AFRICA CENTER OF EXCELLENCE FOR WATER MANAGEMENT

ADDIS ABABA UNIVRSITY

WATER, SANITATION, AND HYGIENE ROLE IN CHILDHOOD INTESTINAL PARASITIC INFECTION AND REINFECTION IN RURAL DIRE DAWA, EASTERN ETHIOPIA

By: Heroda Gebru (BSc, MPH)

Author

A PhD dissertation submitted to the Africa Center of Excellence for Water Management, Addis Ababa University in partial fulfillment of the requirements for The Degree of Doctor of Philosophy in Water and Health (Water and Public Health)

September, 2025
Addis Ababa, Ethiopia

Africa Center of Excellence for Water Management

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Declaration

I, PhD Candidate's Heroda Gebru Gebremedhin, hereby declare that this research Dissertation titled **"Water, Sanitation, and Hygiene Role in Childhood Intestinal Parasitic Infection and Reinfection in Rural Dire Dawa, Eastern Ethiopia"** has been developed by me and has not been submitted to any other institution for award of any academic qualification. The content of the dissertation has not been plagiarized and where works of other researchers have been used; they have been appropriately cited.

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By:

Heroda Gebru (BSc, MPH)

A PHD DISSERTATION SUBMITTED

TO

AFRICA CENTER OF EXCELLENCE FOR WATER MANAGEMENT

ADDIS ABABA UNIVERSITY

APPROVED BY BOARD OF EXAMINERS

This is to certify that we have read this PhD dissertation and that in our opinion; it is fully adequate, in scope and quality, as a PhD dissertation for The Degree of Doctor of Philosophy in Water and Health (Water and Public Health).

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Acronyms

AOR	Adjusted Odds ratio
CDC	Centers for Disease Control
CDI	Chronic daily ingestion
CI	Confidence Interval
COR	Crude Odds Ratio
CSA	Central Statistical Agency
CSF	Cancer slope factor
EIWR	Ethiopian Institute of Water Resources
GIT	Gastro-Intestinal Tract
HIPPIs	Human intestinal protozoan parasitic infections
HP	Hygiene Practices
IPIs	Intestinal parasite infections
NA	Not applicable
NTDs	Neglected Tropical Diseases
PCR	Polymerase Chain Reaction
STH	Soil-transmitted helminths
SSA	Sub-Saharan Africa
UN	United Nation
WASH	Water, sanitation, and hygiene
WHO	World Health Organization
UN	United Nation

Abstract

Background: Numerous infectious disorders brought on by parasitic worms, such as Schistosoma and soil-transmitted helminths, or pathogenic intestinal protozoa, have been grouped as neglected tropical diseases (NTDs). Parasitic illnesses still pose a serious and challenging threat to public health in developing countries. Worldwide, intestinal parasite infections (IPIs) affect about 3 billion individuals. Sanitation and hygiene are crucial to avoid intestinal parasite infections. Children are particularly vulnerable due to their frequent exposure to unhygienic environment and inability to keep adequate personal hygine. Inadequate water quantity limites basic hygienic practices such as hand hygiene and also poor water quality favours the direct transmission of IPIs. Pathogens transmitted through drinking water are mainly of fecal origin and are called enteric pathogens. Eventhough substantial progress has been made in Ethiopia in expanding access to safe drinking water, a significant challenge remains. Approximately 56.7% of the population faced a shortage of clean water. In rural areas, open defecation practices were common, and there was frequent sharing of water sources with animals. All these conditions facilitate fecal contamination of water and poor hygienic practices that favours IPI transmition. Children living in unsanitary and unhygienic environments are often trapped in a vicious cycle of infection and reinfection with intestinal parasites. This recurrent exposure can lead to chronic health issues like malnutrition, stunted growth, impaired cognitive development, and reduced school performance. Moreover, the burden of parasitic infections can persist across generations, reinforcing a cycle of poverty and poor health. In light of this, the present study evaluates the associations between water quality, sanitation, hygiene (WASH) practices, and the occurrence and recurrence of intestinal parasitic infections among children.

Objectives: The objectives of this study are to assess the prevalence of intestinal parasitic infections (IPIs) among children aged 1–14 years and to identify associated risk factors related to sanitation and hygiene practices at the community level. In addition, the study examines the microbial quality of point-of-use drinking water in households with children and evaluates its association with the prevalence of IPIs. Furthermore, to determine the six-month reinfection rate of IPIs among previously treated children and to assess the relationship between their sanitation and hygiene practices and the likelihood of reinfection.

Methods: From April to May 2021, a community-based cross-sectional study was carried out. Nine rural kebeles were randomly selected by the lottery method from a total of 38 kebeles. A total of 778 children aged 1-14 years participated in the survey. Data were collected using a pre-tested structured questionnaire administered through interviews to the participants parent or caregiver. Stool samples were taken for analysis using the direct wet mount method in the field and theformol-ether concentration technique at the institution, respectivly. Descriptive statistics and logistic regression analysis were performed using the Statistical Package for the Social Sciences (SPSS) version 23 to addres the first specific objective.

For objective II, a nested case-control study design was used. From April to May 2021, children with positive stool results for IPIs were identified as cases, while those with negative results were selected as controls based on direct wet mount method and formol-ethe concentration technique. A total of 352 water samples were collected 176 from case households and 176 from control households using sterile water sample collection bottles. For each household, 500 ml point of use water was collected from the actual point where water is consumed (cup or jug) by trained water lab staffs, following the standard procedures for water sample collection. In addition to collecting water samples for microbiological analysis, mothers and other caregivers of children were asked to complete pretested structured questionnaires. Data were entered into Epi Info, and exported to SPSS version 23 for analysis to examine the relationship between IPIs and point-of-use microbiological water quality.

For objective III a case-control study design was employed. Data were collected from 75 IP reinfected cases and 147 unmatched controls. Fecal specimens were examined for parasities using both the direct smear and formol ether methods. Data entery was performed using Epi-Info, and statistical analysis was conducted using SPSS. Logistic regration analysis was used to identify associations between variables, with statistically significant set at $P < 0.05$.

Results:

The prevalence of 5 intestinal parasites was 33.7% (95% CI = 30.4%-37%). *Giardia intestinalis* (15.2%) and *Hymenolepis nana* (11.6%) had the highest prevalence. The odds of IPIs among children of illiterate mothers were 13.1 times higher when compared with children of mothers with secondary education (aOR=13.1, P=.02), and the odds of IPIs among children from households that have unclean latrines were 1.8 times higher when compared with children from

households that have clean latrines. (aOR=1.8, P=.03). Children from households that discard solid waste in open fields had 1.7 times higher odds of having a positive result than children from households that burn their waste (aOR=1.7, P=.03). However, children who didn't swim in accumulated water (naturally or for irrigation purpose) were 0.4 times less likely to test positive for intestinal parasitic infection compared to those who did. Also, children who were asymptomatic for IPIs at the time of the survey were 0.3 times less likely to be diagnosed with intestinal parasitic infection.

Overall, total coliform was detected from 298 point-of-use water samples (94.3% from cases and 75% from the control group), and E. coli was detected totally from 249 (96.6% from cases and 44.9% from the control group) point-of-use water at the household level. The positivity for IPIs was 12.6 times higher among the study subjects from households with point-of-use water detected with total coliform than their counterparts (P=0.001, 95% CI: 3.8-41). Also, IPIs were 14 times more likely to occur among children from households with point-of-use water detected with E. coli than the reference group. This relation has statistical significance (P=0.001, 95% CI: 6.6-30.2). Among microbial risk categories, water with *E. coli* counts in the low-risk range (1–10 CFU/100ml) showed a significantly increased infection risk (AOR = 15.3; p = 0.004), suggesting that even low risk contamination levels may pose substantial health threats in vulnerable populations. However, intermediate and high contamination levels did not retain significance after adjustment. Subjects from households that consum water ≥25 l/c/day had lower odds of infection (P=0.029, CI: 0.3–0.9), indicating a protective effect of adequate water consumption

The overall IP reinfection rate within 24 weeks after treatment was 33.8% (75/222), with a 95% CI = 27.7%–40.5%. The frequency of intestinal protozoa was 18%, and for helminths, it was 15.8%. Children who swam in polluted water had 3.7 times greater odds of IP reinfection than children who did not swim (P = 0.01, 95% CI: 1.4–10.0). Children who regularly bathed in streams and children who bathed both at home and in streams were found to have 12.6 times and 5.8 times higher odds of IP reinfection than children who bathed regularly at home (P = 0.002, 95% CI: 2.5–64.8) and (P = 0.042, 95% CI: 1.1–31.3), respectively. Children from households that owned domestic animals had 4.2 times higher odds of IP reinfection compared to children from housholds without domestic animals (P = 0.013, 95% CI: 1.3–12.5).

Conclusions: The multifaceted nature of intestinal parasite infections and reinfections in children is highlighted in this study, with particular attention paid to the important roles played by environmental exposures, sanitation, hygiene practices, maternal education, and water quality and quantity. Children of illiterate mothers, those living in households with unclean latrines or poor waste management practices, and those exposed to contaminated water sources were more likely to be infected. Additionally, behaviors such as swimming or bathing in contaminated surface waters and close contact with domestic animals were strongly associated with reinfection. These findings are consistent with both local and international studies, reinforcing the urgent need for integrated, community-based interventions that combine health education, improved water and sanitation services, behavioral change communication, and targeted environmental health strategies to reduce the burden of parasitic diseases among vulnerable populations.

Recommendations: To effectively reduce childhood intestinal parasitic infections and reinfections in rural Dire Dawa, a comprehensive approach focusing on water, sanitation, and hygiene (WASH) is essential. To lessen the burden of intestinal parasite infections and reinfections in children, a number of important recommendations are put out in light of the study's findings. First, enhancing community-based health education is essential for promoting safe water management, illness prevention, and better hygiene habits, especially for illiterate mothers. Prioritizing access to clean and sufficient water (≥25 liters per person per day) should be achieved through better infrastructure and encouragement of water treatment and storage at the household level. Community-led total sanitation (CLTS) strategies must discourage open-field waste disposal and encourage routine latrine cleaning in order to improve sanitation and hygiene initiatives. Particularly in high-risk rural areas, it is important to discourage risky activities like swimming and bathing in contaminated surface waters and to encourage safe alternatives. Public health initiatives should also incorporate appropriate domestic animal management, emphasizing the safe disposal of animal waste and minimizing interaction between children and animals. To effectively address the multifactorial causes of intestinal parasitic infections (IPIs), it is essential to establish strong coordination between the health, education, and water sectors.

Keywords: Intestinal Parasitic Infections, Intestinal Parasitic Reinfection, Risk Factors, Water, Sanitation, and Hygiene, Ethiopia.

I. Introduction

1.1. Background

Helminths and protozoa that inhabit and reproduce within the gastrointestinal tract are collectively referred to as intestinal parasites (1). Globally, parasitic infections constitute a significant portion of the infectious disease burden (2). According to estimates from the World Health Organization (WHO), approximately 3.5 billion people are affected by intestinal parasitic infections (IPIs), with around 450 million individuals experiencing clinical illness (3). The most prevalent intestinal parasites include *Ascaris lumbricoides*, *Trichuris trichiura*, hookworms, *Schistosoma* species, *Giardia intestinalis*, and *Entamoeba histolytica*. Around 10.5 million new cases reported each year (4). In Ethiopia, IPIs account for about 250,000 outpatient visits annually, according to the Ethiopian Ministry of Health (5).

Helminths (STH) infect over 1.5 billion people worldwide, or roughly 24% of the global population. In tropical and subtropical regions, particularly sub-Saharan Africa, America, China, and East Asia, soil-transmitted helminth infections are common (6). An estimated 700 million individuals are faced a problem of contracting *schistosomiasis*, which is thought to afflict around 240 million people globally (7). In tropical and subtropical nations, especially in sub-Saharan Africa (SSA), *S. mansoni* and *S. haematobium* infections are common (8). *Schistosomiasis* is one of the most common parasitic infections in Ethiopia; it is believed that over five million persons are affected and over 37 million are at risk of contracting it (9). According to various research, the prevalence of this disease ranges from 24 to 89.9% (10-12).

Hymenolepis nana is frequently called the "dwarf tapeworm" because of its small size, which is only 1 mm wide and 2-4 cm long. It is the most prevalent cestode in humans, affecting around 75 million people worldwide (13). Infections are prevalent in children in the tropics and subtropics, where they can affect up to 55% of children living in rural poverty without access to sanitary facilities or clean drinking water (14). Different regions around the world reported variable prevalence. 33% in Khartoum, Sudan (15), 17.4% in Peru (16), and 25.8% in west Tajikistan (17).

The gastrointestinal parasite worms known as *Enterobius vermicularis*, or *pinworms*, belong to the Nematode species and typically infect youngsters, though they can also infect adults (18).

Compared to the tropics, the temperate regions have a higher prevalence of this infection (19). This feature could account for the low prevalence of *enterobiasis* in Kabeta's study (20) (Ethiopia, which has a tropical environment) as opposed to the survey conducted in Erbil province, Iraq, which has a temperate climate (21).

The two intestinal protozoan infection-causing organisms that are most commonly reported globally are *Giardia intestinalis and Entamoeba histolytica/dispar* (4). Although intestinal protozoa can infect people of any age, children are more susceptible to amebiasis and giardiasis than adults (22). These illnesses are spread by human-to-human fecal-oral contact or by animals, food, or drink tainted with a protozoan cyst (23, 24)). A pooled prevalence of 25.01% for human intestinal protozoan parasite infection was reported by Dires et al. in Ethiopia (25).

An estimated 60 million persons globally are thought to be infected by *Entamoeba histolytica* (26). According to the Debre Berhan study, *Entamoeba histolytica/dispar/moshkovskii* accounted for 18.1% (27). One of the top ten parasites in humans is *G. lamblia* (28). Globally, an estimated 200 million people contract *Giardia intestinalis*. each year, and 500,000 fatalities are recorded (29). According to WHO about 500,000 new cases of *giardiasis* occur each year, primarily in children, and that 200 million people in Asia, Africa, and Latin America exhibit symptoms of the disease. In Ethiopia, schoolchildren accounted for 10–50% of reported cases of *giardiasis* infection (30). According to the Sidama zone survey, the prevalence of *Giardia intestinalis* was 27.1% (31).

Intestinal parasites affect people of all ages, although it is more common in children, who are also more vulnerable to its effects because of their developing immune systems, frequent exposure to unhygienic surroundings, and incapacity to practice adequate personal hygiene (23, 24, 32). Anorexia, vomiting, diarrhea, dysentery, and abdominal distension are among the clinical manifestations of IPIs, even though the majority of them are asymptomatic (33). Additionally, the majority of intestinal parasite infections are ignored for an extended period, leading to many adverse effects on the development of affected children. Intestinal parasitc infections have been associated with iron deficiency anemia, cognitive impairment in school-age children, stunted growth, malnutrition, increased morbidity, and adverse impacts on psychomotor and language development in preschool-aged children (34-38). These consequences contribute

not only to the disease burden but also to the continuation of poverty. Children are particularly vulnerable to the impacts of IPIs, as this stage of life is critical for both physical and mental development and IPIs can impair nutrient absorption, leading to malnutrition, and weakened immune response (32,38,39).

IPI distributions are frequently associated with various factors, such as access to inadequate sanitation and hygiene (40). Even though the infection was global, it caused a significant public health burden on people living in nations with inadequate sanitation and hygiene standards (41). Of the 2 billion people globally without access to adequate sanitation facilities, 799 million lived in sub-Saharan Africa. Of the 673 million people who defecate in the open globally, 229 million live in sub-Saharan Africa, where only 15% of people have access to soap and water for handwashing (42). Over 43 million people did not have access to handwashing facilities, according to the 2016 Ethiopian Demographic and Health Survey. Additionally, 94% of Ethiopian families used unimproved sanitation, 9% shared facilities, 53% used unimproved facilities, and 32% had no facilities (43). IPIs are largely caused by poor hygiene practices because intestinal parasites are primarily spread through the fecal-oral route (44). Microbiological contamination of water occurs in the context of poor waste management, including feces (45)

People's health is still at risk because of poor drinking water quality (46). The presence of harmful microorganisms in drinking water is another major public health concern in many developing countries. A variety of factors can lead to a decline in water quality, and human waste is one of the many sources of contamination (47, 48). Appropriate human health and well-being depend on water of both acceptable quality and sufficient quantity (46).

Water of both acceptable quality and sufficient quantity is critical for proper human health and well-being (46). Human health is impacted by water quality. People's health is still in danger due to inadequate drinking water quality (47). The potential for dangerous microorganisms in drinking water is another significant public health issue in many developing nations. Numerous factors can cause the quality of water to decline. Human waste is one of the several sources of contamination (47, 48). Over half of the 700 million people who lack access to a safe water supply live in sub-Saharan African countries, including Ethiopia. In developing countries, more

than 80% of the disease burden is associated with poor drinking water quality, mainly due to contamination from unsanitary conditions. According to a World Health Organization report (WHO), an estimated 1.8 billion people rely on water contaminated with Escherichia coli (E. coli) (49). Research has demonstrated that drinking water in underdeveloped countries is frequently contaminated during collection and storage in homes (50, 51). In Ethiopia, only 57% of the population has access to improved drinking water sources, while 42% still lack access to clean water, according to the World Factbook. Open defecation and the sharing of water sources with animals are widespread, particularly in rural communities. Moreover, only 28% of the population has access to improved sanitation services, and point-of-use water treatment practices remain low (52,53).

In rural areas of most developing countries, bacterial contamination of drinking water is a significant source of waterborne disease. The problem is particularly severe in third-world countries due to deteriorating environmental conditions caused by high levels of open defecation (54). Ethiopia has some of the world's poorest toilet coverage and drinking water quality (47,48). Therefore, assessing the microbial quality of point-of-use drinking water quality and its relation with IPIs is essential.

If there is insufficient water, hygienic, and sanitation conditions, children may live in an endless cycle of infection and reinfection (55). Reinfection is naturally related with elevated levels of infectious cyst contamination of the environment in unsanitary settings (56). Recurrent parasite infections can have detrimental result that can be passed down to coming generations, proceeding in a poverty and unhealthiness cycle that never ends (57). Scholars, decision-makers, and the affected people will all be better able to comprehend the severity and extent of the issue if they have a better understanding of the prevalence of IP reinfection and IPIs. Childhood infection and reinfection rates of intestinal parasites remain a critical public health concern, indicating the need for a more comperhanseive understanding of the underlying contributing factors. Implementing effective mitigation strategies or developing sustainable intervention requires localized insight into the predictors of these issues. Therefore, the general objective of this study is to assess the role of water, sanitation, and hygiene cconditions in the infection and reinfection of childhood intestinal parasite in the rural Dire Dawa, Eastern Ethiopia.

1.2. Statement of the problem

Public health in underdeveloped countries is significantly impacted by parasite illness. Intestinal protozoan and helminthic illnesses are among the predominant IPIs in people (58). Diarrhea is more commonly caused by intestinal parasites and bacterial pathogens than by viruses in underdeveloped nations, and intestinal protozoa contribute considerably to the worldwide burden of infectious sicknesses (59). Among children in Mozambique who had diarrhea, the intestinal protozoa *Giardia intestinalis* and *Entamoeba histolytica* were the second and third most commonly identified pathogens, respectively (60). Diarrhea is caused by protozoan parasites in 1.7 billion cases worldwide (61). Numerous infectious illnesses developed from pathogenic intestinal protozoa, soil-transmitted helminths, and parasitic worms like Schistosoma clustered under a class of NTDs (62). Despite the enormous efforts of the health ministry, intestinal parasite infections are yet recognized to have a significant effect on Ethiopians' people (63).

IPIs and reinfection are significantly influenced by access to poor water, poor sanitation, and insufficient hygiene (40). Ninety four percent of Ethiopian households use unimproved sanitation, 9% share facilities, 53% use unimproved facilities, and 32% have no facilities, according to the 2016 Ethiopian Demographic and Health Survey (43). Water quality has an impact on human health. Various sources can harm water quality, and water is highly susceptible to pathogens because it travels a great distance from its source to its site of use and might become contaminated at any number of locations (64). Feace is one of the different contaminant sources (9). In rural areas, in addition to the high practice of open-area defecation, water sources are poorly protected and commonly shared by people and animals. Because of this, pathogens can quickly get into water sources, and contamination has become common in the area. Therefore, ensuring microbial drinking water quality is crucial, as poor sanitation and open defecation are common (65). Also, enteric pathogens are primarily fecal in origin and are spread by drinking water (66,67). Therefore, conducting microbial drinking water quality testing is crucial where poor sanitation and open defecation are common.

Although intestinal parasite affects persons of all ages, it is more common in preschool and school age children. Due to their undeveloped resistant systems and frequent exposure to unhygienic surroundings, children the most essential age for physical and cognitive development

are particularly susceptible to intestinal parasite infections (68). IPIs can cause both carnal and intellectual problem due to their adversary results, which also embrace dietary matters (69). The magnitude of intestinal parasitic infections (IPIs) and related issues among Ethiopian school-age children has been widely studied. According to Chelkeba et al. (70), in Ethiopia, 52% of school-age children and 30% of preschool-aged children were found to have intestinal parasites infections. While this study highlighted the high of prevalence of IPIs among Ethiopian children, it also reported a lack of data from certain regions of the country, including the current study area. This underscores the importance of conducting localized surveys that assess both infection and reinfection rates, particularly in relation to key predictive factors such as water, sanitation, and hygiene (WASH) conditions. Targeting vulnerable groups is especially critical due to their increased susceptibility.

Infection predisposes one's health to reinfection. Treatment does not avert subsequent infection (71). Reinfection depends on multiple factors (72). unhygienic behavior and insanitary situations can carry to a lifelong cycle of illness and reinfection in children (55). Recurrent PI can result harmful consequences that are transmissible to subsequent generations, creating a vicious cycle of sickness and poverty (57). The majority of studies on the reinfection of PI in Ethiopia have focused on *Schistosoma* and STH (56,73,74). Dires et al. observed a pooled frequency of 25.01% for intestinal protozoan infection in peoples (25). Additionally, cross-sectional designs were used in the majority of Ethiopian investigations on parasite infection. It is crucial to investigate the main causes of IPI and reinfection at the population level utilizing analytical study designs because these conditions are inherently connected to a number of causes and impacting factors.

The magnitude of IPIs and related issues in Ethiopian school-age children have been the subject of numerous studies. However, one systematic investigation noted that there is a lack of data regarding the frequency of IPIs in the studied area (70). Conducting a survey on IP infection and reinfection in collaboration with the main predicting factors, like WASH, among vulnerable groups like school and preschool-age children is vital to have a better picture and take better measures in tackling the infection.

The region's economy is mainly based on agriculture and animal husbandry, which raises the risk of contracting IPIs via various agricultural tasks, handling animal waste, or coming into direct

contact with afflicted domestic animals. For drinking water, the local populace relied on several unimproved sources. Also, as in many other Ethiopian rural areas, sharing water sources with animals and open field defecation is common. Since most intestinal parasite infection is spread through the fecal-oral route, all these conditions create fertile ground for the occurrence and reoccurrence of IPIs. So, the current study aims to investigate the magnitude of IPI and reinfection, identify prevalent parasites, and quantify associated risks.

1.3. Significance of the study

The findings from this study are expected to strengthen the existing evidence on intestinal parasitic infections (IPIs) and reinfections in the country. By generating updated and localized data, the study will assist health planners, policymakers, and administrators in designing and implementing evidence-based interventions and preventive strategies to mitigate both the health and economic impacts of IPIs and reinfections. A critical contribution of this study is its ability to fill important knowledge gaps in regional data, as previously noted by one systematic review study (70). The study is conducted in a region where information on IPIs has been limited, making its findings particularly relevant for targeted public health interventions.

This study offers valuable insights into local WASH conditions and their associations with both IPIs and reinfection rates. As a result, it provides robust evidence on WASH-related IPI and reinfection outcomes in the study area, supporting the formulation of context-specific strategies to control infection, transmission, and reinfection.

Most previous reinfection studies in Ethiopia have employed a cross-sectional design (56,73,74). Additionally, many studies assessing the relationship between intestinal parasitic infections (IPIs) and water quality have relied primarily on questionnaire-based methods, often using self-reported data. In contrast, although a single water sample was collected, the present study incorporated a laboratory-based investigation of point-of-use water quality to assess microbial contamination, conducted in parallel with stool examinations. Moreover, a case-control study design was employed, offering a stronger ability to determine the direction of associations compared to cross-sectional approaches. Data on water-related sanitation and hygiene practices were also collected using structured questionnaires. This integrated methodology enabled a more precise and comprehensive identification of the direction and strength of associations among multiple variables.

As the study population comprises children under the age of 14, who are among the most vulnerable to IPIs and reinfections, the study aligns with WHO recommendations targeting both preschool- and school-aged children. As such, its findings will contribute directly to the development of effective, age-specific policies and intervention strategies.

In general, the outcomes of this research are expected to enhance awareness among health professionals, policymakers, and communities regarding the public health implications of IPIs and reinfections; guide the development of sustainable and localized interventions; serve as a foundation for future research, and support the creation of sustainable and impactful public health programs in the study area and similar settings.

1.4. Scope of the research

This study designed to determine the prevalence of intestinal parasitic infections (IPIs) using both field- and institution-based stool examinations and to identify key determinant factors, with a focus on sanitation and hygiene-related conditions. It also examined the association between IPIs and microbial water quality by comparing stool test results with microbial contamination levels in household drinking water. Furthermore, the study assessed the prevalence of IPI reinfections and identified predictive factors, particularly sanitation and hygiene-related variables.

The research was conducted across nine rural kebeles: Bishan Behe, Biyoa Wale, Genderege, Harlabelina, Hululmojo, Koiso, Lege Aneni, Legehare Legedol, and Wahil. Data collection involved face-to-face interviews using a pretested, structured questionnaire and laboratory-based diagnostic tests. Fecal specimens were collected from all participants.

In addition, water samples were collected from the participants' household point-of-use water sources for microbial analysis. The study focused on children age with1-14 years considered highly vulnerable to IPIs and employed a quantitative research methodology.

2. Research questions/Hypothesis

2.1. Research questions

This research is designed to address the following questions

1. What is the magnitude of childhood intestinal parasitic infections and the associated risk factors to sanitation and hygiene practices in rural Dire Dawa, eastern part of Ethiopia?
2. Is the microbial quality of drinking water and other water related issues associated with childhood intestinal parasitic infections in rural Dire Dawa, Eastern Ethiopia?
3. What is the prevalence of childhood Intestinal parasitic reinfection and the associated risks to sanitation and hygienic practices in rural Dire Dawa, Eastern Ethiopia?

2.2. Research Hypothesis

Ha 1: Hygiene practices are more strongly associated with the risk of childhood intestinal parasitic infections (IPIs) than sanitation conditions.

Ha 2: There is a significant association between the microbial quality of household point-of-use drinking water and the prevalence of IPIs in children.

Ha 3: Hygiene practices have a greater influence on the risk of childhood intestinal parasitic reinfection than sanitation conditions.

3. Objectives of the Study

3.1. General objective

The general objective of this research is to investigate water, sanitation, and hygiene role in childhood infection and reinfection of intestinal parasite in rural Dire Dawa, Eastern Ethiopia

3.2. Specific objectives

3.2.1. To assess the prevalence of IPIs among children aged 1-14 years and identify associated risk factors related to sanitation and hygiene practices at the community level (objectiveI).

3.2.2. To examine the microbial quality of household point of use drinking water to evaluate its association with the prevalence of IPIs among 1-14years age children (objective II).

3.2.3. To determine the six-month reinfection rate of IPIs among previously treated children and to association between the relationship reinfection and their sanitation and hygiene practices. (objective III).

4. Literature Review

4.1. Overview of Intestinal Parasites

Gastrointestinal parasites are the organisms that inhabit the gastrointestinal region of humans or other organisms. Helminthes and protozoa are two common intestinal parasites of small and large human intestines. The high prevalence and global distribution of intestinal parasite infections, particularly in individuals from tropical and subtropical regions of the poor world, make them a global public health concern (58). As a result of factors like poverty, uneducated, unhygienic practice, scarcity of potable water, and a hot, humid tropical climate, IPIs are more common in countryside of Ethiopia (75,76). Protozoans (such as *Entamoeba histolytica* and *Giardia intestinalis*) and helminths are among the most significant causative agents; the WHO reported soil-transmitted helminths (STH) as one of the NTDs (77).

4.2. Intestinal protozoan parasites

Protozoan parasites consist of a single cell-like unit that is morphologically, functionally complete, and widely distributed (78). Around 6,500 known species of protozoa, 10,000 of which are parasites. The protozoa perform the reproduction either by asexual or by sexual method. Enteric protozoa, which causes human illness, is usually transmitted through food and drink. Enteric protozoan parasites are essential causes of diarrheal disease, especially among children in developing countries (79).

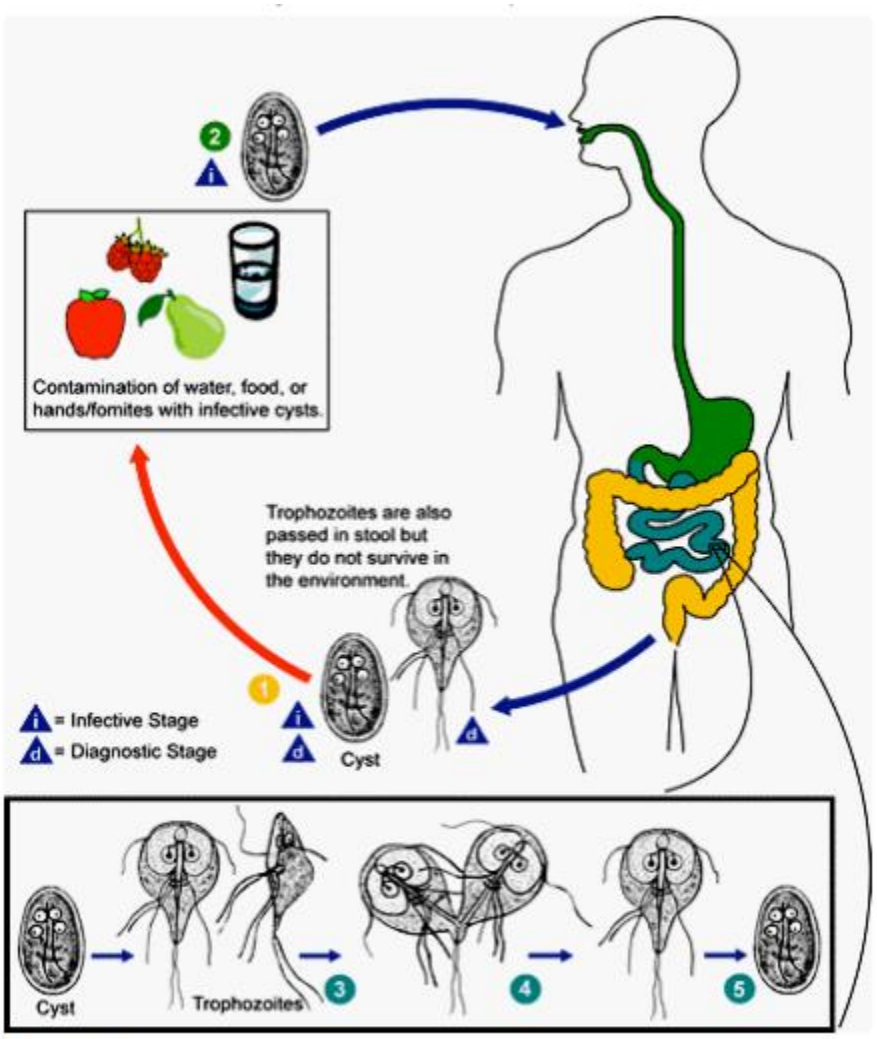
4.2.1. *G. Intestinalis*

Giardiasis is caused by *Giardia intestinalis*, the only pathogenic intestinal flagellate that infects humans. There are two morphological forms: trophozoite and cyst. The trophozoite is an invasive stage of the parasite that is actively motile and inhabits the villi of the small intestine. The cyst is an inactive, non-motile, and non-invading parasite stage responsible for transmitting the disease to others through the fecal-oral route. Giardiasis is acquired by ingesting infective cysts with contaminated food, drink, finger, etc. Giardia intestinalis, sometimes referred to as Lamblia intestinalis, Giardia duodenalis, or Giardia lamblia.

It is distributed worldwide and has the highest prevalence in the tropics and subtropics. It is reported in all age groups but is highly prevalent in children (78).

Numerous domestic and wild animal species and humans have *Giardia* organisms in their digestive tracts. It can be present in contaminated wells and water systems, especially in stagnant water sources, such as naturally occurring ponds, storms, water storage systems, and even clean-looking mountain streams. Intestinal parasitic infection symptoms vary from none to severe diarrhea with poor absorption of nutrients. It results in weakness, loss of appetite, stomach cramps, vomiting (uncommon), bloating, and excessive gas (80).

Figure 1. Life cycle of *Giardia intestinalis*



Source: CDC

4.2.2. *E. histolytica*

Entamoeba histolytica, the only pathogenic *Entamoeba* species, causes amoebiasis. It comes in two morphologic forms: cyst and trophozoite. The parasite's motile and invasive stage is known as the trophozoite form. In the human large intestine, it typically exists as a commensal that eventually differentiates into cyst forms after multiplying via asexual binary fission. By the fecal-oral pathway, the sickness is diffused to other people by the cyst form, an inactive, non-motile, non-invading stage of the parasite. Amoebiasis is acquired by ingesting infectious cysts through water or undercooked food contaminated by human feces. After consuming the cyst, which is resistant to gastric acids and enzymes, excystation occurs in the intestine to form trophozoites (81).

Patients with symptoms first experience diarrhea and lower stomach pain, and then they develop dysentery, which is characterized by blood and mucus in the stool. Fresh blood in loose stools is a hallmark of amoebic colitis with dysentery. The patient typically has mild to moderate stomach ache and is otherwise healthy. Over weeks or even months, the patient's symptoms frequently change and become incapacitating. Stool microscopic analysis is a common diagnostic practice (82).

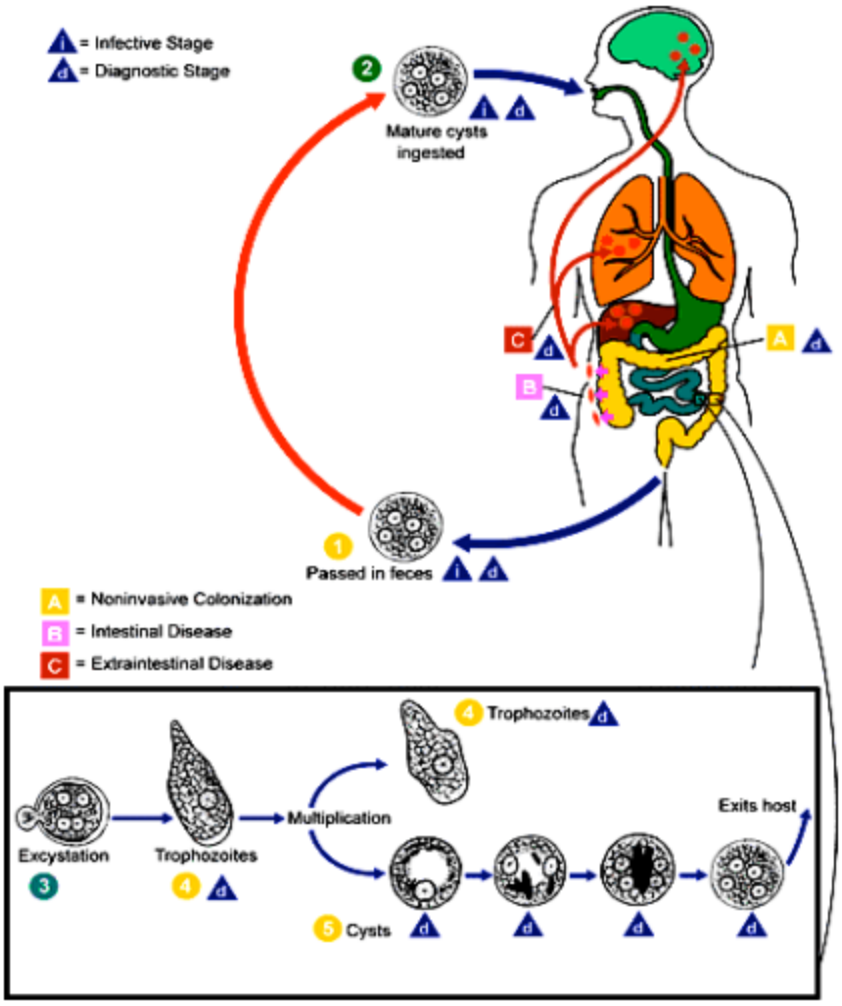


Figure 2. Life cycle of *E. histolytica*

4.3. Intestinal helminths parasites

The helminth parasites are multicellular, bilaterally symmetrical, elongated, flat, or round animals. Helminths have one or more intermediate hosts. They are classified into two phyla: Platyhelminthes and Nemathelminthes. Platyhelminthes is further divided into Class Cestoda and Trematoda, while Nemathelminthes has only one class. Some common helminth parasites are *H.nana*, *Enterobious vermicularis*, and *Schistosoma spp* (83).

4.3.1. *Hymenolepis nana* (dwarf tapeworm)

It is the smallest tapeworm infecting humans. It causes a disease called Hymenolepiasis. By fecal-oral transmission, this infection can spread directly from one infected individual to another

without an intermediary host. Infection is most common in dry, warm regions of the least developed world. *H. nana* infection impact millions of individuals, mainly children, worldwide. When *H. nana* eggs are passed with stool, they become infectious immediately and cannot last in the outside environment for longer than ten days. Cysticercoids, formed when an arthropod intermediate host consumes ova, can infect people or rodents when consumed and mature into adults in the small intestine. The disease's symptoms include diarrhea, irritation, itching around the anus, loss of appetite, and abdominal pain. The diagnosis is confirmed by looking for parasites and ova in the stool (83).

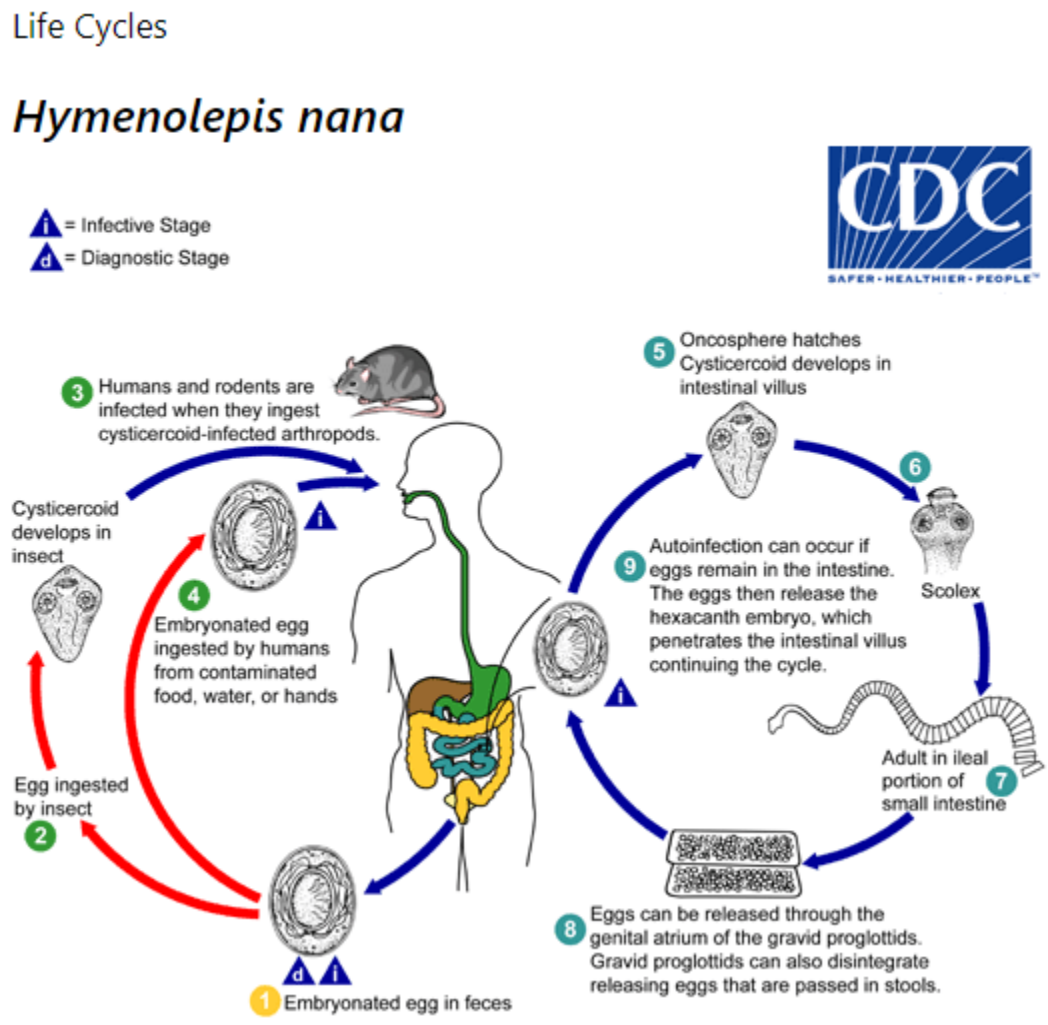
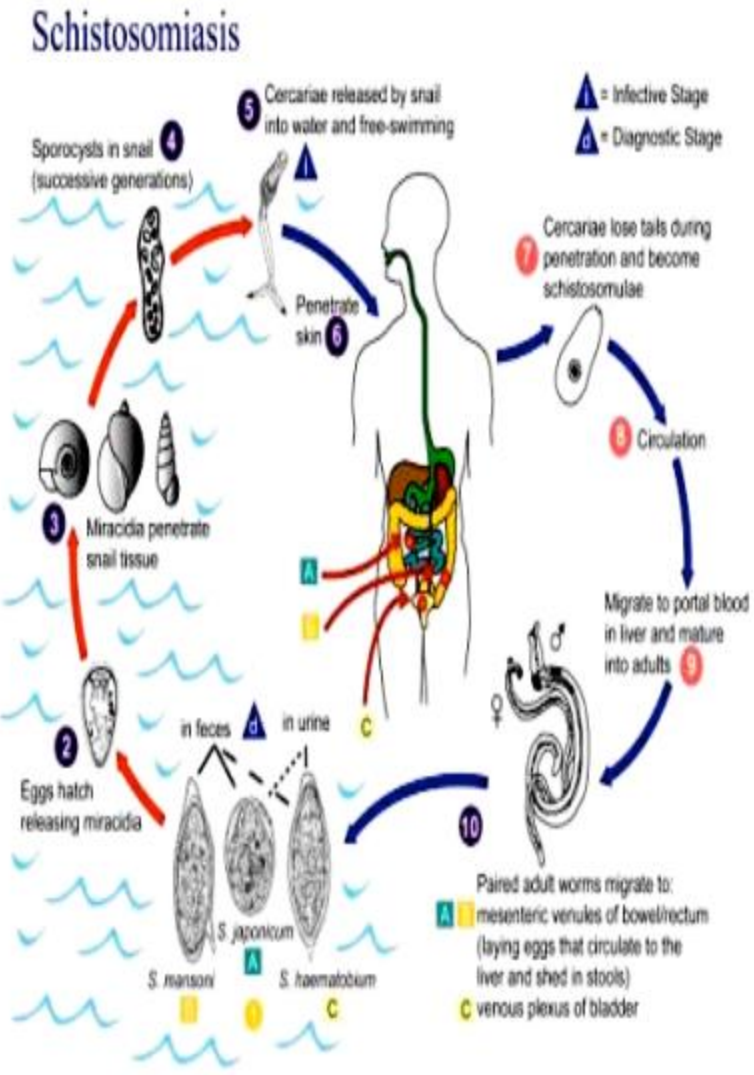


Figure 3: Life Cycle of Hymenolepis Hana

4.3.2. Trematodes (flukes)

Many *Schistosoma* species bring on a trematode disease called schistosomiasis. Six trematode species *Schistosoma guineensis*, *S. haematobium*, *S. intercalatum*, *S. japonicum*, *S. mansoni*, and *S. mekongi* cause schistosomiasis. The two most common causing organisms are *S. mansoni* and *S. haematobium*. *Schistosome* transmission necessitates using a specific freshwater snail as the intermediate host, water contaminated by feces or urine containing ova, and when the body comes into contact with water tainted with infectious cercariae, infection results. However, *S. mansoni*, which causes intestinal schistosomiasis, is the most significant species. It is the widest speared of the human-infecting schistosoma and is present in 54 countries. These countries are predominantly in South America and the Caribbean, Africa, including Madagascar, and the Middle East, and have poor sanitation. Because of the parasite's fecal-oral transmission, bodies of water that contain human waste can be infectious. Infection is more likely to occur in water with high intermediate host snail species concentrations. Due to their propensity to wash and swim in cercaria-infected waterways for more extended periods than adults, young children in these places are most in danger. The identification of eggs in feces validates the diagnosis of infection (84).



Source: CDC

Figure 4. The life cycle of *Schistosoma*

4.3.3. Enterobius

The pinworm (*Enterobius vermicularis*) is also another parasitic roundworm. The eggs of threadworms enter the gastrointestinal system of the humankind via the fecal-oral route. The lifecycle of *E. vermicularis* begins with eggs being ingested; once ingested, the eggs hatch in the small intestine, and the threadworms copulate. The male worms soon die, while the females reside in large numbers in the caecum, appendix, and ascending colon. While the host is at rest, typically at night, the female threadworms migrate out of the anus and lays eggs in the peri-anal

region. The resulting pruritis leads to scratching of the peri-anal region, contaminating the hands with eggs and supporting fecal-oral transmission. Finger-sucking and nail-biting have been shown to increase both the incidence and relapse rates of enterobiasis. When dust-carrying eggs are removed from surfaces, they become airborne and extensively distributed. As a result, the eggs can be inhaled through the mouth and nose and then ingested. The female worms live in significant numbers in the caecum, appendix, and ascending colon, but the males quickly perish. While the host is at rest, typically at night, the female threadworms migrate out of the anus and lays eggs in the peri-anal region. The resulting pruritis leads to scratching of the peri-anal region, contaminating the hands with eggs and supporting fecal-oral transmission. It has been demonstrated that enterobiasis incidence and relapse rates are increased by finger-sucking and nail-biting. When dust-carrying eggs are removed from surfaces, they become airborne and extensively distributed. As a result, the eggs can be ingested after entering the mouth and nose through inhalation (85,86).

The diagnosis of pinworms depends on finding eggs or adult worms. A low-power microscope can see the individual eggs, which are invisible to the unaided eye. However, the adult pinworms, which resemble light-yellowish threads, are easily visible, usually at night when they travel close to the anus or on toilet paper. Enterobiasis is a medical disorder linked to pinworm infection. A third of people infected with pinworms have no symptoms at all. Itching in and around the anus and perineum are the primary symptoms (87).

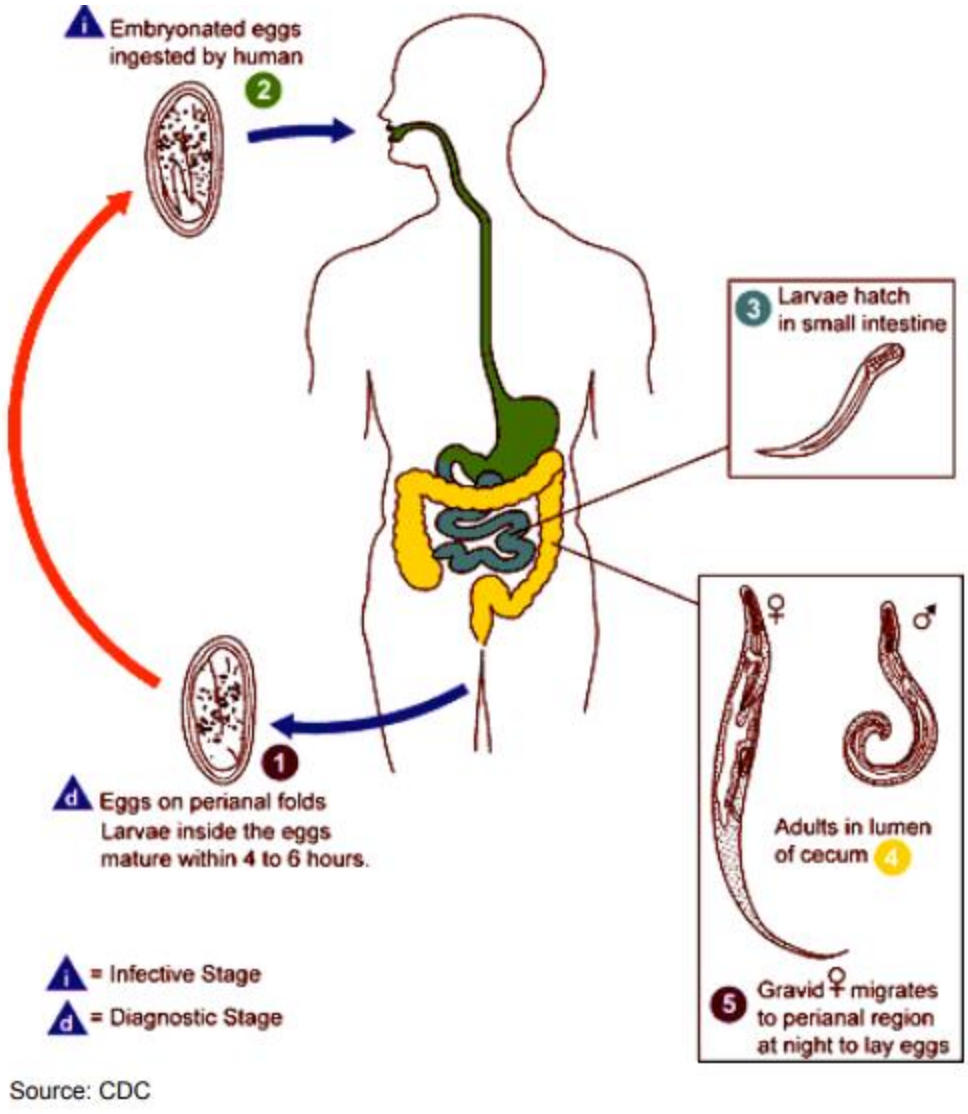


Figure 5. The life cycle of *Enterobius Vermicularis*

4.4. Prevalence of intestinal parasitic infections

The Centers for Disease Control (CDC) reported that intestinal parasite infections are extensively dispersed all over the world (88). A class of illnesses known as intestinal parasitosis is brought on by one or more types of nematodes, cestodes, trematodes, or protozoa (89). Numerous infectious diseases brought on by certain species on the above list are regarded as Neglected Tropical Diseases (NTDs) (90).

4.1. International context

The study conducted in Colombia among rural school children revealed that the frequency of IPI was 100%. *Endolimax nana* (77.35%), *Blastocystis sp*. (71.1%), *Giardia intestinalis* (39.1%), *Entamoeba coli* (25.7%), and the *Entamoeba histolytic a/dispar/moshkovskii* complex (9.2%) were the most prevalent protozoa. *Trichuristrichiura* was the most pervasive helminth (12.3%), followed by *Enterobius vermicular* (6.15%) and *Ascaris lumburicoides* (5.1%) (91).

The survey conducted in Kathmandu, Nepal, the magnitude of IP was 12.4% (24/194), and students were diseased with IP. The most common protozoan and helminth parasites detected in this study were *E. histolytic* a (33.3%, 8/24) and *Taenia spp.* (16.7%, 4/24) respectively (92).

According to a similar cross-sectional study in Southern Iran, the magnitude of IPI was 6.5%. Compared to helminth infections (0.3%), the prevalence of protozoan infections (6.2%) was substantially greater. *Blastocystishominess* (n = 2.1%) and *Giardia lamblia* (n = 2.9%) were the most prevalent protozoan species. Only two cases of *Hymenolepis nana* and two cases of *Enterobius vermicular* were detected (93).

The magnitude of IPs was 52.5% in the other study, which was carried out in the Uzo-want, Nigeria. *Hookworm*, *A. lumburicoides*, *T. trichuria, E. histolytic*, and *G. lamblia* were the parasites identified; their respective prevalences were 14.0%, 11.5%, 10.5%, and 8.5%. *G. lambilia* had the least prevalence (8.5%), whereas *hookworm* and *A. lumburicoides* had the utmost (14.0%) (94).

The other study conducted in a countryside area of Beheira Governorate, Egypt, discovered the overall prevalence of IP among primary school children reached 38.3% (27.8% in males and 10.5% in females) with a prevalence rate of (22.5%), (12.8%) and (3%) for helminths, protozoa, and mixed infections respectively. The identified parasites were *E. vermicular* is (11.8%), *H. nana* (7.2%), *G. lamblia* (6.8%), *E. histolytic a/dispar* (6%), *S. mansoni* (1.7%), *A. lumbricoid* (1.2%), *T. trichiura* (0.3 %) and *S. haematobium* (0.3 %) while mixed infection reached (3%) (95). According to a related investigation carried out in Khartoum, Sudan's AlhagYousif Area, 84% of stool specimen tested positive using the Formol-Ether Concentration method (22).

4.4.2. National context with regional variation

In Ethiopia, intestinal parasitic infections (IPIs) remain a significant public health concern, particularly among children. According to Aleka et al. (2020), the nationwide pooled prevalence of IPIs is estimated at approximately 48.2%, indicating a substantial burden of infection. The most prevalent parasites include Ascaris lumbricoides, Trichuris trichiura, hookworms, Giardia intestinalis, and Entamoeba histolytica/dispar (96).

Significant regional variations in the prevalence of intestinal parasitic infections exist in Ethiopia, influenced by socioeconomic factors, environmental conditions, and access to water, sanitation, and hygiene (WASH) services. For example, in the Amhara region, prevalence rates among rural primary school children often exceed 60% (97). In the Oromia region, reported prevalence ranges widely from 30% to 70%, with higher rates observed in areas with poor sanitation (98). The Southern Nations, Nationalities, and Peoples' Region (SNNPR) reports prevalence rates between 40% and 65%, where protozoan infections such as Giardia and Entamoeba are particularly common in areas with inadequate water quality (99). Another similar study in Addiremets town, western Tigray, Ethiopia, found that the altogether prevalence of IPs was 51.3% (211/411). Hookworm (23.1%) and S. mansoni (26.3%) were the top commonly identified parasites. Intestinal parasites were present in 54.1% of males and 47.3% of females, respectively (100).

At Dona Berber Primary School in Bahir Dar, Ethiopia, a cross-sectional study was carried out among the students. 65.5% of the schoolchildren who took part in the study had an IPIs. Students had a 49.6% single PI rate and a 16.2% double PI rate. *E. histolytic a/dispar* was the top commonly identified parasite in the survey (24.5%), with hook worm coming in second (22.8%) (101).

According to a cross-sectional study done in northwest Ethiopia, 57.88% of students who checked their stool tested positive for mono and double PI. Around forty-two percent (41.9%) of people had mono infection, 6.2% had a double infection, and 1.2% had a triple infection. *Giardia lambilia* was the top dominant (19.95%), tracked by hookworm (13.8%), *Schistsoma mansoni* (10.3%), Entamoeba histolytic a/dispar (5.9%), *Hymenoleps nana* (4.2%), *Taenia species* (3%), and *Ascaris lumbricoid* (0.73%) (102).

Out of 172 fecal samples, 78 (45.3%) of the students at Merawi primary school confirmed positive for various IPs, with *E. Histolytic/dispar* 68 being the top common parasite, making up 70.8% of the total. *Giardia lambia* 18 (18.8%), *Taenia saginata* 5 (5.2%), *Ascaris lumbricoides* 2 (2.1%), *Hook worm* 2 (2.1%), and *Trichuris trichiura* 1 (1.1%) were next in line. Of the 78 children who tested positive, 18 (18.8%) had mixed illnesses, with *Giardia lambia* and *E. histolytic* being the commonest parasites in mixed infections (103).

4.5. Predictors of intestinal parasitic infection

4.5.1. Sociodemographic characteristics

Children's intestinal parasite infection was linked to a variety of factors, including sociodemographic traits including gender, education level, school location and others. According to a study done in the AlhagYousif Area of Khartoum, Sudan, male children were highly exposed when compared to female children to have IP (80% vs. 60%). Additionally, children who found in the 5–7 age group (5%) were highly exposed than the others age groups (104).

Unlike study in Negelle Borena General Hospital reported that intestinal parasites were more prevalent in females than males (P < 0:05). According to this study, females are more vulnerable because, In Ethiopia, females are primarily involved with child care in the home, house cleaning, processing of raw fruits and vegetables, and cleaning of the home compound and clothes more than males. consequently, females are relatively highly susceptible to contaminated soil and water, a major predisposing factor for female infection. Also, the above study's result indicated that the infection's highest prevalence was detected in the age groups ranging from 6 to 10 years in cases (71%) (105).

Another study from White Nile State, Sudan, on Prevalence of Intestinal Parasitic Infections and Associated Risk Factors among School Children in 2019 indicated that the most infected age group was (10-13) with prevalence of 43% (108/253). Females were more infected than males, p-value=0.0001(106). Males were somewhat more likely compared to females to contract S. mansoni, according to a study done in Addiremet town, Ethiopia. Gender and infection did not differ statistically significantly in terms of S. mansoni infection occurrence (P>0.05). According to this study men are more likely to have the infection because they spend more time outside, swim more frequently, and take baths in water bodies infested with cercaria (99).

According to a study by Tigabu et al. from northwest Ethiopia on the magnitude and related variables of IPIs among patients attending Shahura Health Center, male gender was substantially linked with intestinal parasite infections (P=0.049). According to the study, one potential explanation could be that men participate in farming activities at a higher rate than women, exposing them to greater levels of animal interaction, water-body contact, and soil contamination (107).

According to the Jayarani K et al. survey, school-age children had greater frequency of IPIs compared to preschool-aged children (108). Daryani et al.'s meta-analysis study on IPIs in Iranian preschoolers and schoolchildren revealed alike finding (109).

According to a study from southern Nigeria school age children bear the considerable load of IP related morbidity because of their behavior like playing on soiled ground, eating with unclean hands, using unsanitary toilets, and consuming contaminated water and food, in contrast to preschool-aged children who are typically cared for by families (110).

4.5.2. Socioeconomic factors

Pinworm parasites, which thrive in environments with close human-to-human contact, are commonly spread under crowded living conditions (111). A study on intestinal parasitic infections (IPIs) and associated factors among students in three rural Colombian schools found that those living in overcrowded households defined as six or more people living together were significantly more likely to be infected with IPIs(91).The multivariable logistic regression analysis from Debre Berhan town, Northeast Ethiopia, also revealed that the following factors were included (P<0.05) among the significantly associated variables: paternal uneducated, urban-farmer father, manual-worker father, mother's illiteracy and primary education, and family size (above 5). Because children in large families typically receive suboptimal care and have resources scarcity than children in small families, family sizes greater than five were substantially related to IPIs (112).

Large family size was identified as a primary contributing factor, with a significant connection in a 2018 survey carried in Boricha District on the prevalence and issues related to IPs in children aged 6months to 5years. Intestinal parasite infections were positively correlated with children living in larger families (more than eight) compared to those living in smaller families. This

study suggests that this could be because an overcrowded family environment mount the risk of parasite spread. Parents might also lack the time necessary to care for their children (113).

Intestinal parasite infection and family size were shown to be highly correlated in Hailegebriel's 2017 cross-sectional study on the occurrence of intestinal parasite infections and predicting factors among students at Dona Berber Primary School in Bahir Dar, Ethiopia. The likelihood of contracting IPs was approximately five times higher for students with family sizes more significant than five than for those with smaller families. The study's explanation suggests that this association may be linked to environmental sanitation, personal hygiene, and other nutritional issues. Overcrowding, inadequate sanitation, and poor personal hygiene may arise as family sizes rise. Family members may become more susceptible to parasitic illnesses as a result, creating an atmosphere that is favorable for the spread of parasites (101). Similar findings were observed by many investigations (114). Certain jobs, like as farming, need regular interaction with soil and exposure to pollutants in the environment. This raises the possibility of contracting helminth infections, which are spread by coming into touch with tainted soil (40).

The presence of intestinal parasite infection in parents/guardians of pupils with poor educational attainment was one of the characteristics with the largest statistically significant differences in a study conducted in southern Ethiopia. There was a statistically significant difference ($p < 0.05$) in the risk of intestinal parasite infection among children between household heads with higher educational levels and those who could not read or write, as well as those who could only read and write (115). Several studies revealed alike outcome (116,117).

The study by Princess Nora Bint Abdul Rahman University in Riyadh, Saudi Arabia. Moderate in 2015, socioeconomic status, working mothers, and parents' literacy were all significantly related to IPIs risk variables in the region (118). According to a 2018 school-based study on the frequency of intestinal parasitosis and water, sanitation, and hygiene situations among primary school students in Dessie City, Ethiopia, the occurrence of IPIs was significantly related with the maternal education level (AOR = 3.3; 95% CI: 1.20–9.37), paternal education level (AOR = 3.9; 95% CI: 1.40–10.82), and paternal reading and writing skills (AOR = 3.3; 95% CI: 1.25–7.86) (119).

The educational attainment of family members was linked to intestinal parasite infections in children, according to a study conducted in northwest Ethiopia. Childhood PIs were higher

among families with no members whose education status was secondary and above. The investigator explains the result by stating that educated households may know about infectious disease transmission and prevention methods. Education encourages changes in healthy behaviors at the household level (120).

The results of this investigation also showed that the occurrence of IPIs was negatively correlated with maternal education. Compared to children of mothers with secondary education, children of unschooled mothers had 13.1 times increased odds of having IPI (aOR= 13.1, P=.02). This could be because women with better literacy have a good impact on their children's health associated issues (121).

4.5.3. Behavioral factors

Sitotaw et al.'s study on IPI prevalence and predictive factors found that various shoe-wearing habits were substantially ($p < 0.001$) linked with the occurrence of IPIs. Furthermore, the incidence of IPIs varies significantly ($p < 0.005$) among people with varied eating habits for unwashed fruits and vegetables, contact with river water (often, always, or never), and clean fingernails. Children who frequently came into touch with water, ate raw vegetables and unwashed fruits, wore no shoes, and had dirt in their untrimmed fingernails were shown to have high prevalence rates of IPIs (102).

The traditional reply to fallen diet (cleaning and ingestion; "kiss and replace"), the custom of playing with tainted water, the practice of playing with soil, the trend of sucking unclean fingers, and the trend of consumption while playing were factors correlated with the occurrence of intestinal parasitic infections ($p<0.05$), based on a 2021 study carried out in the northeastern Ethiopian town of Debre Berhan by Hailu and Ayele. The risk of acquiring an IPI infection was found to be around eight and six times higher, respectively, for children who engaged in these behaviors than for those who did not. Similarly, youngsters who licked their pen caps or fingers were nearly four times more likely to get an IPI infection than children who didn't. youngsters who ate while playing were almost three times more likely to get IPIs than youngsters who did not follow the norm. In the survey area, it is typical for children to eat snacks while playing outdoor in the late afternoon. In addition to increasing the risk of direct dirt or waste contamination of their hands or food, this exercise may eventually cause them to swallow the ova or cyst. The study found that the cultural response to food being fallen was the main risk factor

that had a strong correlation with IPIs. The likelihood of acquiring IPIs was around eleven times higher in youngsters who practiced cleaning and consuming food that had fallen than in their peers. There may be a connection between this and the contamination of falling food with soil that contains parasite ova or cysts, which increases the danger of consuming the infections (27).

Alemu G et al. carried out a survey on intestinal helminths and related factors three years after southern Ethiopia began mass medication delivery. They discovered a strong link between swimming habit and intestinal parasitic infection (122). Another cross-sectional investigation from health institute on the incidence of intestinal parasites and predictor factors, northwest Ethiopia, indicated that swimming and wearing fewer shoes were substantially associated with S. mansoni and hookworm infections, respectively. The incidence of S. mansoni was higher among study participants who regularly swam (18.9%) than among those who did not. This can indicate that there are contaminated water sources in the study area (123).

Using multivariate analysis, the findings of the study on Schistosoma mansoni infection and related predictors among schoolchildren in Northwest Ethiopia, indicated that frequent swimming and swimming in the river were related to *S. mansoni* infection ($P < 0.05$). Children who swam in the river had 5.12 times (CI: 3.47, 17.89) greater odds of contracting disease with *S. mansoni* than those who did not have a swimming habit. School children who had a swimming frequency of three or more times per week had 4.83 times (CI: 1.37, 18.81) higher probabilities of acquiring infection of *S. mansoni* compared to individuals who did not. *Schistosoma mansoni* infection was also significantly associated with the habit of washing clothes and utensils. Children who wash clothes and utensils using river water had 5.54 (CI: 2.89, 13.76) and 4.91 (2.43, 12.37) greater risk of contracting the infection of *S. mansoni* than their counterparts, respectively. Children who crossed the river barefoot had 3.95 times (CI: 2.13, 7.61) greater probabilities of getting infestation with *S. mansoni* compared to individuals who did not cross the river (10).

In Harbu town, North East Ethiopia, a study on the incidence of IPIs and its contributing factors revealed that subjects who interacted with water had a 4.6-fold increased risk of contracting IPs [AOR=4.6, P = 0.000] (124). The incidence of *S. mansoni* and geohelminth infections, swimming practices, and family water sources were found to be statistically significantly

correlated in another study conducted in Haike primary school children among northern Ethiopia. Binary logistic regression analysis found a strong statistical correlation (p = 0.00) between swimming behavior and parasitic illnesses (AOR = 6.61, 95% CI 3.31–13.12). The usage of lakes by families as a source of water for drinking or washing was also significantly associated with parasite illness (AOR = 5.35, 95% CI 2.97–12.32). The researcher speculates that the outcome may be because lakes and streams are frequently tainted by animal and human waste, which causes parasites to spread when schoolchildren drink the tainted water and use it for other purposes (125). However, in the northwest Ethiopian study on the intestinal parasite infections and associated factors among students, swimming practices did not substantially correlate with the incidence of intestinal parasite infections (p > 0.05) (126).

According to the present community-based cross-sectional investigation on the relationship between sanitation and hygiene habits and IPIs among children under-14 years, eastern Ethiopia the odds of IPIs were lower for children who did not swim than for those who did (aOR=0.4; 95% CI [0.27, 0.58] (121). Similarly, a case-control study on sanitation, hygiene, and intestinal parasite reinfection in children found that children who practiced swimming in polluted water had a 2.9-fold increased risk of contracting intestinal parasite reinfection in comparison to children who did not practice this activity (127). In the region children's swimming habits were surprisingly a risk factor for intestinal parasite infection and intestinal parasite reinfection were considerably correlated (121,127).

Ethiopia's human intestinal protozoan parasite infection prevalence and risk variables were evaluated by Tegen et al. in 2020. The result from this study revealed that playing with soil (OR: 2.15), consumption of uncooked vegetables (OR:1.77), and trimming fingernails (OR: 1.70) were predicting variables for the occurrence of HIPPIs (25).

4.5.4. Hygiene related factors

Intestinal parasite transmission is greatly aided by poor hygiene habits (128). On the other hand, maintaining proper personal hygiene directly promotes health and prevents disease. Maintaining proper personal cleanliness is the most crucial component of good health. Maintaining clean fingernails and washing hands using soap or ash ahead of consumption and toilet are important ways to reduce intestinal parasite infections in children (129). Suliman et al.'s investigation on

the occurrence of IPIs and predicting factors in Sudan, revealed a strong link between hand washing after using the restroom(P-0.0001) (106).

According to a survey done in rural India, intestinal parasite infections were considerably more prevalent in children with poor personal hygiene, particularly those with dirty, untrimmed nails and inadequate hand-washing routines (130). Intestinal parasitosis was shown to be statistically significant in the study population with hand wash habit ($P < 0.05$), according to a 2020 study conducted by Rangit G. (131).

In a case-control study among diarrheal patients attending Negelle Borena General Hospital, G. lamblia, E. histolytica, and Cryptosporidium spp. infections were found to be considerably more likely to occur in patients who did not wash their hands after using toilet and ahead of eating ($P < 0:05$, AOR = 1–14) (132). Similarly, another study from Dagi Primary School found that 77.9% of subjects had intestinal parasite infections overall. Intestinal parasite infections were more common in children with poor personal hygiene practices, such as not washing their hands before meals, after using the restroom, or having unclean fingernails (133).

Hand washing before meals and fingernail cleanliness were found to be strongly related with the presence of intestinal parasitic infections, according to a 2017 study, in Bahir Dar, Ethiopia, by Hailegebriel to evaluate the incidence of IPIs and related predictors among children (101). Additionally, among Jawi Town elementary school students, the cleanliness of fingernails and the practice of washing hands before meals were strongly linked to intestinal parasite infection (102).

Alemu et al.'s study evaluated the magnitude of intestinal parasite infections and related risks in students, in Birbir Town. Compared to children who frequently washed their hands after using the restroom, the odds of infection were about 4.5 times greater for those who did not (AOR = 4.487, 95% CI: 1.998–10.074) (134). According to Admasu H. et al.'s cross-sectional study on the magnitude of IPIs and predicting factors in south Ethiopia, subjects with occasional hand washing practice or never ahead of meals have 1.97-fold higher odds of contracting IPIs than their counterparts (97).

Another cross-sectional study in rural Nepal found that children whose caregivers had clean hands had considerably greater risks of protection against intestinal parasitic infection ($P = 0.01$)

compared to the reference group (135). Clean hands are crucial for avoiding parasite infections, which is supported by studies carried out in eastern Nepal (136,137). In contrast to this finding, another study on the magnitude of intestinal infection among schoolchildren in Baglung District indicated that hand washing practice was insignificantly associated with intestinal parasitosis. However, untrimmed nails showed a significant association (138). Studies carried out in several Ethiopian regions revealed a substantial correlation of fingernail cleanliness and trimming with IPIs (101.102,139).

4.5.5. Sanitation-related factors

An environment favorable to the spread of parasitic diseases is produced by inappropriate waste disposal practices (140). Due to environmental contamination caused by open defecation and improper waste disposal, parasites can flourish (39). In 2018, Gizaw et al. conducted a cross-sectional study on gastroenteritis infection and determinant factors in the northwest Ethiopia, which found that children who live in unsanitary environment (unselective discarding of human excreta, liquid and solid waste) are at a greater odd of infection compared to the reference group (141). The multivariate logistic regression results of Addisu and Mebrate's survey on the magnitude of STH and determinant between students at Sekele school in Western Ethiopia indicated that one of the primary risk variables associated with IPIs was a lack of latrines (142).

According to a 2019 study by Tadesse et al. in Adele town, East Arsi, Ethiopia, which looked at the magnitude of gastroenteritis infection and determinants among student, schoolchildren who practice open field defecation had 6.45more likely to be infected by gastroenteritis parasites compared to their counterparts, with a significant correlation (143).

According to a study on intestinal parasite prevalence and risk factors for children under five from northwest Ethiopia, children without a clean playground and children whose family members exercise defecation in open area have higher odds of gastroenteritis infection. The researcher said the results demonstrated that it was because of parasite eggs and bacteria on unclean surfaces. Additionally, children with intestinal parasites were 3.4 times more likely to have open defecation in the home (144).

Assemie et al.'s 2021 meta-analysis survey on the magnitude of gastroenteritis n and determinants in Ethiopian students indicated that open defecation (OR = 1.67:1.64,4.36) and the lack of latrines (OR = 4.39: 2.50,7.73) were two factors that showed considerable relation in the

study. The researcher speculates that this result may indicate that populations with dirty conditions brought on by open defecation are more susceptible to parasite transmission through food, water, fomites, soil, and other channels (145). Similarly, several studies found a strong correlation between IPIs and an open defecation location close to a dwelling (102,114).

The accessibility and utilization of sanitary facilities were linked to a lower exposure of infection with STI, according to a 2012 meta-analysis study by Ziegelbauer K et al. The ORs, combining sanitation availability and use, were 0.51 (95% CI 0.44–0.61) for soil-transmitted helminths (146). According to a study on the magnitude of gastroenteritis infections and determinant factors among students in southwest Ethiopia, children who buried their solid wastes and those who disposed of them in an open field had an 8-fold (AOR = 8:377; CI = 3:552 − 19:752; p ≤ 0:001) and 12-fold (AOR = 12:127; CI = 4:247 − 34:626; p ≤ 0:001) higher odds to contracting gastroenteritis infection (147).

According to current study, which was carried out in rural Dire Dawa, children from households that disposed of solid waste in open fields had a 1.7-fold higher chance of achieving a favorable outcome than children from households that burned their waste (aOR=1.7, P=.03). Additionally, only 14% of the toilets were clean. Children from households with dirty latrines had 1.8 times greater odds of IPIs than those with clean latrines (121). Open defecation is encouraged by dirty latrines, which facilitates the spread of IPIs through environmental pollution (48)

According to the Keniya study on the relationships between STH infection and water, sanitation, and hygiene situations at the household and school levels, the most important predictor of STH infection was the availability of tissue paper or water for anal washing. When there is no tissue or water available, people frequently clean their anals with their hands after defecating, which increases the risk of fecal pollution and helminth infection. Without proper anal cleansing material, children may wipe their hands on latrine walls, which could increase pathogen exposure to others. In the multivariable models, only pupils attending schools with more frequent availability of tissue or water for use after defecation had 64 % lower odds of any STH and lower rates of IPIs (148).

Abossie and Seid's survey on the frequency of gastroenteritis and its determinants in southern Ethiopia, revealed 44 (95.7%) of the students with gastroenteritis had poorer cleanliness than

households with 13 (41.9) perfect cleanliness. Compared to families with perfect cleanliness, those with poor cleanliness had a higher chance of contracting an infection (Odds ratio 30.42; 95% CI 6.234 to 148.852, $p < 0.01$) (115).

Schoolchildren who used latrines for cleanliness (i.e., no odor or feces inside the latrine structure) were 3.4 times more probable to have good hygiene practices compared to those who used toilet for sex-separation, according to a study on hygiene practices in southern Ethiopia (149). Unselective disposal of solid waste and human excreta, or poor sanitation conditions, causes disease-causing bacteria to contaminate the environment. Since IPIs are spread through the fecal-oral route, environmental pollution will raise the risk of infection (88).

According to Nath et al. (2015), who studied the systematic detection and association of Entamoeba species in stool samples from specific areas in India, the distribution of protozoa was significantly influenced by unsanitary toilets (150). Similarly, according to the current study, children from families with dirty latrines had 1.8 times higher risk for intestinal parasitic infection compared to individuals from households with clean latrines (54).

4.5.6. Water-related Factors

Controlling the spread of diseases requires protecting water supplies from microbiological pollutants. The risk of acquiring a waterborne infection is positively correlated to the level of contamination by pathogenic microorganisms (151). The most significant microbial risk is ingesting water contaminated with human or animal feces (152). Escherichia coli and thermotolerant coliform in water suggest current fecal pollution and the probable existence of infectious agents like bacteria, viruses, and parasites (40,153,154).

About 70% of sampled water from cases and 74% of sampled water from control households were contaminated by Escherichia coli, in Jimma Zone, Ethiopia, community-based matched case referent research examined the connection among bacteriological water quality, sanitation and hygiene exercise, with diarrhea in children (155). Another case-control study in Addis Ababa slums reported that stored water contamination by E. coli was found in 83.3% of the case households and 52.1% of the control households (156). The World health organization and Ethiopian potabile water standard were not followed in a study of microbial and physicochemical potable water standard in Adis Kidame Town, Northwest Ethiopia, which found that nearly all water samples (89%) had total coliforms and 77% of the samples had fecal coliforms (157).

According to a study on the bacteriological quality and determinants related to drinking water in the Eastern Zone of Tigrai, Ethiopia, 32.4% (n = 94) of water sources had total and fecal coliform contamination. Of these, 29% (n = 84) had fecal coliform contamination, and 3.4% (n = 10) had total coliform contamination. Based on WHO criteria, 15% of water sources were classified as high-risk. The water contamination rate was substantially correlated with animal waste and insufficient fencing around water sources (158). In another investigation conducted in the North Gonder zone, Escherichia coli was found in 35.7% of the samples taken from protected springs (159). A survey in Nepal revealed children who drank straight tap water had the greatest percentage (91.60%) of positive instances of parasite infection, which was statistically significant (p=0.0001) (160). According to a Colombian study, inadequate water quality contaminated by cysts produced by humans and animals was the primary source of gastrointestinal parasite infections in the population under investigation (91). The combined findings of eleven Ethiopian studies showed that children who drank unprotected water had a 3.33 higher odds of gastroenteritis protozoan infections compared to those who drank protected water (OR: 3.33, 95% CI: 1.30 to 5.36 (25). The research from Dembiya indicted that unprotected potable water supply were statistically linked with parasite infection in children (141). Children who consumed water from the river had an increased odd of gastrointestinal parasite (36.8%), which was statistically related with gastroenteritis infections, as indicated to a study in north Shoa on the occurrence of gastroenteritis infection among under five children who were admitted to the Debre Birhan Referral Hospital (161).

As revealed by the survey from Debre Elias Primary School on the prevalence of gastroenteritis infection students who consume drink river water and spring/pond water have a 4.38 (AOR=4.38, 95 CI: 3.14-7.93 P value 0.005) and 3.58 (AOR=3.58, 95 CI: 2.19-6.75) increased odds of contracting gastroenteritis infection, respectively than students who consumed pipe water (162). This might predispose children to different types of waterborne parasites. A similar finding was reported from the study done in North Gonder (163). Furthermore, potable water from standpipe protects from Giardia lamblia, based on research on the occurrence and determinant of gastrointestinal protozoa and helminth infection in western Tajikistan's students. The likelihood of infection with Hymonolipis nana, Giardia.lamblia, and E.histolytica/E.dispar was reduced by protected spring water (164). Several multiple surveys revealed comparable findings (30,165). The use of tap water was linked to a lower infection prevalence of G. intestinalis than surface

water, based on a study that examined the magnitude and geographic distribution of Giardia lamblia and Entamoeba histolytica/dispar in schoolchildren (166). A Mexico City study found that storing drinking water in unprotected containers (cisterns, tanks, and bucks) increases the risk of Giardia intestinalis infection in children (167). According to two surveys carried out in Nepal, potable tainted water rises the threat of catching Giardia species (168,137). Lowered odds of STH infection associated with water access and decreased likelihood of infection with any STH were identified in a comprehensive review and meta-analysis on water, sanitation, hygiene, and soil transmitted helminth infection (40).

Esrey et al. conducted another review study that found a correlation between ascariasis and the availability of potable water and water for domestic hygiene (169). In a 2018 study on checking cistern water for parasites in rural Tunisia was investigated, and the high level of gastrointestinal parasitic prevalence of (about 97%) was primarily correlated with protozoan (170). A pre and post interventional trial was conducted to investigate the impact of WASH education on the prevalence of gastrointestinal parasitic infection. The results showed that, although the reduction was not statistically significant, the endline prevalence of intestinal parasite infections was slightly lower than the baseline prevalence, and households' WASH performance was significantly improved at the endline compared to the baseline (171).

Approximately 90% of water samples gathered from children's drinking water cups and households in Burkina Faso (89.4% and 93.7%, respectively) contained total coliform, according to a survey gastrointestinal parasitic illness and determinants among children. Sixty four percent (64.2%) of family potable water and forty-nine percent (48.7%) from potable water mug were tainted, which indicates a lower proportion of samples with Escherichia coli (172). The source of drinking and bathing water was shown to be a significant ($p < 0.05$) risk factor for intestinal parasite infections in the survey on gastrointestinal parasitic infections determinants amongst patients in Jimma health center (173).

The study in the village of Fortín Mbororé, Argentina, found that the most common protozoan parasites in the stool samples were spread through water and the fecal-oral pathway. The remaining families used tap water, whereas most of the population (63.7%) drew their water from boreholes. None of the families reported boiling or using disinfectants (such as bleach) to prepare the water for drinking or cooking. The frequency of waterborne parasites was higher in

families that drank tap water. According to protozoan species analysis, the population that drank water from the public water system was more likely to have a parasitic infection (OR=1.77) and was positively correlated with E. histolytica/dispar infection (174).

According to a survey on the microbiological quality of potable water, A study on microbiological quality of potable water from the water supply and from household, as well as related factors revealed 83.3%; 95% CI (79.8%, 87.1%) of households in Eastern Ethiopia had drinking water contaminated by thermotolerant coliform. Households that shared their home with animals [AOR = 3.73; 95%CI (1.66, 8.37)], as well as households that did not practice household water treatment [AOR = 3.42; 95%CI (1.60, 7.31)], were significantly linked to the decline by bacteriological standard of household potable water (175). Of the total water samples evaluated for microbial water quality, 84.6% of houses potabile water was polluted with coliform bacteria, and 32.7% was contaminated by e. coli, according to the current study on microbial drinking water quality among intestinal parasite-infected and non infected children in eastern Ethiopia. According to WHO guidelines, 5.1% of water samples from the control group and 34.1% from the cases group were classified as high-risk. According to this study, households classified as low-risk and those that retrieve less than 25 liters of water per day were strongly connected with intestinal parasite infection, which also identified a significant correlation between the detection of E. coli and total coliform in the water sample (176).

4.6. Intestinal parasitic reinfection and determinant factors

An infection puts a person at risk for reinfection. Subsequent infection cannot be prevented by treatment. Additionally, distinct parasite reinfection species have been linked to various variables (71). The degree of surrounding contamination by eggs and larvae and an individual's vulnerability to surroundings contamination (behavioral and social factors) are two variables affecting reinfection (72).

Mahmud et al. carried a factorial cluster randomized trial (RCT) study on the successfulness of weekly nail clipping and soap washing at specific times on intestinal parasite reinfections in school-aged children. They found that these measures significantly reduced intestinal parasite reinfection in rats. When youngsters were given soap to wash their hands at crucial moments, their risk of contracting intestinal parasites again was 68% lower than when they were allowed to carry on with their routines. Additionally, compared to children who did not get the nail clipping

intervention, children who had their nails clipped once a week had a decreased risk of intestinal parasite reinfection by 49% (177). According to Uzbek study on the impact of cleanliness promotion on the incidence of intestinal parasite reinfection in children, hygiene promotion is a valuable strategy for lowering the risk of intestinal parasite reinfection in children (178). Northwest Ethiopia showed a similar outcome (126).

Monse and colleagues' longitudinal cohort study in the Philippines showed that schoolchildren who cleaned their hands with soap had lower reinfection rates with soil-transmitted helminths. Compared to 29% of the children who did not receive the handwashing with detergent interposition, 14% of the student who did reported reinfection after a 6-month follow-up period [AOR] 0.32, 95% CI: 0.17 through 0.62]. In contrast, 17% of the student in the nail cutting group had reinfection, while 26% of the student who did not get the interposition did so (AOR 0.51). (179). According to another case-control study conducted in Vietnam on risk factors for the disease in an agricultural community, there was a significant decrease in the probability of *Entamoeba histolytica* infection among those who regularly washed their hands with soap (180). Animals were more likely than people to have fecal contamination of their home environments, including the water supply and water tanks, hands, and ground, according to studies done in Bangladesh and India (180-186).

According to a study conducted in Mexico, the genotypes of *Giardia duodenalis* in schoolchildren, their families, dogs, pets, and their owners had the same subgenotype of *G. intestinalis* (187). An investigation on the prevalence and genetic identification of *Giardia intestinalis* in sheep revealed that domestic animals have often been recognized as a major source of surrounding contamination and potential source for zoonosis (188).

The prevalence of intestinal protozoan infections and associated risks in symptomatic and asymptomatic people in southern Algeria were compared in a cross-sectional study conducted in 2021. The findings demonstrated that in both populations, livestock proximity was the primary predictor for intestinal protozoa transmission. Infection was significantly more common among subjects who owned or cared for animals. Furthermore, the researcher argues that the risk of zoonotic transmission is increased by the proximity of pastoral and nomadic inhabitants to their animals (189). Animals are susceptible to parasite diseases due to their scavenging habits and ingesting food and water from unidentified sources. Thus, close contact with diseased animals

may increase the probability of animal-to-human transfer (190). According to one study from northwest Iran, proximity with livestock was also considered a substantial threat for giardiasis (191).

A cross-sectional study on risk factors associated with the prevalence and severity of intestinal parasite infections in households in Tonga found that reckless river swimming and the types of domestic animals were significantly ($p < 0.05$) associated with intestinal parasite infections (192). Potable water source and shower water was a significant ($p < 0.05$) predictor of gastrointestinal parasitosis when the incidence of gastrointestinal parasitosis and pertinent threats were analyzed among Jimma Health Center patients who requested stool investigations (193).

4.7. Conceptual framework

A literature survey about the research topics was the basis for developing the conceptual framework to highlight the study's primary goals. As a determinant factor for intestinal parasite infections and reinfection, the conceptual framework explains the interaction between determinant factors (sociodemographic, socioeconomic, behavioral and sanitation, hygiene, and water-related factors).

The figure below shows an overview of the determinants for IP reinfection and IPIs grouped under sociodemographic, behavioral, WASH factors. Furthermore, behavioral and personal characteristics like swimming habits, bathing locations, and cloth sharing, social-demographic determinants include the age, sex, and income status of households, housing conditions, and the educational attainment of both parents. IPIs and IP reinfections were found to be primarily determined by factors related to water, including water handling procedures, water quantity and quality, and sanitation and hygiene factors, such as latrine ownership, open field defecation, latrine cleanliness, solid waste disposal systems, and hand hygiene practices at critical time.

Conceptual framework



Figure 6. Conceptual framework

5. Methods and materials

5.1. Study area

The study was conducted in the rural areas of the Dire Dawa Administrative Council, located in eastern Ethiopia. Dire Dawa is one of two adminstrative cities in the country and is geographically located between 9°27′N and 9°49′N latitude and 41°38′E and 42°19′E longitude. It lies approximately 515 kilometers east of the capital city, Addis Ababa, and borders the Oromia and Somali Regional States (194).

Administratively, Dire Dawa is divided into 9 urban and 38 rural kebeles the smallest administrative units in Ethiopia. According to the Central Statistical Agency of Ethiopia's 2019 population projection, the total population of Dire Dawa is approximately 513,000, of which about 313,000 (63%) reside in rural areas. The rural population largely depends on subsistence agriculture and pastoralism, with some engagement in informal trade (195).

The area is characterized by a semi-arid climate. The average temperatures typically range between 25°C and 34°C and average annual rainfall ranges from 500 to 700 mm. The area experiences rainfall with the short rainy season (belg) lasting from January to March and the long rainy season (kiremt) extending from June to August. These climatic conditions influence hygiene practices, and health outcomes in the region (196).

A mixed farming system that involves both crop production and livestock rearing accounts for 93% of the homes' livelihood in the study region. Though progress has been sluggish, efforts are underway to upgrade water infrastructure and supply these areas with safe drinking water (197). Ninety percent of Dire Dawa households use improved drinking water sources, according to the 2016 EDHS. However, water sources are piped into the home or yard in only 5% of rural families (43).

The region's ethnic composition is diverse, mainly consisting of the Oromo, Somali, and Amhara communities, with a mixture of languages, cultural practices, and traditional beliefs. These cultural factors can also influence health-seeking behavior and sanitation practices (198).

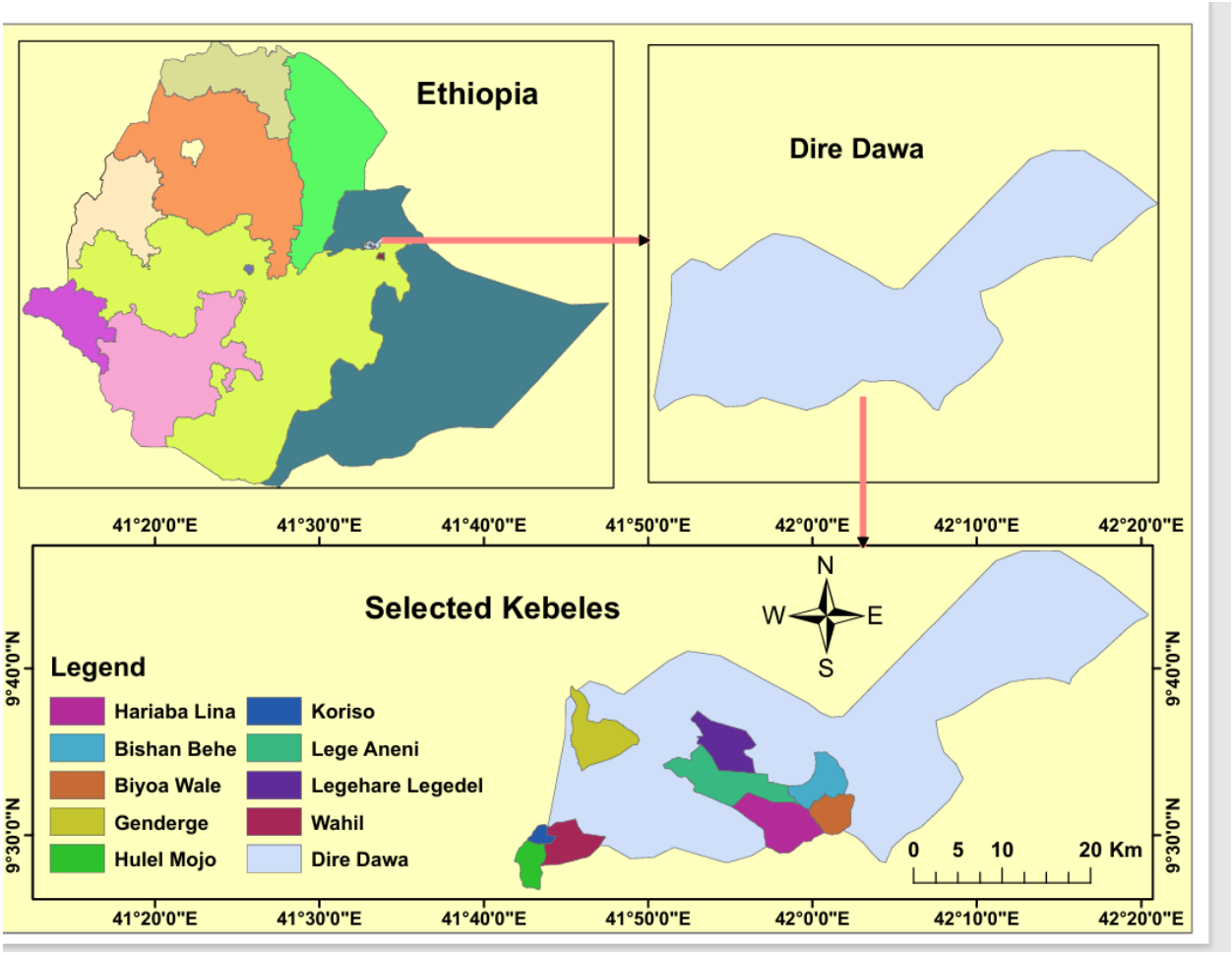


Figure 7. Location Map of the Study Area

5.2. Study design and period

This dissertation used different study designs to address the specific objectives of the dissertation. A community-based cross-sectional survey design was used to investigate the association of sanitation and hygiene practices with intestinal parasitic infections between April and May 2021 (objective I). Nested unmatched case-control design was employed, which was nested from a community based cross-sectional survey to investigate microbial drinking water quality and other water related risks on intestinal parasite infections from April to May 2021(objective II). Unmatched case (positive for IPIs) control (negative for IPIs) study design

was used to investigate childhood intestinal parasitic reinfection and its relation with sanitation and hygiene practice from May to October 2021(objective III).

5.3. Study population

The study population for objective I was children with the age of 1- 14 years old who were chosen from the nine rural kebeles, and the primary respondent to the questionnaire was their mother primary caretaker; for objective II, the study population was selected from the community-based cross-sectional survey(objective I)(119); for this second specific objective, there was a case and control group; the case group consisted of children who had positive intestinal parasite infection results, while the control group consisted of children who did not have positive result for intestinal parasite infection and their point of use water from household level; and for objective III, the study population consisted of all children who had a positive intestinal parasite infection result in the community-based cross-sectional survey(objective I) (119) and those who tested negative after two to three weeks of treatment were monitored to look into factors related to intestinal parasitic reinfections, such as hygiene and sanitation factors.

The inclusive and exclusive criteria are described as follows:

Inclusion criteria

• Children whose parents or guardians completed informed consent for participation, including the submission of stool samples, and who had not received anti-parasitic medication within the two weeks prior to the community-based cross-sectional survey.

• Children whose parents volunteered to provide point of use drinking water samples.

• Children who tested positive for IPI at baseline (objective I) and received anti-parasitic treatment. Those who recovered following the treatment and were able to provide stool samples 6-monthes after treatment were included in the reinfection assessment.

Exclusion Criteria

• Children who were unable to provide stool and/ or point of use water samples at the time of data collection were excluded.

- Children treated for IPIs within three months prior to the baseline survey data collecting period, as well as those whose families had been in the area for less than six months.

- Children who used anti-parasitic medications during the six-month follow-up period, whose parents declined participation in the follow up study, or who remained positive for IPIs after treatment were not included in the reinfection assessment.

5.4. Sample size determination

In this dissertation, different sample size determination formulas were used for each specific objective, considering the nature of the study. The sample size estimation for objective I was based on single population proportion formula.

single population proportion formula $$n = \frac{Z\alpha/2^2 P (1- P)}{d^2}$$

Where:

n = sample size

$Z\alpha/2^2$ = standard normal value at 95% confidence interval = 1.96

P = estimated prevalence of intestinal parasite infection = 0.36 (36%) from previous study (199).

1−P = The non-observed value is = 0.64

d = margin of error = 0.05

$$\frac{3.8416 * 0.36*0.64(0.2306)}{0.0025}$$

354 *2 + 70= 778

The total sample size was 778

The sample size for objective II was calculated using OpenEpi version 3.03a, based on findings from a previous study. Several variables were tested, and the one yielding the largest sample size household use of an unprotected water source was selected for the final computation. The assumptions used for the calculation included a 1:1 ratio of controls to cases, a two-sided significance level (α) of 5% (95% confidence level), and a power of 90% (β = 10%). According

to the referenced study, 24% of households in the case group and 39% in the control group used unprotected water sources (143). Based on these parameters, the initial sample size was estimated to be totally 320 participants (160 cases and 160 controls). A 10% non-response rate was considered for both groups, resulting in a final sample size of 352 participants comprising 176 cases (subjects with positive stool result for IPIs) and 176 controls (subjects with negative stool result for IPIs).

The sample size for objective III was calculated using Open-epi version 2.3. The sample size was calculated for each variable by taking the result of the study conducted previously that would yield the largest sample size. The age of the children was used as a predictor for intestinal parasite reinfection, with 19.02% of cases and 39% of controls to determine the sample size (200). We employed a 2-tailed test with 80% power and a 95% CI. A ratio of case/control = 2 and 10% of the non-response rate was also considered. Cases and controls had respective total sample sizes of 77 and 153.

5.5. Sampling techniques

Different sampling techniques were employed for each specific objective of the study. For Objective I, a two-stage cluster sampling technique was used. In the first sampling stage, nine rural kebeles were selected randomly using the lottery method out of 38 rural kebeles. The second sampling stage, households with eligible children aged 1–14 years were randomly selected within each kebele. The sampling fraction from each kebele was determined proportionately to the population size (PPS) of children 1 to 14 years. The list of households was obtained from the health extension workers, and a number was given for each household. Using simple random sampling method study subjects were selected. Before the data collection process commenced, the validity of the information provided by the health extension workers was cross-checked. When the selected household was closed during the data collection time, the interviewers revisited the household at different time intervals, and we could visit them the following day. When interviewers failed to get the members of that household, the household was excluded from the study, and another nearby household was included. One child was selected randomly from households with more than 1 children aged 1 to14-year-old child.

For Objective II, simple random sampling was applied using ENA software. Participants were chosen from the baseline study (Objective I) based on their stool examination results. From this

group, a total of 352 participants 176 cases (children who tested positive for intestinal parasitic infections) and 176 controls (children who tested negative for IPIs) were selected for further analysis under this objective. Specifically, from the 262 IPI-positive children identified in the baseline study, 176 were randomly selected to form the case group. Similarly, from the 516 IPI-negative children, 176 were randomly chosen to constitute the control group.

A total of 352 point-of-use water samples were collected from each household (176 from case households and 176 from control households) for microbiological analysis. The water sampling was collected in the morning and side by side with the stool sample collection. Water samples were collected aseptically from household points of use using sterilized, labeled 500 ml bottles, ensuring no contact with the bottle's interior or cap. Source and collection time were properly documented Samples were kept in a cool box at approximately 4 °C and transported to the Dire Dawa Water Laboratory within 4 hours, where they were analyzed immediately upon arrival to ensure accuracy in the microbiological assessment.

For Objective III, only children who tested positive for IPIs (262) during the baseline survey (Objective I) were included, while those with negative stool results were excluded (119). Two hundred sixty-two (262) positive children were treated and examined for IPIs after 2–3 weeks of treatment. Again, based on their stool examination result, 230 children with negative results became candidates to be followed up for 24 weeks. After 24 weeks of follow-up, eight children fail to participate in providing information for the questionnaire. So, in this study, a total of 222 children participated both in providing stool samples and questionnaire-based information. Of these 222 children, 75 were cases (reinfected children), and 147 children remained with negative results (controls) during stool examination.

5.6. Study Variables

5.6.1. Independent variables of the study

- Sanitation and hygiene practices
- Socio-demographic characteristics
- Environmental factors
- Behavioral factors

- Microbial quality of drinking water and water-related hygienic factors, drinking water type, access and use factors

5.6.2. Dependent variables of the study

- Intestinal parasitic infections [Objective I]
- Intestinal parasitic infections, infected(cases) and non-infected(controls) [Objective II]
- Intestinal parasitic infection after six month follows up period (Intestinal parasitic reinfection) [Objective III]

5.7. Data and sample collection methods, procedures, and instrument

For this study different data collection methods were applied to address each specific objective. Primary data for each objective was gathered using a pre-tested and structured questionnaire. Initially, it was developed in English and then translated into local languages, Amharic and Afan-Oromo; then it was translated back into English. The questionnaire was administered to the mother or caregiver in the local language through face-to-face interviews. The survey questions were about socio-demographic characteristics, water source type, water storage type, handling practices, hygiene related to water, drinking water access, utilization, sanitation, and hygienic-related behavioral data. Two laboratory technicians collected stool specimens and to evaluate the microbiological water quality, water samples were taken from point of use at household level by two water laboratory technicians, and six nurses gathered the questionnaire-based data.

5.7.1. Stool Specimen Collection and Laboratory Examination

Using appropriately labeled, dry, clean, and wide-mouthed 5 ml plastic containers with applicator sticks, stool specimens were taken from 778 participants for objective I. Every participant in the study received instructions on how to gather stool samples. A piece of each stool specimen was mixed using the saline wet mount technique as soon as it was collected and inspected under a microscope (199) as part of the field examination. The remaining specimen was processed and analyzed using the formol-ether concentration procedure after the other piece was fixed in 10% formalin and brought to the laboratory at Dire Dawa Dil Chora Hospital in a cold box (maintained at 2°C-8°C).

For objective II Stool specimens were collected from 352 participants using appropriately labeled, clean, dry, wide-mouthed 5 ml plastic containers equipped with applicator sticks. All

participants were given clear instructions on proper stool sample collection techniques. Immediately after collection, a portion of each specimen was examined in the field using the saline wet mount technique and observed under a microscope. The remaining portion of the specimen was preserved in 10% formalin and transported in a cold box (maintained at 2°C–8°C) to the laboratory at Dire Dawa Dil Chora Hospital, where it was processed and analyzed using the formol-ether concentration method (201)

For objective III two hundred twenty-two (222) study participants provided fecal samples and questionnaire-based data. The stool samples were performed using direct wet mount method and formal ether concentration technique.



Stool sample collection and examination at filed and institution level

For direct stool examination, one or more saline drops were put on a slide for direct stool analysis. An applicator stick was used to place about 0.05 g of stool samples, which were then combined with a drop of saline and placed on a cover slide. Lastly, the specimen was inspected under a microscope to identify intestinal parasites at magnifications of low power (×10 objective) and high power (×40 objective).

For the formol-ether concentration, 4 milliliters of 10% formol water were used to emulsify an estimated pea-sized amount of stool. Then, using a handshaking motion, 4 milliliters of 10% v/v

formal water was added and thoroughly mixed. After sifting the emulsified stool, four milliliters of diethyl ether were added. After a minute of mixing, the material was promptly centrifuged for one minute at 750–1000 g. Following centrifugation, the stool material was gathered from the layer between the formal and the ether, and the parasite was sedimented at the tube's bottom. After that, slide smears were made from every stool sample that had been processed, and they were inspected for intestinal parasites using an Olympus microscope with 10× and 40× objectives. After that, slide smears were made from every stool sample that had been processed, and they were inspected for intestinal parasites (201). using an Olympus microscope with 10× and 40× objectives. To ensure the validity of the data, two experienced lab technicians who were not aware of the prior results randomly selected 10% of all positive samples and reexamined them.

5.7.2. Water Sample Collection and Laboratory Examination

Water samples were collected from 352 participants for objective II. The collected water samples were transported to the Dire Dawa Water Bureau laboratory using an ice box and reached the laboratory within 6 hours of collection. The membrane filtration method was used to identify indicator bacteria.



Water samples were collected in pre-sterlized, labled 500 ml bottles following standard aseptic procedures to avoid contamination. Samples were taken from poin-of-use drinking water

containers and immediately stored in an icebox maintained at 4^0C, then transported to the laboratory and analyzed within 6 hours of collection. The detection and enumeration of total coliform and E. coil were performed using the membrain filteration technique, in accordance with standard methods. Specifically,100 ml of each water sample was filtered through a sterial membrain filter with a pore size of 0.45µm using a vacuum filteration unit. The membrane was then aseptically placed on selective and diffecrencial culture media:m-Endo agar LES for total coliforms and Chromocultur coliform agar or m-FC agar for E. coli. For total coliform, plates were incubated at 35-37^0C for 24 hours, while for E. coli detection at 44.5^0C for 24 hours. Colonies with a methallic sheen (on m-Endo agar) or blue colonies (on m-FC-agar) were identified as total coliforms and E. coli, respectively (152).



5.8. Quality control and assurance

With the use of a well-designed data gathering instrument, data quality was preserved. Experienced supervisors and enumerators with relevant educational background and fluency in the language were recruited. The methods for gathering data were created, and supervisors and data collectors received extensive training. To check for inconsistency, missing meanings, and concepts questionnaires were translated first into the native tongue and again retranslated to English. To fully familiarize the data collection tools and processes, pre-testing was also carried out. Mothers or primary caregivers were consent providers and targeted responders who provided

information about the participant. To guarantee accurate information, the participants were interviewed in their native tongues. Daily supervision was made by the principal investigator to check the completeness of the questionnaire and consistency of related data. Instruments and reagents were checked for consistency and replicability before starting any test. Data were coded, entered and cleaned using Epi Info version 3.5.2 statistical software.

5.9. Data Entry and Statistical Analysis

The Statistical Package for the Social Sciences (SPSS) was used to analyze the data after they were entered using Epi-info version 3.5.3 software. Descriptive statistics like cross-tabulation and frequency distribution were used to summarize the study variables. To present the data, tables and graphs were made. The link between dependent and independent variables was estimated using crude and adjusted odds ratios with 95% CIs using both bivariate and multivariable conditional logistic regression. For the unadjusted and adjected analysis the significant level of P = 0.025 and 0.05 were set respectively. To determine the relationship between independent and dependent variables, a multivariable logistic regression model was employed. Text, tables, and figures were used to present the results at the end.

5.10. Operational definition of variables

Clean Latrine: A latrine is considered 'clean' if, it is free from visible feces, urine pooling, flies, and foul odor. Determined via direct observation or household self-reporting (42)

Improved Sanitation: Sanitation facilities that hygienically separate human excreta from human contact, including: Flush/pour-flush toilets connected to Piped sewer system, Septic tank, Ventilated improved pit (VIP) latrine, Pit latrine with slab, Composting toilets (42).

Safe Disposal of Children's Faeces: A child's feces is safely disposed of if it is put or rinsed into a toilet/latrine or buried. It is unsafe if disposed of in the open, garbage, or left unburied.

Improved water source: defined as those that are likely to be protected from outside contamination, and from faecal matter in particular. This includes Piped water into dwelling/yard/plot, public tap/Standpipe, Tubewell/borehole, Protected dug well, Protected Spring, Rainwater and Bottled water; whereas unimproved water source includes Unprotected

dug well, Unprotected Spring, Surface water (river, dam, lake, pond, stream, canal, irrigation channels), Cart with small tank/drum, Tanker-truck (202).

Clean water storage container: A container used to store drinking water was considered clean if, during observation, it appeared free of visible dirt, algae, residues, or stains inside and outside, and if it was covered with a proper-fitting lid or cover to protect the contents from contamination. While its reverse could be taken as unclean water storage (202).

Clean water transporting material: A container used to transport drinking water was considered clean if, during observation, it appeared free of visible dirt, algae, residues, or stains inside and outside, and if it is regularly washed with safe water and/or disinfectants.

Households adequate water treatment at point-of-use: Boiling, add bleach/chlorine, water filter (ceramic, sand, composite) and solar disinfection (202).

5.11. Ethical considerations

Ethical clearance was obtained from the Ethiopian Institute of Water Resources (EIWR) at Addis Ababa University (AAU), Assigned No: EIWR/135/08116. A formal support letter was obtained from the regional health bureau to facilitate cooperation in the study area. Kebeles leaders were contacted for permission to conduct the study. Prior to data collection, parents or guardians of participating children were thoroughly informed about the study's objectives, procedures, and the types of samples to be collected. Written informed consent was obtained from each participant's parent or guardian. Throughout the research process, strict measures were taken to ensure the participants privacy and confidentiality of all collected data. Importantly, children who tested positive for intestinal parasitic infections (IPIs) received appropriate treatment, and their infection status was followed up to ensure recovery.

5.12. Dissemination of findings

The overall finding of this study will be disseminated to the targeted districts for the policy makers and concerned bodies to utilize the findings in one way or another as deemed necessary. Maximum effort is done to publish the finding in scientific journal.

6. Results

6.1. General characteristics of the study subjects and socio-demographic information

A total of 778 participants were included in the study, yielding a 100% response rate. This high participation was achieved by conducting village-to-village visits and revisiting households the following day when samples were not initially provided. Males accounted for 487 (62.6%) of the participants. Children aged 5–9 years comprised 355 (45.6%) of the sample, while those aged 10–14 years made up nearly half (48.8%). The average age of participants was 9.3 years (±2.62 SD).

More than two-thirds (69.8%) of mothers were illiterate. Among the 262 children who tested positive for intestinal parasites, 185 (70%) were born to illiterate mothers. Overall, housewife constituted 427 (54.9%) of all mothers. Only 46.3% of respondents were aware of the risk of intestinal parasitic infections (IPIs). At the time of data collection, 94 children (12%) were exhibiting symptoms of IPI. While nearly three-quarters (73%) of respondents recognized IPI symptoms, only 0.4% of mothers reported being aware of the potential complications associated with the infections. This highlights a critical gap in health education (Table 1).

Table 1. The prevalence of IPIs among 1-14years old children (n=778) according to different socio-demographic characteristics of the study population in rural Dire Dawa, Eastern Ethiopia, April–May 2021

Variables	Frequency		Intestinal Parasite			
	N	%	Yes	%	No	%
Child sex						
Male	487	62.6	168	64.1	319	61.8
Female	291	37.4	94	35.9	197	38.2
Age of the children in year						
1 - 4year	43	5.5	11	4.2	32	6.2
5-9year	355	45.6	124	47.3	231	44.8
10-14year	380	48.8	127	48.5	253	49
Mother’s level of education						
Illiterate	543	69.8	185	70.6	358	69.4
Primary	217	27.9	76	29	141	27.3
Secondary	18	2.3	1	0.4	17	3.3
Paternal Education						

Illiterate	298	38.3	91	34.7	207	40.1
Primary	406	52.2	147	56.1	259	50.2
Secondary	74	9.5	24	9.2	50	9.7
Mother's Occupation						
House wife	427	54.9	119	45.4	308	59.7
Farmer	250	32.1	96	36.6	154	29.8
Merchant	79	10.2	41	15.6	38	7.4
Others	22	2.8	6	2.3	16	3.1
Knowledge of IP acquisition						
No	418	53.7	135	48.5	283	45.2
Yes	360	46.3	127	51.5	233	54.8
knowledge of IP symptom						
Yes	569	73.1	206	78.6	363	70.3
No	209	26.9	56	21.4	153	29.7
Current symptom existence						
No	684	87.9	207	79	477	92.4
Yes	94	12.1	55	21	39	7.6
Knowledge of IP complication						
Yes	3	0.4	2	0.8	1	0.2
No	775	99.6	260	99.2	515	99.8
Swimming Habit						
No	354	45.5	95	36.3	259	50.2
Yes	424	54.5	167	63.7	257	49.8

6.1.2. Sanitary condition

A high percentage of households (83.7%) reported using safe methods for disposing of child feces. While 70.8% of households owned a latrine, only a small proportion (14.2%) maintained them in a clean condition. The link between latrine cleanliness and intestinal parasitic infections (IPIs) is evident: 89.5% of infected children came from households with unclean latrines. This indicates that latrine ownership alone is insufficient for preventing infections; the cleanliness and proper use of latrines are equally critical. Poorly kept latrines may facilitate parasite transmission directly or encourage alternative unsafe defecation practices.

Furthermore, 13.2% of households still practiced open defecation an ongoing public health concern. This behavior increases exposure to environmental contamination, especially in communal areas where children often play. Additionally, about 32.0% of households disposed of

solid waste in open fields. Such practices contribute to environmental pollution, creating conditions where parasitic eggs or cysts can survive and spread, further exacerbating the risk of infection (table 2).

Table 2. Bi-variable association of sanitary conditions and intestinal parasitic infections among1-14 years old children (n=778) in rural Dire Dawa, April–May 2021

Variable	Intestinal parasite						COR (95%CI)	P-value
	N	%	Yes	%	No	%		
Latrine ownership								
No Latrine	227	29.2	61	23.3	166	32.2	1	
Have Latrine	551	70.8	201	76.7	350	67.8	0.64(0.5-0.9)	.01
Latrine cleanness								
No	473	85.8	180	89.5	293	83.7	1.67(0.98-2.84)	.06
Yes	78	14.2	21	10.4	57	16.3	1	
Household latrine utilization								
Sometimes	90	16.3	34	16.9	56	16	1.07(0.7-1.72)	.07
Always	461	83.6	167	83.1	294	84	1	
Households disposing of child feces								
Safe	36	83.7	8	72.7	28	75	0.83(0.13-5.1)	0.38
Unsafe	7	16.3	3	27.2	4	25	1	
Households without latrine								
Open field	50	13.2	19	31.1	31	18.7	1.98(1.0-3.8)	0.05
Designed area	197	86.7	42	68.8	135	81.3	1	
Solid waste management								
Buried in one place	137	17.6	43	16.4	94	18.2	1.2(0.8-1.9)	0.4
Burn	139	17.9	34	12.9	105	20	1.7 (1.1-2.8)	0.02
Collected by waste collectors	252	32.4	95	36.2	157	30.4	1.07(0.6-1.3)	0.7
Discarded in the open field	250	32.1	90	34.3	160	31	1	

6.1.3. Hygienic practices

The analysis of handwashing practices and their association with intestinal parasitic infections (IPI) among children revealed several trends, although none reached statistical significance. Of the 778 mothers who participated in the survey, 773 (99%) reported washing their hands after

defecation. However, 307 of them (30.7%) used only water for handwashing. Mothers who did not wash their hands after defecation had 2.9 times higher odds of their children developing infections compared to those who did, although this result was not statistically significant (COR = 2.9, 95% CI: 0.49–17.9, p = 0.26).

Regarding handwashing after cleaning a child's face, mothers who did not perform this practice had twice the odds of their children acquiring infections (COR = 2.0, 95% CI: 0.39–10.4, p = 0.42), and those who used only water rather than soap or ash had even higher odds (COR = 4.4, 95% CI: 0.8–23.9, p = 0.11). While not statistically significant, these findings suggest a possible increased risk of infection.

Handwashing practices before food-related activities showed similar patterns. Mothers who did not wash their hands before cooking had increased odds of infection (COR = 2.65, 95% CI: 0.59–11.9, p = 0.22), while using only water instead of soap or ash showed no difference in risk (COR = 1.0, 95% CI: 0.77–1.4, p = 0.7). Similarly, not washing hands before feeding children was associated with higher odds of infection (COR = 3.6, 95% CI: 0.61–21.52, p = 0.19), though this result was also not statistically significant. Among the 31 children whose mothers used only water to wash their hands before feeding them, seven (22.6%) were diagnosed with IPI. The material used for handwashing before feeding (water vs. soap/ash) also showed no significant effect (COR = 1.45, 95% CI: 0.14–14.6, p = 0.82). In addition, analysis revealed no significant differences in infection risk between those who used water and those who used soap or ash after handling animal waste (COR = 1.1, 95% CI: 0.75–1.63, p = 0.6).

Overall, while none of the associations were statistically significant several hand hygiene practices showed trends toward increased infection risk when proper handwashing was neglected or when only water was used. The consistent direction of the odds ratios, generally favoring the use of soap or ash, suggests a potentially protective effect. However, the substantial imbalance between the "yes" and "no" response groups particularly among those who did not practice handwashing may have limited the statistical power to detect meaningful differences.

Also, these findings indicate several variables suggested that while most mothers practiced handwashing at critical times in the study area, the use of effective cleansing agents like soap or ash was limited. Table 3

Table 3. Bi-variable association of hand hygiene practice of mothers/caretakers and 1-14years of age children (n=778) with intestinal parasitic infections in rural Dire Dawa, April–May 2021.

Variables	Intestinal parasitic infection						COR (95%CI)	P-value
	N	%	Yes	%	No	%		
Mothers hand wash after defecation								
No	5	.7	3	60	2	40	2.9(0.49-17.9)	0.26
Yes	773	99.3	259	33.5	514	66.5	1	
Hand wash with								
Water	307	39.7	102	33%	205	67	0.98(0.72-1.3)	0.9
Soap/ash	466	60.3	157	33.6	309	66.4	1	
Mother hand wash after child face care								
No	8	18.6	3	37.5	5	62.5	2(0.39-10.4)	0.42
Yes	35	81.4	8	22.8	27	77	1	
Hand wash with								
water	9	22.9	4	44%	5	56	4.4(0.8-23.9)	0.11
soap/ash	26	77.1	4	18.5	22	81.5	1	
Mother hand wash before cook								
No	7	1	4	57	3	43	2.65(0.59-11.9)	0.22
Yes	771	99	258	33.4	513	66.5	1	
Hand wash with								
Water	368	47.7	125	34%	243	66	1(0.77-1.4)	0.7
soap/ash	403	52.3	133	33%	270	67	1	
Mother hand wash before child feed								
No	6	13.9	3	50	3	50	3.6(0.61-21.52)	0.19
Yes	37	86	8	21.6	29	78.3	1	
Hand wash with								
Water	31	83.7	7	22.6	24	77.4	1.45(0.14-14.6)	0.82
soap/ash	6	16	1	16.6	5	83.4	1	
Mother hand washing after animal rubbish care								
No	0						NA	
Yes	658		212		446			
Hand wash with								

Water	501	76	164	32.7 %	337	67.3	1.1(0.75-1.63)	0.6
soap/ash	157	23	48	30.5 %	109	69.5	1	
Child hand wash before eating								
No	0						NA	
Yes	735		251		484			
Hand wash with								
Water	280	38	88	(31.4)	192	68.6	0.8(0.59-1.13)	0.2
Soap/ash	455	62	163	35.8	292	64.2	1	

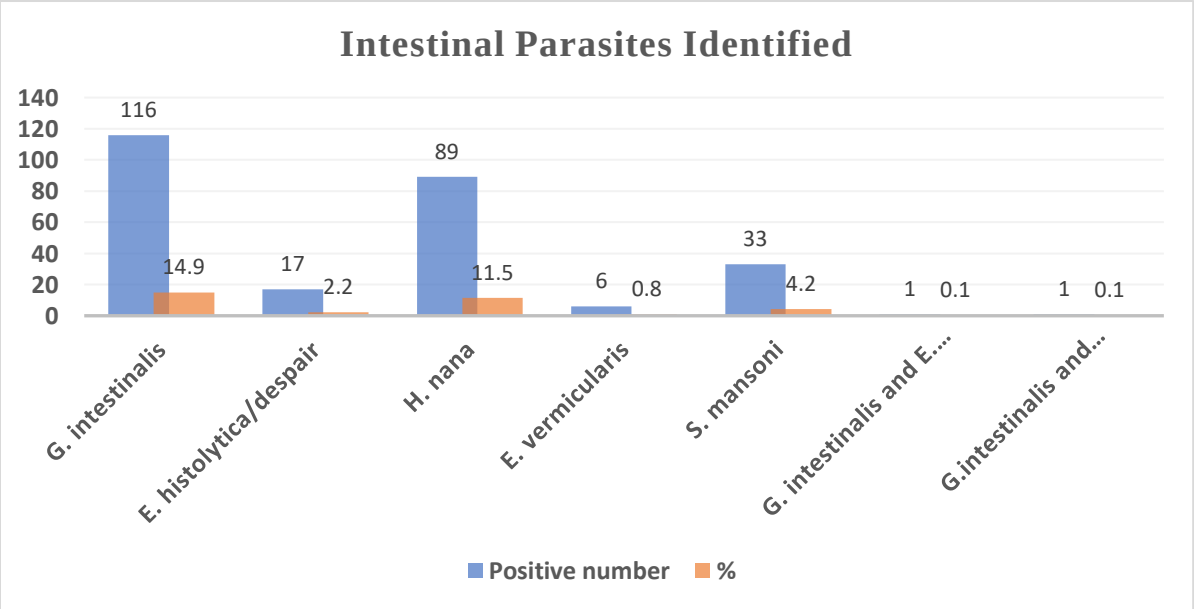


Figure 8: Intestinal Parasites Identified in 1-14 years old children (n=778) in rural Dire Dawa, April–May 2021

6.1.4. Factors associated with intestinal parasite infections

The multivariate analysis of factors associated with intestinal parasitic infections (IPIs) revealed several significant associations. Maternal education level showed a strong relationship with infection risk. Children of illiterate mothers were significantly more likely to be infected compared to those whose mothers had secondary education, with an adjusted odds ratio (AOR)

of 13.1 (95% CI: 1.6–107, p = 0.02). Although primary education appeared associated with higher risk in the crude analysis (COR = 9.1), the adjusted effect was not statistically significant (AOR = 1.1, p = 0.7).

Sanitation factors also played a key role. Households with unclean latrines had significantly higher odds of infection (AOR = 1.8, 95% CI: 1.0–3.3, p = 0.03) compared to those with clean latrines. In terms of solid waste management, children from households that discarded waste in open fields had a significantly greater risk of infection (AOR = 1.7, 95% CI: 1.0–2.7, p = 0.03) than those using burning methods. Other methods of disposal, such as burial or collection by waste collectors, were not significantly associated with infection risk.

Behavioral factors were also important. Children who did not swim had significantly lower odds of infection (AOR = 0.4, 95% CI: 0.27–0.58, p < 0.001), suggesting swimming may be a key exposure route. Similarly, asymptomatic children for IPI were significantly less likely to have intestinal parasitic infections (AOR = 0.3, 95% CI: 0.19–0.49, p < 0.001) than symptomatic children.

Generally, the findings highlight maternal illiteracy, poor sanitation, unsafe waste disposal, swimming habits, and symptom presence as significant factors associated with IPIs table 4.

Table 4. Factors associated with intestinal parasitic infections among under-14 children (n=778) in rural Dire Dawa, Eastern Ethiopia, April–May 2021

Variables	Intestinal Parasite		COR	AOR	P-value
	Yes	No			
Mother's level of education					
Illiterate	185	358	0.95(0.7-1.3)	13.1(1.6-107)	.02
Primary	76	141	9.1(1.2-66)	1.1(0.7-1.5)	.7
Secondary	1	17	1	1	
Latrine cleanness					
No	180	293	1.7(0.98-2.8)	1.8(1.0-3.3)	.03
Yes	21	57	1	1	
Solid waste management					
Buried in one place	43	94	1.2(0.8-1.9)	1.1(0.7-1.7)	.8
Discarded in open field	34	105	1.7 (1.1-2.8)	1.7(1-2.7)	.03

Collected by waste collectors	95	157	0.9(0.6-1.3)	0.8(0.5-1.3)	.4
Burn	90	160	1	1	
Swimming Habit					
No	95	259	0.56(0.4-0.76)	.4(.27-.58)	.00
Yes	167	257	1	1	
Current symptom existence					
No	207	477	0.3(0.19-0.47)	0.3(.19-.49)	.00
Yes	55	39	1	1	

6.2. The risk of microbial drinking water quality on intestinal parasitic infection

A total of 352 children participated in the study, comprising 176 cases and 176 controls. Among these studied subjects, 176 were children who have postive stoll result for intestinal parasitic infection (cases), and 176 were those who have negative stool result for intestinal parasitic infection (controls), which was nested in a community based cross sectional survey.

6.2.1. Characteristics of intestinal parasitic infected and non-infected subjects and their parents

Among the cases, 65.3% were male and 34.7% female, while in the control group, 56.3% were male and 43.8% female. Overall, males accounted for 60.8% of the total participants. In terms of age distribution, the majority of children (53.4%) were aged 5–9 years, followed by those aged 10–14 years (44.9%), and only 1.7% were between 1–4 years old. Regarding maternal education, most mothers were illiterate69.9% among cases and 67.0% among controls making up 68.5% of the total. Only 30.4% had completed primary school. Similarly, the majority of fathers had completed only primary education (53.7%), followed by 35.5% who were illiterate.

Household characteristics showed that more than half of the participants (53.1%) came from families with seven or more members, 43.5% from families with five to six members, and only 3.4% from families with four or fewer. Underwear sharing was reported by 42.6% of the children, while 57.4% did not share. In terms of housing structure, the vast majority (96.0%) lived in brick houses, while only 4.0% resided in wood-and-mud homes. Regarding flooring, 52.3% of households had uncemented (sand) floors, while 47.7% had cemented floors.

Unimproved water sources were used by 56.2% of households overall, with a significantly higher proportion among case households (65.3%) compared to controls (47.2%), indicating a

disparity in access to safe drinking water. Only 43.8% of households used improved water sources, reflecting limited availability of safe and protected water across the study area. In terms of water quantity, a substantial proportion of households (63.4%) consumed less than 25 liters per capita per day (l/c/day). Water scarcity was more pronounced in the case group, where 75% reported insufficient water consumption, compared to 51.7% among controls. Regarding accessibility, 60.8% of households were able to collect water within 30 minutes round-trip, while 39.2% required 30 minutes or more, suggesting that water collection remains time-consuming for a significant segment of the population, particularly among control households.

With regard to point-of-use water treatment, the majority of households (90%) reported consuming untreated water, while only 10% practiced any form of water treatment before drinking. This low rate of water treatment significantly increases the risk of exposure to waterborne pathogens, including intestinal parasitic infections (IPIs), which are often transmitted through the ingestion of contaminated water. The lack of basic water safety measures at the household level highlights a critical gap in water hygiene practices within the study population (Table 5).

Table 5. Socio-demographic characteristics of intestinal parasitic infected children (n=176) and non-infected children (176) in eastern Ethiopia,2021

Variables	Participants stool results		Total (%)
	Cases N (%)	Controls N (%)	
Child sex			
Male	115(65.3)	99(56.3)	214(60.8)
Female	61(34.7)	77(43.8)	138(39.2)
Age of children in years			
1-4	2(1.1)	4(2.3)	6(1.7)
5-9	98(55.7)	90(51.1)	188(53.4)
10-14	76(43.2)	82(46.6)	158(44.9)
Mother’s education			
Illiterate	123(69.9)	118(67.0)	241(68.5)
Primary	52(29.5)	55(31.3)	107(30.4)
Secondary	1(0.6)	3(1.7)	4(1.1)
Father’s education			

Illiterate	58(33.0)	67(38.1)	125(35.5)
Primary	101(57.4)	88(50.0)	189(53.7)
Secondary	17(9.7)	21(11.9)	38(10.8)
Total family size			
≤4	5(2.8)	7(4.0)	12(3.4)
5-6	71(40.3)	82(46.6)	153(43.5)
≥7	100(56.8)	87(49.4)	187(53.1)
Cloth share(underwear)			
No	105(59.7)	97(55.1)	202(57.4)
Yes	71(40.3)	79(44.9)	150(42.6)
House type			
Hut (wood and mud)	5(2.8)	9(5.1)	14(4.0)
Bricks	171(97.2)	167(94.9)	338(96.0)
Floor made			
Uncemented(sand)	84(47.7)	100(56.8)	184(52.3)
Cemented	92(52.3)	76(43.2)	168(47.7)
Households water source			
Improved	61(34.7)	93(52.8)	154(43.8)
Unimproved	115(65.3)	83(47.2)	198(56.2)
Water quantity (Water consumption per capita per day)			
< 25 l/c/day	132(75)	91(51.7)	223(63.4)
≥25 l/c/day	44(25)	85(48.3)	129(36.6)
Time to access water			
< 30minutes	115(65.3)	99(56.3)	214(60.8)
≥30 minutes	61(34.7)	77(43.8)	138(39.2)
Household point of use water treatment practices			
Do not treat	163(92.6)	154(87.5)	317(90)
Treat water at household	13(7.4)	22(12.5)	35(10)
Type of water storage containers			
Wide mouth	96(54.5)	89(50.6)	185(52.6)
Narrow mouth	80(45.5)	87(49.4)	167(47.4)

6.2.2. Intestinal Parasitic Infection in Cases Group

All intestinal parasitic infected cases had mono-parasitic infection.

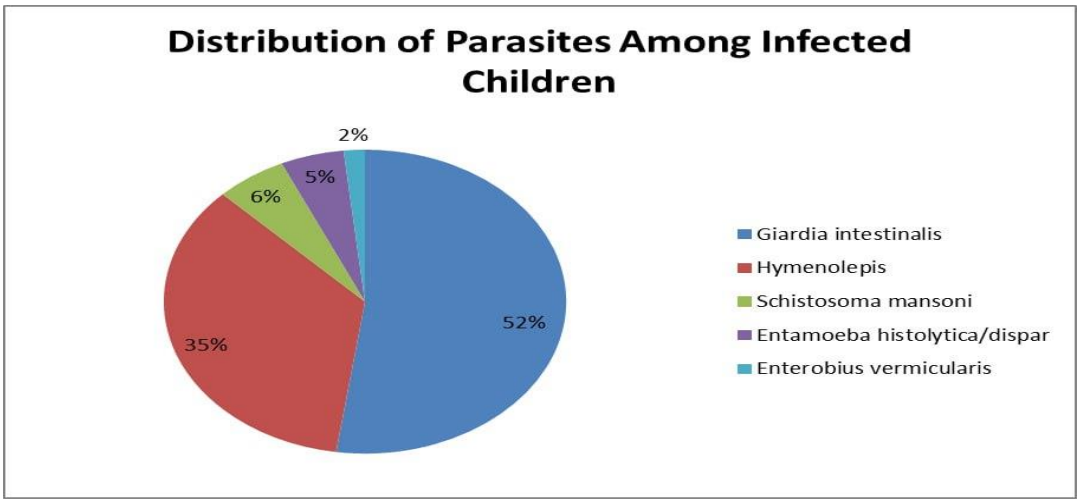


Figure 9: Distribution of Parasites among Infected children

6.2.3. Water-related hygienic factors association with IPIs

The proportion of households with the trend of handwashing before drawing water from a water storage container was 3.7% in the cases group, and 5.9% in the control group, and the difference in washing hands before drawing water was not statistically significant(P=.0.259). There were 111(63.1%) clean and 65(36.9%) unclean water transport containers in the cases group and 122(69.3%) clean and 54(30.7%) unclean containers in the controls group, and the difference was statistically insignificant (OR 1.3 (0.8-2.1)). The proportion of households that regularly wash water storage containers in the cases group was 69.3%, and 71% in the controls group. The crude result for this variable showed an insignificant association (P = 0.729). In both groups, households that wash water containers only with water have similar proportions (21%in the cases and 20.5% in the control group) (P=0896). The result of univariate logistic regression, which was conducted to evaluate the possible factors that have an association with IPIs, indicated that none of the assessed water-related hygienic factors showed significant results (Table 6).

Table 6. Bi-variable logistic Regression analysis for water-related hygienic factors and intestinal parasitic infected cases (n=176) and controls (n=176) in Eastern Ethiopia 2021

Variables	Study participants result		COR (95%CI)	P-value
	Cases N (%)	Controls N (%)		
Wash hands before drawing water from storage (185)				
Yes	7(7.3)	11(12.4)	1	
No	89(92.7)	78(87.6)	1.8(0.7-4.9)	0.259
Hygienic condition of water transport container				
Clean	111(63.1)	122(69.3)	1	
Not clean	65(36.9)	54(30.7)	1.3(0.8-2.1)	0.218
How often do you properly wash water storage?				
Regularly	122(69.3)	125(71)	1	
Sometimes	54(30.7)	51(29)	1.1(0.7-1.7)	0.729
The water container cleaned last				
Less than a week	149(84.7)	136(22.7)	1	
More than a week	27(15.3)	40(60)	0.6(0.4-1.1)	0.079
Type of cleaning agent used to wash the container				
Detergent/ash	139(79)	140(79.5)	1	
Only water	37(21)	36(20.5)	1.0(0.6-1.7)	0.896

Table 7 shows the association between access, use, and drinking water types with IPIs. The improved water source was the primary source for households in the controls group (52.8%), while the unimproved water source was the most common for most households in the cases group (65.3%). This difference was statistically significant (P = 0.001). The rate of consumption from multiple water sources was similar in the cases (78.4%) and control group (76.7%), with no significant association (P = 0.704). In the study area, 82.4% of the cases group and 75.6% of the control group used jerrycan to fetch water (P= 0.119).

Of the 185 households that used wide containers for water storage,96(54.5%) was found in the cases group, while 89(50.6) were in the control group. Among the study participants, knowledge of household point-of-use water treatment was high. One hundred forty-six (83%) of households in the cases group and 158(89.8%) of households in the control group had the knowledge of at least one method to treat water before consumption (P = 0.065). Regardless of the understanding of how to treat water at the point of use, only 7.4% and 12.5% of households from the cases and control groups practice water treatment at the point of use, respectively (P = 0.114). Three-

quarters (75%) of households in the cases group consume <25 l water quantity per day, whereas the rate for the control group was 51.7% with a strong significant association (P = 0.001). More than half of households from both groups, 56.8% for cases and 60.8% for the control group, had clean water storage containers at the time of the survey with no significant association (P = 0.451). At the time of this survey, only 1.5% of cases 4.5%from the control group were adequately covered in their water storage containers(P=0.065).

Table 7. Bi-variable logistic regression analysis of Drinking water type, access, and use with intestinal parasite infected cases(n=176) and controls(n=176), eastern Ethiopia 2021.

Variables	Study subjects stool result		COR (95%CI)	p-value
	Cases N (%)	Controls N (%)		
Households water source				
Improved	61(34.7)	93(52.8)	1	
Unimproved	115(65.3)	83(47.2)	2.1(1.37-3.24)	0.001
More than one water source				
Yes	138(78.4)	135(76.7)	1.1(0.67-1.5)	0.704
No	38(21.6)	41(23.3)	1	
Type of container to fetch water				
Jerrycan	145(82.4)	133(75.6)	1	
Clay pot/other	31(17.6)	43(24.4)	0.7(0.4-1.1)	0.119
Time to access water				
< 30minutes	115(65.3)	99(56.3)	1	
≥30 minutes	61(34.7)	77(43.8)	0.7(0.4-1.0)	0.082
Water quantity (Water consumption per capita per day)				
< 25 l/c/day	132(75)	91(51.7)	1	
≥25 l/c/day	44(25)	85(48.3)	0.4(0.2-0.6)	0.000
Type of water storage containers				
Wide mouth	96(54.5)	89(50.6)	1.1(0.8-1.8)	0.457
Narrow mouth	80(45.5)	87(49.4)	1	
How water drawn from storage				
Deeping	96(54.5)	89(50.6)	1.1(0.8-1.8)	0.457
Pouring	80(45.5)	87(49.4)	1	
Cleanliness of water storage containers				
Clean	100(56.8)	107(60.8)	1.2(0.8-1.8)	0.451
Not clean	76(43.2)	69(39.2)	1	
Water storage containers are adequately covered at the time of the survey.				
No	173(98.3)	168(95.5)	0.4(0.1-13)	0.140

Yes	3(1.7)	8(4.5)	1	
Household point of use water treatment knowledge				
I do not know at all	30(17)	18(10.2)	1.8(0.9-3.4)	0.065
Knows at least one or more methods	146(83)	158(89.8)	1	
Household point of use water treatment practices				
Do not treat	163(92.6)	154(87.5)	1.8(0.8-3.7)	0.114
Treat water	13(7.4)	22(12.5)	1	

Table 8 shows the microbial drinking water quality of IPIs. From case group 166 (94.3%), point-of-use household water samples were detected with total coliform, whereas, for this variable, the share in the control group was 75%, and the difference was statistically significant (P = 0.001). Among the households of the 176 IPI cases group,101(57.4%) and 14(8%) of those in the non-infected group had E. coli in their point-of-use water sample. According to WHO's microbial safety of drinking water risk classification for E. coli, in the case group, 60(34.1%), and in the control group, 9(5.1%) point-of-use water samples were in the high-risk category. In contrast, in the low-risk category, the share in both groups was 7.4% and 1.9% in the cases and controls groups, respectively.

Table 8. Bi-variable association of Microbial quality of households' drinking water with intestinal parasite infected cases and controls, Eastern Ethiopia 2021.

Variables	Case N (%)	Control N (%)	COR (95% CI)	p-value
Total coli-form detected at the point of use of water samples				
Yes	166(94.3)	132(75)	5.5(2.6-11.4)	0.001
No	10(5.7)	44(25)	1	
E. coli detected at point of use drinking water sample				
Yes	101(57.4)	14(8)	15.5(8.4-29)	0.001
No	75(42.6)	162(92)	1	
WHO's guideline for microbial safety of drinking water?				
Safe <1CFU E. coli/100ml	75(42.6)	162(92.1)	1	
Low risk1-10CFU E. coli/100ml	13(7.4)	3(1.7)	9.4(2.6-33.8)	0.001

Intermediate risk 11-100CFU E. coli100ml	28(15.9)	2(1.1)	30(7.0-130)	0.001
High101-1000 CFU E. coli/100ml high risk	60(34.1)	9(5.1)	14(6.9-30.5)	0.001

6.2.4. Multivariable's conditional logistic regression analysis

The results of the multivariable analysis indicated no significant correlation between IPIs and the source of drinking water. Water quantity was also indicted a significant association that children from households consuming ≥25 liters per capita per day had lower odds of infection (AOR = 0.5; 95% CI: 0.3–0.9; P = 0.029). The positivity for IPIs was 12.6 times higher among children from households with point-of-use water detected with total coliform than the referred group with significant association (P=0.001). Likewise, IPIs were 14 times more likely to occur among children from households with a point of use water detected with E. coli than their counterparts (children from households with a point of use water free from E. coli), and this relation was statistically significant(P=0.001). Based on WHO guidelines for microbial safety of drinking water, in this study, children from households that were clustered under the low-risk category (1-10CFUE.coli/100ml) for their water samples had a 15-fold higher chance of having a positive IPI result than the refereed group (P=0.001). This study's other assessed variables were insignificantly associated with IPIs (Table 9).

Table 9. Household Point of use drinking water type, access, use, and microbial water quality associated with intestinal parasitic infection

Variables	Study subjects stool result		COR (95%CI)	p-value	AOR	P-value
	Cases N (%)	Controls N (%)				
Households water source						
Improved	61(34.7)	93(52.8)	1		1	
Unimproved	115(65.3)	83(47.2)	2.1(1.37-3.24)	0.001	1.4(0.7-5)	0.333
Water quantity (Water consumption per capita per day)						
< 25 l/c/day	132(75)	91(51.7)	1		1	
≥25 l/c/day	44(25)	85(48.3)	2.8(1.8-4.4)	0.001	0.5(0.3-0.9)	0.029
Total coliform detected at the point of use of water samples						
Yes	166(94.3)	132(75)	5.5(2.6-11.4)	0.000	12.6(3.8-41)	0.001

No	10(5.7)	44(25)	1		1	
E. coli detected at point of use drinking water sample						
Yes	101(57.4)	14(8)	15.5(8.4-29)	0.000	14(6.6-30.2)	0.001
No	75(42.6)	162(92)	1		1	
WHO's guideline for microbial safety of drinking water?						
Safe <1CFU E. coli/100ml	75(42.6)	162(92)	1		1	
Low risk1-10CFU E. coli/100ml	13(7.4)	3(1.7)	9.4(2.6-33.8)	0.001	15.3(6-38.9)	0.004
Intermediate risk 11-100CFU E. coli100ml	28(15.9)	2(1.1)	30.(7.0-130)	0.001	2.6(0.4-17.3)	0.310
High101-1000 CFU E. coli/100ml high risk	60(34.1)	9(5.1)	14(6.9-30.5)	0.001	1.27(0.4-1.9)	0.189

6.3. The risk of sanitaion and hygiene on intestinal parasitic reinfection

A total of 222 children (75 reinfected cases and 147 controls), participated both in providing stool samples and questionnaire-based information., which yields the non-response rate 2.6% and 3.9% for case and control, respectively. Among these studied subjects, 75 were children who have postive result for intestinal parasitic infection after 6 months follow up period (cases), and 147 were those who have negative result for intestinal parasitic infection after 6 months follow up perioed (controls), which was selected from a community based cross sectional survey.

6.3.1. Characteristics of reinfected and non-reinfected Participants

In the present study, 49 (65.3%) male and 26 (34.7%) female reinfected subjects. While 90 (61.2%) male and 57 (38.8%) female participants were from non-reinfected children. A majority (56.0%) of the participants in the cases group were in the age range of 5–9 years, and a higher portion (49.0%) of the control group was in the age range of 10–14 years. The proportion of children with a swimming habit in polluted water was 77.3% in some cases, and the proportion of children with this behavior in non-reinfected subjects was 53.7%. Of the 13 children who bathed in both places, sometimes at home and other times in the streams, 10 were from the reinfected group, and only three were from the control group. Eighty-four percent of the

households in the reinfected group had domestic animals; 78.2% of those in the non-reinfected group owned domestic animals (Table 10).

Table 10. General Characteristics of Reinfected Children (n=75) and Non-Reinfected Children (n=147) in Eastern Ethiopia, 2021

Variables	Case Control		Frequency
	No (%)	No (%)	No (%)
Child sex			
Male	49(65.3)	90(61.2)	139(62.6)
Female	26(34.7)	57(38.8)	83(37.4)
Age of children in years			
1 – 4	1(1.3)	5(3.4)	6(2.7)
5 -9	42(56.0)	70(47.6)	112(50.5)
10-14	32(42.7)	72(49.0)	104(46.8)
Mother's education			
Illiterate	51(68.0)	97(66.0)	148(66.7)
Primary	24(32.0)	50(34.0)	74(33.3)
Father's education			
Illiterate	28(37.3)	45(30.6)	73(32.9)
Primary	39(52.0)	91(61.9)	130(58.6)
Secondary	8(10.7)	11(7.5)	19(8.6)
Mother's occupation			
Housewife	41(54.7)	61(41.5)	102(45.9)
Farmer	16(21.3)	68(46.3)	84(37.8)
Merchant	18(24.0)	18(12.2)	36(16.2)
Knowledge of IP acquisition			
No	46(61.3)	70(47.6)	116(52.3)
Yes	29(38.7)	77(52.4)	106(47.7)
Knowledge of IP symptom			
No	60(80.0)	120(81.6)	180(81.1)
Yes	15(20.0)	27(18.4)	42(18.9)
Do you have current symptoms?			
No	56(74.7)	115(78.2)	171(77.0)
Yes	19(25.3)	32(21.8)	51(23.0)
Knowledge of IPI complication			
No	74(98.7)	147(100.0)	221(99.5)
Yes	1(1.3)	0(0.0)	1(0.5)
Swimming in streams and reservoirs			

No	17(22.7)	68(46.3)	85(38.3)
Yes	58(77.3)	79(53.7)	137(61.7)
Child's bathing place			
Home	36(48)	74(50.3)	110(49.5)
Local streams and reservoirs	29(38.6)	70(47.6)	99(44.6)
Both	10(13.3)	3(2)	13(5.9)
Do you have a domestic animal existence?			
No	12(16)	32(21.8)	44(19.8)
Yes	63(84)	115(78.2)	178(80.2)

6.3.2. Environmental variables (sanitaionand hygiene) association with intestinal parasitic reinfection

The distribution of cases and controls as well as bivariate analysis in the different categories of Sanitation and Hygiene presented as follows:

6.3.2.1. Sanitation associated with childhood IP reinfection

Of the assessed sanitary factors, latrine ownership and child defecation place were factors crudely associated with intestinal parasitic reinfection. The crude OR for the association between latrine ownership and place of child defecation with childhood IP reinfection was 2.29 (1.2–4.4) and 2.5 (1.3–4.8), respectively. Among the households of the 75 children in the re-infected group, 24 (32%) and 17% of those in the non-reinfected group had no latrine. This difference was statistically significant (P = 0.013). Of the 51 households with infected children, 47 (92.2%) had unclean latrines, significantly more than those with non-reinfected children (86.9%, P = 0.340). Compared to the non-infected group, the reinfected group experienced a higher rate of open field defecation (33.3% vs. 16.3%), which was statistically significant (P = 0.006) (Table 11).

Table 11. Bi-Variable Association of Sanitation with Intestinal Parasitic Reinfected Cases (n=75) and Controls (N= 147) in Eastern Ethiopia, 2021

Variable	Intestinal parasitic infections		COR (95%CI)	p-value
	Reinfected (cases) (%)	Non-reinfected (controls) (%)		
Latrine ownership				
No latrine	24(32.0)	25(17.0)	2.3(1.2-4.4)	.013
Have latrine	51(68.0)	122(83.0)	1	
Latrine utilization				

Sometimes	12(23.5)	17(13.9)	1.9(0.8-4.3)	.137
Always	39(76.5)	105(86.1)		
Latrine cleanliness				
No	47(92.2)	106(86.9)	1.77(0.6-5.6)	.340
Yes	4(7.8)	16(13.1)	1	
Household method of child feces disposal				
Safe		4(80)	NA	
Unsafe	1(100)	1(20)		
Child defecation place				
Open field	25(33.3)	24(16.3)	2.51(1.3-4.8)	.006
Mother take care	1(1.3)	5(3.4)	0.48(0.05-4.2)	.57
Use latrine	49(65.3)	118(80.3)	1	
Solid waste management				
Buried in one place	9(12.0)	31(21.1)	0.46(0.2-1.3)	.152
Collected by waste collectors	29(38.7)	41(27.9)	1.12(0.5-2.7)	.806
Discarded in open field	25(33.3)	56(38.1)	0.71(0.3-1.7)	.439
Burned	12(16.0)	19(12.9)	1	

6.3.2.2. Hygiene associated with childhood IP reinfection

Table 12 shows the crude relationship between hygiene practices and IP reinfection. Among the hygienic behaviors, hand washing only with water after toilet use was significantly associated with intestinal parasitic reinfection in the bi-variable analysis (OR 3.4 (1.9–6.1)). Forty-nine (66.2%) of the cases and 36.6% of the controls practiced hand washing only with water after toilet use, and the difference was statistically significant (P = 0.000). In the control group, of the six mothers who washed their hands after child feces care, two used soap or ashes during hand washing, but this practice was absent in the cases. In both groups, all mothers practiced hand washing before feeding their children, but none used cleaning agents like soap or ashes. The hygienic practice of hand washing before cooking was similar in both groups, but there was a difference in using agents during hand washing. The use of soap or ashes during hand washing before cooking among cases and the control group was one-third (35.6%) of mothers of cases, but significantly more mothers of the controls (47.6%, P = 0.094) used soap. All children in both groups practiced hand washing before eating, whereas using soap or ashes during the practice was 35.6% and 64.4% in the cases and control groups, respectively (P = 0.607).

Table 12. Bi-variable Logistic Regression Analysis for the Association of Hand Hygiene Practice with Reinfected Cases (n = 75) and Controls (n = 147) in rural Dire Dawa, Eastern Ethiopia 2021

Variables	Intestinal parasitic infections		COR (95%CI)	P-value
	Reinfected (cases) (%)	Non-reinfected (controls) (%)		
Hand wash after defecation				
No	1(1.3)	2(1.4)	0.97(0.1-10.9)	.976
Yes	74(98.7)	145(98.6)	1	
Hand wash with				
Water only	49(66.2)	53(36.6)	3.4(1.9-6.1)	.000
Water/soap/ash	25(33.8)	92(63.4)	1	
Mother hand wash after child feces care				
No			NA	
Yes	1(100)	5(100)		
Hand wash with				
Water only	1(100)	3(60.0)	NA	
Soap/ash		2(40.0)		
Hand wash before cooking				
No	2(2.7)	2(1.4)	1.9(0.3-14.4)	.529
Yes	73(97.3)	145(98.6)		
Hand wash with				
Water	47(64.4)	76(52.4)	1.6(0.9-2.9)	.094
Water/soap/ash	26(35.6)	69(47.6)	1	
Mother hand wash before child feed				
No			NA	
Yes	1(100)	5(100)		
Hand wash with				
Water	1(100)	5(100)	NA	
Water/soap/ash				
Mother hand wash after caring for animal waste				
No			NA	
Yes	47(100)	115(100)	1	
Hand wash with				
Water	39(83)	97(84.3)	1.2(0.4-2.3)	.819
Use soap/ash	8(17)	18(15.7)	1	
Children's hand wash before eating				
No				
Yes	74(100)	142(100)	1	

Hand wash with				
water only	27(32.1)	57(67.9)	0.9(0.5-1.5)	.607
Using soap/ash	47(35.6)	85(64.4)	1	

6.3.2.3. Detected Parasites in Reinfected Children After 6 Months Follow-Up Period

The Identified IPs in reinfected children after 6 months of follow-up were *Giardia intestinalis* (40), *Hymenolepis nana* (27), *Schistosoma mansoni* (6), and *Enterobius vermicularis* (2) Protozoan reinfection was 18%. Helminthic reinfections were 15.8% (Figure 7).

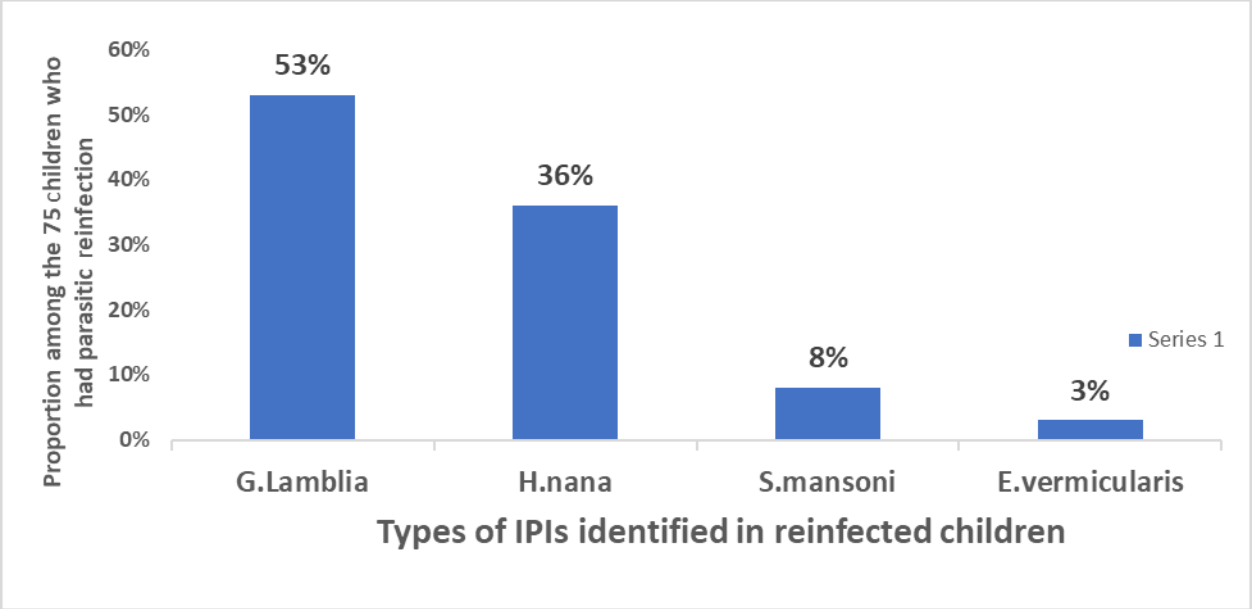


Fig. 10 Intestinal parasites identified in 1-14 years old children six months posttreatment in rural Dire Dawa, eastern Ethiopia, 2021

6.3.3. Multivariable's Conditional Logistic Regression Analysis

In the bivariable analysis, the mother's occupation, habit of swimming in polluted water, place of child bathing, latrine ownership, place of child defecation, washing hands after toilet using water only, and owning domestic animals were factors associated with childhood IP reinfection.

In the multivariable analysis, children who have swimming practice in polluted water were 2.9 times more likely to be exposed to IP reinfection when compared to children without this practice. Reinfection of IP among subjects who regularly bathed in local ponds or streams and children who took baths in both places (some time at home and another time in the local ponds or

stream) was 12.6 and 5.8 times more likely to have IP reinfection as compared with children who took baths at home, respectively. Reinfection of IP was 4.2 times greater in the study subjects from households that own domestic animals than in children from households without domestic animal existence (Table 13)

Table 13. Bi-variable and multivariable logistic regression for the risk factors associated with IP reinfection among 1-14 years old children in rural Dire Dawa, Eastern Ethiopia,2021

Variables	Intestinal parasitic reinfections		COR (95%CI)	AOR (95%CI)	P-value
	Reinfection (cases) (%)	Non-reinfected (Controls (%)			
Swimming practices in local streams and dams					
Yes	58(77.3)	79(53.7)	2.9(1.6-5.5)	3.7(1.4-10.0)	.01
No	17(22.6)	68(46.3)	1	1	
Child bathing place					
Home	36(48.0)	74(50.3)	1	1	
Local ponds/river	29(38.7)	70(47.6)	0.9(0.5-1.5)	12.6(2.5-64.8)	.002
Both	10(13.3)	3(2.0)	6.9(1.8-26.0)	5.8(1.1-31.3)	.042
Domestic animal existence					
Yes	63(84.0)	115(78.2)	1.5(0.7-3.0)	4.2(1.3-12.5)	.013
No	12(16.0)	32(21.8)	1	1	

7. Discussion

7.1. The Association of Sanitation and Hygiene Practices with Intestinal Parasitic Infections

In rural Dire Dawa, the overall prevalence of intestinal parasitic infections (IPIs) among 778 children under 14 years old was 33.7% (95% CI: 30.4–37%). This prevalence is lower than findings reported in other regions of Ethiopia and internationally. For instance, a study in the Sasiga District of southwest Ethiopia reported a prevalence of 62.4% (145), while a community-based study in Argentina recorded an even higher rate of 78.1% (203). In contrast, the prevalence in this study was comparable to findings from Senegal (34.9%) (204) and Haike town in the eastern Ethiopian Highlands (30.5%) (125). However, it was higher than the 25.8% reported in rural Dembiya, near the Lake Tana region (141). These discrepancies may stem from variations in demographic, socioeconomic, sanitary, and behavioral factors such as hygiene practices and access to clean water.

Protozoan infections (17.4%) were more common than helminth infections (12.4%) in this study, aligning with observations from Jawi and Senegal (204). This distribution may reflect the ongoing deworming efforts in the study area, which likely reduced the burden of helminth infections. In contrast, a study in Birbir town reported a higher prevalence of helminths (96). Compared to the national average protozoan infection rate of 25% in Ethiopia, the protozoan prevalence in the present study was lower (25). Schistosoma mansoni was detected in only 4.2% of children, a figure far below the 18.0% reported in a systematic review by Hassen (205), potentially due to different exposure sources. Hymenolepis nana was the second most common parasite, consistent with findings from Dessie City (206). This may be attributed to the lack of praziquantel-based preventive treatment. Giardia intestinalis was the most frequently identified parasite (15.2%), similar to reports from the Boricha District in southern Ethiopia (113). However, in Harbu (northeastern Ethiopia), it was among the least common (124). Geographic variation, sanitation differences, and exposure to contaminated farmland or animals may influence infection patterns.

An inverse association was observed between maternal education and IPI prevalence. Illiterate mothers were significantly more likely to have children with IPI compared to those with secondary education, aligning with findings from Turkey (117), research from Bahir Dar,

Ethiopia (207) and Kenya 208), which shown that maternal literacy is associated with improved hygienic habits and heightened knowledge of disease prevention, which lowers the incidence of infection in children. In a similar vein, maternal education was identified as a critical determinant of child health outcomes, including parasitic infections, in a study conducted in Bangladesh (209).

Furthermore, asymptomatic children in this study had significantly lower odds of infection compared to symptomatic ones. Similar trends were observed in a study from Nepal, which found a higher prevalence among symptomatic individuals (66.7%) than asymptomatic ones (33.3%) (210). indicating that clinical symptoms remain an important indicator of IPI presence.

Environmental sanitation factors also contributed to IPI prevalence. In line with research conducted in southern Ethiopia (211) where inadequate latrine hygiene facilitated the spread of parasites, dirty latrines were linked to almost twice the risk of infection. Also, this supports findings from a study in western Ethiopia, which reported that latrine cleanliness strongly influenced hygiene behavior (149). This study's findings that improper solid waste disposal, particularly open-field dumping, greatly raised the risk of infection are consistent with research from rural Uganda and India, where uncontrolled garbage draws rodents and flies, who are known mechanical vectors of intestinal parasites. Poor disposal of solid and human waste fosters environmental contamination, facilitating fecal-oral transmission pathways for IPIs (146).

Swimming behavior was another significant factor. Children who did not swim in contaminated water had a 0.4 times lower risk of infection. This finding is supported by research from Harbu, which showed a 4.6-fold higher risk among children exposed to contaminated water sources (124). This underscores the role of environmental exposure in the transmission of intestinal parasites.

7.2. Microbial drinking water quality among Intestinal parasite-infected and non-infected children

In the current study, most households that collect water from unprotected sources were found in the cases group (65.3%), which is higher than the control group (47.2%). Household water source was significantly associated with IPIs in the bivariate analysis but not in the multivariate

analysis. The result from a study conducted in Burkina Faso, which showed an insignificant association between water sources and IPIs (172). while the study in Argentina found a statistically significant association between unimproved drinking water sources and STH, individuals who got water from unimproved drinking water sources have 2.2 times higher odds of STH infection (212). The study in Nepal reported that the water source was a decisive determinant factor for IPIs(P=0.001) (213). Another survey from northwest Ethiopia indicated that the chance of being positive for intestinal parasitic infections was 7.79 times higher for children from households collecting water from unprotected sources, with significant association (141). Also, the study in the Merhabete District revealed a significant association between the two variables (P-0.001) (214). This could be because unimproved water sources have no protection. They are vulnerable to different sources of contamination that can be transferred to consumers.

Moreover, the probabilities of infection were much lower for children living in households that consumed at least 25 liters of water per person each day. This protective effect validates studies conducted in northern Ethiopia (141) and supports WHO minimum water quantity standards (215), which demonstrated that water scarcity restricts handwashing, cooking hygiene, and household cleanliness, contributing to higher parasitic burden.

The bacteriological analysis of household point-of-use water showed that of the total 352 water samples, coliform was detected in 298(84.7%) water samples, and E. coli was detected in 115(32.7%). Similarly, the study in the western region of Cameroon reported of the 22 water samples analyzed, 20 (90.91%) were positive for total coliform. This study reported that a high level of contamination was observed in unimproved water sources (216). The bacteriological analysis of drinking water in rural Dembiya indicated that 158(70.2%) of the households' used water was unsafe for consumption (141). Another study in Adis Kidame town revealed that 89% (80/90 and 77% (69/90) of the water samples tested positive for total coliform (TC) and faecal coliform (FC), respectively (157). The study from Fiche town reported that households were the main point of contamination for drinking water (217). In the current study, among the cases group, water samples detected with total coliform was 94.3%. In comparison, the figure for the control group was 75%, and water samples with E. coli were 57.4 % and 8% among the cases and control group, respectively. The result from Adis Kidame town indicated that only 10%

(3/30) of water samples from households' containers were at no risk (157), while, in the current study, 15.3% of water samples from the point of use were at no risk.

This study showed a statistically significant association between microbial water quality and IPIs. In contrast to this study, the result from Burkina Faso reported an insignificant association between the two variables. The study noted that water samples from children's drinking water cups and households showed significantly higher contamination with Escherichia coli. In multivariate analysis, no significant association was found between the water quality of children's drinking water cups and their infection status with total pathogenic intestinal protozoa (172). The result of the current study indicated that the positivity for IPIs was 12.6 times higher among children from households with point-of-use water detected with total coliform than the referred group with significant association (P=0.000). Also, IPIs were 14 times more likely to occur among children from households with point-of-use water detected with E. coli than their counterparts (children from households with point-of-use water free from E. coli). And this relation has statistical significance (P=0.000). The study's strong correlation between IPIs and microbial contamination specifically, E. coli and the presence of total coliform confirms findings from WHO reports (218) and Mozambican studies (219) that highlight point-of-use contamination as a serious health concern.

7.3. Childhood Intestinal Parasitic Reinfection, Sanitation and Hygiene Practice

Of the total 33.8% (75) of reinfected cases, 18% (40) and 15.8% (35) were protozoan and helminthic infections, respectively. After a 5-month follow-up, a study conducted in Cote d'Ivoire also found that the prevalence of protozoan reinfections was higher (70.39%) than that of helminthic reinfections (7.79) (220). Similarly, the Kenyan trial found that protozoan infections were more common than helminth infections in the intervention group at the end line (221). One year following treatment, 36.3% of soil-transmitted helminths (STH) were found to be re-infected, according to a study conducted in northwest Ethiopia (73), and another study in southern Ethiopia reported 36.8% of STH reinfection within 12 weeks after treatment (115). In the present study, S. mansoni was among the identified IPs in reinfected children, accounting for 2.7%. In the northwest Ethiopian survey, 13.9% of cases of this infection were stated (74). Another study from northern Minas Gerais State (Brazil) reported a 21.9% S. mansoni reinfection rate after one year of treatment (222). The geographic location, length of follow-up,

or the hygienic and sanitation practices of the residents may all be factors in the difference in the reinfection rate.

In the current study, *G. intestinal* was the only and most prevalent parasite unlike that of research conducted in northwest Ethiopia on the Effects of WASH education on childhood intestinal parasitic infections, indicating *A. lumbricid* as the most prevalent parasitic infection after a year of intervention (171). This could be due to differences in the study design. The current study used a case-control design, while the study from northwest Ethiopia used uncontrolled before and after intervention. So, the intervention measures might make the difference. Also, the deworming program may not target the protozoan group and may result in the prevalent infection in this study. Participants' age differences, geographic locations, and differences in sanitary and hygienic practices could all be contributing factors to the variance.

The percentage of cases that swam in contaminated water was higher (77.3%) than that of the controls (53.7%). The current study result showed that the odds of IP reinfection were 3.7 times higher for children who practice swimming in polluted water compared to the reference group (children without swimming practices), with a significant association (P = 0.01). Likewise, the study in northeast Ethiopia showed a strong and significant association (P=0.00) between swimming practice and IPI (125). In addition, the survey in Rama town indicated that a higher prevalence of IPs (3.1) was found among school-age children who have swimming habits in a contaminated water body than their counterparts with a significant association (P=0.021) (223). Another systematic and meta-analysis study revealed that swimming in rivers increases the risk of contracting intestinal parasitic infection by 1.9 odds with significant association (224). Unhealthy lifestyles may facilitate the spread and recurrence of intestinal parasites. The infection could also be contracted by bathing in contaminated water. Among cases, those children who bathed sometimes in local ponds or rivers and at home at other times were 13.3%, while the percentile for non-reinfected children with this trend was only 2%. The odds of reinfection of intestinal parasites were 12.6 times higher in children who bathed in local streams or ponds and 5.8 times higher in children who sometimes bathed at home and other times in local streams or ponds than in children who bathed regularly at home, with significant statistics. The results from patients in Jimma revealed that the source of water for bathing was a significant factor ($p < 0.05$) for intestinal parasitic infection (225). This could be attributed to the fact that water bodies found

in areas with open field defecation practices and poor sanitation conditions are susceptible to contamination, and this situation creates a good circumstance for IP reinfection.

Contracting parasites may occur through several routes, including close contact with pets. Eighty-four percent of the children in the case group were from families with domestic animals. This may increase their contact with animals during animal care and other activities, making them vulnerable to infection from infected animals. The odds of IP reinfection were 4.2-fold higher among children from households with domestic animals than their counterparts. A study in Iran also found a significant association between protozoan infection and contact with animals (P= 0.001) (226). A comparative cross-sectional study in Ethiopia reported that playing with domestic animals was significantly associated with protozoan infections (227). Also, a survey in Cameron showed a significant association of IPIs with domestic animals (192). A comparative cross-sectional study in Algeria indicated that contact with animals was the key risk factor for transmission of protozoan in symptomatic and asymptomatic subjects (188). The study in Burkina Faso also showed a significant association (P=0.008) between domestic animals roaming freely within households compared to their counterpart and the prevalence of *G. intestinalis* (172). Research from northeast Ethiopia (228) and Brazil (229), which found that zoonotic transmission of helminths and protozoa was associated with inadequate animal waste management and close contact with cattle

7.4 Validity and Generalizability

7.4.1 Internal Validity

Multiple measures were taken to keep internal validity of the study by controlling selection bias, information bias, recall bias and confounding. The primary steps adopted to minimize information bias during measurement were employing skilled data collectors, ensuring that study participants understood the questions being asked in the local language, and using a pre-tested questionnaire prior to data collection.

7.4.2 External Validity

The term "external validity" describes how well the research findings apply to individuals living beyond the study location. The research protocols were strictly followed in this investigation. The study participants were selected using a probability sampling technique, and the sample size was increased to a sufficient degree to account for anticipated non-responses. Any of these two

approaches could increase the study's generalizability to the source population and associated populations.

7.5. Strengths and Limitations

7.5.1. Strengths

This study had a number of strengths. Among these strengths, the community-based nature of this study is representative of all children in the age group of 1 to 14 years, which is essential to an appropriate policy strategy for effective prevention of intestinal parasites.

The strengths of this study include as it used nested case-control study design which is valid and efficient design and can minimized both selection and recall bias.

Data was collected after validation of data collection tools. The probability sampling technique was employed to select the required adequate sample size. The questionnaire was pre-tested to evaluate the face validity and modified based on the local context before data collection. Data collectors and supervisors were adequate training on data collection and interview techniques was given before data collection.

7.5.2. Limitations

This study has limitations as respondents might not give their exact observable fact towards some given questions, which leads to social desirability biases. This could be minimized by providing training to data collectors and conducted pre-test before actual data collection launched.

This study has certain limitations that include the study design that we used, which demonstrated a snapshot of the water sample test result. Although one-time sampling information is very useful, it does not allow us to capture the burden of their presence in drinking water at multiple points in time.

Even though wet mount and formal ether concentration techniques were employed for stool examination, it did not incorporate molecular diagnostic techniques such as polymerase chain reaction (PCR), which are essential for accurately distinguishing morphologically identical parasites particularly *Entamoeba histolytica* and *Entamoeba dispar was one limitation*. And another limitation was that infection intensity and drug efficacy were not considered.

7.6. The study's contribution

This research evaluated IPIs and reinfection and their relation with WASH. This is critical in enhancing our understanding and preventing and mitigating IPIs and reinfection effects on human health. This work also makes significant contributions and implications, such as:

- This study evaluates the prevalence and identifies the predominant type of IPIs

  The study identified socio-demographic and other risk factors. Understanding these risks at the local level is essential for carrying out targeted interventions. In addition, the study identifies the most prevalent IPIs and quantifies their prevalence. This information is necessary for assessing the magnitude of the problem, establishing baseline data for comparison in different regions or populations, and filling the void left by the lack of data on the IPIs in the area, as highlighted by one systematic review study.

  Sanitation and hygienic risk assessment

Hygiene and sanitation are seen to be essential elements in enhancing health. By evaluating these factors locally, necessary steps can be taken to achieve long-term control of intestinal parasite infections and reinfection. Prioritizing and identifying local solutions is beneficial. Furthermore, epidemiological research is essential for proving links between hygiene, sanitation, IPIs, and reinfection. As a result, this study offers a broad overview of the region's hygienic and sanitation conditions and their relationship to IPIs and reinfection.

- Community awareness, education, and community empowerment

This research helps raise community awareness about the potential health risks of IPIs and reinfection. Education campaigns based on scientific evidence can empower individuals to make informed decisions regarding their sanitation, hygiene practices, and microbial water quality. Generally, the study empowers communities by providing information about their specific IPI and reinfection risks. This knowledge allows communities to take proactive measures, such as practicing safe sanitation and hygiene, dealing with some habits (swimming habit), implementing protective measures in animal husbandry like keeping the appropriate distance between domestic animals and resident places, proper handling of their wastes and treating water at household level before its use.

Health interventions

The results of this study help identify children who are more susceptible to IP reinfection and IPIs. Targeting health treatments and managing health issues associated with IP reinfection and IPIs require this knowledge.

8. Conclusions and Recomendations

8.1. Conclusions

This study demonstrated that intestinal parasitic infections (IPIs) remain a considerable public health concern among children aged 1to 14 years in rural Dire Dawa, with an overall prevalence of 33.7%. Protozoan infections, particularly *Giardia intestinalis*, were more common than helminths, likely due to ongoing deworming interventions. Several environmental and behavioral factors were significantly associated with the occurrence of IPIs. Children from households with unclean latrines, open-field waste disposal, and those who swam in contaminated water bodies were at higher risk of infection. Furthermore, children of illiterate mothers were significantly more likely to be infected, highlighting the influence of maternal education on child health. The findings also showed that symptomatic children were more likely to test positive, reinforcing the role of clinical symptoms in identifying IPIs. Overall, the study underscores the importance of improving sanitation, promoting hygiene education particularly among mothers and reducing environmental exposure to contaminated water sources. Strengthening these areas through integrated public health efforts could substantially reduce the burden of IPIs in the area.

The multifaceted nature of intestinal parasite infections and reinfections in children is highlighted in this study, with particular attention paid to the important roles played by environmental exposures, sanitation, hygiene practices, maternal education, and water quality and quantity. Children of illiterate mothers, those living in households with unclean latrines or poor waste management practices, and those exposed to contaminated water sources were more likely to be infected. Additionally, behaviors such as swimming or bathing in contaminated surface waters and close contact with domestic animals were strongly associated with reinfection. These findings are consistent with both local and international studies, reinforcing the urgent need for integrated, community-based interventions that combine health education, improved water and sanitation services, behavioral change communication, and targeted environmental health strategies to reduce the burden of parasitic diseases among vulnerable populations.

8.2. Recommendations

1. **Strengthen Health Education Programs:**
   Targeted health education should be implemented to improve maternal awareness about hygiene, safe water handling, and disease prevention. Special focus should be given to illiterate mothers through community-based communication strategies.

2. **Improve Access to Safe and Sufficient Water:**
   Efforts should be made to ensure households have access to microbiologically safe drinking water and sufficient water quantity for consumption (≥25 liters per person per day). This includes improving water supply infrastructure and promoting safe water storage and treatment practices at the household level.

3. **Promote Sanitation and Hygiene Practices:**
   Community-led total sanitation (CLTS) approaches should be strengthened to improve latrine cleanliness and discourage open waste disposal. Regular latrine cleaning and appropriate waste management methods (e.g., burning or safe burial) should be promoted.

4. **Discourage Risky Water Contact Behaviors:**
   Public health campaigns should discourage children from swimming or bathing in contaminated streams, rivers, and ponds. Safe alternative bathing practices at home should be encouraged, especially in high-risk areas.

5. **Integrate Animal Management into WASH Programs:**
   Given the association between domestic animals and reinfection, awareness campaigns and programs should address proper animal husbandry, including separation of animal shelters from living areas and proper handling of animal waste.

6. **Routine Monitoring of Water Quality:**
   Local health and water authorities should conduct regular microbial water quality testing at both source and point-of-use levels to ensure compliance with WHO guidelines and reduce the risk of infection.

7. **Policy and Multi-sectoral Collaboration:**
   Government bodies, NGOs, and stakeholders should collaborate across sectors health,

education, water, and agriculture to implement integrated interventions addressing the environmental and behavioral factors contributing to IPIs.

8. References

1. World Health Organization. Prevention and control of intestinal parasitic infections. In: World Health Organization Technical Report. Geneva: WHO; 1987

2. Ortega YR, Eberhard ML, Kris H. 2008. Protozoan diseases: cryptosporidiosis, giardiasis and other intestinal protozoan diseases, p 354 –366. In International encyclopedia of public health. Academic Press, Oxford, United Kingdom

3. WHO (2010) Intestinal Parasites. Torgerson PR, Devleesschauwer B, Praet N, Speybroeck N, Willingham AL, Kasuga F, et al. (2015) World Health Organization Estimates of the Global and Regional Disease Burden of 11Foodborne Parasitic Diseases, 2010: A Data Synthesis. PLoS Med 12(12): e1001920. doi: 10.1371/journal.pmed.1001920 http://apps.who.int/ctd/intpara/burdens.htm

4. WHO, "Working to overcome the global impact of neglected tropical diseases: first WHO report on neglected tropical diseases," 2010

5. World Health Organization, Programme for the Control of Diarrheal Diseases. The Treatment of Diarrhea: A Manual for Physicians and Other Senior Health Workers, 2015, WHO Press, Geneva, Switzerland.

6 Soil-transmitted helminth infections. 2022. https://www.who.int/news- room/fact-sheets/detail/soil-transmitted-helminth-infections. Accessed 26 Aug 2024

7 World Health Organization. What is schistosomiasis? Geneva: World Health Organization; 2016. https://www.who.int/schistosomiasis/disease/en/. Accessed 19 Mar 2023

8. World Health Organization. Schistosomiasis fact sheet N°115. Geneva: World Health Organization; 2014. http://www.who.int/mediacentre/factsheets/ fs115/en/. Accessed 17 Mar 2023

9. Deribe K, Meribo K, Gebre T, Hailu A, Ali A, Aseffa A, et al. The burden of neglected tropical diseases in Ethiopia, and opportunities for integrated control and elimination. Parasit Vectors. 2012; 5:240

10.Worku L, Damte D, Endris M, Tesfa H, Aemero M.. Schistosoma mansoni Infection and Associated Determinant Factors among School Children in Sanja Town, Northwest Ethiopia. Journal of Parasitology Research Volume 2014, Article ID 792536, 7 pages http://dx.doi.org/10.1155/2014/792536

11. B. Alemayehu and Z. Tomass, "Schistosoma mansoni infection prevalence and associated risk factors among schoolchildren in Demba Girara, Damot Woide District of Wolaita Zone, Southern Ethiopia," Asian Pacific Journal of Tropical Medicine, vol. 8, no. 6, pp. 457–463, 2015

12. M. Bajiro, D. Dana, M. Ayana et al., "Prevalence of Schistosoma mansoni infection and the therapeutic efcacy of praziquantel among school children in Manna District, Jimma Zone, southwest Ethiopia," Parasites & Vectors, vol. 9, no. 1, article no. 1833, 2016

13. Macnish, M. (2001(Macnish, M. (2001) Characterization of community-derived Hymenolepis in Australia. PhD thesis, Australia, Perth: Murdoch University Medical Science.

Retrieved February 20, 2020 from https:// researchrepository.murdoch.edu.au/id/eprint/176/2/02Whole.pdf; Thompson, 2015

14. Neglected zoonotic helminths: Hymenolepis nana, Echinococcus canadensis and Ancylostoma ceylanicum. Clin. Microbiol. Infect., 21(5): 426 – 432. DOI: 10.1016/j. cmi.2015.01.004) or

15. Muzamil Mahdi Abdel Hamid , Ibrahim A Eljack , Mohammad Khatim M Osman , Arwa Hassan Elaagip , Mohamed S Muneer.The prevalence of Hymenolepis nana among preschool children of displacement communities in Khartoum state, Sudan: a cross-sectional study. Travel Med Infect Dis. 2015 Mar-Apr;13(2):172-7. doi: 10.1016/j.tmaid.2014.12.011

16. Cabada MM, Morales ML, Lopez M, Reynolds ST, Vilchez EC, Lescano AG, Gotuzzo E, Garcia HH, White Jr CA Hymenolepis nana Impact among Children in the Highlands of Cusco, Peru: An Emerging Neglected Parasite Infection. Am. J. Trop. Med. Hyg., 95(5), 2016, pp. 1031–1036. doi:10.4269/ajtmh.16-0237

17. Matthys, B., Bobieva, M., Karimova, G. *et al.* Prevalence and risk factors of helminths and intestinal protozoa infections among children from primary schools in western Tajikistan. *Parasites Vectors* **4**, 195 (2011). https://doi.org/10.1186/1756-3305-4-195

18. Wendt S, Trawinski H, Schubert S, Rodloff A, Mössner J, Lübbert C. The Diagnosis and Treatment of Pinworm Infection. Deutsches Ärzteblatt international 116(13):213-219. Cks.nice.org.uk. 2018. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6522669/

19. David T. John, William A.. Markell and Voge's medical parasitology. 9th ed. Missouri: Saunders Elsevier; 2006

20. Kabeta, A.; Assefa, S.; Hailu, D.; Berhanu, G. Intestinal parasitic infections and nutritional status of pre-school children in Hawassa Zuria Distrtic, South Ethiopia. Afr. J. Microbiol. Res. 2017, 11, 1243–1251

21. Ahmed A. and Eman N. Impact of Enterobius vermicularis infection on biochemical parameters in the blood of children in Erbil Province, Iraq. BMC Infectious Diseases (2020) 20:336 https://doi.org/10.1186/s12879-020-05064-w

22. Iyer, LR, Banyal, N., Naik, S., and J., P. (2017). Antioxidant Enzyme Profile of Two Clinical Isolates of Entamoeba Histolytica Varying in Sensitivity to Antiamoebic Drugs. World J. Clin. Infect. Dis. 7, 6. doi: 10.5495/wjcid.v7.i2.21

23. Despommier D, Griffin D, Gwadz R, Hotez P, Knirsch C. Parasitic diseases. 6th ed. New York: Parasites Without Borders, Inc.; 2017.

24. Fletcher SM, Stark D, Harkness J, Ellis J. Enteric protozoa in the developed world: a public health perspective. Clin Microbiol Rev 2012; 25:420-49. PUBMED | CROSSREF

25. Tegen D, Damtie D, Hailegebriel T. Prevalence and associated risk factors of human intestinal protozoan parasitic infections in Ethiopia: a systematic review and meta-analysis. 2020 Hindawi. J Parasitol Res. 2020;2020:1–15. doi:10.1155/2020/888406485

26. R. Murray, S. Rosenthal, S. Kobayashi, and A. Pfalle, Medical Microbiology, Mosby, London, 4th ed. edition, 2002

27. Gedamu G, and Esubalew T. Assessment of the prevalence of intestinal parasitic infections and associated habit and culture-related risk factors among primary schoolchildren in Debre Berhan town, Northeast Ethiopia BMC Public Health (2021) 21:112 https://doi.org/10.1186/s12889-020-10148-y

28. Farthing M, Kelly P. Protozoan Gastrointestinal Infections. Medicine. 2005; 33: 81–83

29. Luis Q, Gloria M, Aaron J, Jose A, Marco A. Prevalence and Associated Risk Factors for Giardia and Cryptosporidium Infections among Children of Ghana A Cross-Sectional Study. BMC Public Health. 2017; 17: 25–32. https://doi.org/10.1186/s12889-016-3982-0 PMID: 28056931

30. Maru DS. Prevalence of Intestinal Parasitic Infections and Associated Risk Factors among School Children in Adigrat Town, Northern Ethiopia. Int J Emerging Trends Sci Tech. 2017; 4: 43–48

31. Hajare ST, Chekol Y, Chauhan NM (2022) Assessment of prevalence of Giardia lamblia infection and its associated factors among government elementary school children from Sidama zone, SNNPR, Ethiopia. PLoS ONE 17(3):e0264812. https://doi.org/10.1371/journal.pone.0264812).

32.Harhay MO, Horton J, Olliaro PL. Epidemiology and control of human gastrointestinal parasites in children. Expert Rev Anti Infect Ther. 2010;8:219–34

33. Vaumourin E, Vourc'h G, Gasqui P, Vayssier-Taussat M. The importance of Mult parasitism: examining the consequences of co-infections for human and animal health. Parasites Vectors. 2015; 8:545

34. World Health Organization. Preventive chemotherapy in human helminthiasis: coordinated use of anthelminthic drugs in control interventions: a manual for health professionals and programme managers. Geneva: World Health Organization Press; 2006. https://www.who.int/neglected_diseases/preventive_chemotherapy/9789241547109/en/. Accessed 6 Nov 2024

35. Gamboa MI, Navone GT, Orden AB, Torres MF, Castro LE, Oyhenart EE. Socio-environmental conditions, intestinal parasitic infections and nutritional status in children from a suburban neighborhood of La Plata, Argentina. Acta Trop. 2011; 118:184–9

36. Turner J, Badireddy M. Anemia—StatPearls—NCBI. Anemia. 2022.

https://www.ncbi.nlm.nih.gov/books/NBK499994/. Accessed 2Sep2024,

37. Oliveira D, Ferreira FS, Atouguia J, Fortes F, Guerra A, Centeno-Lima S. Infection by intestinal parasites, stunting and anemia in school-aged children from southern Angola. PLoS ONE. 2015;10(9): e0137327.24

38. Stoltzfus RJ, Kvalsvig JD, Chwaya HM, Montresor A, Albonico M, Tielsch JM, et al. Efects of iron supplementation and anthelmintic treatment on motor and language development of preschool children in Zanzibar: double blind, placebo-controlled study. BMJ. 2001; 323:1389–93.

39. Oberhelman RA, Guerrero ES, Fernandez ML, Silio M, Mercado D, Comis key N, et al. Correlations between intestinal parasitosis, physical growth, and psychomotor development among infants and children from rural Nicaragua. Am J Trop Med Hyg. 1998; 58:470–5

40. Strunz EC, Addiss DG, Stocks ME, Ogden S, Utzinger J, Freeman MC. Water, sanitation, hygiene, and soil-transmitted helminth infection: a systematic review and meta-analysis. PLoS Med 2014;11 (03): e1001620

41. World Health Organization (WHO). Soil-transmitted helminth infections: key facts. 2019. Available from: https://www. who.int/news-room/fact-sheets/detail/soil-transmitted-helminth infections. Accessed November 16, 2023

42. Progress on drinking water, sanitation and hygiene 2000–2017|UNICEF https://www.unicef.org/reports/progress-on-drinking-water-sanitation-and-hygiene-2019

43.Ethiopia Demographic and Health Survey 2016. Addis Ababa, Ethiopia, and Rockville, Maryland, USA: CSA and ICF. Accessed December 25, 2021. https://www.usaid.gov/sites/default/files/documents/1860/Ethiopia%20 DHS%202016%20KIR%20-%20Final%2010-17-2016.pdf

44. Alum A, Rubino JR, Ijaz MK. The global war against intestinal parasites should we use a holistic approach? Int J Infect Dis. 2010;(14):732–8

45. Boretti A, L., Rosa., (2019) Reassessing the projections of the World Water Development Report. Clean Water 2:1

46. UN-Water. Summary progress update 2021: SDG 6 – water and sanitation for all. https://www.unwater.org/sites/default/files/app/uploads/2021/12/SDG-6-Summary-Progress-Update-2021_Version-July-2021a.pdf

47. Adank M, Butterworth J, Godfrey S,Abera M. Looking beyond headline indicators: water and sanitation services in small towns in Ethiopia. J water, Sanitation Hyg Dev.2016,6(3):435-46

48. Drinking water, sanitation and hygiene in Ethiopia. http.//www.wearewater. org/en/drinking-water-sanitation-and-hygiene-in-ethiopia-253215.

49. Agensi A, Tibyangye J, Tamale A, Agwu E, Amongi C. Contamination potentials of household water handling and storage practices in Kirundo sub-county, Kisoro District. Uganda J Environ Public Health. (2019) 2019:1–8. doi: 10.1155/2019/7932193

50. Mohanan N, Manju E, Sonia J (2017) The effect of different types of storage vessels on water quality. Int J Innov Res Sci Eng Technol 6(10):20362–20368)

51. Banda K, Sarkar R, Gopal S, Govindarajan J, Harijan BB, Jeyakumar MB, et al.Water handling, sanitation and defecation practices in rural southern India: a knowledge, attitudes and practices study. Trans R Soc Trop Med Hyg. (2007) 101:1124–30. doi: 10.1016/j.trstmh.2007.05.004218. 52. Ethiopia Population Projections. 2022 Ethiopia Population 2022 (Demographics, Maps, Graphs). Available from: https:// worldpopulationreview.com/countries/ethiopia-population (accessed 20 August 2024. newly inserted reference

53.CSA IC. Central statistical agency [Ethiopia] and ICF International: Ethiopia demographic and health survey. Addis Ababa (Ethiopia): Central Statistical Agency [Ethiopia] and ICF International. 2011.

54. Gwimbi P, George M, Ramphalile M. Bacterial contamination of drinking water sources in rural villages of Mohale Basin, Lesotho: exposures through neighborhoods' sanitation and hygiene practices. Environ Health Prev Med. (2019) 24:33. doi: 10.1186/s12199-019-0790-z

55. Balbino LF, Alves Filho A, Farias BES, et al. Intestinal protozoan infections and environment conditions among rural school children in Western Brazilian. Ama Brazil J Biol. 2023;83:e247530. doi:10.1590/1519-6984.247530

56. Santos HLC, Rebello KM. An overview of mucosa associated protozoa: challenges in chemotherapy and future perspectives. Front Cell Infect Microbiol. 2022; 12:860442. doi:10.3389/fcimb.2022.860442

57. Malange EN. The Cholera epidemic and barriers to healthy hygiene and sanitation in Cameroon. Umea University. Epidemiol Public Health. 2010; 2:2

58.Brooker S, Kabatereine NB, Smith JL, et al. An updated atlas of human helminth infections: the example of East Africa. Int J Health Geogr. 2009; 8:42

59. Farthing M, Salam MA, Lindberg G, et al. Acute diarrhea in adults and children: a global perspective. J Clin Gastroenterol. 2013; 47:12-2)

60. Nhampossa T, Mandomando I, Acacio S, et al. Diarrheal disease in rural Mozambique: burden, risk factors, and etiology of diarrheal disease among children aged 0-59 months seeking care at Health Facilities. PloS One. 2015;10: e0119824

61.Efstratiou, A.; Ongerth, J.E.; Karanis, P. Waterborne transmission of protozoan parasites: Review of worldwide outbreaks—An update 2011–2016. Water Res. 2017, 114, 14–22. [CrossRef] [PubMed])

62.(60. WHO. Integrating neglected tropical diseases into global health and development: fourth WHO report on neglected tropical diseases. Geneva: World Health Organization; 2017. Accessed November 21, 2021. http://www.who.int/ neglected_diseases/en

63.Eyayu T, Kiros T, Workineh L, Sema M, Damtie S, Hailemichael W, et al. (2021) Prevalence of intestinal parasitic infections and associated factors among patients attending at Sanja Primary Hospital, Northwest Ethiopia: An institutional-based cross-sectional study. PLoS ONE 16(2): e0247075. https://doi.org/10.1371/journal.pone.0247075

64.Keredin & Prasada 2016, Keredin T. S. Prasada P. R. 2016 Review on water resources and sources for safe drinking and improved sanitation in Ethiopia. International Journal of Applied Research 2(3),78–82

65.Utterworth, J., Sutton, S., & Mekonta, L. (2013). Self-supply as a complementary water services delivery model in Ethiopia. Water Alternatives, 6(3), 405).

66. Ashbolt, N.J., Grabow, W.O.K., Snozzi, M., 2001. Indicators of microbial water quality. In: Fewtrell, L., Bartram, J. (Eds.), Water Quality: Guidelines, Standards and Health. Risk

assessment and management for water-related infectious disease. IWA Publishing, London (Chapter 13), pp. 289–315|A

67. Hunter, P.R., Waite, M., Ronchi, E., 2002. Drinking Water and Infectious Disease: Establishing the Links. IWA Publishing, London.

68.Valiathan R, Ashman M, Asthana D. Effects of ageing on the immune system: Infants to elderly. Scand J Immunol. 2016; 83:255-266

69. Shaima SN, Das SK, Ahmed S, et al. Anthropometric indices of Giardia infected under-five children presenting with Moderate-to-Severe diarrhea and their healthy community controls: Data from the Global Enteric Multicenter Study. Children. 2021; 8:1186

70.Chelkeba L, Mekonnen Z, Alemu Y, Emana D. Epidemiology of intestinal parasitic infections in preschool and school-aged Ethiopian children: a systematic review and meta-analysis. BMC Public Health. 2020; 20:117)

71.Wilkins HA. Reinfection after treatment of schistosome infections. Parasitol Today 1989; 5:83–8. https:// doi.org/10.1016/0169-4758(89)90008-2 PMID: 15463185

72.Cundill B, Alexander N, Bethony JM, Diemert D, Pullan RL, Brooker S. Rates and intensity of re-infection with human helminths after treatment and the influence of individual, household, and environmental factors in a Brazilian community. Parasitology. 2011; 138(11):1406–16. https://doi.org/10.1017/ S0031182011001132 PMID: 21819640

73.Ayalew J, Abebe G, Solomon A, John S. Treatment efficacy and re-infection rates of soil-transmitted helminths following mebendazole treatment in schoolchildren, Northwest Ethiopia: cross-sectional study. Trop Med Int Health. 2020;48(1):90. doi:10.1186/s41182-020-00282-z

74. Woldegerima E, Bayih AG, Tegegne Y, Aemero M, Jejaw Zeleke A.. Prevalence and reinfection rates of schistosoma mansoni and praziquantel efficacy against the parasite among primary school children in Sanja Town, Northwest Ethiopia. J Parasitol Res Vol. 2019; 3697216:8. doi:10.1155/2019/ 3697216

75.Arnold BF, Colford JM. Treating water with cholorine at point-of-use to improve water quality and reduce child diarrhea in developing countries: a systematic review and meta-analysis. Am J Trop Med Hyg. 2007;76(2):354–64

76. Legesse M, Erko B. Prevalence of intestinal parasites among schoolchildren in a rural area close to the southeast of Lake Langano, Ethiopia. The Ethiopian Journal of Health Development. 2004;18(2).

77.WHO. Neglected tropical diseases. 2018. http://www.who.int/neglected_ diseases/diseases/en/. Accessed 22 Sept 2023].

78. Chatterjee, K.D.2009. Parasitology (Protozoology and Helminthology) in relation to clinical medicine. 13thed. CBS Publisher and Distributor, India, 264pp

79. Putignani, L.; Menichella, D. Global Distribution, Public Health and Clinical Impact of the Protozoan Pathogens. Interdiscip. Perspect. Infect. Dis. 2010, 2010, 753512).

80. World Health Organization. Global distribution and prevalence of soil-transmitted helminth infections. Geneva: World Health Organization key fact sheet. 2020.

81. Ryan, K.J. and Ray, C.G., Eds. (2004) Sherris Medical Microbiology. 4th Edition, McGraw-Hill, New York.

82. Kasırga E. The importance of stool tests in diagnosis and follow-up of gastrointestinal disorders in children. Turk Pediatri Ars 2019; 54(3): 141–8.

83. Arora D.R. and Arora, B. 2012. Medical Parasitology 14th ed. CBS Publisher and Distribusher, 138 pp.

84. WHO (2002) Prevention and Control of Schistosomiasis and Soil-Transmitted Helminthiasis: Report of a WHO expert committee. Geneva,Switzerland: World Health Organization.

85. Shoup B. Diagnosis and management of pinworm infection. Primary Care Update for OB/GYNS. 2001;8(6):240–3.

86. Dudlova A, Juris P, Jarcuska P, Vasilkova Z, Vargova V, Sumkova M, et al. The incidence of pinworm (Enterobius vermicularis) in pre-school and school aged children in the eastern Slovakia. Helminthologia. 2018;55(4):275–80.

87. Pezzani BC, Minvielle MC, de Luca MM, Córdoba MA, Apezteguía MC, Basualdo JA. Enterobius vermicularis infection among population of General Mansilla, Argentina. World J Gastroenterol. 2004;10(17):2535–9.

88. Mattia, D.D., Manikonda, K., Hall, A.J., Wise, M.E., et al. Surveillance for Foodborne Disease Outbreaks - United States, 2009–2015, CDC, 2018 / 67(10);1–11

89. Enrique, C., Cruz, A., 2017. Intestinal protozoal diseases. 2017. https :// e medicine. medsc ape.com/artic le/99928 2-overview

90.WHO, W., 2015. WHO ESTIMATES OFTHE GLOBAL BURDEN OF FOODBORNE DISEASES: foodborne disease burden epidemiology reference group 2007-2015.

91. Hernandez PC, Morales L, Chaparro-Olaya J, Sarmiento D, Jaramillo JF, Ordoñez GA, et al. Intestinal parasitic infections and associated factors in children of three rural schools in Colombia. A cross-sectional study. PloS one. 2019;14(7).

92.Dahal C. Intestinal Parasitic Infection among the School Children of Kathmandu, Nepal 2018.

93. Turki H, Hamedi Y, Heidari-Hengami M, Najafi-Asl M, Rafati S, Sharifi-Sarasiabi K. Prevalence of intestinal parasitic infection among primary school children in southern Iran. Journal of Parasitic Diseases. 2017;41(3):659-65).

94. Odo G, Agwu J, Ekeh F, Ezea C, Aguoru G, Anya C, et al. Prevalence of intestinal parasites among school children in Uzo-Uwani local governemnt area of Enugu State. 2016.

95. Ahmed B, Mohamed AR, Anwar AH, Ahmed AS, Islam AK. Parasitic Profile among Primary School Children in A Rural Area at Beheira Governorate, Egypt. Egyptian Journal of Hospital Medicine. 2018;70(12).

96. Aleka, Y. T., et al. (2020). A systematic review and meta-analysis of intestinal parasitic infections among children in Ethiopia. Tropical Medicine and Health, 48(1), 1-11. https://doi.org/10.1186/s41182-020-00254-7

97. Abate, E., et al. (2019). Prevalence of intestinal parasitic infections and associated risk factors among rural school children in Amhara region, Ethiopia. BMC Infectious Diseases, 19(1), 897. https://doi.org/10.1186/s12879-019-4496-9

98.Tadesse, G., et al. (2018). Epidemiology of intestinal parasites and associated risk factors among children in Oromia, Ethiopia. BMC Public Health, 18, 1239. https://doi.org/10.1186/s12889-018-6130-x

99.Mekonnen, Z., et al. (2017). Prevalence of intestinal parasites and associated risk factors among children in SNNPR, Ethiopia. Journal of Parasitology, 103(5), 540–546. https://doi.org/10.1645/16-167

100. Kebede, T., et al. (2016). Intestinal parasitic infections among children in rural areas of Tigray, northern Ethiopia. Journal of Parasitology Research, 2016, 6743632. https://doi.org/10.1155/2016/6743632

101. Hailegebriel T. Prevalence of intestinal parasitic infections and associated risk factors among students at Dona Berber primary school, Bahir Dar, Ethiopia. BMC infectious diseases. 2017;17(1):362.).

102. Sitotaw B, Mekuriaw H, Damtie D. Prevalence of intestinal parasitic infections and associated risk factors among Jawi primary school children, Jawi town, north-west Ethiopia. BMC infectious diseases. 2019;19(1):341.

103. Alemu M, Anley A, Tedla K. Magnitude of Intestinal Parasitosis and Associated Factors in Rural School Children, Northwest Ethiopia. Ethiopian journal of health sciences. 2019;29(1)) .

104. Siddig HS, Mohammed IA, Mohammed MN, Bashir AM. Prevalence of intestinal parasites among selected group of primary school children in Alhag Yousif Area, Khartoum, Sudan. Int J Med Res Health Sci. 2017;6(8):125-31

105. Firdu Z. and Mulatu K., Prevalence of Intestinal Parasites and Associated Risk Factors among Diarrheal Patients Attending Negelle Borena General Hospital: A Case-Control Study Journal of Parasitology Research Volume 2023, Article ID 1990468, 9 pages https://doi.org/10.1155/2023/1990468).

106. Suliman MA, Magboul AM, Mohammed HY, Tamomh AG, Bakhit HA et al. (2019) Prevalence of Intestinal Parasitic Infections and Associated Risk Factors among School Children in White Nile State, Sudan. J Infect Dis Diagn 4: 125. doi:10.4172/2576-389X.1000125).

107.Tigabu A, Taye S, Aynalem M, Adane K. Prevalence and associated factors of intestinal parasitic infections among patients attending Shahura Health Center, Northwest Ethiopia BMC Res Notes (2019) 12:333 https://doi.org/10.1186/s13104-019-4377-y.

108. Jayarani K, Sandhya-rani T, Jayaranjani K. Intestinal parasitic infections in preschool and school going children from rural area in Puducherry. Curr Res Microbiol Biotechnol. 2014;2(4):406–9

109.Daryani A, Hosseini-Teshnizi S, Hosseini S-A, Ahmadpour E, Sarvi S, Amouei A, et al. Intestinal parasitic infections in Iranian preschool and school children: a systematic review and meta-analysis. Acta Trop. 2017; 169:69–83

110.Nwosu A. The community ecology of soil-transmitted helminth infections of humans in a hyperendemic area of southern Nigeria. Ann Tropical Med Parasitol. 1981;75(2):197–203.

111. Hotez, P. J., Fenwick, A., Savioli, L., & Molyneux, D. H. (2019). Rescuing the bottom billion through control of neglected tropical diseases. The Lancet, 373(9674), 1570-1575

112. Hailu G and Ayele E. Assessment of the prevalence of intestinal parasitic infections and associated habit and culture-related risk factors among primary schoolchildren in Debre Berhan town, Northeast Ethiopia. BMC Public Health (2021) 21:112 https://doi.org/10.1186/s12889-020-10148-y

113.Tsegaye B, Yoseph A, and Beyene H. BMC Pediatrics (2020) 20:28 Prevalence and factors associated with intestinal parasites among children of age 6 to 59 months in, Boricha district, South Ethiopia, in 2018. https://doi.org/10.1186/s12887-020-1935-3

114.Tembo S, Mubita P, Sitali L, Zgambo J. Prevalence, Intensity, and Factors Associated with Soil-Transmitted Helminths Infection among Children in Zambia. The Open Public Health Journal, 2019, Volume 12 285 DOI: 10.2174/1874944501912010284, 2019, 12, 284-293.

115. Abossie A and Seid M. Assessment of the prevalence of intestinal parasitosis and associated risk factors among primary school children in Chencha town, Southern Ethiopia. d BMC Public Health 2014, 14:166 http://www.biomedcentral.com/1471-2458/14/166.

116. Hakizimana E, Kim JY, Oh S, Yoon M, Yong TS. Intestinal parasitic infections among children aged 12–59 months in Nyamasheke District, Rwanda. Parasites Hosts Dis 2023;61(3):304-30,

117. Doni NY, Gurses G, Simsek Z, Zeyrek FY. Prevalence and associated risk factors of intestinal parasites among children of farm workers in the southeastern Anatolian region of Turkey. Ann Agric Environ Med. 2015; 22:438.

118. Al-Megrin, WA. 2015. "Risk factors among preschool children in Riyadh, Saudi Arabia", Res J Parasitol, 10: 31-41. DOI: 10.3923/jp.2015.31.41.

119. Aschale A, Adane M, Getachew M, Faris K, Gebretsadik D, Sisay T, et al. (2021) Water, sanitation, and hygiene conditions and prevalence of intestinal parasitosis among primary school children in Dessie City, Ethiopia. PLoS ONE 16(2): e0245463. https://doi.org/10.1371/journal.pone.0245463.

120. Gizaw Z, Addisu A, Gebrehiwot M. Socioeconomic Predictors of Intestinal Parasitic Infections Among Under-Five Children in Rural Dembiya, Northwest Ethiopia: A Community-Based Cross-sectional Study. Environmental Health Insights Volume 13: 1–6 2019 ttps://doi.org/10.1177/1178630219896804).

121. Gebru H, Deyessa N, Medhin G and Kloos H. The Association of Sanitation and Hygiene Practices with Intestinal Parasitic Infections Among Under-14 Children in Rural Dire Dawa,

Eastern Ethiopia: A Community Based Cross-sectional Study. Environmental Health Insights 2023 Volume 17: 1–9 https://doi.org/10.1177/11786302231180801).

122. Alemu G, Aschalew Z, Zerihun E. Burden of intestinal helminths and associated factors three years after initiation of mass drug administration in Arbaminch Zuria district, southern Ethiopia. BMC Infect Dis. 2018; 18:435. https://doi.org/10.1186/s12879-018-3330-3

123. Abate A, Kibret B, Bekalu E, Abera S, Teklu T, Yalew A, Endris M, Worku L, Tekeste Z. Cross-Sectional Study on the Prevalence of Intestinal Parasites and Associated Risk Factors in Teda Health Centre, Northwest Ethiopia. Volume 2013, Article ID 757451, 5 pages http://dx.doi.org/10.5402/2013/757451).

124. Gebretsadik D, Tesfaye M, Adamu A, Zewde G. Prevalence of Intestinal Parasitic Infection and Its Associated Factors Among School Children in Two Primary Schools in Harbu Town, North East Ethiopia: Cross-Sectional Study. Pediatric Health, Medicine and Therapeutics 2020:11

125. Feleke DG, Arega S, Tekleweini M, Kindie K, Gedefie A. Schistosoma mansoni and other helminthes infections at Haike primary school children, North-East, Ethiopia: a cross-sectional study. BMC Res Notes. 2017;10(1):609. doi:10.1186/s13104-017-2942-9

126. Gelaw A, Anagaw B, Nigussie B, et al. Prevalence of intestinal parasitic infections and risk factors among schoolchildren at the University of Gondar Community School, Northwest Ethiopia: a cross-sectional study. BMC Public Health. 2013;13(1):304. doi:10.1186/1471-2458-13-304).

127. Gebru H, Deyessa N, Medhin G and Kloos H. Childhood Intestinal Parasitic Reinfection, Sanitation and Hygiene Practice in Eastern Ethiopia: Case Control Study. Infection and Drug Resistance 2024:17 1791–1802 https://doi.org/10.2147/IDR.S455037

128. Gupta R, Rayamajhee B, Sherchan SP, Rai G, Mukhiya RK, Khanal B, Rai SK. Prevalence of intestinal parasitosis and associated risk factors among school children of Saptari district, Nepal: a cross-sectional study. Trop Med Health. 2020 Aug 24; 48:73. doi: 10.1186/s41182-020-00261-4. PMID: 32848503; PMCID: PMC7444033

129. Ahmadu BU, Rimamchika, Ibrahim A, Nnanubumom AA, Godiya A, Emmanuel P. State of personal hygiene among primary school children: a community-based cohort study. Sudan J Paediatr 2013; 13(1):38-42.

130. Dongre AR, Deshmukh PR, Boratne AV, Thaware P, Garg BS. An approach to hygiene education among rural Indian school going children. Online J Health Allied Scs. 2007;4:2. URL:http://www.ojhas.org/issue24/2007-4-2.htm

131. Ranjit Gupta, Binod Rayamajhee, Samendra P. Sherchan , Ganesh Rai, Reena Kiran Mukhiya , Binod Khanal1 and Shiba Kumar Rai. Tropical Medicine and Health (2020) 48:73 https://doi.org/10.1186/s41182-020-00261-4Ra

132. Firdu Z, Mulatu K. Prevalence of Intestinal Parasites and Associated Risk Factors among Diarrheal Patients Attending Negelle Borena General Hospital: A Case-Control Study. Journal of Parasitology Research Volume 2023, Article ID 1990468, 9 pages https://doi.org/10.1155/2023/1990468.

133. Alamir M., Awoke W, Feleke A. Intestinal parasites infection and associated factors among school children in Dagi primary school, Amhara National Regional State, Ethiopia. Health 2013; 5 (10), 1697-1701. Available at: http://dx.doi.org/10.4236/health.2013.510228

134. Alemu G, Abossie A, Yohannes Z. Current status of intestinal parasitic infections and associated factors among primary school children in Birbir town, Southern Ethiopia. BMC Infectious Diseases (2019) 19:270 https://doi.org/10.1186/s12879-019-3879-5

135. Shrestha A, Six J, Dahal D, Marks S, Meierhofer R. Association of nutrition, water, sanitation and hygiene practices with children's nutritional status, intestinal parasitic infections and diarrhoea in rural Nepal: a cross-sectional study. BMC Public Health (2020) 20:1241. https://doi.org/10.1186/s12889-020-09302-3).

136. Sah RB, Bhattarai S, Yadav S, Baral R, Jha N, Pokharel PK. A study of prevalence of intestinal parasites and associated risk factors among the school children of Itahari, Eastern Region of Nepal. Trop Parasitol. 2013; 3:140–4

137. Shakya B, Shrestha S, Madhikarmi NL, Adhikari R. Intestinal parasitic infection among school children. J Nepal Health Res Counc. 2012; 10:20–3

138. Shrestha A, Narayan KC, Sharma R. Prevalence of intestinal parasitosis among school children in Baglung districts of Western Nepal. Kathmandu Univ Med J KUMJ. 2012; 10:3–6

139. Weidengus GG. Current status of intestinal parasites and associated risk factors among schoolchildren of Homesha District in Northwest Ethiopia. Int J Curr Res. 2017;9(7):54369–74.

140. Al-Hindi, A. I., & Elmanama, A. A. (2018). Prevalence of intestinal parasites among primary school children in Gaza Strip, Palestine. The Korean Journal of Parasitology, 56(5), 465-472

141. Zemichael G, Tsegaye A, Jember A, Ayenew A and Daniel H. Childhood intestinal parasitic infection and sanitation predictors in rural Dembiya, northwest Ethiopia. Environmental Health and Preventive Medicine (2018) 23:26 https://doi.org/10.1186/s12199-018-0714-3

142. Tolera A, Dufera M. The Prevalence of Soil-Transmitted Helminths and Associated Risk Factors among School Children at Sekela Primary School, Western Ethiopia. Journal of Parasitology Research. 2020;2020(1):8885734.

143. Tadesse M, Dobo B, Birmeka M. Prevalence and associated risk factors of intestinal parasitic infections among school children in Bamo no. 2 primary school, Adele town, East Arsi, Ethiopia. Sub-Saharan Afr J Med 2019; 6:77-85

144. Mekonnen, H.S., Ekubagewargies, D.T Prevalence and factors associated with intestinal parasites among under-five children attending Woreta Health Center, Northwest Ethiopia. BMC Infectious Diseases (2019) 19:256 https://doi.org/10.1186/s12879-019-3884-8

145. Assemie MA, Shitu Getahun D, Hune Y, Petrucka P, Abebe AM, Telayneh AT, et al. (2021) Prevalence of intestinal parasitic infection and its associated factors among primary school students in Ethiopia: A systematic review and meta-analysis. PLoS Negl Trop Dis 15(4): e0009379. https://doi. org/10.1371/journal.pntd.0009379

146. Ziegelbauer K, Speich B, Ma¨usezahl D, Bos R, Keiser J, et al. (2012) Effect of Sanitation on Soil-Transmitted Helminth Infection: Systematic Review and Meta-Analysis. PLoS Med 9(1): e1001162. doi: 10.1371/journal.pmed.1001162

147. Sitotaw B, Mekuriaw H, Prevalence of Intestinal Parasitic Infections and Associated Risk Factors among the First-Cycle Primary Schoolchildren in Sasiga District, Southwest Ethiopia. Journal of Parasitology Research Volume 2020, Article ID 8681247, 13 pages https://doi.org/10.1155/2020/8681247

148.. Freeman, M.C., Chard, A.N., Nikolay, B. *et al*. Associations between school-and household-level water, sanitation and hygiene conditions and soil-transmitted helminth infection among Kenyan school children. Parasites & Vectors (2015) 8:412. DOI 10.1186/s13071-015-1024-

149. Shehmolo M, Gari T, Jember Tesfaye D, Boti N, Oumer B. Magnitude and factors associated with hygiene practice among primary school children in Mareko District, southern Ethiopia: A cross-sectional study. J Multidiscip Healthcare. 2021; 14:311-320

150. Nath J, Banyal N, Gautam D, Ghosh S, Singha B, Paul J. Systematic detection and association of Entamoeba species in stool samples from selected sites in India. Epidemiology Infection. 2015; 143 (1):108–19. https://doi.org/10.1017/S0950268814000715 PMID: 24703238).

151. Edition, Fourth. Guidelines for drinking-water quality, WHO Chronicle 38 (4) (2011) 104–108

152. WHO (World Health Organization). Guidelines for Drinking-water Quality, Incorporating 1st and 2nd Addenda, Volume 1, Recommendations, 3rd ed.; WHO: Geneva, Switzerland, 2008

153. Speich B, Croll D, Fürst T, Utzinger J, Keiser J. Effect of sanitation and water treatment on intestinal protozoa infection: a systematic review and meta-analysis. Lancet Infect Dis. 2016; 16:87–99

154. WHO. Guidelines for drinking-water quality. Geneva: World Health Organization; 2011

155. Soboksa NE, Gari SR, Hailu AB, Alemu BM (2020) Association between microbial water quality, sanitation and hygiene practices and childhood diarrhea in Kersa and Omo Nada districts of Jimma Zone, Ethiopia. PLoS ONE 15(2): e0229303. https://doi.org/10.1371/journal. pone.0229303

156. Adane M, Mengistie B, Medhin G, Kloos H, Mulat W. Piped water supply interruptions and acute diarrhea among under-five children in Addis Ababa slums, Ethiopia: A matched case-control study. PLoS One. 2017; 12: e0181516. https://doi.org/10.1371/journal.pone.0181516 PMID: 28723927

157. Sitotaw B., & Geremew M. Bacteriological and Physicochemical Quality of Drinking Water in Adis Kidame Town, Northwest Ethiopia International Journal of Microbiology Volume 2021, Article ID 6669754, 6 pages https://doi.org/10.1155/2021/6669754).

158. Gebrewahd A, Adhanom G, Gebremichail G, Kahsay T, Berhe B, Asfaw Z, Tadesse S, Gebremedhin H, Negash H, Tesfanchal B, Haileselasie H. Bacteriological quality and associated

risk factors of drinking water in Eastern zone, Tigrai, Ethiopia, 2019. Tropical Diseases, Travel Medicine and Vaccines (2020) 6:15 https://doi.org/10.1186/s40794-020-00116-0

159. Abera S, Zeyinudin A, Kebede B, Deribew A, Ali S, Zemene E. Bacteriological analysis of drinking water sources. Afr J Microbiol Res. 2011;5(18):2638–41.

160. Yadav K, Prakash S. Study of Intestinal Parasitosis among School Children of Kathmandu Valley, Nepa. Asian Journal of Biomedical and Pharmaceutical Sciences 2016 Volume 6 Issue 59

161. Zemene T, Shiferaw MB. Prevalence of intestinal parasitic infections in children under the age of 5 years attending the Debre Birhan referral hospital, North Shoa, Ethiopia. BMC Res Notes (2018) 11:58 https://doi.org/10.1186/s13104-018-3166-3

162. Workneh T, Esmael A, Ayichiluhm M (2014) Prevalence of Intestinal Parasitic Infections and Associated Factors among Debre Elias Primary Schools Children, East Gojjam Zone, Amhara Region, North West Ethiopia. J Bacteriol Parasitol 5: 181. doi: 10.4172/2155-9597.1000181).

163. Asrat AY, Tewodros DE, Alemayehu WO (2011) prevalence and risk factors of intestinal parasites among delgi school children, North Gonder. Ethiop J Health and Biomed Sci 3: 75-81.

164. Matthys B, Bobieva M, Karimova G, Mengliboeva Z, Jean-Richard V, Hoimnazarova M, Kurbonova M, Lohourignon LK, Utzinger J, Wyss K, Prevalence and risk factors of helminths and intestinal protozoa infections among children from primary schools in western Tajikistan. Parasites & Vectors 2011, 4:195 http://www.parasitesandvectors.com/content/4/1/195

165. Steinmann P, Usubalieva J, Imanalieva C, Minbaeva G, Stefiuk K, Jeandron A, Utzinger J: Rapid appraisal of human intestinal helminth infections among schoolchildren in Osh oblast, Kyrgyzstan. Acta Trop 2010

166. Ouattara M, N'Guéssan NA, Yapi A, N'Goran EK. Prevalence and spatial distribution of Entamoeba histolytica/dispar and Giardia lamblia among schoolchildren in Agboville area (Côte d'Ivoire). PLoS Negl Trop Dis. 2010; 4(1): e574

167. Cifuentes E, Suarez L, Espinosa M, Juarez L, Martinez-Palomo A. Risk of Giardia Intestinalis Infection in Children from an Artificially Recharged Groundwater Area in Mexico City. Epidemiology. 2006 Nov 1;17(6): S392-3.

168.Tandukar S, Sherchand JB, Xue J, Uprety S, Sherchan SP, Bhandari D, et al. Prevalence and associated risk factors of Giardia duodenalis infection among school-going children in Nepal. Parasitol Res. 2018; 117:287–93.

169. Esrey SA, Potash JB, Roberts L, Shiff C. Effects of improved water supply and sanitation on ascariasis, diarrhoea, dracunculiasis, hookworm infection, schistosomiasis, and trachoma. Bulletin of the World Health organization. 1991;69(5):609

170. Ben Ayed L, Belhassen K, Sabbahi S, Karanis P, Nouiri I, health. Assessment of the parasitological quality of water stored in private cisterns in rural areas of Tunisia. Journal of water health. 2018; 16 (5):737–49. https://doi.org/10.2166/wh.2018.117 PMID: 30285955

171. Gizaw Z, Addisu A, Dagne H. Effects of water, sanitation and hygiene (WASH) education on childhood intestinal parasitic infections in rural Dembiya, northwest Ethiopia: an uncontrolled before and-after intervention study. Environmental Health and Preventive Medicine (2019) 24:16 https://doi.org/10.1186/s12199-019-0774-z.

172. Erismann S, Diagbouga S, Odermatt P, Knoblauch AM, Gerold J, Shrestha A, Grissoum T, Kaboré A, Schindler C, Utzinger J, Cissé G. Prevalence of intestinal parasitic infections and associated risk factors among schoolchildren in the Plateau Central and Centre-Ouest regions of Burkina Faso. Parasites & Vectors (2016) 9:554 DOI 10.1186/s13071-016-1835-4

173. Belete YA, Kassa TY, Baye MF (2021) Prevalence of intestinal parasite infections and associated risk factors among patients of Jimma health center requested for stool examination, Jimma, Ethiopia. PLoS ONE 16(2): e0247063. https://doi.org/10.1371/journal.pone.0247063).

174. Candela E, Goizueta C, Periago MV, Muñoz-Antoli C. Prevalence of intestinal parasites and molecular characterization of Giardia intestinalis, Blastocystis spp. and Entamoeba histolytica in the village of Fortín Mbororé (Puerto Iguazú, Misiones, Argentina). (2021) 14:510 https://doi.org/10.1186/s13071-021-04968-z

175. Alemeshet Asefa Y, Alemu BM, Baraki N, Mekbib D, Mengistu DA (2021) Bacteriological quality of drinking water from source and point of use and associated factors among households in Eastern Ethiopia. PLoS ONE 16(10): e0258806. https://doi.org/10.1371/journal.pone.0258806

176. Gebru H, Deyessia N, Medhin G and Kloos H. Microbial drinking water quality among Intestinal parasite infected and non-infected children, Eastern Ethiopia: Case control study (not published)

177. Mahmud MA, Spigt M, Bezabih AM, Pavon IL, Dinant G-J, Velasco RB (2015) Efficacy of Handwashing with Soap and Nail Clipping on Intestinal Parasitic Infections in School-Aged Children: A Factorial Cluster Randomized Controlled Trial. PLoS Med 12(6): e1001837. doi:10.1371/ journal. pmed.1001837

178. Gungorena B, Latipov R, Regallet G, Musabaev E. Effect of hygiene promotion on the risk of reinfection rate of intestinal parasites in children in rural Uzbekistan. Trans R Soc Trop Med Hyg 2007; 101:564– 569. PMID: 17418321

179. Monse B, Benzian H, Naliponguit E, Belizario V, Schratz A, Helderman WVP. The Fit for School health outcome study—a longitudinal survey to assess health impacts of an integrated school health programme in the Philippines. BMC Public Health 2013; 13:256. doi: 10.1186/1471-2458-13-256 PMID: 23517517.

180. Pham Duc P, Nguyen-Viet H, Hattendorf J, Zinsstag J, Dac Cam P, Odermatt P. Risk factors for Entamoeba histolytica infection in an agricultural community in Hanam Province, Vietnam. Parasit Vectors 2011; 4:102. doi: 10.1186/1756-3305-4-102 PMID: 21663665

181. Boehm AB, Wang D, Ercumen A, Shea M, Harris AR, Shanks OC, et al. Occurrence of host-associated fecal markers on child hands, household soil, and drinking water in rural Bangladeshi households. Environ Sci Technol Lett. 2016; 3:393–8

182. Odagiri M, Schriewer A, Daniels ME, Wuertz S, Smith WA, Clasen T, et al. Human fecal and pathogen exposure pathways in rural Indian villages and the effect of increased latrine coverage. Water Res. 2016; 100:232–244

183. Harris AR, Pickering AJ, Harris M, Doza S, Islam MS, Unicomb L, et al. Ruminants contribute fecal contamination to the urban household environment in Dhaka, Bangladesh. Environ Sci Technol. 2016; 50:4642–9

184. Ercumen A, Pickering AJ, Kwong LH, Arnold BF, Parvez SM, Alam M, et al. Animal feces contribute to domestic fecal contamination: evidence from E. coli measured in water, hands, food, flies, and soil in Bangladesh. Environ Sci Technol. 2017; 51:8725–34

185. Schriewer A, Odagiri M, Wuertz S, Misra PR, Panigrahi P, Clasen T, et al. Human and animal fecal contamination of community water sources, stored drinking water and hands in rural India measured with validated microbial source tracking assays. Am J Trop Med Hyg. 2015; 93:509–516

186. Penakalapati G, Swarthout J, Delahoy MJ, McAliley L, Wodnik B, Levy K, et al. Exposure to Animal Feces and Human Health: A Systematic Review and Proposed Research Priorities. Environ Sci Technol. 2017; 51:11537–52

187. García-Cervantes PC, Báez-Flores ME, Delgado-Vargas F, Ponce-Macotela M, Nawa Y, De-la-Cruz-Otero MDC, et al. Giardia duodenalis genotypes among schoolchildren and their families and pets in urban and rural areas of Sinaloa, Mexico. J Infect Dev Ctries. 2017;11(2):180–7

188. Benhassine S, Baroudi D, Hakem A, Thomas M, Laatamna A, Belkessa S, et al. Occurrence and molecular characterization of Giardia duodenalis in lambs in Djelfa, the central steppe of Algeria. Parasitol Res. 2020; 119:2965–73

189. Sebaa S, Behnke JM, Baroudi D, Hakem A, Abu-Madi MA. Prevalence and risk factors of intestinal protozoan infection among symptomatic and asymptomatic populations in rural and urban areas of southern Algeria. BMC Infect Dis (2021) 21:888 https://doi.org/10.1186/s12879-021-06615-5

190. Bansal D, Gupta P, Singh G, Bhatia M, Singla H. Intestinal Parasitic Infestation in School Going Children of Rishikesh, Uttarakhand, India. Indian Journal of Community Health. 2018; 30(1

191. Bahrami F, Haghighi A, Zamini G, Khadem-Erfan MB, Azargashb E| (2018) Prevalence and associated risk factors of intestinal parasitic infections in Kurdistan province, northwest Iran, Cogent Medicine, 5:1, 1503777, DOI: 10.1080/2331205X.2018.1503777. https://doi.org/10.1080/2331205X.2018.1503777

192. Igore KGG, Payne VK, Nadia NAC, Cedric Y (2020) Risk Factors Associated with Prevalence and Intensity of Gastro-Intestinal Parasitic Infections within Households in Tonga Sub-Division, West Region, Cameroon. J Infect Dis Epidemiol 6:123. doi.org/10.23937/2474-3658/1510123).

193.Yohannes A, Tilahun Y, Baye MF. Prevalence of intestinal parasite infections and associated risk factors among patients of Jimma health center requested for stool examination, Jimma, Ethiopia. PLoS One. 2021;16(2): e0247063. doi: 10.1371/journal.pone.0247063

194. FDRE Central Statistical Agency (CSA). (2013). Ethiopia: Statistical Abstract. Addis Ababa: CSA. https://www.statsethiopia.gov.et)

195. Central Statistical Agency (CSA). (2019). Population Projections for Ethiopia 2017–2037: Regional and Zonal Level. Addis Ababa: CSA.[Available at: https://www.statsethiopia.gov.et

196. National Meteorology Agency of Ethiopia, 2020; Asfaw et al., 2021; USAID, 2018

197. World Health Organization (WHO). (2015). *Sanitation and Cultural Beliefs*

198. Feyisa, D., & Abdi, M. (2020). Socio-cultural determinants of health-seeking behavior in pastoralist communities of eastern Ethiopia: The case of Dire Dawa. *Ethiopian Journal of Health Development*, 34(2), 109–117.

199. Reji P, Belay G, Erko B, Legesse M, Belay M. Intestinal parasitic infections and malnutrition amongst first-cycle primary schoolchildren in Adama, Ethiopia. Afr J Prim Health Care Fam Med. 2011; 3:5. doi:10.4102/phcfm. v4i1.198

200. Zerdo Z, Yohanes T, Tariku B. Soil-transmitted helminth reinfection and associated risk factors among school-age children in chencha district, southern Ethiopia: a cross-sectional study. J Parasitol Res Vol. 2016; 4737891:7. doi:10.1155/2016/4737891

201. Cheesbrough M. District Laboratory Practice in Tropical Countries. Vol. 1. 2nd ed. Cambridge University Press; 2009.

202. World Health Organization, United Nation Children's Fund. Core questions on drinking water and sanitation for household surveys. Joint Monitoring Programme (JMP); 2006. Available from: http://awareness.who.int/water_sanitation_health/publications/core_questio

203. Zonta ML, Cociancic P, Oyhenart EE, Navone GT. Intestinal parasitosis, undernutrition, and socio-environmental factors in schoolchildren from Clorinda Formosa, Argentina. Revista de Salud Pública. 2019; 21:224-231.

204. Sylla K, Kouly Tine RC, Sow D, et al. Epidemiological profile of intestinal parasitic infection among preschool and school chuldren living in a rural community in Senegal: a crosss Sectional Survey. J Bacteriol Parasitol. 2018; 9:343. doi:10.4172/2155-9597.1000343.

205. Hussen S, Assegu D, Tadesse BT, Shimelis T. Prevalence of Schistosoma mansoni infection in Ethiopia: a systematic review and meta-analysis. Trop Dis Travel Med Vaccines. 2021; 7:4-4.

206. Gebretsadik D, Metaferia Y, Seid A, Fenta GM, Gedefie A. Prevalence of intestinal parasitic infection among children under 5 years of age at Dessie Referral Hospital: cross sectional study. BMC Res Notes. 2018; 11:771.

207.Yimer, M., Abera, B., & Mulu, W. (2021). Prevalence and associated factors of intestinal parasitic infections among children in Bahir Dar, Northwest Ethiopia. *BMC Infectious Diseases*, 21, 408. https://doi.org/10.1186/s12879-021-06098-0

208. Wanyiri, J. W., Kanyi, H., Maina, S., Wang, D. E., & Kamau, N. (2020). Association of maternal education and hygiene practices with parasitic infections in Kenyan children. *East African Medical Journal*, 97(7), 255–263.

209. Ahsan, S. F., Ghazali, A. S., & Haque, R. (2018). The role of maternal education in controlling intestinal parasitic infections among children in Bangladesh. *American Journal of Tropical Medicine and Hygiene*, 99(4), 970–976. https://doi.org/10.4269/ajtmh.18-0123

210. Dahal C, Katwal P, Thapa A, Sharma D, Khadka R. Intestinal parasitosis among the School Children of Kathmandu, Nepal. Tribhuvan Univ J Microbiology. 2018;5:89-96

211.Tulu, B., Gebreyesus, H., & Tadesse, A. (2022). Sanitation, hygiene practices and intestinal parasitic infections among school children in southern Ethiopia. *PLOS ONE*, 17(3), e0264973. https://doi.org/10.1371/journal.pone.0264973

212. Echazú A, Bonanno D, Juarez M, Cajal SP, Heredia V, Caropresi S, et al. (2015) Effect of Poor Access to Water and Sanitation as Risk Factors for Soil-Transmitted Helminth Infection: Selectiveness by the Infective Route. PLoS Negl Trop Dis 9(9): e0004111. doi: 10.1371/journal.pntd.0004111

213. Bijay K, Manita T, Jenish S, Anu R , Bidhya D , R , J , Kabiraj K , Santoshi G , Sujata C , Lata C, and Ashu G. Prevalence and Related Risk Factors of Intestinal Parasitosis among Private School-Going Pupils of Dharan Submetropolitan City, Nepal. Journal of Parasitology Research Volume 2021, Article ID 6632469, 10 pages https://doi.org/10.1155/2021/6632469

214. Dagne N, and Alelign A. Prevalence of Intestinal Protozoan Parasites and Associated Risk Factors among School Children in Merhabete District, Central Ethiopia. Hindawi Journal of Parasitology Research Volume 2021, Article ID 9916456, 7 pages https://doi.org/10.1155/2021/9916456

215. Mengistu, A. G., Zeleke, A. J., & Alemayehu, A. A. (2019). Water handling practices and prevalence of intestinal parasites among rural households in northern Ethiopia. *Journal of Water and Health*, 17(1), 55–64. https://doi.org/10.2166/wh.2018.157

216. Rodrigue M, Sali B, Patrick M, Martin S, Jean Blaise K and Vittorio C. Microbiological quality of water sources in the West region of Cameroon: quantitative detection of total coliforms using Micro Biological Survey method Mabvouna Biguioh et al. BMC Public Health (2020) 20:346 https://doi.org/10.1186/s12889-020-8443-0

217. Sebsibe I, Degaga B, Feye G, Tekle T. Bacteriological and physical quality of Fiche drinking water from households and reservoirs, Oromia, Ethiopia, Water Practice and Technology (2021) 16 (3): 924–934. https://doi.org/10.2166/wpt.2021.043)

218. WHO, Guidelines for Drinking-Water Quality, WHO, Geneva, Switzerland, 4th edition, 2017

219. Graziano, A., da Silva, A., & Mandlate, F. (2022). Drinking water quality and intestinal parasitic infections in Mozambique: Risk at the point of use. *International Journal of Environmental Health Research*, 32(6), 1267–1276. https://doi.org/10.1080/09603123.2021.1900555

220. Eveline H, Silué KD, Fabien Z, et al. Effect of an integrated intervention package of preventive chemotherapy, community-led total sanitation and health education on the prevalence of helminth and intestinal protozoa infections in Côte d'Ivoire. Parasites Vectors. 2018;11(1):115. doi:10.1186/ s13071-018-2642-x

221. Gitahi MW, Otieno GO, Atieli HE, Kabiru EW. Effects of public health interventions on intestinal parasitic infections among school-going children n Murang'a county, Kenya afr. J Health Sci. 2021;34(5):577–586.

222. Gazzinelli A, Oliveira-Prado R, Matoso LF, et al. Schistosoma mansoni reinfection: analysis of risk factors by classification and regression tree (CART) modeling. PLoS One. 2017;12(8):e0182197. doi:10.1371/journal.pone.0182197

223.Yordanos G, Hagos Z, Tesfahun M, Aseer M, Serawit L. and Abinet T.Prevalence and associated risk factors of intestinal parasites among school children from two primary schools in Rama town, northern Ethiopia. Can J Infect Dis Med Microbiol. 2020;8. doi:10.1155/2020/5750891

224. Minichil L, Destaw D, Dires T. Prevalence and associated risk factors of human intestinal helminths parasitic infections in Ethiopia. 2022, ID 3905963,15: a systematic review and meta-analysis. Sci World J. 2022:2:1.

225.Yohannes A, Tilahun Y, Baye MF. Prevalence of intestinal parasite infections and associated risk factors among patients of Jimma health center requested for stool examination, Jimma, Ethiopia. PLoS One. 2021;16(2):e0247063. doi:10.1371/journal.pone.0247063

226. Bahador S, Ghasem H, Mohammad H, Mohammad F, Abdolali M. Prevalence and risk factors of intestinal protozoan infections: a population-based study in rural areas of Boyer-Ahmad district, Southwestern Iran. BMC Infect Dis. 2016;16(1):703. doi:10.1186/s12879-016-2047-4

227. Feleke BE, Beyene MB, Feleke TE, Jember TH, Abera B, Fan CK. Intestinal parasitic infection among household contacts of primary cases, a comparative cross-sectional study. PLoS One. 2019;14(10):e0221190. doi:10.1371/journal.pone.0221190

228. Kebede, A., Seid, M., & Teshome, D. (2021). Zoonotic intestinal parasites among children and domestic animals in Wollo, Northeast Ethiopia. *Parasite Epidemiology and Control*, 14, e00204. https://doi.org/10.1016/j.parepi.2021.e00204

229. Lima, L. C., Silva, M. J., & Nogueira, M. B. (2018). Zoonotic intestinal parasites in children and domestic animals in Brazil: Risk of household transmission. *Veterinary Parasitology*, 258, 43–48. https://doi.org/10.1016/j.vetpar.2018.05.002

Annex 1:

Supplementary material 2nd questionnaire

Data Collection Instrument

HOUSEHOLD LEVELQUESTIONNAIRE

for the **Study of Childhood Intestinal Parasitic Reinfection, Sanitation and Hygiene practice in eastern Ethiopia** (2021) (English)

IDENTIFICATION						
Site Name						
Name of Household Head						
Kebele/Village Number						
Household Number						
QUESTIONNAIRE ADMINSTERING VISITS						
Visit	1	2	3	4	5	6
Date						
Result*						
Next Visit: Date						
Time						
Name and Signature of the interviewer					Date	
Result codes: 1= completed, 2=postponed, 3=refused, 4=other (specify) _____						

Section 1 Socio-demographic characteristics of the respondents

No.	Questions and filters	Coding categories	Skip to
1	What is your child age in year? (Ageold)	1.1-4 2.5-9 3.10-14	
2	Sex of the child	1.Male 2.Female	
3	Relation of the head of the household to the child	1.Father 2. Mother 3.Elder brother/siter 4.Other (specify) _____	
4	What is your religion?	1.Islam 2.Orthodox Christian 3.Protestant Christian 4.Other (specify)_____	
5	What is your ethnic group?	1.Amhara 2.Oromo 3.Somali 4.Others	
6	What is your family size in the household?	1. 1-3 2. 3-6 3. >6	
7	What is maternal education level?	1.Illiterate 2. Primary 3.Secondry	

		4.Tertiary	
8	What is paternal education level?	1.Illiterate 2.Primery 3.Secondry 4.Tertiary	
9	What is maternal main occupation?	1.House wife 2.Farmer 3.Merchant 4.Other	
10	What is paternal main occupation? Concideration	1.Farmer 2.Merchant 3.Daily laborer 5.Other	
11	What is your family size in the household?	1. 1-3 2. 3-6 3. >6	
12	Is there sharing of underwear b/n siblings?	1.Yes 2.No	
13	Does the child have mud/pica eating habit?	1. Yes 2. No	
14	Does your child eat food items sold on the street?	1. Yes 2. No	
15	Does your child have behavior of fingernails trimming/thumb sucking	1. Yes 2. No	
16	Shoe wearing habit	1. Yes 2. No	
17	Habit of swimming in a contaminated water	1.Yes 2.No	
18	Child's bathing place	1.Home 2. Local streams and reservoirs 3.Both	
19	What is the source of fuel in your household	1.Wood 2.Dung 3. Coal 4. Petroleum 5. Other	
20	Do you have domestic animal	1.Yes 2.No	
21	If your answer is yes, Is the primary living house shared with livestock during night?	1.Yes 2.No	
22	How much is your average monthly income?	Birr [_____]	

Part 2 Knowledge related questionnaire

No.	Questions	**Responses**	Skip to
23	Do you know how a child gets infection with intestinal parasites?	1.Yes 2.No	
24	If your answer is yes, how can a person acquire IPIs? • ***Don't read the list*** ***Circle all responses that apply***	1.By drinking of contaminated water 2.By eating of contaminated food 3.due to poor personal hygiene 4. From domestic animals like dogs, cat, goats, chickens	

		5. Other (specify)…….	
25	What are the main signs and symptoms of IPIs? • ***Don't read the list*** ***Circle all responses that apply***	1.diarrhea 2.vomiting 3.Aneroxia 4.abdominal pain 5. Other (specify)…. 6.Don't know	
26	Do you think intestinal parasitic infection have any health-related complication?	1.Yes 2.No	
27	If your answer is yes, which complication/consequences of intestinal parasitic infection do you know	1. growth retardation 2. thinness 3. weakness/lethargy 5. Other (specify)…….	
28	Have your child ever been diagnosed with intestinal parasitic infection?	1.Yes 2.No	
29	If your answer is yes does your child ever been treated?	1.With drug from health institution 2.With traditional drugs 3.Not at all	
30	Have your child ever taken de worming?	1.No 2.Yes 3.Don't remember	

PART-Three Sanitation related questionnaire

No.	Questions	**Responses**	Skip to
31	Do you have latrine in your compound?	1.Yes 2.No	
32	If yes What kind of latrine is found in your compound?	1.Pit latrine___ 2.Private wooden slab 3.Private cement slab latrine 4.Private VIP latrine 5.Shared wooden slab latrine 6.Shared VIP latrine 7.Flash to sewerage system 8.Other (specify)……	
33	When do you use latrine	1.Always 2.Sometimes 3.Other------	
34	Do you clean the latrine?	1.Yes 2.No	
35	If yes, how often do you clean the latrine?	1. Every day 2. 1-2 times per week 3. 1-2 time per month 4.Other specify----------	
36	If yes, how is the cleanliness/hygienic condition of the latrine? (observational)	1.Clean (If there is no feces around or on the floor of latrine) 2.not clean	
37	Ways for soild waste managment	1.Buried in one place 2.Burn 3.Collected by waste collectors	

		4.Discared in the open field	
38	Where does your child defecate?	1.Use latrine 2.Open field 3. Mothers/care givers take care of it.	
39	How does the child care after using latrine?	1. With water 2.With soft tissue/paper 3.Rock 4. Other, specify…	
40	If the answer for Q# 37 is no, where do the households defecate?	1. Designated area 2. Bush 3. At the back yard 4. Open field 5. Others (specify)___	
41	If Mothers take care of it, where is baby's faece dispose?	1.Dispose into latrine 2.Put into solid waste 3.Throw it on the ground 4.Others	

PART-4 hygienic behavior factors related questionnaire

No.	Questions	**Responses**	Skip to
42	Does the child wash hand after defecation?	1.Yes 2.No	
43	If yes what does the child use for hand wash	1. water only 2. soap/ Ash 3.other(specify)……	
44	Does the mother wash her hand after taking care of her child feces.	1.Yes 2.No	
45	If yes what the mother uses for hand washing after caring of her child feces?	1. Water only 2.Soap/ash 3. Other specify------	
46	Does the mother wash her hands before cooking?	1.Yes 2.No	
47	If yes, what does she use to wash her hands with?	1.Water only 2.Soap/ash 3. Other specify------	
48	Does the mother wash her hands after handling animal rubbish	1.No 2.Yes	
49	If yes, what does she use to wash her hands with	1.Water only 2.Soap /ash 3. Other specify------	
50	Does the mother wash her hands before child feed	1.Yes 2.No	
51	If yes, what does she use to wash her hands with	1.Water only 2.Soap /ash 3. Other specify------	
52	Does the mother wash her hands after toilet use?	1.No 2.Yes	
53	If yes, what does she use to wash her hands with	1.Water only 2.Soap /ash 3. Other specify------	

Section 5 Description of dwelling (*Interviewer's observation*)

No.	Questions and filters	Coding categories	Skip to
54	The walls are made mainly of:	1.Wood and mud 2 Mud bricks 3.Cement blocks 4.Other (specify)_____	
55	Material that the floor made from	1.Uncemented 2.Cement 3.Other (specify)_____	
56	Material that the roof made from	1.Grass 2.Plastic material 3. iron sheets 4.Other (specify)_____	

That is the end of our interview. Thank you very much for taking time to answer our questions. We appreciate your help.

Checklist for completing the questionnaire correctly and confirmation by supervisors.

Name	Signature	Date
Data collector		
Supervisor		

Household questionnaire for the **Study of Childhood Intestinal Parasitic infection and microbial water quality in eastern Ethiopia** (2021) (English)

IDENTIFICATION						
Site Name						
Name of Household Head						
Kebele/Village Number						
Household Number						
QUESTIONNAIRE ADMINSTERING VISITS						
Visit	1	2	3	4	5	6
Date						
Result*						
Next Visit: Date						
Time						

Name and Signature of the interviewer	Date
Result codes: 1= completed, 2=postponed, 3=refused, 4=other (specify) _____	

Section 1 Socio-demographic characteristics of the respondents

No.	Questions and filters	Coding categories	Skip to
1	What is your child age in year? (Ageold)	1.1-4 2.5-9 3.10-14	*
2	Sex of the child	1.Male 2.Female	*
3	Relation of the head of the household to the child	1.Father 2. Mother 3.Elder brother/siter 4.Other (specify) _____	
4	What is your religion?	1.Islam 2.Orthodox Christian 3.Protestant Christian 4.Other (specify)_____	*
5	What is your ethnic group?	1.Amhara 2.Oromo 3.Somali 4.Others	*
6	What is your family size in the household?	1. 1-3 2. 3-6 3. >6	*
7	What is maternal education level?	1.Illiterate 2. Primary 3.Secondry 4.Above secondry	*
8	What is paternal education level?	1.Illiterate 2.Primery 3.Secondry 4. Above secondry	*
9	What is maternal main occupation?	1.House wife 2.Farmer 3.merchant 4.Other	*
10	What is paternal main occupation? Concideration	1.Farmer 2.Merchant 3. Daily laborer 4.Other	*
20	Do you have domestic animal	1.Yes 2.No	
21	If your answer is yes, Is the primary living house shared with livestock during night?	1.Yes 2.No	
22	How much is your average monthly income?	Birr [_____]	

Part 2 Drinking water access and utilization

No.	Questions	**Responses**	Skip to
23	What is main drinking water source for your household?	1. Piped water into dwelling or compound 2. Public tap/ stand alone pipe	*

		3. Tube Well or borehole 4. Dug well protected 5. Dug well unprotected 6. Spring protected 7. Spring unprotected 8. Private water vendor 9. Rain water 10. Unprotected source (River, pond, etc) 11. Others/Specify……	
24	How is the hygienic condition of water transport container(observation)	1. Clean 2. Not clean	*
25	What type of water container do you use to fetch?	1.Bucket 2.Clay pot 3.Jerry can	
26	How far the water source from your household?	1. On the premises 2. Below 250meter 3. Between 250-500meter 4. Between 500-1000meter 5. Above 1000meter 6. Don ‘t know	
27	How long does it take to go to your main water source to get water and come back?	1. less than 30 minutes 2.more than 30 minutes 3. Don ‘t know	
28	In your opinin, do you get water all the time?	1.Yes 2.No	
29	In the past 2 weeks, is drinking water available?	1. Yes 2. No	
30	How much water did you collect or fetch per day? (**Multiply the number of water collection container by their capacities by the number of trips (frequency) taken to get the total water collected)**	1. Number of jerry cans (5 Liter)_____) 2. Number of jerry cans (10 Liter)_____) 3. Number of jerry cans (20 Liter)_____) 4. Number of jerry cans (25 Liter)_____) 5. Number of buckets (10 Liter) _____) 6. Number of buckets (20 Liter)_____) 7. Other water vessels capacity……. Liters and number of water collected per day……. Total water collected_____ liters	
31	Household drinking water storage	1. Pot 2 Bucket 4. Jerrican 5. Barrel 6. Other/specify……	
32	Can you show me where you store drinking water?	1.No 2.Yes	

	[CHECK WITH VISUAL OBSERVATION] (Mark ―Yes‖ for safe drinking water storage – if the drinking water storage container is narrow neck, clean and kept covered. Otherwise, Mark ‘’No’’		
33	How often do you properly wash water storage?	1. Rarely 2. Sometimes 3. Always	
34	Type of cleaning agent you use to wash the container	1.Ash or Grawa 2 Detergent/soap 3.Only water	
35	How is the hygienic condition of water storage material(observation)	1.Clean 2.Not clean	
36	Do you know any method to treat drinking water at the household level to make it safe?	1.Yes 2.No	
37	If yes, please mention the method(s) you know:	1. Boiling 2. Filtration with cloth 3. Water chemicals (Water guared, Pur etc) 4. Sun light 5. Use of filter Other-------	
38	Do you treat drinking water at household level prior to consumption?	1. Yes 2.No……	
39	If yes, how do you treat water at household level?	1.Boiling 2.Filtration with cloth 3.Water chemicals (Water guared, Pur etc) 4.Sun light 5.Use of filter 6.Other-------	
40	Do you wash your hands before drawing water from storage?	1.Yes 2.No	
41	Is the water container inadequately covered during the survey time?	1.Yes 2.No	
42	Total coliform bacteria detected at point of use water	1.Yes 2.No	
43	Escherichia coli detected at pointof use water source	1.Yes 2.No	

44.	Drinking water quality at the point of use Total coliform bacteria	1.0CFU/100 mL 2.1-10 CFU/100 mL 3.10-100 CFU/100 mL 4.100-1000 CFU/100 mL 5.>1000 CFU/100 mL	
45.	Escherichia coli	1.0CFU/100 mL 2.1-10 CFU/100 mL 3.10-100 CFU/100 mL 4.100-1000 CFU/100 mL 5.>1000 CFU/100 mL	

PART-Three Sanitation related questionnaire

No.	Questions	**Responses**	Skip to
31	Do you have latrine in your compound?	1.Yes 2.No	
32	If yes What kind of latrine is found in your compound?	1.Pit latrine___ 2.Private wooden slab 3.Private cement slab latrine 4.Private VIP latrine 5.Shared wooden slab latrine 6.Shared VIP latrine 7.Flash to sewerage system 8.Other (specify)……	
33	When do you use latrine	1.Always 2.Sometimes 3.Other------	
34	Do you clean the latrine?	1.Yes 2.No	
35	If yes, how often do you clean the latrine?	1. Every day 2. 1-2 times per week 3. 1-2 time per month 4.Other specify----------	
36	If yes, how is the cleanliness/hygienic condition of the latrine? (observational)	1.Clean (If there is no feces around or on the floor of latrine) 2.not clean	
37	Ways for soild waste managment	1.Buried in one place 2.Burn 3.Collected by waste collectors 4.Discared in the open field	
38	Where does your child defecate?	1.Use latrine 2.Open field 3. Mothers/care givers take care of it.	
39	How does the child care after using latrine?	1. With water 2.With soft tissue/paper 3.Rock 4. Other, specify…	
40	If the answer for Q# 37 is no, where do the households	1. Designated area	

	defecate?	2. Bush 3. At the back yard 4. Open field 5. Others (specify)___	
41	If Mothers take care of it, where is baby's faece dispose?	1.Dispose into latrine 2.Put into solid waste 3.Throw it on the ground 4.Others	

PART-4 hygienic behavior factors related questionnaire

No.	Questions	**Responses**	Skip to
42	Does the child wash hand after defecation?	1.Yes 2.No	
43	If yes what does the child use for hand wash	1. water only 2. soap/ Ash 3.other(specify)……	
44	Does the mother wash her hand after taking care of her child feces.	1.Yes 2.No	
45	If yes what the mother uses for hand washing after caring of her child feces?	1. Water only 2.Soap/ash 3. Other specify------	
46	Does the mother wash her hands before cooking?	1.Yes 2.No	
47	If yes, what does she use to wash her hands with?	1.Water only 2.Soap/ash 3. Other specify------	
48	Does the mother wash her hands after handling animal rubbish	1.No 2.Yes	
49	If yes, what does she use to wash her hands with	1.Water only 2.Soap /ash 3. Other specify------	
50	Does the mother wash her hands before child feed	1.Yes 2.No	
51	If yes, what does she use to wash her hands with	1.Water only 2.Soap /ash 3. Other specify------	
52	Does the mother wash her hands after toilet use?	1.No 2.Yes	
53	If yes, what does she use to wash her hands with	1.Water only 2.Soap /ash 3. Other specify------	

Section 5 Description of dwelling (*Interviewer's observation*)

No.	Questions and filters	Coding categories	Skip to
54	The walls are made mainly of:	1.Wood and mud 2 Mud bricks 3.Cement blocks 4.Other (specify)_____	

55	Material that the floor made from	1.Uncemented 2.Cement 3.Other (specify)_____	
56	Material that the roof made from	1.Grass 2.Plastic material 3. iron sheets 4.Other (specify)_____	

That is the end of our interview. Thank you very much for taking time to answer our questions. We appreciate your help.

Checklist for completing the questionnaire correctly and confirmation by supervisors.

Name	Signature	Date
Data collector		
Supervisor		

KAAYYOO GAAFFII 3FFAA

Gaaffilee manaa Qorannoo **infekshinii Paraasitii garaachaa daa'immanii fi qulqullina bishaan maaykiroobaayil baha Itoophiyaa** (2021) (Afaan Oromoo)

IBSA						
Maqaa bufaataa						
Maqaa Itti Gaafatamaa Maatii						
Maqaa Ganda						
Lakkoofsa Manaa						
GAAFFIILEE DAAWWANNA BULCHIINSAA						
Daawwanna	1	2	3	4	5	6
Guyyaa						
Bu'aa*						
Daawwannaa Itti Aanu: Guyyaa						
Yeroo						
Maqaa fi Mallattoo nama gaaffii fi deebii taasise					Guyyaa	
Koodii bu'aa: 1= xumurame, 2=yeroo biraatti darbe, 3=dide, 4=kan biroo (ibsi) _____ .						

Kutaa:- 1 Amaloota deebii kennitootaa hawaasaa

Lakki.	Gaaffii fi filtara	Ramaddiiwwan koodii	Irraa darbi
1	Umuriin daa'ima keessanii waggaa meeqa?	1.1-4 irratti kan argamu 2.5-9 irratti kan argamu 3.10-14 irratti kan argamu	
2	saalaa daa'imaa	1.Dhiira 2.Dubartii	
3	Hariiroo daa'imni maatii waliin qabu	1.Abbaa 2. Haadha 3.Obboleessa hangafaa/ siter 4.Kanneen biroo (ibsi) _____	
4	Amantiin keessan maali?	1.Islaamummaa 2.Kiristaana Ortodoksii 3.Kiristaana Pirootestaantii 4.Kanneen biroo (ibsi)_____	
5	Sabni keessan maali?	1.Amaaraa 2.Oromoo 3.Soomaalee 4.Kanneen biro	
6	Baay'inni maatii keessanii mana keessatti meeqa?	1. 1-3 2. 3-6 3. >6	
7	Sadarkaan barnoota haadholii maali?	1. kan hin barranee Dubbisuu fi barreessuu kan hin dandeenye 2. Sadarkaa tokkoffaa 3. Sadarkaa Lammaffaa 4.Sadarkaa lammaffaa ol	
8	Sadarkaan barnoota abbaa maali?	1. kan hin barranee Dubbisuu fi barreessuu kan hin dandeenye 2. Sadarkaa tokkoffaa 3. Sadarkaa Lammaffaa 4. Sadarkaa lammaffaa ol	
9	Hojiin haadholii inni guddaan maali?	1.Haadha manaa manaa 2.Qonnaan bulaa 3.daldalaa 4.Kanneen biroo	
10	Hojiin ijoo abbaa maali? Yaadannoo	1.Qonnaan bulaa 2.Daldalaa 3. Hojjetaa guyyaa guyyaa 4.Kanneen biro	
20	Beeylada manaa qabdaa	1.Eeyyee 2.Lakk	
21	Deebiin kee eeyyee yoo ta'e, Manni jireenyaa inni jalqabaa halkan horii waliin ni qoodama?	1.Eeyyee 2.Lakki	
22	Galiin ji'a ji'aan argattu giddu galeessaan meeqa?	Birrii [_____] .	

Kutaa:- 2 Bishaan dhugaatii argachuu fi itti fayyadama

Lakki.	Gaaffilee	**Deebiiwwaan**	Irraa darbi
23	Maddi bishaan dhugaatii guddaan mana keessaniif maali?	1. Bishaan tuuboodhaan gara mana jireenyaa dhufuu 2. Tuboo ummataa/ stand alone pipe 3. bishaan boolla keessaa bahuu 4. harkaan qotamee kan sirreffame	

		5. harkaan qotamee kan Eegumsa gaarii kan hin qabne 6. Bishaan burqaa kan sirreffame 7. Bishaan burqaa kan hin sirreffamne 8. Gurguraa bishaanii dhuunfaa 9. Bishaan roobaa 10. Madda eegumsa hin qabne (Laga, bishaan kuufamaa fi kkf) 11. Kanneen biroo/Ibsi.....	
24	Haalli qulqullina konteenara geejjibaa bishaanii akkam(ilaalcha) .	3. Qulqulluu 4. Qulqulluu miti	
	bishaanii waraabachuf Meeshaa gosa akkamii fayyadamta ?	1.Baaldii 2.Qodaa suphee 3.Jarkaanii	
24	Maddi bishaanii mana keessan irraa hangam fagaata?	1. Bakka jireenyaa manaa 2. Meetira 250 gadi 3. Meetira 250-500 gidduutti 4. Meetira 500-1000 gidduutti 5. Meetira 1000 ol 6. Hin beeku	
25	Bishaan argaachuu fi deebi'uuf gara madda bishaanii keessanii deemuuf yeroo hangamii fudhata?	1. daqiiqaa 30 gadi 2.daqiiqaa 30 ol 3. Hin beeku	
26	Akkaa ilalchaa keessanitti yeroo hunda bishaan ni argatuu?	1.Eeyyee 2.Lakk	
27	Torban 2 darban keessa bishaan dhugaatii argatanitu?	1. Eeyyee 2. Lakki	
28	Guyyaatti bishaan hangaam warrabatu? (Lakkoofsa meeshaa bishaan walitti qabuu dandeettii isaaniitiin baay'ina imala (frequency) bishaan waliigalaa walitti qabame argachuuf fudhatameen baay'isi)	1. Baay'ina jarkanaa (Liitira 5)_____) . 2. Baay'ina jarkanaa (Liitira 10)_____) . 3. Baay'ina jarkanaa (Liitira 20)_____) . 4. Baay'ina jarkanaa (Liitira 25)_____) . 5. Baay'ina baaldi (Liitira 10) _____) . 6. Baay'ina baaldi (Liitira 20)_____) . 7. Dandeettii meeshaalee bishaanii biroo..... Liitira fi baay'ina bishaan guyyaatti walitti qabamu..... Waliigala bishaan walitti qabame_____ liitira	
29	Kuusaa bishaan dhugaatii manaa	1. Qodaa suphee 2. Baaldi 4. Jarkanaa 5. Barmeela 6. Kan biroo/ibsi.....	

30	Bishaan dhugaatii bakka itti kuufattu natti agarsiisuu dandeessaa? [ILAALCHA SURAAN DEGGARAAME ILAALII] (Kuusaa bishaan dhugaatii qulqulluu ta'eef_____ ''Eeyyee'' mallatteessi_____ yoo meeshaan bishaan dhugaatii itti kuusan morma dhiphoo ta'e, qulqulluu fi haguugamee akka turu. Yoo kana hin taane, "Lakki" mallatteessi_____	1.Lakki 2.Eeyyee	
	Kuusaa bishaanii yeroo meeqa sirriitti dhiqattu?	4. Darbee darbee 5. Yeroo tokko tokko 6. Yeroo hunda	
	Gosa qulqulleessituu meeshaa dhiqachuuf itti fayyadamtu	1. Darraan 2. Saamunaan 3. Bishaan qofa	
	Haalli qulqullina meeshaa kuusaa bishaanii akkam (ilaalcha)	1. Qulqulluu 2.Qulqulluu miti	
31	Bishaan dhugaatii osoo hin fayyadamin dura sadarkaa maatiitti ni qulqulleessitu?	1. Eeyyee 2. Lakki	
	Yoo eeyyee ta'e sadarkaa manaatti bishaan akkamitti qulqulleessitu?	6. Daanfiisuun 7. Huccuudhaan calaluu 8. Keemikaalota bishaanii (Water guardiad , Pur etc) 9. Ifa aduun 10. Filtaraan fayyadamun 11. Kan biraa-------	
	Kuusaa irraa bishaan baasuu dura harka dhiqattu?	1. Eeyyee 2. Lakki	
	Yeroo qorannootti meeshaan bishaan itti kuusaan hala gahaa ta'ee hin haguugamnee?	1. Eeyyee 2. Lakki	
	Walummagalaatti Baakteeriyaan koolifoormii bakka itti fayyadama bishaanitti argamerraa?	1. Eeyyee 2. Lakki	
	Escherichia coli fayyidaa irraa yeroo oluu madda bishaanii irratti argamerraa?	1. Eeyyeen 2. Hin argamnee	
	Qulqullina bishaan dhugaatii bakka itti fayyadamaatti Baakteeriyaa koolifoormii waliigalaa	1. 0CFU/100 mL kan ta'u 2. 1-10 CFU/100 mL kan ta'u 3. 10-100 CFU/100 mL kan ta'u 4. 100-1000 CFU/100 mL ta'a 5. >1000 CFU/100 mL ta'uu isaati	
	Escherichia coli	1. 0CFU/100 mL kan ta'u 2. 1-10 CFU/100 mL kan ta'u 3. 10-100 CFU/100 mL kan ta'u 4. 100-1000 CFU/100 mL ta'a 5. >1000 CFU/100 mL ta'uu isaati	

Kutaa:-Sadii Gaaffii Qulqullina waliin walqabatu

Lakki.	Gaaffilee	**Deebiiwwaan**	Irraa darbi
31	Mooraa keessan keessatti mana fincaanii qabduu?	1. Eeyyee 2. Lakki	
32	debbin keessaan Yoo eeyyee ta'e mana fincaanii gosa akkamiituu mooraa keessan keessatti argama?	1. Mana fincaanii boollaa___ . 2. Mana fincaanii mukaa hojjetaame 3. Mana fincaanii simintoo hojjetaame 4. Mana fincaanii VIP dhuunfaa 5. Mana fincaanii mukaa ummataa waliin hojjetan 6. Mana fincaanii VIP waliin qaban 7. sirna lola'aa baafannaa irraatti kan hondaa'e 8. Kanneen biroo (ibsi).....	
33	Yoom mana fincaanii fayyadamtu	1. Yeroo hunda 2. Yeroo tokko tokko 3. Kan biroo------ .	
34	Mana fincaanii ni qulqulleessitaa?	1. Eeyyee 2. Lakki	
35	debbin keessaan Yoo eeyyee ta'e, yeroo meeqa mana fincaanii qulqulleessita?	1. Guyyaa hunda 2. Torbanitti yeroo 1-2 3. Ji'atti yeroo 1-2 4.Kanneen biroo ibsi---------- .	
36	debbiin keessaan Yoo eeyyee ta'e qulqullinni/haalli qulqullina mana fincaanii akkam ? (ilaalchan) .	1. Qulqulluu (naannoo mana fincaanii ykn lafa mana fincaanii irratti manca'aan hin jirre) . 2. qulqulluu miti	
37	Halaa balfaa/koosin itti gataamuu	1.Iddoo tokkotti awwaaluu 2.Gubuu 3.Bakka balfa/koosin walitti qabamuutti gatuun 4.Dirree banaa irraatti gatuu	
38	Mucaan keessan eessatti fincaan qulquulla'a?	1.Mana fincaanii fayyadamuu 2.Dirree banaa 3. Haadholiin/kunuunsitoonni ni kunuunsu	
39	Daa'imni erga mana fincaanii fayyadamee booda maliin irraa qulqullessu?	1. Bishaaniin 2.Tishuu/waraqaa lallaafaa dhaan 3.Dhagaan 4. Kan biroo, ibsi...	
40	lakkofsaa 37 Deebii hin qabu yoo ta'e maatiin keessaan eessatti fincaan qulquulla'u?	1. Bakka argamutti 2. Bosoonaa keessaatti 3. Mooraa duubaa irratti 4. Dirree irraatti 5. Kanneen biroo (ibsi)___ .	
41	Haadholiin yeroo kunuunsan daa'immani godhanii bodaa manca'aa daa'imaa eessatti gatuu ?	1.Mana fincaanii keessa gatuu 2.Balfa/koosi jajjaboo keessatti gatuu 3.Lafatti/dirree irraatti gatuu 4.Kanneen biro	

Kutaa:- 4 gaaffilee sababoota amala qulqullinaa wajjin walqabatan

Lakk	Gaaffilee	**Deebiiwwaan**	irraa darbi
42	Mucaan erga fincaan qulqulla'e booda harka ni dhiqataa?	1.Eeyyee	

		2.Lakki	
43	Yoo eeyyee ta'e daa'imni harka dhiqachuuf maal fayyadama	1. bishaan qofa 2. saamunaa/ darraa 3.kan biroo (ibsi).....	
44	Haati daa'ima ishee erga qulqullesitee booda harka ishee ni dhiqattii ?	1.Eeyyee 2.Lakki	
45	Yoo eeyyee ta'e haati erga manca'aa daa'ima ishee kunuunsitee booda harka dhiqachuuf maal itti fayyadamti ?	1. Bishaan qofa 2.Saamunaa/darraa 3. Kan biroo ibsi------ .	
46	Haati nyaata bilcheessuun dura harka ni dhiqattii?	1.Eeyyee 2.Lakki	
47	Yoo eeyyee ta'e maaliin harka dhiqatti?	1.Bishaan qofa 2.Saamunaa/ darraa 3. Kan biroo ibsi------ .	
48	Haati balfa/koosi beeyeladota erga qabattee booda harka ni dhiqattii?	1. Eeyyee 2.Lakki	
49	Yoo eeyyee ta'e maaliin harka dhiqatti?	1.Bishaan qofa 2.Saamunaa /darraa 3. Kan biroo ibsu------ .	
50	Haati daa'imaa nyaata nyaachisuun dura harka ni dhiqattii?	1.Eeyyee 2.Lakk	
51	Yoo eeyyee ta'e maaliin harka dhiqatti?	1.Bishaan qofa 2.Saamunaa /darraa 3. Kan biroo ibsi------ .	
52	Haati mana fincaanii erga fayyadamtee booda harka dhiqattii?	1.Lakki 2.Eeyyee	
53	Yoo eeyyee ta'e maaliin harka dhiqatti?	1.Bishaan qofa 2.Saamunaa /darraa 3. Kan biroo ibsi------ .	

Kutaa:- 5 Ibsa mana jireenyaa (Ilaalcha gaafataa)

Lakk	Gaaffii fi filtara	Ramaddiiwwan koodii	irraa darbi
54	Manii/dallaawwan kun maal irraa kan hojjetamanidha?	1.Mukaa fi dhoqqee 2 Cilee dhoqqee 3.Bilooketti simintoo 4.Kanneen biroo (ibsi)_____ .	
55	Meeshaan lafti manaa irraa hojjetame?	1.Simintoo malee 2.Simintoo 3.Kanneen biroo (ibsi)_____ .	
56	Meeshaan gubban mana irraa hojjetame?	1.Marga 2.Meeshaalee pilaastikii 3. sibiilaa sibiilaa 4.Kanneen biroo (ibsi)_____ .	

Gaaffii fi deebii keenya kanaan xumura. Yeroo fudhattanii gaaffii keenyaaf deebii nuuf kennitaniif hedduu galatoomaa. Gargaarsa keessan ni dinqisiifanna.

Tarree sakatta'iinsaa gaaffilee sirritti guutuu fi supparvaayizarootaan mirkaneessuu.

Maqaa	Mallattoo	Guyyaa
Walitti qabaa odeeffannoo		
To'ataa		

Check for updates

The Association of Sanitation and Hygiene Practices With Intestinal Parasitic Infections Among Under-14 Children in Rural Dire Dawa, Eastern Ethiopia: A Community Based Cross-sectional Study

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Sage

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ABSTRACT

BACKGROUND: Intestinal parasitic infections (IPIs) are neglected tropical diseases. Sanitation and hygiene are vital components for achieving sustainable control of intestinal parasitic infections. Children are the most vulnerable to intestinal parasitic infections because of their immature immune systems and frequent exposure to unsanitary environments. The aim of this study was to assess the magnitude of IPIs and associated risk factors, including sanitation and hygiene practices, among under-14-year-old children in rural Dire Dawa, eastern Ethiopia.

METHODS: This community-based cross-sectional 'study included 778 subjects aged 1 to 14 years. Data were collected using questionnaires and stool examinations. The direct wet-mount method and formol-ether concentration techniques were performed to identify IPIs. Data Analysis: A descriptive statistic was used to show the prevalence of IPIs. Bi-variable and multivariable analysis using the logistic regression model was carried out.

RESULTS: The outputs are presented using an adjusted odds ratio (aOR) with 95% confidence intervals (CIs). The prevalence of 5 intestinal parasites was 33.7% (95% CI = 30.4%-37%). *Giardia intestinalis* (15.2%) and *Hymenolepis nana* (11.6%) had the highest prevalence. The odds of IPIs among children of illiterate mothers were 13.1 times higher when compared with children of mothers with secondary education (aOR = 13.1, $P = .02$), and the odds of IPIs among children from households that have unclean latrines were 1.8 times higher when compared with children from households that have clean latrines. (aOR = 1.8, $P = .03$). Children from households that discard solid waste in open fields had 1.7 times higher odds of having a positive result than children from households that burn their waste (aOR = 1.7, $P = .03$). However, children without a swimming habit (aOR = 0.4, $P = .000$) and asymptomatic children (aOR = 0.3, $P = .000$) were protective against IPIs.

CONCLUSIONS: IPIs continue to be a public health problem in rural parts of Dire Dawa. The prevalence of *Giardia intestinalis* and *H. nana* could be of public health importance in this setting. Solid waste management, latrine cleanliness, mothers' level of education, and child swimming habits in unclean accumulated water were significantly associated with IPIs. Therefore, efforts should be made to ensure intervention, considering such risks.

KEYWORDS: Helminths, prevalence, protozoa, risk factors, and Ethiopia

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Introduction

The public health impacts of parasitic infections are still high and difficult to reduce in developing countries. Globally, about 3.5 billion people (the majority of whom were children) were infected with intestinal parasites. Intestinal helminthic and protozoan infections are among the most prevalent IPIs in humans.[1] In Ethiopia, a systematic study from Legese reported that the prevalence of IPIs was 48%.[2] Intestinal protozoa contribute significantly to the burden of infectious diseases worldwide, and diarrhea is more commonly caused by intestinal parasites and bacterial pathogens than viruses in developing countries.[3] The second and third most common intestinal protozoa identified in Mozambique children with diarrhea were *Giardia intestinalis* and *Entamoeba histolytica*, respectively.[4]

Soil-transmitted helminths (STHs) and schistosomiasis are among the 17 neglected tropical diseases (NTDs) identified by the World Health Organization (WHO).[5] Worldwide, more than 1.5 billion people are infected with soil-transmitted helminths, most of them in sub-Saharan Africa, Central and South America, China, and East Asia.[6] Ending the epidemics of NTDs is 1 of the Sustainable Development Goals (SDGs) of the United Nations (UN).[7] Ethiopia comprises a significant

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Infection and Drug Resistance

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ORIGINAL RESEARCH

Childhood Intestinal Parasitic Reinfection, Sanitation and Hygiene Practice in Eastern Ethiopia: Case Control Study

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Background: The recurrence of intestinal parasitic infections (IPIs) can lead to different problems that can be transferred from generation to generation. Sanitation and hygienic practices have vital role in the parasitic reinfection. In poor hygienic and sanitation condition children may live in a continuous cycle of infection and reinfection.

Objective: To assess childhood IP reinfection and its association with sanitation and hygienic practice in eastern Ethiopia.

Methods: A population-based case-control design was used in this study. Data were collected from 75 reinfected cases and 147 unmatched controls. Fecal specimens were observed for parasites using direct smear and formol ether techniques. Epi-Info and SPSS (the statistical package for social science) were used for data entry and analysis, respectively. Logistic regression analysis was conducted to identify significant associations ($P<0.05$) between variables.

Results: The overall IP reinfection rate within 24 weeks after treatment was 33.8% (75/222), with a 95% CI=27.7%–40.5%. The frequency of intestinal protozoa was 18%, and for helminths was 15.8%. Children who swam in a polluted water had 3.7 times greater odds of IP reinfection than children who did not swim ($P=0.01$, 95% CI: 1.4–10.0). Children who regularly bathed in streams and children who bathed both at home and in streams were found to have 12.6 times and 5.8 times higher odds of IP reinfection than children who bathed regularly at home ($P=0.002$, 95% CI:2.5–64.8) and ($P = 0.042$, 95% CI:1.1–31.3), respectively. Children in households that owned domestic animals had 4.5 times higher odds of IP reinfection than the reference group ($P = 0.013$, 95% CI: 1.3–12.5).

Conclusion: IP reinfection rates were significantly associated with habits of swimming in a polluted water, places of bathing, and ownership of domestic animals. Therefore, efforts should be made considering such factors to minimize IP reinfection in the area.

Keywords: Ethiopia, hygiene, reinfection, sanitation

Introduction

Even though human parasitic infections are avoidable NTD,[1] they are nonetheless widespread in developing nations like Ethiopia. According to Chelkeba,52% of school-age children and 30% preschool-aged children were infected with IP.[2] Among primary school children the pooled prevalence of IPIs was determined to be 46.09% and Entamoeba spp (16.11%), Ascaris lumbricoides (13.98), Hookworm (12.51%) and Giardia lamblia (9.98%) are among the most prevalent parasitic infections according to a systematic review and meta-analysis study in Ethiopia.[3]

Helminth infections that persist over time can result in anorexia, diarrhea, and malabsorption, increasing the risk of anemia, growth retardation, and compromised cognitive development.[4] Anemia and growth retardation are caused by protozoan infections, which also cause nutritional depletion and weakened immunity.[5] *G. intestinalis* infection can result in both acute and chronic diarrhea.[6,7] Serious health and social issues associated with parasitic infection include malabsorption, diarrhea, bleeding, stunting, wasting, cognitive decline, and diminished job ability. These issues place a significant financial strain on communities.[8–10]

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