |
| Regularly                                      | 441       | 76.3|
| Finger Nail status of the child                |           |     |
| Trimmed                                        | 315       | 51.6|
| Untrimmed                                      | 295       | 48.4|
| Child hand cleanliness                         |           |     |
| Clean                                          | 367       | 60.2|
| Unclean                                        | 243       | 39.8|
| Current GI symptom (N = 134)                   |           |     |
| Yes                                            | 134       | 22  |
| No                                             | 476       | 78  |
| Type of GI (N = 134)                           |           |     |
| Abdominal pain                                 | 24        | 3.9 |
| Diarrhoea                                      | 80        | 13.1|
| Fever                                          | 2         | .3  |
| Vomiting                                       | 2         | .3  |
| Diarrhoea and abdominal pain                   | 26        | 4.3 |
| Diarrhoea episode in last two weeks            |           |     |
| Yes                                            | 166       | 27.2|
| No                                             | 444       | 72.8|
| Diarrhoea episode of child this year(N = 578)  |           |     |
| 1–2                                           | 213       | 36.9|
| 3–4                                           | 56        | 9.7 |
| 5–6                                           | 10        | 1.7 |
| No                                            | 299       | 51.7|
| Presence of skin diseases                      |           |     |
| Yes                                            | 174       | 29.5|
| No                                             | 436       | 71.5|
| Type of skin disease (N = 174)                 |           |     |
| Scabies                                        | 22        | 3.6 |
| T. capitis                                     | 125       | 20.5|

(Continued)
Children who played regularly in soil [AOR = 1.66; 95% CI = 0.953, 2.881], had untrimmed finger nail [AOR = 1.576; 95% CI = .598, 4.15], 6-11months age [AOR = 1.5; 95% CI = 0.48, 4.40], who had unclean hands [AOR = 1.2; 95% CI = .71, 1.9] were 1.7, 1.6, 1.5, and 1.2 times more likely to contract diarrhoea, respectively. However, these differences were not statistically significant (Table 4).

Factors associated with diarrhoea and malnutrition among 6–59 months children.
From Table 5 we can see that, children from a household who have ≥4 family members were
1.4 times more likely [AOR = 1.4; 95% CI = 0.94, 2.2] to be under-weight compared to families with <4 members. However, the differences of mother’s employment and family size were not statistically significant. Children whose family members numbered less than 4 were 60% less

Table 4. Multivariate logistic regression analysis of diarrhoeal disease with selected predictor variables among 6–59 months children in Tigray region, Northern Ethiopia (June- August 2017).

| Predictor Variables                                  | Diarrhoea [N =166] | COR (95%CI) | P-value  | AOR (95%CI) | P-value |
|------------------------------------------------------|--------------------|-------------|----------|-------------|---------|
|                                                      | Yes                | No          |          |             |         |
| Mother hand washing at all critical times            |                    |             |          |             |         |
| All practiced                                       | 1                  | 36          | Ref.     |             | Ref.    |
| Partially practiced                                 | 165                | 408         | 14.6[1.98,107.06] | 0.009** | 15.42[2.02,117.8] | 0.008** |
| Source of drinking water of the family               |                    |             |          |             |         |
| Improved                                             | 17                 | 123         | Ref.     |             | Ref.    |
| Unimproved                                          | 149                | 321         | 3.36[1.95,5.78] | 0.000** | 3.69[2.03,6.7]** | .000** |
| Mother’s washing with soap before child feeding     |                    |             |          |             |         |
| Always                                               | 36                 | 150         | Ref.     |             | Ref.    |
| Some times                                           | 113                | 231         | 1.83[0.361,0.94] | 0.027** | 2.04[1.63,2.56] | 0.030** |
| Never                                                | 17                 | 63          | 2.36[0.35,0.257] | .013** | 3.706[2.67,6.3] | 0.000** |
| Child hand cleanliness                               |                    |             |          |             |         |
| Clean                                                | 86                 | 281         | Ref.     |             | Ref.    |
| Unclean                                             | 80                 | 163         | 1.604[1.12,2.300] | 0.010** | 1.16[0.71,1.89] | 0.56 |
| Habit of child soil playing [n = 578]                |                    |             |          |             |         |
| Never                                                | 10                 | 38          | Ref.     |             | Ref.    |
| Some times                                           | 113                | 231         | 0.552[0.31,0.99] | 0.045** | 1.336[0.378,4.73] | .653 |
| Regularly                                            | 35                 | 150         | 1.12[.588,2.15] | 0.123 | 1.66[.953,2.88] | 0.072 |
| Solid waste disposal                                 |                    |             |          |             |         |
| Proper                                               | 22                 | 29          | Ref.     |             | Ref.    |
| Improper                                             | 144                | 415         | 2.19[1.22,3.93] | 0.009** | 12.81[2.50,65.62] | 0.002** |
| Latrine presence                                     |                    |             |          |             |         |
| Yes                                                  | 96                 | 268         | Ref.     |             | Ref.    |
| No                                                   | 70                 | 176         | 1.12 [.78,1.61] | 0.556 | 1.02[0.39,2.72] | 0.962 |
| Finger nail status                                   |                    |             |          |             |         |
| Trimmed                                              | 76                 | 239         | Ref.     |             | Ref.    |
| Untrimmed                                            | 90                 | 205         | 1.38 [.97,1.98] | 0.077 | 1.576[.598,4.15] | 0.358 |
| Distance from water source                           |                    |             |          |             |         |
| <30                                                  | 45                 | 150         | Ref.     |             | Ref.    |
| 30–59                                                | 60                 | 153         | 0.765[.489,1.20] | 0.241 | 1.279[.366,4.491] | 0.701 |
| 60–120                                               | 61                 | 141         | 0.69 [.443,1.08] | 0.110 | 1.079[.280,4.155] | 0.912 |
| Child age(Months)                                    |                    |             |          |             |         |
| 6–11                                                 | 6                  | 26          | 2.31 [.90,5.947] | 0.082 | 1.46[.48,4.40] | 0.507 |
| 12–23                                                | 38                 | 70          | 0.982[.589,1.638] | 0.946 | 0.611[.342,1.09] | 0.095 |
| 24–35                                                | 41                 | 119         | 1.55 [.96,2.50 ] | 0.075 | 1.26 [.751,2.13] | 0.377 |
| 36–47                                                | 25                 | 124         | 2.65[1.54,4.53] | 0.00** | 2.57[1.45,4.55] | 0.001** |
| 48–59                                                | 56                 | 105         | Ref.     |             | Ref.    |
| Household water treatment                            |                    |             |          |             |         |
| Yes                                                  | 46                 | 104         | 0.798[.53,1.20] | 0.274 | 0.997[.63,1.6] | 0.997 |
| No                                                   | 120                | 340         | Ref.     |             | Ref.    |

** = statistically significant

https://doi.org/10.1371/journal.pone.0207743.t004
Table 5. Multivariate logistic analysis of malnutrition with selected predictor variables among 6–59 months in Tigray region, northern Ethiopia, June-August, 2017.

| Predictor variables | Stunting | COR(95%CI) | P-value | AOR(95%CI) | P-value |
|---------------------|----------|------------|---------|------------|---------|
|                     |          | Yes        | No      |            |         |
| Mother's hand washing at all critical times |          |            |         |            |         |
| All practiced       | 16       | 21         | Ref.    | Ref.       |         |
| Partially practiced | 192      | 368        | 192     | 368        | 1.46[.75, 2.86] | 0.27 |
| Cleaning materials used to wash hands |          |            |         |            |         |
| Water only          | 76       | 163        | Ref.    | Ref.       |         |
| Water and soap      | 132      | 226        | 132     | 226        | .0798[.56, 1.43] | 0.203 |
| Source of drinking water of the family |          |            |         |            |         |
| Improved            | 54       | 83         | Ref.    | Ref.       |         |
| Unimproved          | 150      | 306        | 1.29 [.87, 1.92] | .201 | 1.15[.80, 1.65] | .449 |
| Latrine presence    |          |            |         |            |         |
| Yes                 | 132      | 224        | Ref.    | Ref.       |         |
| No                  | 76       | 165        | 1.92 [.877, 4.21] | .103 | 1.78 [.81, 3.94] | .152 |
| Age of the infant (Months) |          |            |         |            |         |
| 6–11                | 14       | 17         | 1.92 [.877, 4.21] | .103 | 1.78 [.81, 3.94] | .152 |
| 12–23               | 35       | 69         | 1.2 [.697, 2.01] | .532 | 1.15 [.675, 1.96] | .605 |
| 24–35               | 49       | 105        | 1.09 [.68, 1.76] | .727 | 1.10 [.68, 1.78] | .704 |
| 36–47               | 62       | 86         | 1.68 [1.05, 2.7] | .03 | 1.66[1.03, 2.67] | .037** |
| 48–59               | 48       | 112        | Ref.    | Ref.       |         |

| Number of family |          |            |         |            |         |
| <4                | 45       | 99         | .73 [.48, 1.06] | .097 | 0.59[.368, 0.96] | .033** |
| >4                | 181      | 284        | Ref.    | Ref.       |         |
| Occupation of the mother |          |            |         |            |         |
| House wife        | 215      | 346        | Ref.    | Ref.       |         |
| governmental employee | 7      | 15         | 0.43 [.14, 1.31] | .137 | .49[.016, 1.54] | .225 |
| Self employed     | 4        | 22         | 0.51 [.215, 1.22] | .13 | .54[.22, 1.34] | .186 |
| Mother's hand washing at all 5 critical times |          |            |         |            |         |
| All practiced     | 8        | 29         | Ref.    | Ref.       |         |
| Partially practiced | 218   | 354        | 2.2 [1.00, 4.97] | 0.049 | 1.96[.85, 4.51] | 0.114 |
| Age of the infant |          |            |         |            |         |
| 6–11               | 13       | 19         | Ref.    | Ref.       |         |
| 12–23              | 49       | 58         | 1.235 [.55, 2.75] | .606 | 1.23 [.54, 2.79] | .618 |
| 24–35              | 49       | 111        | .645 [.295, 1.41] | .272 | .57[.26, 1.27] | .167 |
| 36–47              | 71       | 78         | 1.33 [.61, 2.89] | .47 | 1.13 [.51, 2.49] | .771 |
| 48–59              | 44       | 117        | .55 [.25, 1.21] | .136 | .46 [.21, 1.03] | .059 |

| Wasting |          |            |         |            |         |
| Age of the infant |          |            |         |            |         |
| 6–11     | 2        | 30         | 1.47[.29, 7.41] | .643 | 1.2 [.21, 6.76] | .838 |
| 12–23    | 18       | 90         | 4.4 [1.77, 10.9] | .001 | 4.38[1.61, 11.9] | **.002** |
| 24–35    | 11       | 148        | 1.64[.62, 4.33] | .322 | 1.74 [.62, 4.89] | .29 |
| 36–47    | 10       | 139        | 2.4[1.51, 3.9] | 0.000 | 2.3 [1.45, 3.85] | **.001** |
| 48–59    | 7        | 154        | Ref.    | Ref.       |         |
| Educational level of the mother |          |            |         |            |         |
| Illiterates | 26 | 327        | 4.9 [2.1, 5.59] | 0.289 | 4.3[1.46, 2.142] | 0.318 |
| Primary school completed | 18 | 175        | 3.4 [1.45, 6.68] | .25 | 3.4 [1.09, 5.37] | .29 |

(Continued)
likely to be wasted compared those who were ≥ 4 [AOR = 0.60; 95% CI = .368, 0.959]. Children whose age was from 36–47 months had 1.7 times more likely [AOR = 1.66; 95% CI = 1.03, 2.67] to be stunted compared to those in the 48–59 months age which was statistically significant (p = 0.037). Likewise, children at the age of 12–23 months [AOR = 4.4; 95% CI = 1.61, 3.85] and 36–47 months [AOR = 2.4; 95% CI = 1.45, 3.85] were 4.4 and 2.4 times more wasted, respectively compared to the children at the age of 48–59 months (Table 5).

Discussion

This study investigated prevalence of diarrhoea and malnutrition among children in the 6 month -59 month age range in a rural community which is an important public health concern. Overall, the prevalence of diarrhoea, stunting, underweight, and wasting were 27.2%, 36.1%, 37%, and 7.9%, respectively. Diarrhoea prevalence 166/610 (27.2%) in the study area was in line with the findings of previous studies in Nekemte town, western Ethiopia 28.9% [20], Jigjiga District, eastern Ethiopia 27.3% [29], northeast Ethiopia 26.1% [26], Sheko district, southwest Ethiopia 25.5% [21], and Kashmir, India 25.2% [30].

However, the current finding was approximately 3 times higher than the finding of the 2016 EDHS, in which the magnitude of diarrhoeal disease among children younger than 5 years old was 12% [14]. It was also higher than the findings of similar studies conducted in other parts of Ethiopia such as, Shebedino district, southern Ethiopia 19.6% [31], Bahir Dar, northwest Ethiopia 24.9% [32], Mecha district, northwest Ethiopia 18.0% [15] Jabi threshnan District, northwest Ethiopia 21.5% [19], Sebeta town, southwest Ethiopia 9.9% [33], Harer, eastern Ethiopia 22.5% [17], Sheko district, southwest Ethiopia 6.4% [21], and Rusizi district, Rwanda 8.7% [34]. Our result was lower than two studies conducted in Arba Minch district, south Ethiopia 31.0% [16] and 30.5% [35], Uttar Pradesh, India 55.6% [36], and northwest Burundi 32.6% [37]. The difference could be attributed to the sample size, seasonal variation in data collection, environmental factors, socio-economic and cultural differences of the study participants.

The higher prevalence of diarrhoea in this study could be due to the fact that our data collection time was from June-August which is rainy season in Ethiopia, whilst the others [17,19,21,29] were collected in the dry season. Seasonal variation has been associated with the occurrence of diarrhoea [36, 38, 39], with higher diarrhoea prevalence during rainy season than dry season [40]. This is due to the contamination of water sources such as rivers, streams, and wells by flood with human excreta from open defecation which is the main risk factor for diarrhoeal disease, especially for children who routinely play in the unhygienic environment.

Similarly, the higher prevalence of diarrhoea than that of Rwanda 8.7% [34], could be due to the fact that the duration for diarrhoea in Rwanda was within 7 days preceding data collection; whereas in our case it was 14 days. Hence the longer time in our case could have increased the chance to get more diarrhoeic children than the 7 days. Other possible reason for our result to be higher than other similar studies [17,19,21,32, 31–33, 41] is that we included
children from 6–59 months while they included all under five children including 0–6 months. This could have its impact in the diarrhoea prevalence since children below six months are exclusively breastfed and don’t have exposure to the external environment, therefore, their odds of having diarrhoea is lower than those who have started complementary food, which in turn decreases the diarrhoeal prevalence [35,42].

Source of drinking water was independently associated with the occurrence of childhood diarrhoea. Children who drink from unimproved source of water were 3.7 times [AOR = 15.419, 95%CI = 2.02, 117.78] more likely to have diarrhoea compared to those who use improved water sources. This was similar to the study of Abdiwahab et al. [29]. The wider confidence interval is because the number of households who have accesses to improved water source were few (23%) compared to those who don’t have (77%).

Poor maternal hand washing practice without soap before child feeding was positively associated with the occurrence of diarrhoeal morbidity among children. Children whose mothers always wash their hand using soap before child feeding had 56% [AOR = 0.56; 95% CI = 0.33, 0.93] lower risk of becoming diarrhoeic compared those who don’t wash. This was supported by other similar studies that proper hand washing before feeding children plays a great role in the prevention of diarrhoea and other diseases [30, 35, 43–46].

In addition, mothers’ habit of hand washing at all critical times showed a remarkable difference with childhood diarrhoea in this study. Only 6.1% of the interview mothers replied that they regularly wash their hands at all the five critical times. As a result, the odds of diarrhoea among children whose mothers didn’t wash at all the critical times was 15 times [AOR = 15.4; 95% CI = 2.02, 117.78] higher compared to children whose mothers practiced hand washing at critical time with soap. This was in agreement with similar studies conducted elsewhere [21, 47–50].

We have also found that improper solid waste disposal is an independent predictor for diarrhoea in the study area. The odds of a child contracting diarrhoea was 12 times higher [AOR = 12.81; 95% CI = 2.50, 65.62] among the households who dispose of their solid waste improperly compared to those who dispose properly. This result was consistent with other reports [21, 47, 48, 51], where poor waste disposal is the environmental factor most often linked to diarrhoea. Poor waste disposal is attributed to direct contact with human excreta when the child starts to crawl, and easily accessible for vector and rodents, which are means of diarrhoea transmission.

In this study, children whose mothers had no formal education had higher incidence of diarrhoea compared with those children whose mothers were educated. However, in a multivariate analysis it was not statistically significant. This contrasts with previous studies who reported significant association between diarrhoea and education status of the mother [21, 26, 29, 35,52].

Surprisingly, household water treatment (boiling and chlorination were the most commonly used in the study area) was not found to be statistically significant in diarrhoea prevention among children in the study area. This is in contrast with studies from Rwanda [34] and Burundi [37]. This could be due to the storage condition and hygienic status of the storage material that creates a risk of recontamination of water after treating. We also observed that mothers complained about the change in water taste after chlorination and children preferred to drink the un-chlorinated rather than chlorinated water. This highlights the need for other household point of care for water treatment like solar disinfection (SODIS) which have shown promising results in child hood diarrhoea reduction in countries such as South Africa [53], Cambodia [54], and southern India [55].

The odds of diarrhoea in children aged 36–47 months [AOR = 2.57; 95% CI: 1.45–4.55] was 2.57 times more compared to children aged 48–59 months which was similar to previous studies [43, 44]. Studies in Thailand reported children aged 6–23 months were at a higher risk of developing diarrhoea [42, 35]. Other researchers [17, 26, 34, 35, 41, 56] have reported more diarrhoea among children in the age groups 6–11 and 12–23 months. This variation of
diarrhoea with age of the infants could be explained by fact that children in the age group of 6–12 start complementary food, have immature immunity, start crawling and have high risk to ingest contaminated materials which may put them at higher risk for diarrhoea [35, 42]. The higher diarrhoea prevalence in children 36–47 months in our study could be due to their higher exposure to external environment, play in unhygienic places, eating by themselves with unclean hands, starting to clean themselves after defecation all of which put them at a higher risk for diarrhoea [43,44].

Family size and child sex [19, 38], number of under five children [17, 26], family monthly income [21], latrine availability [16, 29, 57, 58] were reported as risk factors for the occurrence of diarrhoea by other investigators, but we found no evidence of this.

Nutritional status in this study showed that prevalence of child stunting (36.1%) and wasting (7.9%) were slightly lower in the study area in comparison with the regional prevalence reported by Ethiopian DHS 2016 of 39.3% stunting and 11.1% of wasting. On the contrary, prevalence of underweight (37%) in the study area was very high compared to the regional 23% Ethiopian DHS report [14]. The difference might be due to our small sample size compared to the national data, and the fact that we excluded children under the age of six months. Our stunting prevalence was similar to the study conducted among a pastoralist community of Ethiopia 34.4% [59]. However, it was lower than reported from Bule Hora district, south Ethiopia 47.6% [23]. Variations in nutritional status of children could be the result of socioeconomic, feeding habit of child, environmental hygiene, and cultural difference among societies.

Though it was not statistically significant children whose mothers were either illiterate, or who had only completed elementary school were 4.3 and 3.4 times, respectively, more likely to have wasting than those whose mother were diploma holders. Similarly, stunting was 1.5 times more prevalent among children from mothers who do not have formal education than those who are diploma holders. A statistically significant association has been reported in previous studies between maternal education status with stunting, wasting [60,61], and underweight [59].

High energy expenditure, lower appetite, nutrient losses and mal-absorption caused by diarrheal infections are associated with malnutrition [7]. In this study, however, presence of diarrhoea in the last two weeks prior to data collection was not statistically significant with stunting, underweight and wasting, which contrasts other studies [59,62,63]. This indicates other factors may lead to malnutrition such as shortage of food, limited access to balanced diet both for the mother and the child, and child feeding practices.

Family size (less than 4) [adjusted OR = 0.56; 95% CI: 0.368–0.959] was inversely associated with wasting. This was in line with the report of Ethiopian DHS 2016 which shows that there is an inverse relationship between the length of the preceding birth interval and the proportion of children who are wasted [14]. The longer the interval, the less likely it is that the child will be wasted [59, 64]. One possible reason might be due to the fact that families with more children face more economic problem for food consumption therefore more likely to suffer from poor nutritional status.

Being between the ages of 12–23 months was a predictors for wasting [AOR = 4.38; 95% CI:1.61–11.90], and being underweight [AOR = 4.4; 95% CI:1.7–11.2], respectively. Similarly, 36–47 months [AOR = 1.7;95% CI: 1.03–2.67] was associated with stunting. Sex, monthly income, source of drinking water, maternal occupation, and latrine presence were not associated with malnutrition in the study area.

Limitations of the study

As the occurrence of diarrhoea was determined according to the mothers/guardians self-reporting without the confirmation of doctor, the study might be affected by social desirability
bias. However, to alleviate this problem, we recruited female health extension workers who are part of the community and who have strong relations with mothers to convince mothers to provide the actual information during data collection. Another limitation was since mothers were also asked the number of diarrhoea episodes of their children in the last one year, there could be a recall bias. Again, due to the nature of the study design, cross-sectional, it was not possible to make any interpretation on causal relationship among variables. Lastly, we did not collect data on mother’s size and weight before pregnancy, the birth weight of the children, and the daily caloric intake which could have helped in interpreting the nutritional results of the children.

Conclusions
The study revealed that more than one fourth of the children in the rural community were diarrhoeic. Access to clean water, safe disposal of solid waste and mother’s hand washing were found to be a risk factor for the diarrhoea in the study areas. Hence regional government and other stakeholders should address the availability of safe drinking water and health education on hygiene in the rural community. Our results also highlight the need for more investment and commitment to minimize the magnitude of childhood diarrhoea by designing and implementing prevention strategies, such as mothers’ education on personal and environmental hygiene by integrating with the existing national health extension program. Similarly, prevalence of stunting, underweight, and wasting were high among the children. Therefore, this study underlines the need for an interventions focusing on improving promotion of nutrition, education, and family planning.

Supporting information
S1 Table. Questionnaire.

(DOCX)

Acknowledgments
We would like to thank all the children and their parents and/or guardians for their collaboration. The cooperation of the Tigray Regional Health Bureau and respective Health bureaus of the weredas/districts are also highly acknowledged by the authors. The authors also like to express their sincere gratitude to the health extension workers in each site for their help in data collection and communication with each mother at a household level.

Author Contributions
Conceptualization: Araya Gebreyesus Wasihun, Tsehaye Asmelash Dejene, Mekonen Teferi, Javier Marugán, Letemichal Negash, Dejen Yemane, Kevin G. McGuigan.

Data curation: Letemichal Negash.

Formal analysis: Araya Gebreyesus Wasihun, Tsehaye Asmelash Dejene, Dejen Yemane, Kevin G. McGuigan.

Methodology: Araya Gebreyesus Wasihun, Tsehaye Asmelash Dejene, Dejen Yemane, Kevin G. McGuigan.

Project administration: Kevin G. McGuigan.

Supervision: Mekonen Teferi, Javier Marugán, Kevin G. McGuigan.

Writing – original draft: Araya Gebreyesus Wasihun.
Writing – review & editing: Araya Gebreyesus Wasihun, Tsehaye Asmelash Dejene, Mekonen Teferi, Javier Marugán, Letemichal Negash, Kevin G. McGuigan.

References

1. Walker CL, Rudan I, Liu L, Nair H, Theodoratou E, Bhutta ZA, O’Brien KL, Campbell H, Black RE. Global burden of childhood pneumonia and Diarrhoea. Lancet 2013: 381: 1405–1416. https://doi.org/10.1016/S0140-6736(13)60222-6 PMID: 23582727

2. UNICEF. Levels and trends in child mortality, 2011 report. www.unicef.org/media/files/ChildMortalityReport2011Final.pdf. Accessed 15 Sept 2016.

3. Liu L, Johnson HL, Cousens S, Perin J, Scott S, Lawn JE, et al. Child Health Epidemiology Reference Group of WHO and UNICEF. Global, regional, and national causes of child mortality: an updated systematic analysis for 2010 with time trends since 2000. Lancet 2012; 379 (9832):2151–61.7. https://doi.org/10.1016/S0140-6736(12)60560-1 PMID: 22579125

4. Black RE, Victora CG, Walker SP, Bhutta ZA, Christian P, Onis MD et al. Maternal and child malnutrition and overweight in low-income and middle-income countries. Lancet 2013: 382: 427–451. https://doi.org/10.1016/S0140-6736(13)60937-X PMID: 23746772

5. Guerrant RL, Oria RB, Moore SR, Oria MO, Lima AA. Malnutrition as an enteric infectious disease with long-term effects on child development. Nutr Rev 2008; 66: 487–505. https://doi.org/10.1111/j.1753-4887.2008.00082.x PMID: 18752473

6. Kazandjian S, Dupierrix E, Gaash E, Love IY, Zivotofsky AZ, De Agostini M, Chokron S. Egocentric reference in bi-directional readers as measured by the straight-ahead pointing task. Brain Res 2009; 1247: 133–141. https://doi.org/10.1016/j.brainres.2008.09.098 PMID: 18973747

7. Mazumder RN, Ashraf H, Hoque SS, Kabir I, Majid N, Wahed MA et al. Effect of an energy-dense diet on the clinical course of acute shigellosis in under-nourished children. Br J Nutr 2000; 84: 775–779. PMID: 11177193

8. Neumann CG, Gewa C, Bwibo NO. Child nutrition in developing countries. Pediatr Ann 2004; 33: 658–674. PMID: 15515353

9. Martorell R, Yarbrough C, Yarbrough S, Klein RE. The impact of ordinary illnesses on the dietary intakes of malnourished children. Am J Clin Nutr 1980; 33: 345–350. https://doi.org/10.1093/ajcn/33.2.345 PMID: 7358006

10. Masibo PK, Makoka D. Trends and determinants of under-nutrition among young Kenyan children: Kenya Demographic and Health Survey; 1993, 1998, 2003 and 2008–2009. PublicHealth Nutr 2012; 15: 1715–1727.

11. Acharya A, Paunio MK. Environmental Health and Child Survival: Epidemiology, Economics, Experiences. World Bank: Washington, DC, 2008.

12. Ngure FM, Reid BM, Humphreys JH, Mbuya MN, Pelto G, Stoltzfus RJ. Water, sanitation, and hygiene (WASH), environmental enteropathy, nutrition, and early child development: making the links. Ann N Y Acad Sci 2014: 1308: 118–128. https://doi.org/10.1111/nyas.12330 PMID: 24571214

13. Argaw H: The health extension programme of Ethiopia: summary of concepts, progress. WHO: Achievements and Challenges; 2007.3

14. Central Statistical Agency (CSA) [Ethiopia] and ICF. 2016. Ethiopia Demographic and Health Survey 2016: Key Indicators Report. Addis Ababa, Ethiopia, and Rockville, Maryland, USA. CSA and ICF.

15. Mulukken D, Abera K, Worku T. Predictors of under-five childhood diarrhoea: Mecha District, West Gojam Ethiopia. Ethiop J Health Dev. 2011; 25 (3):192–200.

16. Shikur M, Mareign T, Dessalegn T. Morbidity and associated factors of diarrhoea diseases among under-five children in Arba Minch district, Southern Ethiopia. Sci J Public Health. 2013; 1(2):102–6.

17. Bezatu M, Yemane B, Alemayehu W. Prevalence of diarrhoea and associated risk factors among children under-five years of age in Eastern Ethiopia: A cross-sectional study. J Prev Med. 2013; 3(7):446–53.

18. Amare D, Fasil T, Belaineh G. Determinants of under-five mortality in Gilgel Gibe Field Research Center, Southwest Ethiopia. Ethiop J Health Dev. 2007; 21:2.

19. Anteneh ZA, Andargie K, Anteneh MT. Prevalence and determinants of acute diarrhoea among children younger than five years old in Jabiherennan District, northwest Ethiopia, 2014. BMC Public Health 2017; 17:99. https://doi.org/10.1186/s12889-017-4021-5 PMID: 28103908

20. Birke WA. Stepwise regression analysis on under-five diarrhoeal morbidity prevalence in Nekemte town, western Ethiopia. East Afr J Public Health. 2008; 5(3):199–6. PMID: 19374323
21. Gebru T, Taha M, Kassahun W. Risk factors of diarrhoeal disease in under-five children among health extension model and non-model families in Sheko district rural community, Southwest Ethiopia: comparative cross-sectional study. *BMC Public Health*. 2014; 14:395. https://doi.org/10.1186/1471-2458-14-395 PMID: 24758243

22. Desalegne A, Ayenew N, Baye T, Birtukan A, Birehanu A. Prevalence of Under nutrition and Its Associated Factors among Children below Five Years of Age in Bure Town, West Gojjam Zone, Amhara National Regional State, northwest Ethiopia. *Advances in Public Health*: 2016 (2016). doi.org/10.1155/2016/7145708.

23. Asfaw M, Wondaferash M, Taha M, Dube L. Prevalence of undernutrition and associated factors in children aged 6–59 months among rural dwellers of damot gale district, south Ethiopia: community based cross sectional study. *International Journal for Equity in Health* 2017; 16:11. https://doi.org/10.1186/s12939-016-0502-x

25. "Population and Housing Census—2007" (PDF). FDRE Population Census Commission. Retrieved 6 October 2016.

26. Wondwoson W, Bikes BD and Zemichael G. Socioeconomic factors associated with diarrhoeal diseases among under-five children of the nomadic population in northeast Ethiopia. *Tropical Medicine and Health* 2016; 44:40. https://doi.org/10.1186/s41182-016-0040-7 PMID: 27980451

27. Keusch Gerald T., Olivier F, Alok B, Cynthia BP, Bhutta Zulfiqar A., Eduardo G et al. Disease Control Priorities in Developing Countries. 2nd edition. Washington (DC): The International Bank for Reconstruction and Development / The World Bank; 2006. Chapter 19.

28. WHO. WHO child growth standards: length/height-for-age, weight-for-age, weight-for-length, weight-for-height and body mass index-for-age. Geneva: World Health Organization; 2006.

29. Abdiwahab H, Abera K, Janvier G. Prevalence of Diarrhoea and Associated Factors among Under-Five Children in Jiggiga District, Somali Region, Eastern Ethiopia. *Open J Prev Med*. 2016; 6(10):233–46.

30. Ahmed S, Farheen A, Muzaffar A. Prevalence of diarrhoeal disease, its seasonal and age variation in under-fives in Kashmir India. *Int J Health Sci.* 2008; 2(2):126–33

31. Tamiso A, Yitayal Y, Awoke A. Prevalence and determinants of childhood diarrhoea among graduated households, in rural area of Shebedino District, Southern Ethiopia. *Sci J Public Health*. 2013; 2(3):243–51

32. Gedefaw M, Takele M, Aychiluhem M, Tarekegn M. Current status and predictors of diarrhoeal diseases among under-five children in a rapidly growing urban setting: the case of city administration of Bahir Dar, northernwest Ethiopia. *Open J Epidemiol*. 2015; 5: 89–97.

33. Al M and Li Z. Environmental health factors associated with diarrhoeal diseases among under-five children in the Sebeta town of Ethiopia. *Southern African Journal of Infectious Diseases* 2016; 31(4):122–129

34. Sinharoy SS, Schmidt WP, Cox K, Clemence Z, Mfura L, Wendt R et al. Child diarrhoea and nutritional status in rural Rwanda: a cross-sectional study to explore contributing environmental and demographic factors. *Tropical Medicine and International Health* 2016; 21 (8): 956–964. https://doi.org/10.1111/tmi.12725 PMID: 27199167

35. Shikur M and Dessalegn T. The burden of diarrhoeal diseases among under five years of age in Arba Minch District, Southern Ethiopia, and Associated Risk Factors: A Cross-Sectional Study. *International Scholarly Research Notices Volume* 2014, Article ID 654901, 6 http://dx.doi.org/10.1155/2014/654901.

36. Joshi PC, Kaushal S, Aribam BS, Khattri P, D’Aoust O, Singh MM, et al. Recurrent floods and prevalence of diarrhoea among under five children: Observations from Bahraihi district, Uttar Pradesh, India. *Glob Health Action*. 2011; 4:10.3402/gha.v4i0.6355.

37. Katharina D, Patrik T, Jochen R, and Michael M. Diarrhoea prevalence in children under five years of age in rural Burundi: an assessment of social and behavioural factors at the household level. *Glob Health Action* 2014; 7: 24895 http://dx.doi.org/10.3402/gha.v7.24895 PMID: 25150028

38. Gladstone BP, Mulyil JP, Jaffar S, Wheeler JG, Le Fevre A, Iturriza-Gomara M, et al. Infant morbidity in an Indian slum birth cohort. *Arch Dis Child*. 2008; 93(6):479–84. https://doi.org/10.1136/adc.2006.114546 PMID: 17916597

39. Hung BV. The most common causes of and risk factors for diarrhoea among children less than five years of age admitted to Dong Anh Hospital, northern Vietnam [Master of Philosophy in International Community Health]. Oslo: University of Oslo; 2006
40. Agustina R, Sari PT, Satroamidjojo S, Bovee-Oudenhoven MJ, Edith JM Feskens, Kok Frans J. Association of food-hygiene practices and diarrhoea prevalence among Indonesian young children from low socioeconomic urban areas. BMC Public Health 2013; 13(1):1–12.

41. Amare D, Negesse A, Tsegaye B, Assefa B, Ayenie B. Prevalence of Undernutrition and Its Associated Factors among Children below Five Years of Age in Bure Town, West Gojjam Zone, Amhara National Regional State, northwest Ethiopia. Advances in Public Health: 2016 (2016). doi:10.1155/2016/7145708.

42. Calistus W and Alessio P, “Factors associated with diarrhoea among children less than 5 years old in Thailand: a secondary analysis of Thailand multiple indicator cluster survey,” Journal of Health Research, 2009; 23:17–22.

43. Deshmukh PR, Dongre AR, Sinha N, Garg BS. Acute childhood morbidities in rural Wardha: Some epidemiological correlates and health care seeking. Indian J Med Sci. 2009; 63(8):345–54 https://doi.org/10.4103/0019-5359.55886 PMID: 19770525

44. Sur D, Manna B, Deb AK, Deen JL, Danovaro-Holliday MC, von Seidlein L, et al. Factors associated with reported diarrhoea episodes and treatment-seeking in an urban slum of Kolkata, India. J Health Popul Nutr. 2004; 22(2):130–8 PMID: 15473516

45. Vieira GO, Silva LR, and Vieira TDO, “Child feeding and diarrhoea morbidity,” Jornal de Pediatria, 2003; (79) 5: 449–454.

46. Central Statistical Authority and ORC Macro, Ethiopia Demo- graphic and Health Survey 2011, Addis Ababa, Ethiopia, 2011.

47. Heller L, Colosimo A, Antunes C: Environmental sanitation conditions and health impact: a case–control study. Rev Soc Bras Med Trop 2003; 36(1):41–50. PMID: 12715062

48. Root GPM: Sanitation, community environment and childhood diarrhoea in rural Zimbabwe. J Health popul Ntr. 2001; 19(2):73–82.

49. Baker KK, Fahmida Dil F, Farzana F, Shahnawaz A, Sumon Kumar D, Faruque ASG, et al. Association between moderate-to-severe diarrhoea in young children in the global enteric multicenter study (GEMS) and types of hand washing materials used by caretakers in Mirzapur, Bangladesh. Am J Trop Med Hyg. 2014; 91(1):181–9. https://doi.org/10.4269/ajtmh.13-0509 PMID: 24778193

50. Luby SP, Halder AK, Huda T, Unicomb L, Johnston RB. The effect of hand washing at recommended times with water alone and with soap on child diarrhoea in Rural Bangladesh: an observational study. PLoS Med. 2011; 8(6): e1001052. https://doi.org/10.1371/journal.pmed.1001052 PMID: 21738452

51. Teklemariam S, Getaneh T, Bekele F: Environmental determinants of diarrhoeal morbidity in under-five children, Keffa-Sheka zone, south west Ethiopia. Ethiop Med J 2000; 38(1):27–34. PMID: 11144877

52. Anteneh A, Kurnie A: Assessment of the impact of latrine utilization on diarrhoeal diseases in the rural community of Hulet Eju Enessie Woreda, East Gojjam Zone, Amhara Region. Ethiop Journal Health Dev 2010; 24 (2).

53. Du Preez M, McGuigan KG, Conroy AM. Solar Disinfection of Drinking Water In the Prevention of Dysentery in South African Children Aged under 5 Years: The Role of Participant Motivation. Environ. Sci. Technol. 2010; 44, 8744–8749. https://doi.org/10.1021/es103328j PMID: 20977257

54. McGuigan KG, Samalipar P, du Preez M, and Conroy RM. High Compliance Randomized Controlled Field Trial of Solar Disinfection of Drinking Water and Its Impact on Childhood Diarrhoea in Rural Cambodia. Environ. Sci. Technol. 2011; 45, 7862–7867. https://doi.org/10.1021/es201313x PMID: 21827166

55. Rose A, Roy S, Abraham V, Holmgren G, George K, BalrajV, Abraham S, Muliyil J, Joseph A, Kang, G. Solar disinfection of water for diarrhoeal prevention in southern India. Arch. Dis. Child. 2006; 91 (2), 139–41. https://doi.org/10.1136/adc.2005.077867 PMID: 16403847

56. Motarjem Y, Käferstein F, Moy G. and Quevedo F. Contaminated weaning food: A major risk factor for diarrhoea and associated malnutrition. Bulletin of the World Health Organization 1993; (71):79–92.

57. Getaneh T, Assefa A, Tadesse Z: Diarrhoea morbidity in an urban area of southwest Ethiopia. East Afr Med J 1997; 74(8):491–4. PMID: 9487413

58. Wanzahun G, Bezatu M: Environmental factors associated with acute diarrhoea among children under-five years of age in Derashe district, southern Ethiopia. Science Journal of Public Health 2013; 1 (3):119–24.

59. Demissie S, Worku A. Magnitude and Factors Associated with Malnutrition in Children 6–59 Months of Age in Pastoral Community of Dollo Ado District, Somali Region, Ethiopia. Science Journal of Public Health. 2013; 1(4):175–83.

60. Amsalu S, Tigabu Z. Risk factors for severe acute malnutrition in children under the age of five. Ethiop J Health Dev. 2008; 22(1):21–5.
61. Hien N, Hoa N. Nutritional status and determinants of malnutrition in children under three years of Age in Nghean. *Vietnam Pak J Nutr*. 2009; 8 (7):958–64.

62. Teshome B, Kogi-Makau W, Getahun Z, Taye G. Magnitude and determinants of stunting in children under five years of age in food surplus region of Ethiopia: the case of west gojam zone. *Ethiop J Health Dev*. 2009; 23(2):99–106.

63. Yimer G. Malnutrition among children in Southern Ethiopia: level and risk factors. *Ethiopia Journal of health development*. 2000; 14(3):283–92.

64. Fentaw R, Bogale A, Abebaw D. Prevalence of child malnutrition in agro-pastoral households in Afar Regional State of Ethiopia. *Nutr Res Pract*. 2013; 7(2):122–3. https://doi.org/10.4162/nrp.2013.7.2.122 PMID: 23610605