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ABSTRACT

BACKGROUND: The WHO/UNICEF Joint Monitoring Program (JMP) service ladders are worldwide indicators for monitoring drinking water, sanitation, and hygiene elements of the sustainable development goal targets. However, evidence on how the prevalence of childhood diarrhea looks across the service ladders is limited. This study aimed to assess the relationship between WASH service ladders and the prevalence of childhood diarrhea in Haramaya Demographic and Health Surveillance site, Eastern Ethiopia.

METHODS: A cross-sectional study using a structured questionnaire, observational checklist, and water quality analysis was conducted on 535 households with children under 5 years of age. Poisson regression with a robust error variance estimator was used to investigate the relationship between dependent and independent variables.

RESULTS: The prevalence of diarrhea among under-five children in the surveillance site was 24.8% (95% CI: 22.3-27.6). The regression model revealed that water and sanitation service ladders were associated with childhood diarrhea. Childhood diarrhea was found to be 73% (APR = 0.27; 95% CI: 0.12-0.57) less common in families with a basic water service ladder than in households with a surface water service ladder. In addition, children in households with basic sanitation services had 83% (APR = 0.17; 95% CI: 0.05-0.56) lower diarrhea prevalence than children in households where open defecation was practiced.

CONCLUSION: The present study found that childhood diarrhea differed considerably among WASH service levels and continues to be a serious health problem at the surveillance site. This study also shows that much work is needed to improve WASH services.

KEYWORDS: Childhood diarrhea, water, sanitation, and hygiene service ladder, Ethiopia

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Introduction

In Ethiopia, a remarkable improvement in the coverage of improved drinking water sources (eg, from 53.7% in 2011 to 69% in 2019) and sanitation facilities (eg, from 8.3% in 2011 to 20% in 2019) has been achieved.[1] Despite the improvement, the coverage of WASH services, mainly the higher service ladders, is still low. Less than half of the population has basic drinking water services, 27% has limited services, 19% has unimproved services, and 5% are dependent on surface water as a source of drinking water supply. Basic drinking water services had a 1.5% annual rate of change for the reference period, 2000 to 2015 (ie, 1.5% increase per year for only basic service).[2] The sanitation service level in the country is also significantly minimal. Only 9% has basic service, 9% has limited service, 65% has unimproved service, and 17% of the population practiced open defecation. The annual rate of change in basic service level was 0.3%, and open defecation was −3% at the national level. Similarly, the hygiene service level is behind the target for achieving the 2030 SDGs agenda, with only 8% of the total population having basic hygiene services. In contrast, nearly half of the population has limited services, and the rest, 38%, has no handwashing facility at home, with a 0.07% annual rate of change in basic service.[2]

WASH service ladder is the new global indicator for monitoring drinking water, sanitation, and hygiene elements of the Sustainable Development Goal (SDG) targets. These targets is to achieve universal and equitable access to safe and affordable drinking water, sanitation, and hygiene for all and end open defecation.[3] The WHO/UNICEF Joint Monitoring Program (JMP) established the service ladders to show the wider range of services households receive rather than a binary improved/unimproved indicator. The levels are important indicators in getting people in the higher rungs of the ladder since moving up the ladder reduces the risk of WASH-related diseases.[4,5] Based on this ladder, drinking water services are classified as safely managed, basic, limited, unimproved, and surface water. Similarly, the Sanitation services ladders are labeled as safely managed, basic, limited, unimproved, and open defecation. Finally, the hygiene service ladders are classified as basic, limited, and no hygiene facility (refer to Table 1 for definitions).[3]

In 2020, one-fourth of the world's population (approximately 2 billion people) lacked access to safely managed drinking water, 3.6 billion had no access to safely managed sanitation services, and 2.3 billion lacked access to basic hygiene services, such as handwashing facilities with soap at home.[2] Consequently, hundreds of millions of people are at risk of Water, Sanitation, and

Hygiene (WASH) related diseases. In 2016, about 1.6 million deaths, representing 2.8% of all global deaths, and 104.6 million global disability-adjusted life years (DALYs) were from WASH-attributable disease burden.[8] In the same year, diarrhea alone caused 829 000 deaths and 49.8 million DALYs.[8] Sub-Saharan Africa continues to have the highest number; for example, roughly 53% of all deaths and 60% of all DALYs occur in this region due to inadequate WASH services.[9] Furthermore, the burden of inadequate WASH services is severe in children under 5 years of age, with nearly 297 000 deaths due to diarrhea disease (ie, 5.3% of all deaths in this age group).[8] Among the various mechanisms for combating such public health issues, improving access to water, sanitation, and hygiene is particularly important for preventing diarrheal diseases.[10]

The recent assessment indicates that inadequate WASH service remains a crucial factor for global disease burden, especially among young children.[8] Earlier studies showed the association between WASH facilities and diarrheal diseases in Ethiopia. For example, Soboksa[11] examined the relationship between childhood diarrhea and the utilization of improved water supply and sanitation facilities using data from the Ethiopian Demographic and Health Survey (EDHS). Sahiledengle and Agho also studied the factors of under-five children's diarrhea, only focusing on improved WASH facilities. According to the authors, children who live in rural areas and those not vaccinated against measles are substantially more likely to get diarrhea.[12] Similarly, Bitew et al[13] reported a 2-week prevalence of diarrhea among children under five, linked with inadequate drinking water sources and sanitation facilities. However, most of the studies just looked at the presence or lack of WASH facilities and their use, and they did not reveal how the prevalence of childhood diarrhea varied with the indicators (service ladders). A recent study, using multiple rounds of the Ethiopian demography and health surveillance (EDHS) data between 2000 and 2016, revealed that the improvement of lower service ladders such as surface water and open defecation resulted in a decline in childhood diarrhea.[14]

Categorizing the WASH services into ladders according to the WHO/UNICEF guide for measuring the service level is the recent notion, and evidence on how childhood diarrhea looks across these service ladders is limited. Therefore, the current study is intended to assess the WASH service ladder and the prevalence of childhood diarrhea in the Haramaya Demographic and Health Surveillance site. We hypothesized that higher service ladders have a lower prevalence of childhood diarrhea than lower service ladders. To the best of our knowledge, this is the first study to estimate the prevalence of childhood diarrhea throughout the JMP WASH "ladders" in the context of a case study in Ethiopia.

Methods

Study area and period

This study was conducted in Haramaya Demographic and Health Surveillance (HDHS) site located in Eastern Ethiopia in March 2020. Haramaya district is approximately 505 km from the Ethiopian capital, Addis Ababa. The surveillance site is situated between gradients 9°8′–9°30′ N latitude and 41°53'–42°8′ E longitude (Figure 1). Agriculture is the primary source of livelihood in the area. Regarding health service facilities in the district, there are 1 hospital, 7 health centers, and 34 health posts providing health care services.

Study design and population

A cross-sectional study was conducted on water, sanitation, and hygiene service ladders and the prevalence of childhood diarrhea (ie, the percentage of children with diarrhea [3 or more loose stools per day] that occurred at least once in the past 2 weeks preceding the survey). All households with under-five children in the surveillance site were the source population. The study population consisted of randomly selected households with at least 1 child under 5 years of age. The unit of analysis and the focus of our study was households with under-five children.

Sample size and sampling

The sample size was determined by using Epi Info version 7.2.2.6 software considering the following assumptions: a 95% confidence level, an 80% power with a one-to-one ratio between children with improved and unimproved WASH services, a 13.5%[15] and 23.8%[16] prevalence of childhood diarrhea among majority households utilizing improved and unimproved water supply and sanitation service, respectively, in northwest Ethiopia. The final sample size was 535 households by adding a 10% non-response rate.

Study participants were selected using a simple random sampling technique from a sampling registry obtained from the Haramaya Demographic and Health Surveillance registration book (Supplemental Table 1). The number of households studied in each Kebele (Ethiopia's smallest administrative division) was determined by proportional allocation using formula (1).[17]

$$n_j = \left(n' / N\right)^* N_j \tag{1}$$

Where n' is the total sample size, N is total households in selected Kebeles, N_j is households in each Kebele, and n_j is the sample size of each Kebele. Study households were selected from each Kebele using systematic sampling, with the first household determined by lottery method. The codes of households with under-five children were taken from the surveillance site coordinating office. The index child was selected by a lottery method for households with more than 1 child.

Data collection procedures

Household data collection. Data were collected by face-to-face interviewing study participants (ie, mothers/caregivers) using a structured questionnaire and an observational

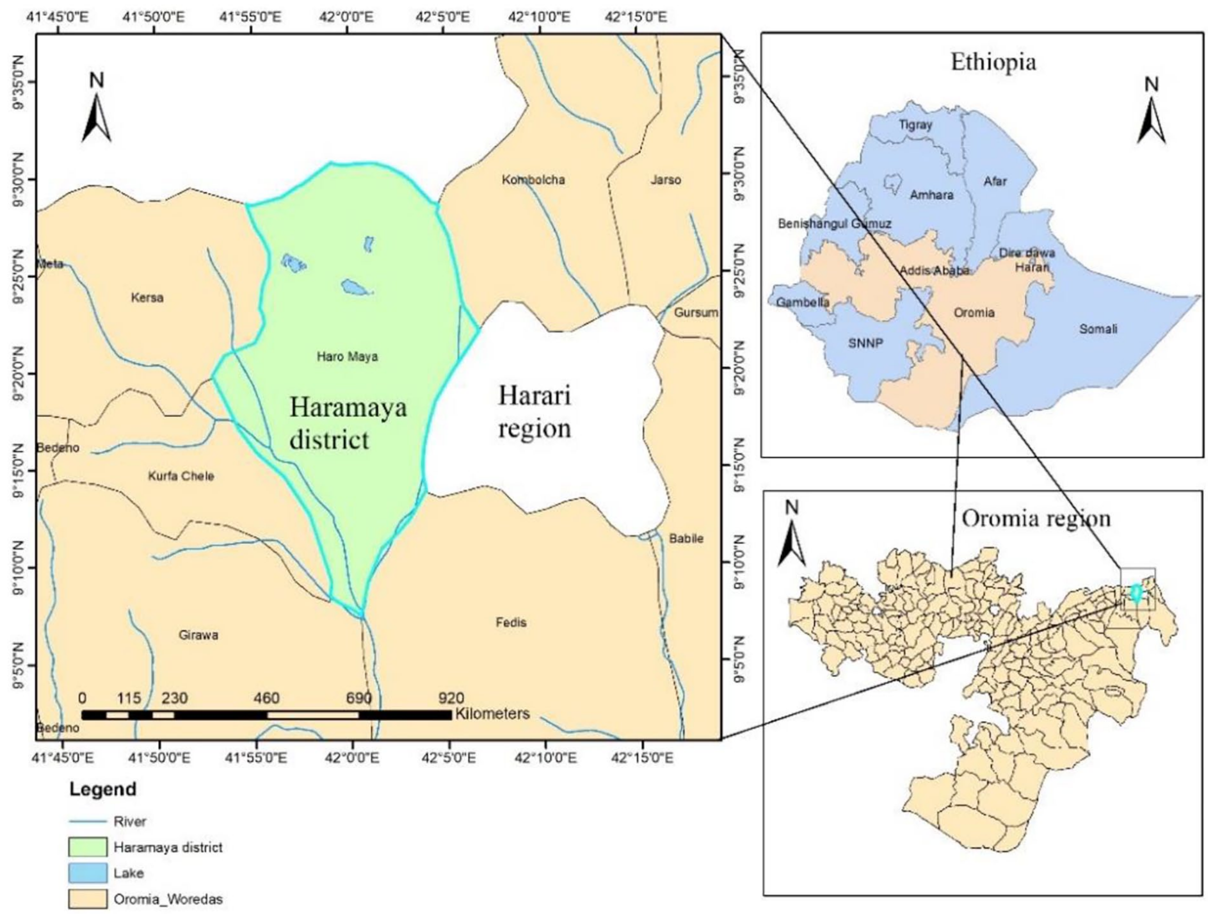

Figure 1. Map showing the Haramaya Demographic and Health Surveillance site, Eastern Ethiopia.

checklist. The questionnaire was prepared in English and translated to the local language, Afaan Oromo, and then translated back to English to assure accuracy. The respondents were primarily mothers, but the next primary caregiver was interviewed in the absence of the mother. Before the actual data collection, a pretest was conducted on 25 households in Dire Tiyara Woreda,[1] Harari region, eastern Ethiopia, to make the necessary corrections.

Water sample collection at point-of-use and sources. For water quality assessment, 100 ml of drinking water samples were collected from each household drinking water storage container using their drinking cups. The water sample was aseptically collected using a sterilized polyethylene plastic container. Similarly, 100 ml of water samples were taken from the sources. The sources included in the study were: 20 protected wells with a mechanized pump, 25 unprotected wells with a mechanized pump, 18 boreholes with a hand pump, and 2 surface water sources (ie, ponds), which were selected based on their proximity to the study households.

Water quality analysis. Water samples were collected and tested to determine the level of fecal contamination of drinking water. We used the portable water quality testing kit (Wagtech Potakit—Model PTW 10030) to quantify fecal coliform counts using a membrane filtration technique. This comprehensive Wagtech portable water testing kit allows tests to be carried out routinely in the field following WHO guidelines.[18] Membrane lauryl sulfate broth was used as a selective media prepared and sterilized. Samples were analyzed in the field within 30 minutes of collection and incubated at 44°C for at least 24 hours, per the manufacturer's instructions. The analysis was done aseptically to prevent cross-contamination between consecutive analyses using sterilization with 99.9% Methanol and waited for 15 minutes. A control sample was analyzed for every 10–15 water samples to check the effectiveness of sterilization. The values were recorded as the number of fecal (Thermotolerant [TT]) coliforms or Colony Forming Unit (CFU) per 100 ml of water. Formula (2) computes the number of thermotolerant coliforms per 100 ml.

$$\text{TT coliforms} / 100\text{ml} = \frac{\textit{No. of TT coliform colonies counted}}{\textit{Amount of sample filterd (ml)}} \, x\, 100 \qquad (2)$$

WASH service level definitions and measurements techniques

Table 1 shows the definitions of water, sanitation, and hygiene service ladder based on the WHO/UNICEF joint monitoring

Table 1. WASH service level definitions and measurement techniques.

SERVICE LADDER	DEFINITION	MEASUREMENT TECHNIQUE
Drinking water ladder		
Safely managed	Drinking water from an improved water source[a], which is located on the premises, is available for use when needed and devoid of disease-causing contaminants like fecal and priority contamination.	Questionnaire survey, observational checklist, and microbial water quality were used. However, we determined that conducting a chemical quality test for the priority chemicals was unnecessary since the study region was located in a water-scarce rural area, it was unlikely to find houses that met the criteria mentioned. On the other hand, because the link between fecal coliforms and diarrhea has been scientifically established,[6,7] we decided that bacteriological water quality was critical.
Basic	Drinking water from an improved source provided collection time is less than 30 min for a roundtrip, including queuing.	Observation and time measurement: the data collectors measured the collection time through a demonstration walk starting from the water source. They had to reach the water sources first as it was mandatory to collect sanitary information and bacteriological quality. Then the time was approximately recorded for every next household. These methods were used to distinguish between basic vs. limited service.
Limited	Drinking water from an improved source where collection time exceeds 30 min for a roundtrip, including queuing.	
Unimproved	Drinking water from an unprotected dug well or unprotected spring.	Questionnaire survey: questions were asked about the main drinking water sources. This is used to classify households into unimproved and surface water levels.
Surface water	Drinking water is directly collected from a river, dam, lake, pond, stream, canal, or irrigation channel.	
Sanitation service ladder		
Safely managed	Use of an improved sanitation facility[b], which is not shared with other households and where excreta are safely disposed in situ or transported and treated off-site.	Observation, questionnaire survey, and causal interview: the type of facility that household members usually use was observed. Then questions were asked about sharing the facility, years of service (ie, construction year), and treatment practices. Furthermore, causal interviews with the respondents were used to classify the households into safely managed, basic, limited, and unimproved services. In the case of no facility, the data collectors observe the absence of latrine (even with the neighbor), which could also be confirmed by human excrement in the surroundings.
Basic	Use of improved facilities, which are not shared with other households.	
Limited	Use of improved facilities shared between 2 or more households.	
Unimproved	Use of pit latrines without a slab or platform, hanging latrines, and bucket latrines.	
Open defecation	Disposal of human feces in fields, forests, bushes, open bodies of water, beaches, or other open spaces or with solid waste.	
Hygiene service ladder		
Basic	Handwashing facility with soap and water in the household	Questionnaire survey and observation: first, questions about the facilities were asked, followed by observation (eg, the data collectors check the availability of a handwashing facility with soap and water at the household level).
Limited	Handwashing facility without soap or water	
No facility	No handwashing facility	

[a]Improved water source includes; piped water, boreholes or tube wells, protected dug wells, protected springs, and packaged or delivered water.
[b]Improved sanitation facilities include: flush/pour-flush to a piped sewer system, septic tank, or pit latrine; ventilated improved pit latrine, composting toilet, or pit latrine with a slab.

program and the measurement approaches to classify households under the service levels.

Data analysis

We used Poisson regression models to determine the difference in childhood diarrhea prevalence between service level groups. The collected data were checked for completeness and consistency, coded and entered into Epi Data 3.1 software package, and exported to STATA version 14.2 for analysis. Descriptive statistics for continuous variables and proportion for discrete variables were analyzed. The models were adjusted for potential confounding variables, including socio-economic and WASH variables.

To avoid the overestimation problem, Poisson regression with a robust error variance estimator was used instead of logistic regression. Cross-sectional studies with binary outcomes evaluated using logistic regression are common in public health research. However, the odds ratio estimation by logistic regression is less efficient. It overestimates the relative risk (or the prevalence ratio) when the prevalence of a binary outcome variable is a common event (eg, childhood diarrhea prevalence), which is the case in this study.[19,20] Thus, the modified Poisson regression is an alternative to logistic regression for the analysis of cross-sectional studies with binary outcomes.[19,21] In addition, previous studies showed that Poisson regression with robust variance produces correct estimates for the analysis of cross-sectional studies with binary outcomes because the prevalence ratio is more interpretable and simpler to communicate the result.[21,22] The variables with a P-value < .05 were considered statistically significant.

Regarding variable selection, initially, all the independent variables (ie, 29 variables) were screened by performing a bivariate analysis to select relevant variables for the model (Supplemental Table 2) and 18 variables with a P-value less than .25 (as a rule of thumb) were selected. Then, the sample size was checked for each variable. Two variables, including the educational level of mothers/caregivers and the occupation of mothers/caregivers, were dropped out of the model due to the detection of sample size insufficiency. Furthermore, multicollinearity was checked using a correlation test; thus, no strong correlation was found among the selected variables included in the model. Supplemental Table 3 displays the correlation matrix for possible collinear variables (eg, fecal coliform and water service ladders) with correlation coefficients (r) less than 0.55 ($r \leq 0.35$ considered as low or weak correlations, .36 to .67 modest correlations, and .68 to 0.9 strong or high correlations[23]). As a result, the final model was constructed by incorporating a dependent variable (ie, childhood diarrhea prevalence) and 16 independent variables: water service ladder; sanitation service ladder; hygiene service ladder; fecal coliform contamination; indexed child's age; indexed child's sex; storage container covered; drinking water drawing method from storage container; storage accessible to the child; household water treatment practice; child faces disposal; share a room with animals; wash hands with soap after visiting latrine; wash hand with soap before feeding a child; vaccinated against measles; and mothers/caregivers had diarrhea.

Sample Characteristics

Socio-demographic characteristics

The mean age of the mothers/caregivers was 26.8 years (SD ±5.7) and the indexed child was 19.7 months (SD ±14.9). About half of caregivers, 271 (50.6%), did not attend formal education, and 355 (66.4%) were housewives. More than half, 296 (55.32%), of the mothers/caregivers had 2 or more children (Table 2).

Childhood diarrhea and behavioral characteristics of the mothers/caregivers

In this study, 133 (24.8%) of the under-five children has experienced diarrhea in the 2 weeks preceding the survey. Nearly half (48.9%) of the children were vaccinated against measles, and more than three-fifths (65.6%) of the indexed children were breastfed during the study period. Of the total mothers/caregivers, 386 (72.2%) fed the child soon after food preparation (Table 3).

Results

Water service ladder and childhood diarrhea

None of the households had safely managed services in the surveillance site, and only 86 (16.1%) were reliant on basic water services. Among the households, 241 (45%) and 191 (35.7%) utilized limited and unimproved water services, respectively, while the remaining were dependent on surface water. The distribution of childhood diarrhea across the water service ladder shows that about one-third of children in the households using surface water had a 2-week prevalence of childhood diarrhea, and prevalence is lowest (15%) among households having a basic water service ladder (Figure 2).

Sanitation service ladder and childhood diarrhea

In the study area, there were no households that utilized safely managed sanitation services. Eighty-six (16%) households had a basic sanitation service. While 68 (12.7%) and 50 (9.4%) households, respectively, had limited and unimproved sanitation services. More than half, 331 (61.9%) of households practiced open defecation. Childhood diarrhea inclines from households in the basic service ladder (2%) to the unimproved service ladder (68%) (Figure 3).

Hygiene service ladder and childhood diarrhea

Based on the observation for hygiene service, 494 (92.3%) of the households do not have a handwashing facility near/attached to the latrine (Supplemental Table 4). Regarding the hygiene service ladder, only 9 (1.7%) of the households utilized basic hygiene services, while only 32 (6%) relied on limited hygiene services. The larger majority of the households (92.3%) had no handwashing facility at all. The distribution of childhood diarrhea across the hygiene service ladder shows that childhood diarrhea prevalence is higher (about 26%) in households with no handwashing facility compared to basic (22%) and limited-service ladder (9%) (Figure 4).

Table 2. Socio-demographic characteristics of study participants in Haramaya Demographic and Health Surveillance site, Eastern Ethiopia.

VARIABLE	CATEGORY	FREQUENCY	PERCENT
Mother's/caregiver's age (in years)	<20	38	7.1
	20-24	135	25.2
	25-29	198	37.0
	30-34	96	17.9
	⩾35	68	12.7
Indexed child's age (in months)	<5	97	18.1
	6-11	107	20.0
	12-23	133	24.9
	24-35	86	16.1
	36-59	112	20.9
Educational status of mother/caregiver	Unable to read and write	271	50.6
	Read and write only	24	4.5
	Primary education	220	41.1
	Secondary education	11	2.1
	College and above	9	1.7
Occupation of mother/caregiver	Housewife	355	66.4
	Farmer	131	24.5
	Government employee	12	2.2
	Merchant	37	6.9
Family size	⩽5	334	62.4
	>5	201	37.6
Monthly household income	<50 US$*	197	36.8
	⩾50 US$	338	63.2
Number of under-five children in the household	1	247	46.2
	>2	288	53.8

*1 United States Dollar (US$) = 35 ETB (Ethiopian Birr), the exchange rate in June 2020.

Drinking water source, quality, and handling at the point of use

Protected well with mechanized pumps, unprotected well with mechanized pumps, boreholes with a hand pump, and surface water were the most frequent drinking water sources in the area. One hundred ninety-one (35.7%) of the families utilized unprotected wells as their principal source of drinking water, while 179 (33.5%) used protected wells. The respondents' daily per capita water consumption was less than 20 l for 503 (94.0%). Four hundred twenty households (74.5%) take more than 30 minutes of round trips to collect the water. Of the total study households, 357 (66.7%) utilized a "Jerrican" as a primary drinking water storage container, with 495 (92.5%) having a cover and 376 (70.3%) cleaning the container before filling the water. More than half of households, 304 (56.8%), stored their drinking water for more than a day, while 139 (25.9%) of them placed their drinking cups on the floor (Supplemental Table 5).

The water quality analysis of drinking water samples from the households indicates that 518 (96.8%) were positive for thermotolerant coliform. The mean thermotolerant coliforms in the water at point-of-use was 61.2 CFU/100 ml. All the households that utilize drinking water from unprotected wells

Table 3. Childhood diarrhea and behavioral characteristics of the mothers/caregivers in Haramaya Demographic and Health Surveillance site, Eastern Ethiopia.

VARIABLE		FREQUENCY	PERCENT
The under-five child had diarrhea	Yes	133	24.8
	No	402	75.2
An indexed child vaccinated against measles	Yes	262	48.9
	No	273	51.1
Indexed child breastfed during the study period	Yes	351	65.6
	No	184	34.4
Mother/caregiver fed the child soon after food preparation.	Yes	386	72.2
	No	149	27.8

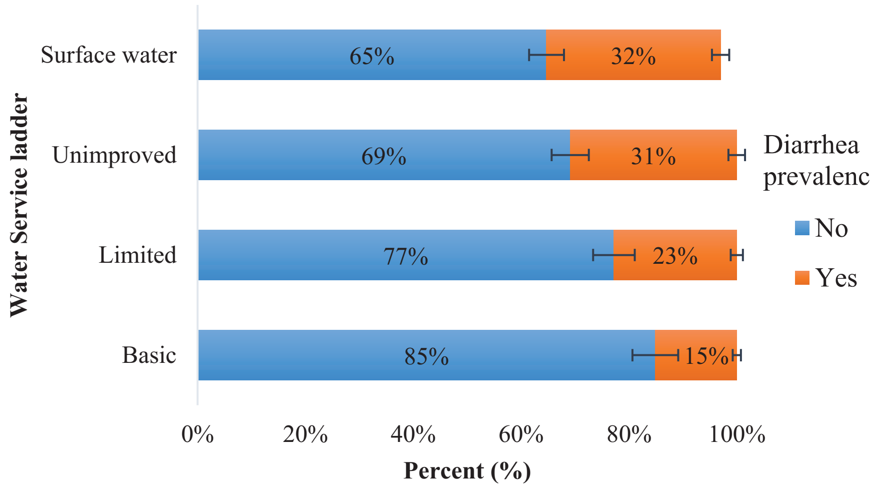

Figure 2. Childhood diarrhea along water service ladder in Haramaya Demographic and Health Surveillance site, Eastern Ethiopia.

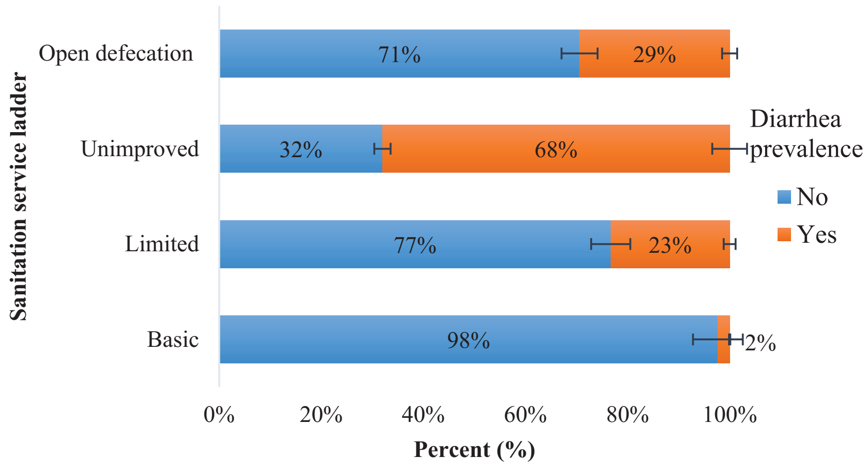

Figure 3. Childhood diarrhea along sanitation service ladder in Haramaya Demographic and Health Surveillance site, Eastern Ethiopia.

and surface water were positive for fecal coliforms. On the other hand, the water quality analysis for the sources showed that 95% of the protected wells (n = 20), all (100%) of the unprotected wells (n = 25), 83.3% of the boreholes (n = 18), and all of the surface water samples (n = 2) were positive for thermotolerant coliform with a mean value of 17.5 CFU/100 ml, 32.1 CFU/100 ml, 15.4 CFU/100 ml, and 96.5 CFU/100 ml, respectively.

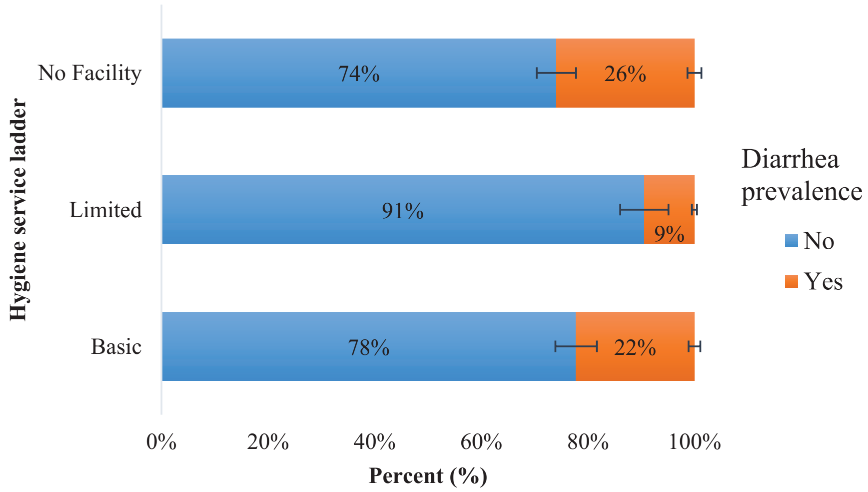

Figure 4. Childhood diarrhea along hygiene service ladder in Haramaya Demographic and Health Surveillance site, Eastern Ethiopia.

WASH service ladders and childhood diarrhea

The Poisson regression on the WASH service ladder and its contribution to under-five children's diarrhea show that water and sanitation service ladders were significantly associated with childhood diarrhea. Households utilizing basic services (APR = 0.27; 95% CI: 0.12-0.57) and limited services (APR = 0.45; 95% CI: 0.23-0.89) had significantly reduced the prevalence of diarrhea compared to those using surface water. Similarly, households in the basic sanitation service ladder had 83% less childhood diarrhea (APR = 0.17; 95% CI: 0.05-0.56) compared to those practicing open defecation (Table 4).

In addition to WASH service ladders, diarrheal disease was also associated with indexed child age. The children with age of 6 to 11 months and 12 to 23 months had 54% (APR = 1.54; 95% CI: 1.03-2.29) and 58% (APR = 1.58; 95% CI: 1.01-2.46) higher prevalence of diarrhea, respectively, than children below the age of 5 month. Similarly, how caregivers use or draw water from storage containers significantly as with diarrhea prevalence. Households that practice the pouring method had a 67% lower diarrhea prevalence than those that practice the dipping method (APR = 0.33; 95% CI: 0.23-0.46). Moreover, handwashing after using the latrine by mothers/caregivers had a 65% lower diarrhea prevalence than those who do not practice handwashing after latrine use (APR = 0.35; 95% CI: 0.25-0.48) (Table 4).

Discussion

The current study revealed that the 2-week prevalence of diarrheal disease among under-five children in Haramaya Demographic and Health Surveillance site is about one-fourth of the sample population. The water service ladder in the surveillance site indicates no household with safely managed water; only 16.1% of the households were dependent on basic services, 45.0% were dependent on limited services, and 3.2% were dependent on surface water. Less than 20% of the households had basic sanitation services, 12.7% were reliant on limited sanitation services, and more than half (61.9without%) of the households had no sanitation facility, thus practicing open defecation. The hygiene service ladder also revealed that 92.3% of the households do not have handwashing facilities.

The diarrheal disease among children living in households utilizing basic and limited water services was less likely than children living in households that use surface water. This finding is consistent with studies done in the Jimma zone, Ethiopia,[24] Nigeria,[25] and India[26] that show the contribution of unsafe water sources for the occurrence of the disease. According to WHO, households that changed water service from unimproved to improved water had reduced the risk of diarrheal disease by 23%.[10]

Water sources that are classified as basic service ladder, such as boreholes with a hand pump, exceeded the WHO recommended level of fecal contamination (ie, zero CFU/100 ml of drinking water). Earlier studies in developing countries showed that improved sources such as boreholes are not always free from fecal contamination, mainly due to a combination of mixing water sources at the household level, unsafe storage and handling practices, and inadequate or no household treatment.[27-29] This might be one of the main reasons for the prevalence of diarrhea disease (15%) among households dependent on basic services. Similarly, households that utilize drinking water with no risk of fecal contamination had reduced childhood diarrhea; however, the association was not significant after adjustment. This could be the confounding association between fecal coliform concentration and childhood diarrhea. There is substantial evidence that fecal contamination-free water has little effect on diarrhea in highly polluted locations with poor WASH services and environmental factors.[30] Cohabitation with animals, for example, can expose humans to pathogens from animal feces, particularly in rural settings,[31] as was the case in our study. On the other hand, drinking water drawing from the storage container by pouring was found to be less risk of having childhood diarrhea compared to those drawing by dipping their finger with a can. Studies supported that inappropriate water handling and unhygienic activities contribute to drinking water contamination at the point of

Table 4. Poisson regression on childhood diarrhea in Haramaya demographic and health surveillance site, Eastern Ethiopia.

VARIABLE	REPORTED DIARRHEA		CPR		APR (95% CI)
	YES, N (%)	NO, N (%)	95% CI	*P*-VALUE	
Water service ladder					
Basic	13 (15)	73 (85)	0.43 (0.19-0.97)*	**.04**	0.27 (0.12-0.57)**
Limited	55 (23)	186 (77)	0.65 (0.33-1.28)	.11	0.45 (0.23-0.89)*
Unimproved	59 (31)	132 (69)	0.88 (0.44-1.72)	.21	0.53 (0.26-1.06)
Surface water	6 (35)	11 (65)	Ref		Ref
Sanitation service ladder					
Basic	2 (2.3)	84 (97.7)	0.10 (0.03-0.40)**	**.00**	0.17 (0.05-0.56)**
Limited	20 (29.4)	48 (69.6)	0.54 (0.23-0.78)	.24	0.61 (0.34-0.92)
Unimproved	34 (68)	16 (32)	0.89 (0.54-1.20)	.06	0.98 (0.69-1.40)
Open defecation	77 (23)	254 (77)	Ref		Ref
Hygiene service ladder					
Basic	2 (22.2)	7 (77.8)	0.86 (0.25-2.94)	.25	0.94 (0.42-1.36)
Limited	3 (9.3)	29 (90.7)	0.36 (0.12-1.07)	.07	0.52 (0.19-1.14)
No facility	128 (25.9)	366 (74.1)	Ref		Ref
Fecal coliform concentration (CFU/100 ml)					
0	2 (11.7)	15 (88.3)	0.45 (0.11-1.76)	.25	0.31 (0.08-1.15)
11-100	114 (25)	339 (75)	0.96 (0.62-1.49)	.86	0.89 (0.62-1.17)
>101	17 (26)	48 (74)	Ref		Ref
Indexed child age (in months)					
<5	17 (17.5)	80 (82.5)	Ref		Ref
6-11	37 (34.6)	70 (64.4)	1.97 (1.19-3.27)*	**.01**	1.54 (1.03-2.29)*
12-23	34 (25.6)	99 (74.4)	1.46 (0.87-2.45)	.16	1.58 (1.01-2.46)*
24-35	25 (29)	61 (79)	1.66 (0.96-2.86)	.07	1.55 (0.99-2.43)
36-59	20 (17.8)	92 (82.2)	1.02 (0.50-1.83)	.95	0.88 (0.54-1.42)
Sex indexed child					
Male	77 (26.7)	211 (73.3)	Ref		Ref
Female	56 (22.7)	191 (77.3)	0.85 (0.63-1.14)	.25	0.88 (0.69-1.13)
Storages: the storage container has a cover					
Yes	120 (24.3)	375 (75.7)	0.75 (0.46-1.21)	.22	1.32 (0.92-1.89)
No	13 (32.5)	27 (67.5)	Ref		Ref
Drinking water drawing method from storage container					
Pouring	42 (10.6)	354 (89.4)	0.16 (0.12-0.22)**	**.00**	0.33 (0.23-0.46)**
Dipping	91 (65.5)	48 (34.5)	Ref		Ref

(continued)

Table 4. (Continued)

VARIABLE	REPORTED DIARRHEA		CPR		APR (95% CI)
	YES, N (%)	NO, N (%)	95% CI	*P*-VALUE	
Storage accessible to the child					
Yes	76 (31)	170 (69)	Ref		Ref
No	57 (19.7)	232 (80.3)	0.64 (0.47-0.86)**	**.00**	0.91 (0.70-1.17)
Household water treatment					
Yes	20 (18)	92 (82)	0.67 (0.42-1.03)*	**.05**	0.86 (0.61-1.22)
No	113 (26.7)	310 (73.3)	Ref		Ref
Child faces disposal					
Disposed to latrine	107 (26.2)	301 (73.8)	0.78 (0.53-1.14)	.20	0.87 (9.63-(1.20)
Disposed of in open space	26 (20.5)	101 (79.5)	Ref		Ref
Share room with animals					
Yes	58 (31.5)	126 (68.5)	Ref		Ref
No	75 (21.4)	276 (78.6)	0.68 (0.51-0.91)*	**.01**	0.92 (0.72-1.19)
Wash hands with soap after visiting the latrine					
Yes	47 (11)	379 (89)	0.14 (0.10-0.20)**	**.00**	0.35 (0.25-0.48)**
No	86 (79)	23 (21)	Ref		Ref
Wash hand with soap before feeding a child					
Yes	20 (13)	135 (87)	0.43 (0.28-0.67)**	**.00**	0.73 (0.51-1.06)
No	113 (29.7)	267 (70.3)	Ref		Ref
Vaccinated against measles					
Yes	71 (27)	191 (73)	1.00 (0.85-1.68)	.24	0.95 (0.60-1.58)
No	62 (22.7)	211 (77.3)	Ref		Ref
Mothers/caregivers had diarrhea					
Yes	28 (93.3)	2 (6,7)	Ref		Ref
No	105 (21)	400 (79)	0.22 (0.12-0.27)**	**.00**	0.49 (0.34-0.70)**

Abbreviations: APR, adjusted prevalence ratio; CI, confidence interval; CPR, crude prevalence ratio; Ref, reference category.
Statistically significant at $^{**}P < .01$ and at $^{*}P < .05$.

use.[7,32,33] Therefore, to maintain water safety, it is essential to have household water treatment, safe water handling, storage practices, and improved hygiene.[29,34]

The sanitation service ladder starts from the basic service in the surveillance site. Households in the basic sanitation service ladder had about 83% less prevalence of childhood diarrhea compared to households in the service ladder of open defecation. Various studies in low- and middle-income countries supported the lack of safe sanitation facilities as the leading risk factor for child health.[24,35-37] On the other hand, households practicing open defecation had a lower diarrhea prevalence (29%) than the next upper service ladder (ie, unimproved service, [68%]). This might be due to the poor condition of the latrines in the study area (mostly pit latrines without a slab), which could act as a transmission hub and introduce fecal contamination into the houses, resulting in even more health problems than open defecation. A recent study on sanitation ladders and childhood undernutrition also reported that unimproved services might be as unsafe as open defecation when it comes to cross-contamination.[38]

Regarding the hygiene service ladder, our finding indicated that having a handwashing facility with soap and water (ie, basic service) has shown a higher prevalence of diarrhea than limited service and is nearly similar to having no handwashing facility. This indicates that having a basic service alone would not bring a reduction in diarrhea since additional factors, such as effective handwashing practice at critical times, are required (ie, handwashing after defecation, after handling child feces, before preparing food, before feeding a child, and before eating[39]). This is the case in this study, where mothers/caregivers have lower hand hygiene practice, particularly before feeding the child. Strong evidence suggests that good handwashing practice at a critical time is critical to breaking the fecal-oral transmission route.[15,39,40]

The 2-week prevalence of childhood diarrhea in the surveillance site is comparable with a study in northwest Ethiopia[41] and Kersa Demographic and Health surveillance site.[42] However, it is higher than the study conducted in Bahir Dar city, northwest Ethiopia, 14.5%,[43] in Dale District, southern Ethiopia, 13.6%,[44] and in Addis Ababa, the Ethiopian capital, 11.7%.[45] The finding is also comparable with studies conducted in other countries like Mwanza city, Tanzania, 20.4%,[46] and in India, 21.7%,[47] but higher than study conducted in Malaysia 4.4%,[15] and slightly lower than a study done in Mbour, Senegal, 26%.[48] The discrepancy might be due to differences in living standards, provision of WASH services, and socio-demographic characteristics of the households.

Mothers'/caregivers' health indicates childhood health. Our finding showed that mothers/caregivers with diarrhea had a 51% chance of having diarrhea in their children. As mothers/caregivers are the most frequent primary care providers for their children, there is a high possibility that the child acquires the disease,[25,49,50] which is the case in this study, where about 61.1% of them did not wash their hands with soap after visiting the latrine. On the other hand, the indexed child's age shows a significant association with diarrhea among children. The children aged 6-11 months (58%) and 12-23 months (54%) had a higher prevalence of diarrhea, respectively than those below 5 months. This finding is consistent with other studies in the country.[51,52] This might be because the chance of acquiring diarrhea increases when the child starts crawling and ingesting contaminated materials.

The study has strengths and limitations. One of the strengths is that we implemented a Poisson regression with a robust error variance estimator to avoid overestimation that could be occurred from logistic regression due to high outcome prevalence. On the contrary, the study has some limitations. One of the limitations is social desirability bias that could be occurred due to mothers'/caregivers' decisions regarding childhood diarrhea. There might also be poor reporting of behavioral factors such as handwashing practice at critical times, solid and liquid waste disposal practice, the child's faces disposal practice, and drinking water handling practices. In addition, we assessed the prevalence of diarrhea with a 2-week recall period, which might underestimate the prevalence due to recall bias.[53] Future studies might thus consider using a shorter prevalence window such as a 7-day recall period.[54]

Conclusions

The present study used a new approach to measure the prevalence of childhood diarrhea with the joint monitoring program service levels, which are worldwide indicators for monitoring SDG 6. The prevalence of childhood diarrhea was statistically associated with water and sanitation service ladders. The prevalence decreased from basic water service ladder to surface water and from basic sanitation service to households practicing open defecation, confirming our hypothesis. It was also statistically associated with behavioral factors such as drinking water drawing method from the storage container, and handwashing with soap after visiting the latrine. The findings suggest the importance of higher WASH service ladders. As a result, much work remains to be done to improve water, sanitation, and hygiene service levels and behavioral change in terms of safe water handling, handwashing at critical times, and sanitary disposal of household waste.

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Author Contributions

SW contributed to the initiation of the research question, prepared the research proposal, carried out the research, the data entry, and analysis. AG approved the proposal with some revisions, participated in data analysis, and revised subsequent drafts of the paper. AG and HG drafted and wrote the manuscript and participated in subsequent revisions. All authors have read and approved the final manuscript.

Data Availability Statement

All relevant data are included in the paper, or its supplementary information and additional data will be made available upon request to the corresponding author.

Ethical Considerations

Ethical clearance was obtained from Haramaya University, College of Health and Medical Sciences, Institutional Health Research Ethics Review Committee (IHRERC). Mothers/caregivers were informed about the study's purpose, benefits, and risks, and written informed consent was obtained. During the whole study period, the necessary precautions to prevent the spreading of COVID-19 were followed.

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Supplemental Material

Supplemental material for this article is available online.

NOTE

1. The third level administrative division in Ethiopia.

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