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Prevalence and Distribution of Geo-Helminths and Intestinal Protozoa Infections among School-Going Children in Nyeri County, Kenya

Muthee Anthony Menaine[1]
Mary Gitahi[2]
Rael Musili[3]
Martin Mutuku[4]

[1]antonymenaine@gmail.com (+254722227005)
[2]gitahi.mary@ku.ac.ke (+254722934732)
[3]rmusili@kemri.go.ke (+254720977614)
[4]mmutuku@kemri.go.ke (+254723722762)

[1,2]Kenyatta University, Kenya, [3,4]Kenya Medical Research Institute, Kenya

ABSTRACT

The goal of this study was to determine how common and widespread geo-helminths, STH, and intestinal protozoa infections are in the Mathira constituency of Nyeri County, Kenya. The study aimed to determine the prevalence of geohelminths and intestinal protozoa, as well as the distribution of STH and intestinal protozoa infections in school-going children. Cochran formulae guided the design of a cross-sectional study on a population of 174 children, yielding complete data for 164 of them. The social determinants of the health model guided this study. A structured questionnaire was applied to data collection to establish the demographic characteristics of the study participants in the identified three primary schools in the study site. They were examined for STH and protozoa infections by the quantitative Kato-Katz technique for STH and formal ether concentration techniques for intestinal protozoa infection. Statistical analysis was done using R Studio and the risk ratio. Findings showed that of the 56 samples examined in Kihuro primary school, 12 (21.4%) and 6 (10.7%) were positive for protozoan and STH infections. Similarly, 33% of the children in Gathuini primary school were found to be positive for protozoan infections, while 13% were infected with STH. In Gikumbo primary school, 20.4% of the children were infected with protozoan parasites, compared to 13% of STH infections. However, there was a variation in infection prevalence based on gender across the three selected sites. Children in Kihuro primary school were 0.12 times more at risk of STH infection compared to 0.3 times more at risk of protozoa infections. The intestinal protozoa infection was higher than that for the geohelminths infection in Gathuini primary school. Children in Gathuini primary school were 0.12 times more at risk of STH infection compared to 0.46 times more at risk of protozoa infections. Children in Gikumbo primary school were 0.1 times at risk of STH infection compared to 0.26 times at risk of protozoa infections, implying that they were more prone to protozoan infections than STH infections. The study concluded that the age and gender of students had no statistical significance. The study recommended that government institutions and non-governmental organizations should intervene and undertake adequate control measures against geo-helminth parasites by making sure there is access to safe water and improved sanitation in the area. Moreover, health education programs should be intensified in the area and beyond to raise awareness of geo-helminths and intestinal protozoa infection, means of transmission and control measures, and the improvement of hygiene practices for both children and parents.

Keywords: Geo-Helminths, Intestinal Protozoa, Prevalence, School-going Children

I. INTRODUCTION

The intestinal parasites can be grouped into two groups: helminths and protozoa. Soil-transmitted helminths refer to intestinal worms that infect humans and are transmitted primarily through contaminated soil (fecal-oral route), according to Rahimi et al. (2023a). They include *Ascaris lumbricoides*, hookworms (*Ancylostoma duodenale* and *Necator americanus), Trichuris trichiura, Strongyloides stercoralis*, and *Enterobius vermicularis* as the most prevalent soil-transmitted helminths (STH). They are multi-cellular parasitic organisms and thus rely on the nutrient loss of the host to survive. Humans become infected by encountering parasites in ova-contaminated soil, open discharge, or unsanitary human waste disposal (Jourdan et al., 2018).

Unicellular parasites called intestinal protozoa cause intestinal damage, resulting in malnutrition, diarrhea, and dysentery. Parasites are typically spread to humans by infected, undercooked, or uncooked food and beverages. The most common pathogenic protozoa include Cryptosporidium, *Giardia lamblia*, *Entamoeba histolytica*, and *Balantidium coli*. Various regions of Kenya are endemic for intestinal parasite illnesses (Masaku et al., 2023). Helminthic diseases are transmitted through the soil and afflict roughly 1.5 billion individuals, or 24% of the global population (Ercumen et al., 2019).

Infections are sometimes found in tropical places all over the world, with Sub-Saharan Africa, the Americas, China, and East Asia having the highest frequencies (Aula et al., 2021). Over 267 million preschool and 568 million school-age children living in areas where pests are widespread need treatment and prevention (Chelkeba et al., 2020). Intestinal parasitic infections (IPIs) continue to be a public health issue in communities, mainly among children in rural regions. Common undiagnosed parasites, such as helminth (STH) and intestinal protozoa invasion, are some of the leading causes of illness and disease, especially in unprotected areas (Li et al., 2022).

Changes in people's health and illness patterns are influenced by cultural, social, economic, and environmental factors (Kawachi & Berkman, 2014). Intestinal parasites, particularly the soil-transmitted helminth (STH), have been in contact with people since the dawn of time, according to paleoparasitology (Rahimi et al., 2023a). Intestinal parasite proliferation has decreased dramatically in various parts of the world over time, owing mostly to changes in socioeconomic conditions and sanitation standards, as witnessed in industrialized countries (Jourdan et al., 2017). In contrast, due to a lack of basic sanitation and adequate hygiene practices, intestinal illnesses (IPIs) continue to impact the majority of the poor and needy, like Indigenous peoples in low- and middle-income nations (Sharma & Adhikar, 2022).

These IPIs are frequent among communities associated with poverty and are mostly malnourished and live in destitute neighborhoods. They are afflicted by overcrowding, pollution, low education standards, and a lack of access to clean drinking water, all of which keep them trapped in a cycle of poverty and misery (Chakkaravarthy, 2019). These diseases exacerbate economic insecurity and social exclusion, impoverishing the poor through a vicious cycle of starvation and recurring illnesses, resulting in serious illness and its consequences, especially in children. IPIs are also frequently regarded as a significant public health hazard (Bethony et al., 2006).

Giardiasis, which is instigated by *Giardia duodenalis*, and *Giardia lamblia* are the common species of intestinal protozoan illness, affecting roughly 200 million people globally, with an estimated infection rate of 2.0 to 7.0% in industrialized nations and 20.0 to 30.0% in many underdeveloped countries (Hajare et al., 2022). Amoebiasis, which afflicts roughly 180 million people and kills 40,000 to 110,000 people a year, is triggered by *E. histolytica* (Shirley et al., 2020). *Cryptosporidium sp*., a parasite opportunist, has emerged as the leading catalyst of diarrheal illnesses worldwide, amongst young children and non-disabled patients, with a pervasiveness of 4% in wealthy nations and three to four times higher in developing nations.

1.1 Statement of the Problem

In Nyeri County, most schoolchildren are in danger of geo-helminths and intestinal protozoa infections because they engage in farming activities in the school garden, after school, and during school vacations, when they engage in home food management without sufficient sanitation and are thus more likely to spread infections to others (Ojja et al., 2018). Research has shown high soil-borne helminth infections among children in warm tropical areas in Kenya (Neto et al., 2023). Nonetheless, little research has been carried out to ascertain this notion despite reports on gastrointestinal diseases, chronic illness, anemic conditions, and poor growth and development among schoolchildren in Nyeri. Konyu Plains in Nyeri, closely situated near Mount Kenya Forest, was selected as the study site. Konyu area is a plain of no man’s land used for small-scale, non-mechanized subsistence farming by people within the neighboring villages. Moreover, anecdotal laboratory reports (2019) from health facilities in the study area (Kaiyaba Health Center and Itiati Dispensary) show a high incidence of parasitic infection among the patients visiting the facility.

1.2 Research Objective

To establish the prevalence of geo-helminths and intestinal protozoa in school-going children in Nyeri County

II. LITERATURE REVIEW

2.1 Theoretical Review

This study was anchored on the Social Determinants of Health model, which was developed by Michael Marmot and Bell (2010). The model postulates that environmental, social, and economic factors predict health quality (Shokouh et al., 2017). The model assumes that better health outcomes are a product of enhanced social and economic conditions. Nonetheless, some critics argue that the model overlooks generic factors that also play a significant role in health outcomes and that the link between social determinants and health is complex and multifaceted. The model is relevant to this study as it underscores the underlying individual and social determinants contributing to the issues related to health. It helps to check on such factors as access to clean water and sanitation and living conditions that impact the risk of parasitic infections among children (Garg et al., 2019). Based on the context of this study, the risk factors can be shaped through access to clean water, sanitation practices, housing conditions, and quality education in both school and home environments. Most importantly, the SDH model should be complemented with other perspectives to offer a comprehensive analysis.

2.2 Empirical Review

There are three core categories of soil-transmitted helminths, namely: nematodes (*Ascaris lumbricoides)*, hookworms (*Ancylostoma duodenale* and *Necator americanus*), *Strongyloides stercoralis, Trichuris trichiura*, and *Enterobius vermicularis*. Cestodes: Schistosomes (*Schistosoma haematobium, Schistosoma japonicum, and Schistosoma mansoni);* and trematodes: *Taenia solium, Taenia saginata*, and *Hymenolepis nana* (Jourdan et al., 2017). Intestinal protozoa such as *Entamoeba histolytica* flagellates like *Giardia lamblia*, ciliates like *Balantidium coli*, and coccidian carrying like *Cryptosporidium* and *Cyclospora* species (Hajissa et al., 2022). The most prevalent infections among populations in developing countries (Rahimi et al., 2023) are attributed to soil-transmitted helminths (*Schistosoma mansoni, Ascaris lumbricoides, Enterobius vermicularis, Hymnolepsis nana, Hymenolepis diminuta, and* Hookworm) and protozoan parasites (*Giardia lamblia, Iodomeba bustchilii, and Entamoeba coli*). The disease burden attributed to parasitic infections is about 3.5 billion people, with about 50 million people falling ill because of these infections, the majority being children (Clasen et al., 2013).

STH is confirmed to be endemic in Kenya. All three types (roundworms, whipworms, and hookworms) are widely distributed across Kenya, with more than 16.6 million people believed to be at risk of infection with one or more of the three types of worms (Njenga et al., 2022). In densely populated places, STH is a primary cause of physical and mental development problems, as well as developmental delays and disabilities in children (Mohamed et al., 2023). The World Health Organization, United Nations Children's Fund, and World Bank, among others, support deworming programs for school-aged children as cost-effective solutions for alleviating the load of infections (Pastorino et al., 2023). The Copenhagen Consensus ranks worm kills for schoolchildren as the fourth of the 16 most effective finance options for the top ten global concerns (Croke & Atun, 2019).

STH occurs singly or in combination in certain individuals or communities living in geographical areas where more than one STH is co-endemic. The pattern of occurrence involves some sub-counties within the Lake Victoria region, parts of Central Kenya, Lower Eastern, and the Coast regions. Approximately 6 million people are estimated to be at risk of infection with schistosomiasis in Kenya (Masaku et al., 2023). Protozoan infections are among the leading causes of morbidity and mortality throughout the world, with more than 58 million diarrheal cases detected each year (Berhe et al., 2020). However, it is difficult to estimate the actual burden of protozoan infections due to Croke et al. (2019). Moreover, intestinal parasites contribute to malnutrition, protein and iron deficiencies, an increase in health costs, as well as long-term deleterious effects (Fauziah et al., 2022).

Diarrheal diseases transmitted from person to person, waterborne, foodborne, and zoonotic transmissions (Putignani et al., 2014), are the major modes of transmission to humans. Giardiasis and Entamoebasis are the major causes of acute and persistent diarrhea in humans worldwide, with the latter being the latter being more pervasive in developing countries (Soares et al., 2016). Giardiasis is reported to infect about 280 million people every year and contributes to 2.5 million annual deaths. Annually, an estimated 1.2 million giardiasis cases occur around the globe (Kalyoussef et al., 2010). On the other hand, amoebiasis is reported to cause an estimated 50 million cases annually, with 100,000 deaths. Thus, intestinal protozoan infections are ranked second to malaria as the cause of morbidity and mortality (Mengistie et al., 2014).

The descriptive epidemiology of intestinal parasites by gender is important in understanding their distribution. There has been a gradual decline in the prevalence of STH and other parasitic infections in Kenya over the years. This has been attributed to school health programs implemented since 1998, improved living conditions, access to potable water, sanitation, and hygiene (Ngonjo et al., 2016). Polyparasitism in schools is attributed to environmental conditions, Water Sanitation and Hygiene (WASH) socio-economic conditions, and existing infection levels (Ngonjo et al., 2016). Polyparasitism may impact the nutritional status of children because the combined effect of multiple parasites in one individual leads to increased nutritional demand from the host (Ngonjo et al., 2016). School-aged children (SAC) are designated as high-risk groups because of their increased daily activities and the impact of the disease (Chelkeba et al., 2020). When environmental contamination is reduced by treating a high-risk population, infection in the wider community is lowered as a result (Desai & Majumde, 2020).

2.2.1 Mode of Transmission

Intestinal parasites enter the human body by a variety of routes, including ingestion, skin penetration, inhaling, and autoinfection (Zouboulis & Dassoni, 2018). Contamination of the ova by the soil is a common cause of intestinal helminth disease infection. Infection with *Entorobium vermicularis, Taenia solium,* and *Hymenolepis nana,* as well as cryptosporidium, can lead to spontaneous infection. Older helminths live in the gut and produce hundreds of eggs daily, contaminating the soil (Mody, 2004). If eggs are attached to fruits or vegetables that are not properly cooked, washed, or peeled, they can lead to infection in humans if consumed. If children play in soiled locations and put their hands in their mouths as a as a fecal-oral route of infection, they can eat eggs or drink unclean water (Stürchler, 2023). Many parasitic infections are transmitted orally, meaning that their infection is mainly caused by inadequate sanitation, which thus means contamination of water sources with human waste.

Insect eggs and cysts are detected in dust, cuts, doorknobs, and even on the medium of exchange (Bernabeu et al., 2024). By eating cysts or eggs found in excrement, putting them into food, or mechanically conveying them, flies and cockroaches can act as vectors (Alemayehu et al., 2024). Poverty, sewage pollution, and poor hygiene are all major sources of human infection (for example, not being able to clean hands with soap after visiting the toilet and before eating and walking barefoot). The most frequent intestinal protozoa transmitted through polluted water are *E. histolytica* and *G. lamblia*. Their cysts pollute the environment and water systems as well and can withstand environmentally harsh conditions, e.g., *G. lamblia* can survive at 21 °C for a month (Ahmed, 2023). *Endolimax nana* and *Entamoeba coli* are not harmful, although they can be indicators of fecal contamination in the environment.

The pattern of disease and health persistence among people is influenced by cultural, social, and environmental changes (Firdu & Mulati, 2023). Intestinal parasitic infections (IPI) have been termed "the malignancies of poor countries" because of the devastation they inflict, especially on children and young women of reproductive age. IPI is caused by a persistent infection, and it's a quiet condition that can be persistent if not well treated and thus traumatizing. Strong and severe IPIs, particularly pathogenic Entamoeba and Giardia, cause deadly diarrhea in children and are frequently linked to traumatic diarrhea. Furthermore, Entamoeba can induce unwelcome intestinal infections or can migrate to the liver (and, in rare circumstances, the lungs and brain), resulting in amoebic liver tumors, which kill about 100,000 people per year, making amoebiasis the second greatest cause of protozoan disorders after malaria (Nasrallah et al., 2022). Recent research has also focused on the impact of polyparasitism on the immune system, with findings indicating that polyparasitism is connected to greater mortality rates and may increase the risk of secondary infections when compared to single parasite infections (Bisanzio et al., 2014).

III. METHODOLOGY

3.1 Study Site

The study site was Konyu, which is a land where demarcation has not been done and thus belongs to the whole community and not an individual. It's approximately 143 km north of Nairobi. It is situated close to Mount Kenya forest and supplied with water from springs that drain into the Miambano River. It has a population of 110,376 according to KNBS (2019). Gathuini Primary School is located at 00 24. 827'S, 037 05 448'E, at an altitude of 1686 meters above sea level. Gikumbo Primary School is located at 00 26 237'S, 037 07 259'E, at an altitude of 1802 meters above sea level. Kihuro Primary School is located at 0°39′08″S, 037°15′89″E, at an altitude of 2,009.0 meters. The main economic activity of the residents is mainly subsistence non-mechanized farming (arrow roots farming), which grows primarily in swampy areas, and small-scale cow farming.

3.2 Research Design

The research adopted a cross-sectional study design involving primary school children from Gathuini Primary School, Gikumbo Primary School, and Kihuro Primary School in Nyeri County, Kenya. The use of a cross-sectional study design was ideal because it described a subgroup within the population of the study area concerning an outcome and a set of risk factors for STH and intestinal protozoa infection (Spector, 2019).

3.3 Target Population

The target population was made up of students in grades 1–6 (ages 7–12 years) from the three primary schools in the Mathira constituency and was purposively sampled. The schools' selection was done by their proximity to the plain, no man's land, which belongs to the whole community, where open defecation takes place since there are no latrines due to a lack of land ownership and the villagers go to conduct their non-mechanized small-scale farming. Schools provide a high-risk infection population, making them an ideal location to perform STH and intestinal protozoa surveys.

3.4 Sampling Techniques and Sample Size

Schools were selected by their proximity to Konyo Plains, which acted as a breeding and transmission site for geo-helminths and intestinal protozoa, whereas study subject (pupils) selection was by random sampling method within the selected schools. Class registers were used to generate the sampling frame. The selected children were given numbers, which were used as their unique identifiers (confidentiality). The number of research participants was determined using the Cochran formula (Cochran et al., 1963).

$$n_0 = \frac{Z^2pq}{e^2}$$

No=sample size,
Z^2 is the abscissa of the normal curve which cuts off an area α at the tails.
(1 – α) equals the desired confidence level, e.g., 95%)
e is the desired level of precision,
and p denotes the population's estimated proportion of a given attribute (13.5%) (Mwandawiro et al., 2019) national-wide geo-helminths proposition.
q is 1-p. Thus
=1.96^2*0.135(1-0.135)
0.05^2
=177.64
Sample No.=178

3.5 Tools for Data Collection

The research instrument formulated was a questionnaire, and the questions set led to the set goals: Deworming less than three months ago, latrine usage in the school and while at home, hand washing practice after visiting the toilet and before eating and drinking boiled water. Proper latrine usage while on the school farms and while farming at home (in the no-mans-land), walking barefoot or swimming in the river or swamps, wearing protective clothing while farming, and the and the presence of flies or cockroaches at home or in school. The questionnaires were filled in by the pupils with the help of their parents a day before the collection of stool specimens, after which they were provided with sterile specimen bottles to bring stool samples.

3.6 Reliability and Validity of the Research Tools

The pre-test was done at Kaiyaba Health Centre, which is the sub-county hospital, has a large catchment area (due to its location), and has a well-equipped laboratory, so testing of research tools (the questionnaire) was not a problem. Empirical assessment was used to enhance the validity of the instrument. Concurrent validity, a type of criterion validity, was established to confirm whether one measure is equal to or better than another accepted measure while testing the same thing concurrently (Mussel et al., 2018). Split-half reliability was employed, and constructs were split into two sets of five. The instrument was administered to 10 respondents (5 males and 5 females). The total score for each half for each of the 10 respondents and the correlation were calculated. A reliability coefficient of 0.84 was obtained, thus the instruments were deemed reliable.

3.7 Data Collection Procedures and Collection of Samples

There was a meeting (baraza) before the beginning of the study where FGD was performed with the help of the local administration (chief and village elders). Participants were given polypots that had unique codes developed from the class register, and the stool specimens were collected, processed, and microscopically examined. Data on the presence and intensity of infection was recorded in an Excel spreadsheet and recorded as per the slide reading. Infection status was determined by the presence or absence of protozoa or helminths seen.

3. 8 Samples Processing and Tests

Samples were processed using two main procedures: the formal ether concentration technique for the diagnosis of intestinal protozoa and the Kato-Katz technique for the diagnosis of STH. Formal-Ether Concentration as described by Becker et al. (2011): The specimen was well-mixed, and then a wet cheesecloth gauze was placed on top of the disposable tube to filter 5 ml of stool sample mixture (according to its consistency) into a 15 ml circular tube. The volume was then put in a centrifuge tube of up to 15 ml, 0.85% saline, or 10% formalin, and mixed thoroughly using a vortex. Then 4 mL of ethyl acetate was added and vortexed again. The tube was closed and stirred vigorously for 30 seconds on the converted surface. The sample was then spun for 10 minutes at 32000 RPM.

The supernatant was removed, and the residue was layered on a clean microscope slide, ready for examination under a microscope. The results were tabulated on an Excel sheet. The procedure of the Kato-Katz technique as described by Bosch et al. (2021): The microscope slide was labeled with a unique sample identification code, then small pieces of stool were placed on a newspaper and covered with a piece of nylon screen, wiped with a spatula until only debris was left, and then some filtered stool samples were put on the template hole (50 mg). Air bubbles were avoided when layering on the template. Carefully, the template was removed and placed in a pail of water containing strong detergents for reuse. The stool sample was covered with one piece of cellophane soaked overnight in a solution of malachite green glycerol, and to distribute the stool sample circle, a clean slide was placed on top and pressed evenly on the working bench. To avoid splitting the cellophane strand, the slide was carefully removed by moving it to one side. A microscopic examination was then conducted, and the results were reported in an Excel sheet.

3.10 Data Processing and Analysis

Data was processed and tested twice before and after logging in. Only those participants who had complete records of data, including the results of intestinal parasites using a stool test and a complete list of questions, were included in the final analysis. Parameter estimates were considered significant at α (alpha) = 0.05 (significance level). The data was computed by a chi-square test ($\chi 2$), a t-test, and an ANOVA (one way) to determine the relationship between prevalence and gender and the relative risk to determine the likelihood of getting infected by the parasites. The difference in means was considered significant at a p-value ($p \leq 0.05$). Quantitative data was presented using tables and graphs.

IV. FINDINGS & DISCUSSIONS

4.1 Demographic Information of the School Children

The research instruments solicited demographic information of the students. The demographic information of the various students was sought based on gender and age. The structured questionnaire was administered to the students with the help of the parents and guardians, and they completed the demographic characteristics on the age and gender of their children.

4.1.1 The Schools' Distribution of the Respondents by Gender

The study was administered to 164 school-going children of >7 years from three selected primary schools, namely, Kihuro, Gathuini, and Gikumbo in Nyeri County. The data from this study indicates that male children were the majority (56.2%) of the participants compared to female children (43.8%) (**Table 1**). Overall, based on light microscopy examination, 34.6% (57/164) of the children were found to be positive for at least one intestinal protozoa and geo-helminth infection. In addition, the same observation was shown in respective schools where male children were more than female children. Out of a total of 57 infected school-going children, the distribution of the infections in males and females was 19% (31/164) and 16% (26/164), respectively.

Table 1
Distribution by Gender

School	Gender	Frequency	Percentage
Kihuro Primary School	Male	34	60.00%
	Female	22	40.00%
	Total	56	100.00%
Gathuini Primary School	Male	29	53.50%
	Female	25	46.50%
	Total	54	100.00%
Gikumbo Primary School	Male	30	54.90%
	Female	24	45.10%
	Total	54	100.00%

4.1.2 Distribution of Participants by Age

The children who participated in this study had an age distribution of 7–12 years. However, the majority of the children were between 8 and 10 years of age, comprising approximately 80% of the total children in the selected school (**Table 2**). The mean age of the children in this study was 9 years, with a minimum and maximum age of 7 years and 12 years, respectively. Data from this study revealed that children aged 8 years were the majority in Kihuro and Gikumbo Primary Schools, whereas in Gathuini Primary School, the majority of children were 9 years old.

Table 2
Distribution of Participants by Age

School	Age	Frequency	Percentage
Kihuro Primary School	7 years	4	6.67%
	8 years	25	44.00%
	9 years	13	24.00%
	10 years	7	12.00%
	11Years	4	8.00%
	12 years	3	5.33%
Total		**56**	**100.00%**
Gathuini Primary School	7 years	2	4.23%
	8 years	15	26.76%
	9 years	21	39.44%
	10 years	9	16.90%
	11 years	4	7.04%
	12 years	3	5.63%
Total		**54**	**100.00%**
Gikumbo primary School	7 years	0	0.00%
	8 years	22	40.85%
	9 years	15	28.17%
	10 years	9	18.31%
	11Years	3	7.04%
	12 years	3	5.63%
Total		**54**	**100.00%**

4.2 Prevalence and Intensity of Geo-Helminths and Intestinal Protozoa for School-Going Children in Selected Schools in Nyeri County

The findings from this study revealed that of the total 164 stool samples examined, prevalence findings indicate that the children in all three primary schools were more prone to protozoa infections than geo-helminths infections. Figure 1 presents the findings from the samples for the three selected schools.

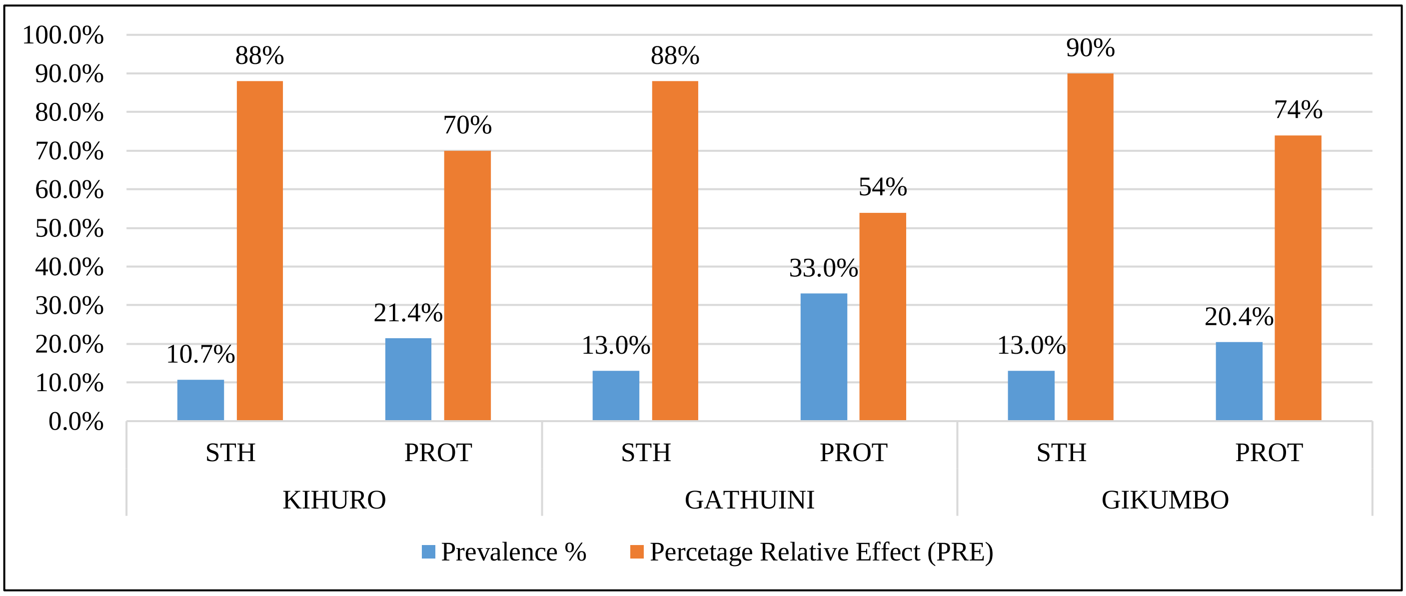

Figure 1
Prevalence of STH and Intestinal Protozoa vs Percentage Relative Effect

Findings in Figure 1 show that of the 56 samples examined in Kihuro primary school, 12 (21.4%) and 6 (10.7%) were positive for protozoan and STH infections. Similarly, 33% of the children in Gathuini primary school were found to be positive for protozoan infections, while 13% were infected with STH. In Gikumbo primary school, 20.4% of the children were infected with protozoan parasites, compared to 13% of STH infections.

Table 3
Prevalence of STH and Intestinal Protozoa by Gender

	KIHURO		GATHUINI		GIKUMBO	
	STH	PROT	STH	PROT	STH	PROT
MALE	5%	14%	7%	16%	9%	9%
FEMALE	5%	7%	16%	9%	1.9%	11%
Risk Ratio	0.12	0.3	0.12	0.46	0.1	0.26

Findings in Table 3 suggest that there is a variation in infection prevalence concerning gender across the three selected sites. This implies that there were variations in exposure, susceptibility, and access to healthcare services between males and females in each site. Further findings showed that children in Kihuro primary school were 0.12 times at risk of STH infection compared to 0.3 times at risk of protozoa infections. Similarly, these children had an 88% reduction in the risk of STH infection when compared to a 70% reduction in the risk of protozoa infection. These findings indicate that the children in Kihuro primary school are more susceptible to protozoan infections than STH infections. The intestinal protozoa infection was higher than that for the geohelminths infection in Gathuini primary school. Children in Gathuini primary school were 0.12 times more at risk of STH infection compared to 0.46 times more at risk of protozoa infections.

Similarly, these children had an 88% reduction in the risk of STH infection when compared to a 54% reduction in the risk of protozoa infection. These findings indicate that the children in Gathuini Primary School are more susceptible to protozoan infections than STH infections. Children in Gikumbo primary school were 0.1 times more at risk of STH infection compared to 0.26 times more at risk of protozoa infections. Similarly, these children had a 90% reduction in the risk of STH infection when compared to a 74% reduction in the risk of protozoa infection (Table 3). These findings indicate that the children in Gikumbo Primary School are more prone to protozoan infections than STH infections.

4.3 Discussions

Findings show that there is variation in the prevalence of both STH and protozoa infections among the three locations. This suggests that the risk of parasitic infections is not uniform and may be influenced by local factors such as environmental conditions, sanitation, and hygiene practices. Gathuini Primary School has the highest prevalence of protozoa infections (33%) among the three locations. This may indicate specific environmental or socio-economic factors that contribute to a higher risk of protozoa infections compared to the other locations. It was noted that the STH infections were caused by *A. lumbricoides,* with no cases of *T. trichiura* or *S. mansoni*. The proportion of the infected children varied significantly from the uninfected children, with more infections caused by intestinal protozoa as compared to STHs. The whole population tested negative for *T. trichiura* and *S. mansoni,* contrary to the claim by Laidemitt et al. (2022) that Schistosomes (*Schistosoma haematobium, Schistosoma japonicum, and Schistosoma mansoni*) and cestodes such as *Taenia solium, Taenia saginata*, and *Hymenolepis nana* are common trematodes. *Ascaris lumbricoides* had an infection of (mean =.40, standard deviation =1.230). These findings revealed a lower rate of prevalence as compared with those of STHs and intestinal protozoa among children under five years, which revealed an overall prevalence of STHs of 52.3% (Obala et al., 2013).

The findings of this study showed that *Ascaris lumbricoides* and *Entamoeba histolitica and Giardia lamblia* were predominant, with a prevalence rate of 12.2% and 24.9%, respectively. These findings imply that the parasites found, *Entamoeba histolitica*, *Giardia lamblia*, and *Ascaris lumbricoides*, are more likely to spread in humans because of their interaction with the environment. The fact that mud soil offers adequate moisture and little sunlight. The tightly adhering particles prevent parasitic larvae from moving to deeper soil layers, allowing most parasites to survive for a long time, supporting this conclusion (Yahia et al., 2023).

Protozoa infections are caused by giardiasis, which has a prevalence range of 20–30% in developing countries (Adam, 2001), which supports the study finding of 24.9%. Studies in Thika District indicate that protozoa infections are 38.9% in rural public schools (Ngonjo et al., 2016). The high prevalence of protozoa infections represented by Giardiasis may have been a result of children swallowing Giardia cysts from untreated and/or contaminated water, food, hands, surfaces, or objects in schools and the environment where they live (Siwila et al., 2020).

These findings corroborate those of a recent cross-sectional study in Egypt by Yahia et al. (2023) which revealed that Ascariasis and Trichuriasis ova were the most prevalent parasites, predominantly isolated from vegetables. The presence of *Giardia lamblia* could be attributed to the fact that they are one of the pathogenic intestinal protozoa that can survive in the water for up to one month at 21 °C (Yahia et al., 2023), a range of temperatures that is similarly experienced in the area under the current study. This is attributed to the fact that the study was done in a higher altitude and wet area of the country, as egg development in the soil is dependent upon several factors, including optimal temperature, adequate shade, and moisture. The surface morphology of many green vegetables, especially leafy ones, encourages the attachment of sticky-natured parasite eggs and cysts that easily adhere to the matrix of these foods, according to Eslah et al. (2016) and McGavin et al. (2023). As a result, with an increase in outbreaks of food-borne illnesses linked to the consumption of fresh produce, these food products have become essential carriers for the transmission of food-borne infections.

Additionally, Ascariasis eggs have thick shells by nature, making them more resistant to a variety of unfavorable conditions like chemical exposure and dehydration, allowing them to tolerate harsh environmental conditions and endure longer in soil habitats necessary for growth (Paller et al., 2019). The temperature of the study area affects the development of this parasite in soil (McCreesh et al., 2015), giving it more chances to survive and infect its surroundings, including the vegetables that are growing, thus needing further investigation. According to studies, these eggs can live in ambient samples for more than ten months in tropical conditions and mature at their best at 32 °C (Shahsavari et al., 2017). No one tested positive for either *Trichuris trichiura* or *Schistosoma mansoni*, according to the results. Because of the geographical location of the study area, which is endemic for those STH, it can still not be ruled out even if the investigation showed negative results (Jember et al., 2022). This may also be connected to the random sampling technique used for the stool in this study (study sample) (Taherdoost, 2016). It is also important to keep in mind that Trichuris species are frequently ineffective living forms, which means that they could eventually become ineffective and pose serious health risks. Nevertheless, one embryonated helminthic egg may be enough to start an infection (Colombo et al., 2020). Similarly, the age of the child did not have any significant association with infection (Apidechkul, 2015).

V. CONCLUSIONS & RECOMMENDATIONS

5.1 Conclusions

In the study, a total of 41 students were infected with *G. lamblia/E. histolitica* infection, while 20 were infected with *A. lumbricoides* out of the 164 pupils sampled, thus making geo-helminths and intestinal protozoa a common health problem in the study area of Nyeri County. The age and gender of the students had no statistical significance. The ages that had the highest population of study subjects were between 8 and 9 years, giving a good distribution (median) of the participants. Apart from the unique local factors that cause the existence of intestinal protozoa, the area generally has a highly common factor that influences the high prevalence of infections.

5.2 Recommendations

The study recommended that government institutions and non-governmental organizations should intervene and undertake adequate control measures against geo-helminth parasites by making sure there is access to safe water and improved sanitation in the area. Moreover, health education programs should be intensified in the area and beyond to bring awareness of geo-helminths and intestinal protozoa infection means of transmission and control measures and improvement of hygiene practices for both the children and the parents. Health initiatives or clubs in school should be introduced and should focus on primary disease prevention. Awareness should be created about treatment for students and their parents, especially for intestinal protozoa, in addition to the mass deworming programs available in schools.

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