Journal of Medical Research and Health Sciences
Received 24 Nov | Revised 27 Dec 2023 | Accepted 22 Jan 2024 | Published Online 05 Feb 2024

DOI: https://doi.org/10.52845/JMRHS/2023-7-2-1

JMRHS 7 (2), 2985–3004 (2024)

ISSN (O) 2589-9031 | (P) 2589-9023

Original Article **Open Access Journal**

Clinical, Environmental and Anthropozoonotic Factors Associated with Giardiasis in a Kenyan Rural Setting

Erick Barasa[1], Briston R. Indieka[2], Nathan Shaviya[1], Clement Shiluli[3] and Tom Were[4*]

[1]Department of Medical Laboratory Sciences, Masinde Muliro University of Science and Technology, P. O. Box 190-50100, Kakamega, Kenya

[2]Department of Biomedical Science and Technology, Maseno University, Kenya; Postal address, Private Bag Maseno

[3]Department of Microbiology, UZIMA University, Kisumu, Kenya

[4]Department of Medical Microbiology and Parasitology, Masinde Muliro University of Science and Technology, P. O. Box 190-50100, Kakamega, Kenya

Correspondig Author: Erick Barasa

Abstract

Background: Giardiasis is an important neglected tropical disease caused by the enteric protozoal parasite *Giardia intestinalis*. The infection is often asymptomatic but cases of symptomatic infections lead to significant morbidity and mortality especially in the developing nations. However, the transmission of this infectious disease largely involves complex interplay of demographic, environmental and zoonotic factors attracting medical and veterinary approaches in delineating its epidemiology. To date, only a few studies have been conducted in Kenya focusing prevalence, less is known about the factors associated with giardiasis in a rural setting. As such, this hospital-based cross-sectional case-control study evaluated the demographic, clinical, environmental and anthropozoonotic factors associated with giardiasis in a rural area of Western, Kenya. A total of 147 individuals referred to the laboratory for stool analysis; cases (n = 78) and controls (n = 69), were recruited into the study. Demographic analysis indicated, gender, age < 18 year, underweight, overweight, ≤ primary education levels, small-scale business, subsistence farming, peri-urban residences, mud-walled, grass-thatched roof, unscreened window houses, household with < 3 members, history of travel or eating at hotels, funeral and from food vendors, were associated with likelihood of giardiasis (P < 0.05). Likewise presenting with fever, headache, vomiting, bloating, stomach upset, abdominal pain, diarrhoea and history of nitroimidazole use were associated with giardiasis (P < 0.05). Stool analysis showed; semi-formed, loose, pus cells, mucus, foul smelling or greasy stools were associated with giardiasis. Sources of water; boreholes, shallow well, stream, spring or pipetted, chlorination as well as storage in super-drums had higher odds for giardiasis, while boiling of drinking water and handwashing had lower odds for giardiasis (P < 0.05). Having cattle, goats, poultry, and/or cats at home were also associated with higher odds for giardiasis (P < 0.05). Altogether, these results indicated that demographic, environmental and zoonotic factors are important factors in the transmission of giardiasis in this rural setting.

Keywords: Giardiasis, *Giardia intestinalis*, clinical, environmental and anthropozoonotic factors, rural setting

Introduction

Giardiasis is a major neglected contagious disease of humans, domestic and wild animals caused by the protozoan parasite *Giardia intestinalis* (also known as *G. lamblia* or *G. duodenalis*) (1). Nearly, 183 million people in the world are infected with *G. intestinalis*, and the African region experiencing 809 cases per 100,000 population each year (2,3). Additionally, giardiasis contributes about 171 thousands disability life adjusted years (DALYs), globally with almost 50% occurring in the African region (2,4). Furthermore, giardiasis is a common enteric disease accounting for nearly 20% of water-borne protozoan disease outbreaks in the world from 2017 to 2020 (5). In Kenya, the correct prevalence of giardiasis is unknown. However, based on available studies, an estimated *G. intestinalis* prevalence of 5-45% has been reported in two rural areas (6,7). In Busia county, the current study setting, 33% of out-patients complaining of abdominal symptoms had microscopically confirmed giardiasis (8). However, the underlying factors contributing to the high burden of giardiasis in rural settings are not fully understood.

The consumption of treated water, hand washing with soap and clean water before eating and after visiting the toilet, residing in an informal settlement, and undernutrition are associated with giardiasis in urban settings (9,10). Likewise, gender, younger age, weight, underweight and overweight, less than primary school level education, working on the farm, living in earthen floor or grass thatched houses, history of travel and history of eating at hotels, cafeteria and from food vendors are linked to *G. intestinalis* infection in rural Africa (9,11,12). Additionally, ingestion of cyst contaminated water, such as from boreholes, shallow wells, streams, rivers, springs, and poor treatment and storage of water are correlated with increased risk of *G. intestinalis* infection in rural areas (10). Furthermore, studies in Uganda, Ethiopia and Malaysia have indicated that interactions with domestic or wild animals, such as cattle, dogs, cats and wild primates is connected to a greater risk of getting giardiasis (13–15). From the aforementioned, it appears that socio-demographic, environmental and zoonotic factors, including water safety are important factors in the epidemiology of giardiasis in rural Africa.

Giardiasis results from ingestion of the infective cysts in contaminated food or water, as well as from direct faeco-oral or anal sexual contact (9,16). Subsequently, the parasite migrates and infects the duodenum and ileum causing local and systemic inflammation. From the inflammation, cytokine release and other soluble mediators trigger fever, headache and gastrointestinal symptoms that characterize the disease. Furthermore, upon entering the enterocytes the parasite cause damage and loss of epithelial brush border which is accompanied with microvilli shortening and loss of function (17). Even though, some patients remain asymptomatic and void formed stool, destruction of the intestinal wall with exfoliation of epithelial cells leads to a variable degree of passing foul smelling, semi-formed or loose stools containing pus cells, mucus or steatorrhea in symptomatic patients (18,19). Additionally, the history of nitroimidazole (metronidazole, albendazole, secnidazole, or tinidazole) use can alter the course and severity of the clinical manifestations of the *G. intestinalis* infections (20,21). Although, the constitutional symptoms and signs of the disease are not pathognomonic, microscopic confirmation of the presence of the giardia trophozoite and/or cysts in the stool specimens is the gold standard widely used in guiding treatment and preventive programs. As such, this study aimed at examining the relationship of demographic, clinical, environmental and zoonotic interaction with *G. intestinalis* infection in a rural setting of Western Kenya.

Material and Methods

Study area, study design and population. This hospital-based case-control study was conducted at Busia County Referral Hospital, Busia County, Western Kenya. Busia County is located to the North of Lake Victoria bordering Uganda and currently is experiencing an influx of people in search of better economic opportunities. It has a bimodal weather pattern comprising of a wet season from April to October and a dry season from November to March. The main economic

activities in the county include small-scale businesses, subsidence farming, including sugarcane farming, livestock raring, fishing and keeping of pet animals such as dogs and cats (22). The county has a high population density of 527 people per square kilometer, an average household size of 5 people, literacy levels of 56% and a poverty index of 66% (23,24). The study comprised 147 patients presenting with abdominal complains and referred to the clinical laboratory for stool examination. The cases and controls were defined by the presence or absence of microscopically confirmed *G. intestinalis* trophozoites and/or cysts, respectively.

Inclusion and exclusion criteria. Only consenting individuals with abdominal complains and referred to the clinical laboratory for stool analysis were enrolled into the study. Individuals declining consent, and those unable to provide a stool specimen at the time of visiting the hospital were excluded from the study.

Information and stool specimen collection. A structured questionnaire was used to collect demographic information (gender, age, height, weight, education level, occupation, house floor, window and roof type, household size, history of eating at hotel, funeral or from food vendors, residence (either rural or peri-urban) and travel history (outside the county or country). Height was measured to the nearest 0.1 cm using a Holtain stadiometer (Holtain Ltd, UK), while the body weight was measured to the nearest 0.1 kg using a portable digital electronic balance (AND Fv-150 KA1, A&D Ltd, Japan). The body mass index (BMI, kg/m^2) was calculated from the weight and height measurements and classified into normal ($\geq 18.5 < 25.0$), underweight (< 18.5), overweight (≥ 25.0) based on the WHO classification of the nutrition status (25). A checklist questionnaire was used to record the patients' presenting history of signs and symptoms (fever or temperature > 37 ^{o}C, headache, vomiting, bloating, stomach upset, abdominal pain and diarrhoea experienced in the preceding two weeks before visiting the hospital for clinical care. Besides, history of nitroimidazole use (metronidazole, ordinazole or secnidazole), tinidazole, and/or albendazole use within the previous two weeks prior to the study was also recorded. Environmental information on water sources (boreholes, shallow wells, streams, river, spring, rain water and piped water), treatment (boiling or chlorination), and storage (jerricans, tank or super drum), domestic and pet animals (cattle, goat, sheep and poultry, dogs and cats) were recorded.

Stool sampling and analyses was performed as per the Center for Diseases Control and Prevention (CDC) guidelines on laboratory identification of parasites of medical importance in stool specimens (26). Briefly, upon receipt of stool examination request form from the doctor, each patient, patient's parent or guardian was provided with a clean and leak-proof plastic container with an applicator stick attached to a well fitted screw cup. Each patient was then requested to aseptically collect a stool sample into the stool container. The stool specimen was immediately transported to the laboratory for macroscopic (formed, semi-formed, loose, pus cells, mucus, foul smell or greasy stool) and microscopic (saline and iodine wet preparation) analysis. A pigeon pea size (~1.0 g) stool sample was placed on a dry clean microscope slide, emulsified using a drop of 0.9% normal saline or 5% Lugol's iodine and covered with a clean 22-mm cover slip. The microscope slide was then examined under objective lens x10 and x40 for the presence and quantification of trophozoites and cysts of *G. intestinalis*, respectively (Figure 1). The parasite density (trophozoite or cyst/µL of stool) was classified as scanty (1-3), few (4-10), moderate (11-20), many (21-40) and very many (> 40) trophozoites and/or cysts (27).

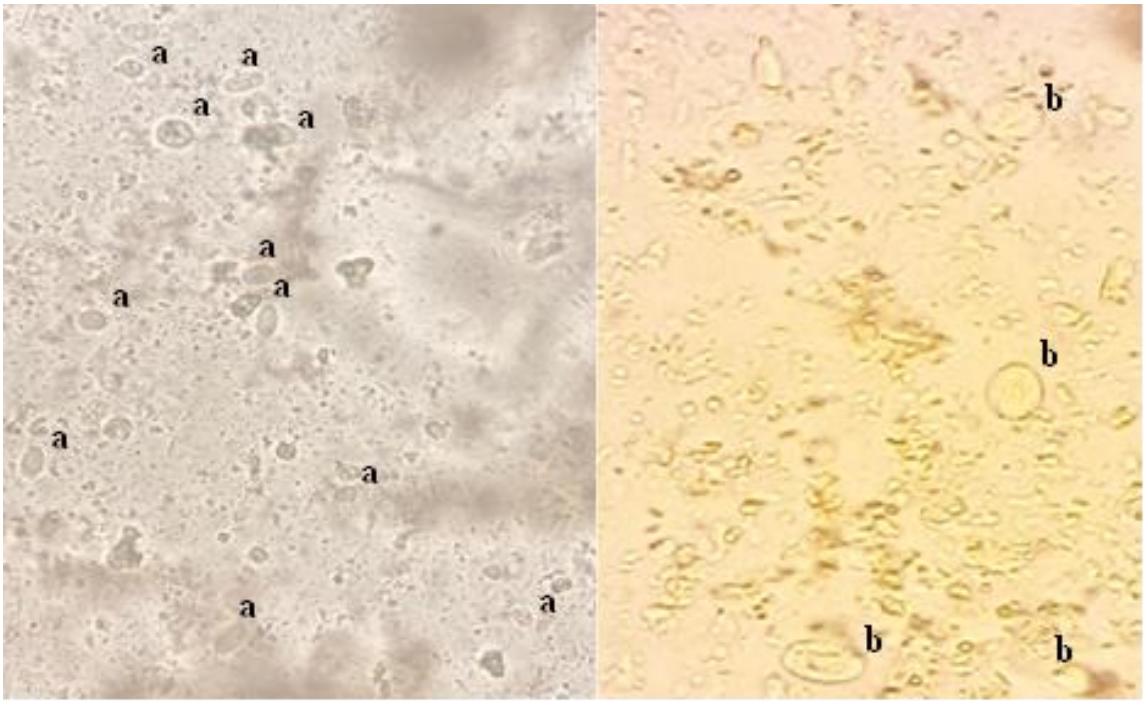

Figure 1. Giardia intestinalis trophozoites (a) and cysts (b) on 0.9% normal saline wet mount and 5% Lugol's iodine wet preparation at x40 objectives.

***Data management and analysis*.** Data was analyzed using the statistical package for the social sciences (IBM® SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp., USA). Categorical variables (gender, nutrition status, occupation, clinical, environmental and anthropozoonotic factors) were compared between the cases and controls using the Fisher's exact tests or the Pearson's Chi-square test. Continuous variables (age, weight, height, and BMI) were compared between the cases and controls using the Mann Whitney U tests. Associations of the demographic, clinical, environmental and anthropozoonotic factors with giardiasis was determined using the binary logistic regression analyses. All tests were two-tailed and a value of $P < 0.05$ was used for statistical inferences.

***Ethical consideration*.** This study was conducted in accordance with the tenets of the Helsinki Declaration. Ethical approvals were sought from the Maseno University Ethical Review Committee (Protocol: MU/403012-V36). The research permit was obtained from the Busia County Referral Hospital Management. A written consent was obtained from each adult and parent/guardian of each child prior to enrollment into the study. The consent form clearly indicated the study purpose, any anticipated consequences of the research, the anticipated uses of the data, possible benefits and harm, data confidentiality, and the option to withdraw from participation. The positive cases of giardiasis participants received treatment as per the Ministry of Health (MoH) in Kenya guidelines.

Results

Demographic characteristics of the study patients. The demographic characteristics of the study participants are presented in Table 1. There were more males among the cases (cases, 62.8% *vs*. controls, 40.6%; OR, 2.474; 95% CI, 1.273 - 4.809; $P = 0.008$) with higher odds for giardiasis. Although, age was similar between the cases and controls, a majority of the cases were younger (<18) years and had higher probability of giardiasis (cases, 53.8% *vs*. controls, 20.3%; OR, 4.194; 95% CI, 2.194 - 9.573; $P < 0.0001$). Assessment of the physical measures showed lower body weights in the cases (median [IQR] kg; cases, 57.0 [41.0] vs. controls, 70.0 [27.0]; $P = 0.038$). Similarly, the cases had lower BMI (median [IQR] kg/m^2; cases, 19.0 [10.2] vs. controls, 25.0, [8.0]; $P = 0.021$), and higher rates of underweight (cases, 18.9% *vs*. controls, 16.2%; OR, 2.784; 95% CI, 1.312 - 5.907; $P = 0.008$) and overweight (cases, 44.6% *vs*. controls 26.5%; OR,

2.362; 95% CI, 1.897 - 6.219; *P* = 0.022) that were linked to higher odds of presenting with giardiasis.

Evaluation of the education profiles showed that most of the patients had primary education which was associated with *G. intestinalis* infection (cases, 69.2% *vs*. controls, 44.9%; OR, 2.314; 95% CI, 1.133 - 4.726; *P* = 0.027). Besides, a majority of the patients engaged in small-scale businesses (cases, 57.7% *vs*. control, 42.0%; OR, 2.211; 95% Cl, 1.001 - 4.882; *P* = 0.004), and subsistence farming (cases, 17.9% *vs*. controls, 5.8%; OR, 1.534; 95% CI, 1.381 - 3.239; *P* = 0.003) which had higher odds of giardiasis. Similarly, most of the cases resided in peri-urban areas, and had higher odds of giardiasis (cases, 71.8% *vs*. controls, 46.4%; OR, 2.201; 95% CI, 1.141- 4.360; *P* = 0.024). Assessment of the housing structure indicated that most of the cases residing in the mud-walled houses were likely to have *G. intestinalis* infection (cases, 34.6% *vs*. controls, 18.8%; OR, 2.938; 95% CI, 1.501 - 5.753; *P* = 0.002). Likewise, patients residing in grass-thatched houses (cases, 16.7% *vs*. controls, 7.2%; OR, 5.743; 95% CI, 1.821 - 8.119; *P* = 0.003) or houses with unscreened windows (cases, 54.8% *vs*. controls, 18.6%; OR, 3.278; 95% CI, 1.122 - 4.635; *P* = 0.003) dominated among the cases and had higher probability of having giardiasis. In addition, most households with greater than 3 people were more prevalent in the cases and were associated with higher risk of giardiasis (cases, 53.2% *vs*. controls, 23.2%; OR, 2.911; 95% CI, 1.376 - 6.158; *P* = 0.005). Evaluation of the history of travel and eating habits indicated that most individuals in the cases had a history of travel (cases, 42.3% *vs*. controls, 21.7%; OR, 2.640; 95% CI, 1.276 - 5.464; *P* = 0.009), eating at hotels (cases, 85.9% *vs*. controls, 56. 5%; OR, 1.692; 95% CI; 1.718 - 3.985; *P* = 0.026), eating at funerals (cases, 23.1% *vs*. 7.2%; OR, 3.560; 95% CI, 1.863 - 7.596; *P* = 0.046) or eating from food vendors (cases, 20.5% *vs*. 8.7%; OR, 2.710; 95% CI, 1.995 - 7.378; *P* = 0.031) which were all associated with greater probability of presenting with giardiasis.

Table 1: Demographic profiles of the study patients

Characteristics	**Cases, n=78**	**Controls, n=69**	***P***	**OR**	**95% Cl**	****P***
Gender, n (%)						
Male	49 (62.8)	28 (40.6)	**0.007**	2.474	1.273-4.809	**0.008**
Female	29 (37.2)	41 (59.4)		**Ref**		
Age, years	24.3 (24.9)	25.3 (24.5)	0.315			
<18	42 (53.8)	14 (20.3)	**<0.0001**	**4.194**	2.194-9.573	**<0.0001**
≥18	36 (46.2)	55 (79.7)		**Ref**		
Height, cm	156.0 (39.0)	158.0 (15.0)	0.473	-	-	-
Weight, kg	57.0 (41.0)	70.0 (27.0)	**0.038**	-	-	-
BMI, kg/m^2	19.0 (10.2)	25.0 (8.0)	**0.021**	-	-	-
Nutrition status, n (%)						
Underweight	14 (18.9)	9 (16.2)	**0.017**	2.362	1.897-6.219	**0.022**
Overweight	33 (44.6)	18 (26.5)		2.784	1.312-5.907	**0.008**
Normal	27 (36.5)	18 (26.5)		**Ref**		
Education, n (%)						
≤Primary	54 (69.2)	31 (44.9)	**0.025**	2.314	1.133-4.726	**0.027**
≥ Secondary	24 (30.8)	38 (55.1)		**Ref**		
Occupation, n (%)						
Small-scale business	45 (57.7)	29 (42.0)	**<0.0001**	2.211	1.001-4.882	**0.004**
Subsidence farming	14 (17.9)	4 (5.8)		1.534	1.381-3.239	**0.003**
Formal employment	19 (24.4)	36 (52.2)		**Ref**		
Residence, n (%)						

Peri-urban	56 (71.8)	32 (46.4)	**0.023**	2.201	1.141-4.360	**0.024**
Rural	22 (28.2)	27 (53.6)		**Ref**		
House type, n (%)						
Mud-walled	27 (34.6)	13 (18.8)	**<0.0001**	2.938	1.501-5.753	**0.002**
Brick-walled	51 (65.4)	56 (81.2)		**Ref**		
Roof type, n (%)						
Grass-thatched	13 (16.7)	5 (7.2)	**0.001**	5.743	1.821-8.119	**0.003**
Tin roofed	65 (83.4)	64 (92.8)		**Ref**		
Window type, n (%)						
Unscreened	34 (54.8)	11 (18.6)	**0.002**	3.278	1.122-4.635	**0.003**
Screened	28 (45.2)	48 (81.4)		**Ref**		
Household size, n (%)						
>3	33 (53.2)	16 (23.2)	**0.006**	2.911	1.376-6.158	**0.005**
1-3	29 (46.8)	53 (76.8)		**Ref**		
Travel history, n (%)						
Yes	33 (42.3)	15 (21.7)	**0.019**	2.640	1.276-5.464	**0.009**
No	45 (57.7)	53 (76.8)		**Ref**		
Eating history, n (%)						
Hotels						
Yes	67 (85.9)	39 (56.5)	**0.021**	1.692	1.718-3.985	**0.026**
No	11 (14.1)	30 (43.5)		**Ref**		
Funerals						
Yes	18 (23.1)	5 (7.2)	**0.043**	3.560	1.863-7.596	**0.046**
No	60 (76.9)	63 (91.8)		**Ref**		
Food vendors						
Yes	16 (20.5)	6 (8.7)	**0.030**	2.710	1.995-7.378	**0.031**
No	62 (79.5)	62 (89.9)		**Ref**		

Data presented are number (n) and proportion (%) of subjects and as odds ratios (OR) with 95% confidence interval (CI). BMI; body mass index; Normal; ≥18.5≤25.0 kg/m^2, Underweight <18.5 kg/m^2, Overweight ≥25.0 kg/m^2. [P]Fisher's exact tests; [R]Chi-square test, *P*; **P*, logistic regression analysis. Bolded are significant *P*-values.

Presenting history. The presenting history of the patients is summarized in Table 2. Assessment of the patient presenting history indicated greater rates of fever (cases, 50.0% *vs*. controls, 31.9%; OR, 2.136; 95% CI, 1.090 - 4.189; *P* = 0.027), headache (cases, 51.3% *vs*. controls, 27.5%; OR, 2.770; 95% CI, 1.389 - 5.523; *P* = 0.004), vomiting (cases, 44.9% *vs*. controls, 27.5%; OR, 2.142; 95% CI, 1.073 - 4.277; *P* = 0.031), bloating (cases, 65.4% *vs*. controls, 17.4%; OR, 8.972; 95% CI, 4.122-19.531; *P* < 0.0001), stomach upset (cases, 47.4% *vs*. controls, 29.0%; OR, 2.211; 95% CI, 1.116-4.382; *P* = 0.023), abdominal pain (cases, 62.8% *vs*. controls, 44.9%; OR, 2.071; 95% CI, 1.070 - 4.008; *P* = 0.038), diarrhoea (cases, 52.6% *vs*. controls, 13.0%; OR, 4.546; 95% CI, 3.222 - 16.936; *P* < 0.0001) except history of nitroimidazole use (cases, 37.2% *vs*. controls, 53.6%; OR, 0.326; 95% CI, 0.010-0.777; *P* = 0.034) and were associated with increased risk of presenting with giardiasis.

Table 2. Presenting history of the study participants

	Cases, n=78	**Controls, n=69**	***P***	**OR**	**95% CI**	****P***
Signs and symptoms						
Fever, n (%)						
Yes	39 (50.0)	22 (31.9)	**0.026**	2.136	1.090-4.189	**0.027**

No	39 (50.0)	47 (68.1)		**Ref**		
Headache, n (%)						
Yes	40 (51.3)	19 (27.5)	**0.003**	2.770	1.389-5.523	**0.004**
No	38 (48.7)	50 (72.5)		**Ref**		
Vomiting, n (%)						
Yes	35 (44.9)	19 (27.5)	**0.030**	2.142	1.073-4.277	**0.031**
No	43 (55.1)	50 (72.5)		**Ref**		
Flatulence, n (%)						
Yes	18 (23.1)	17 (24.6)	0.825	0.918	0.429-1.962	0.827
No	60 (76.9)	52 (75.4)		**Ref**		
Bloating, n (%)						
Yes	51 (65.4)	12 (17.4)	**<0.0001**	8.972	4.122-19.531	**<0.0001**
No	27 (34.6)	57 (82.6)		**Ref**		
Stomach upset, n (%)						
Yes	37 (47.4)	20 (29.0)	**0.022**	2.211	1.116-4.382	**0.023**
No	41 (52.6)	49 (71.0)		**Ref**		
Abdominal pain, n (%)						
Yes	49 (62.8)	31 (44.9)	**0.031**	2.071	1.070-4.008	**0.038**
No	29 (37.2)	38 (55.1)		**Ref**		
Diarrhoea, n (%)						
Yes	41 (52.6)	9 (13.0)	**<0.0001**	4.546	3.222-16.936	**<0.0001**
No	37 (47.4)	60 (87.0)		**Ref**		
Nitroimidazole use, n (%)						
Yes	29 (37.2)	37 (53.6)	0.030	0.326	0.010-0.777	**0.034**
No	49 (62.8)	32 (46.4)		**Ref**		

Data presented are number (n) and proportion (%) of subjects and as odds ratios (OR) with 95% confidence interval (CI). [P]Fisher's exact tests; [R]Chi-square test, *P*; **P*, logistic regression analysis. Bolded are significant *P*-values.

Stool analysis. A summary of the stool characteristics is presented in Table 3. Stool examination revealed that voiding formed (cases, 2.6% *vs*. controls, 60.9%; OR, 0.005; 95% CI, 0.004 - 0.008; $P < 0.0001$), semi-formed (cases, 51.3% *vs*. controls, 30.4%; OR, 2.406; 95% CI, 1.221 - 4.741; $P = 0.0011$) or loose (cases, 61.5% *vs*. controls, 43.5%; OR, 2.080; 95% CI, 1.076 - 4.021; $P = 0.029$) stools, and presence of pus cells (cases, 37.2% *vs*. controls, 8.7%; OR, 6.214; 95% CI, 2.391 - 16.149; $P < 0.0001$), mucus (cases, 55.1% *vs*. controls, 7.2%; OR, 8.726; 95% CI, 5.707-15.333 - 16.149; $P < 0.0001$), foul smell (cases, 50.0% *vs*. controls 13.0%; OR, 6.667; 95% CI, 2.909 - 15.279; $P < 0.0001$) and steatorrhea (cases, 53.8% *vs*. controls, 13.0%; OR, 7.778; 95% CI, 3.3391 - 17. 838; $P < 0.0001$) in the faeces were associated with giardiasis. Furthermore, enumeration of the trophozoite densities indicated a median (IQR) level of 7.0 (4.0) trophozoites/µl of stool with most of the patients having few (60.5%) or moderate (13.2%) parasite densities.

Table 3. Stool characteristics of the *G. intestinalis* infected individuals

Stool characteristics	**Cases, n=78**	**Controls, n=69**	***P***	**OR**	**95% CI**	***P**
Formed, n (%)						
Yes	2 (2.6)	42 (60.9)	**<0.0001**	0.005	0.004-0.008	**<0.0001**
No	76	27 (39.1)		**Ref**		
Semi-formed, n (%)						

Yes	40	21 (30.4)	**0.010**	2.406	1.221-4.741	**0.011**
No	38	48 (69.6)		**Ref**		
Loose, n (%)						
Yes	48	30 (43.5	**0.029**	2.080	1.076-4.021	**0.029**
No	30	39 (56.5)		**Ref**		
Pus cells, n (%)						
Yes	29	6 (8.7)	**<0.0001**	6.214	2.391-	**<0.0001**
No	49	63 (91.3)		**Ref**		
Mucus, n (%)						
Yes	43	5 (7.2)	**<0.0001**	8.726	5.707-	**<0.0001**
No	35	64 (92.8)		**Ref**		
Foul smell, n (%)						
Yes	39	9 (13.0)	**<0.0001**	6.667	2.909-	**<0.0001**
No	39	60 (87.0)		**Ref**		
Steatorrhea, n (%)						
Yes	42	9 (13.0)	**<0.0001**	7.778	3.3391-	**<0.0001**
No	36	60 (87.0)		**Ref**		
Trophozoites/µl stool, median	7.0 (4.0)	-				
Trophozoites levels, n (%)						
Scanty	20	-				
Few	46	-				
Moderate	10	-				

Data presented are number (n) and proportion (%) of subjects and as odds ratios (OR) with 95% confidence interval (CI). Parasite density were expressed as numbers (n) and proportion (%) of scanty (1-3) trophozoites, few (4-10) trophozoites and moderate (11-20) trophozoites. [P]Fisher's exact tests; [R]Chi-square test, *P*; **P*, logistic regression analysis. Bolded are significant *P*-values.

Water sources, treatment and storage practices. A summary of water sources, treatment, storage and hygiene practices is shown in Table 4. Evaluation of water sources showed that boreholes (cases, 66.7% *vs*. controls, 31.9%; OR, 2.273; 95% CI, 2.140 - 8.530; $P < 0.0001$), shallow wells (cases, 26.9% *vs*. controls, 8.7%; OR, 3.510; 95% CI, 1.596 - 9.354; $P = 0.003$), and streams (cases, 71.8%) *vs*. controls, 47.8%; OR, 2.777; 95% CI, 1.403 - 5.497; $P = 0.004$) were the major sources of water and had higher odds of presenting with *G. intestinalis* infection. Boiling (cases, 7.7% *vs*. controls, 21.7%; OR, 0.300; 95% CI, 0.109 - 0.804; $P = 0.020$) and chlorination (cases, 21.8% *vs*. controls, 8.7%; OR, 0.926; 95% CI, 0.082 - 7.915; $P = 0.034$) were the main water treatment methods associated with giardiasis. Among storage methods reported, use of super drums dominated in the cases (cases, 78.1% *vs*. controls, 59.4%; OR, 2.451; 95% CI, 1.192 - 5.039; $P = 0.015$) and was associated with increased risk of giardiasis. Furthermore, hand washing before meals (cases, 38.5% *vs*. controls, 76.8%; OR, 0.821; 95% CI, 0.071 - 0.915; $P = 0.020$) and after visiting the toilet (cases, 69.2% *vs*. controls, 88.4%; OR, 0.721; 95% CI, 0.182 - 0.827; $P = 0.036$) was linked to lower risk of *G. intestinalis* infection.

Table 4. Water sources, treatment, storage and hygiene practices

Practices	**Cases, n=78**	**Controls, n=69**	***P***	**OR**	**95% CI**	***P**
Water sources, n (%)						
Borehole						
Yes	52 (66.7)	22 (31.9)	**<0.0001**	2.273	2.140-8.530	**<0.0001**

No	26 (33.3)	47 (68.1)		**Ref**		
Shallow well						
Yes	21 (26.9)	6 (8.7)	**0.002**	3.510	1.596-9.354	**0.003**
No	57 (73.0)	62 (91.3)		**Ref**		
Stream						
Yes	56 (71.8)	33 (47.8)	**0.003**	2.777	1.403-5.497	**0.004**
No	22 (28.2)	36 (52.2)		**Ref**		
River						
Yes	16 (20.5)	15 (21.7)	0.856	0.929	0.420-2.054	0.856
No	62 (79.5)	54 (78.3)		**Ref**		
Spring						
Yes	6 (7.7)	0 (0.0)	**0.018**	-	-	-
No	72 (92.3)	69 (100.0)		-	-	-
Rain water						
Yes	69 (88.5)	60 (87.0)	0.781	1.150	0.429-3.084	0.783
No	9 (11.5)	9 (13.0)		**Ref**		
Piped water						
Yes	13 (16.7)	0 (0.0)	**<0.0001**	-	-	-
No	65 (83.3)	69 (100.0)		-	-	-
Water Treatment, n (%)						
Boiling						
Yes	6 (7.7)	15 (21.7)	**0.015**	0.300	0.109-0.804	**0.020**
No	72 (92.3)	54 (78.3)		**Ref**		
Chlorination						
Yes	17 (21.8)	6 (8.7)	**0.029**	2.926	1.082-7.915	**0.034**
No	61 (78.2)	63 (91.3)		**Ref**		
Water Storage, n (%)						
Jerricans						
Yes	75 (96.2)	68 (98.6)	0.623	2.720	0.276-6775	0.691
No	3 (3.8)	1 (1.4)		**Ref**		
Super drums						
Yes	61 (78.1)	41 (59.4)	**0.014**	2.451	1.192-5.039	**0.015**
No	17 (21.8)	28 (40.6)		**Ref**		
Tanks						
Yes	9 (11.5)	13 (18.8)	0.216	1.178	0.709-4.466	0.219
No	69 (88.5)	56 (81.2)		**Ref**		
Hygiene practices, n (%)						
Hand washing before meal						
Yes	30 (38.5)	53 (76.8)	**0.017**	0.821	0.071-0.915	**0.020**
No	48 (61.5)	16 (23.2)		**Ref**		
Hand washing after toilet						
Yes	54 (69.2)	61 (88.4)	**0.035**	0.721	0.182-0.827	**0.036**
No	24 (30.8)	8 (11.6)		**Ref**		

Data presented are number (n) and proportion (%) of subjects and odds ratios (OR) with 95% confidence interval (CI). [P]Fisher's exact tests; [R]Chi-square test, *P*; **P*, logistic regression analysis. Bolded are significant *P*-values.

Association of domestic and common pet animals with giardiasis. A summary of common domestic and pet animals associated with giardiasis is presented in Table 5. Analysis of the relationship of commonly kept domestic and pet animals with giardiasis illustrated that cattle

(cases, 43.6% *vs*. controls, 30.4%; OR, 1.623; 95% CI, 1.554 - 6.052; *P* = 0.042), goats (cases, 21.8% *vs*. controls, 1.4%; OR, 8.951; 95% CI, 2.449 - 6.648; *P* = 0.005), poultry (cases, 48.7% *vs*. controls, 33.3%; OR, 1.574; 95% CI, 1.297 - 7.110; *P* = 0.046), and cats (cases, 39.7% *vs*. controls, 11.6%; OR, 5.029; 95% CI, 2.117 - 8.949; *P* < 0.0001) were prevalent in the cases and were linked to greater chances of having giardiasis.

Table 5. Domestic and pet animals

Domestic animals and pets, n (%)	**Cases, n=78**	**Controls, n=69**	***P***	**OR**	**95% CI**	****P***
Cattle						
Yes	34 (43.6)	21 (30.4)	**0.036**	1.623	1.554-6.052	**0.042**
No	44 (56.4)	48 (69.6)		**Ref**		
Goat						
Yes	17 (21.8)	1 (1.4)	**<0.0001**	8.951	2.449-6.648	**0.005**
No	61 (78.2)	68 (98.6)		**Ref**		
Poultry						
Yes	38 (48.7)	23 (33.3)	**0.034**	1.574	1.297-7.110	**0.036**
No	40 (51.3)	46 (66.7)		**Ref**		
Dog						
Yes	24 (30.8)	17 (24.6)	0.408	1.359	0.656-2.817	0.409
No	54 (69.2)	52 (75.4)		**Ref**		
Cat						
Yes	31 (39.7)	8 (11.6)	**<0.0001**	5.029	2.117-8.949	**<0.0001**
No	47 (60.3)	61 (88.4)		**Ref**		

Data presented are number (n) and proportion (%) of subjects and as odds ratios (OR) with 95% confidence interval (CI). [P]Fisher's exact tests; [R]Chi-square test, *P*; **P*, logistic regression analysis. Bolded are significant *P*-values.

Discussion

Demographic characteristic of the study patients. Demographic evaluations indicating that more males and younger people (age <18 years) were likely to have giardiasis, suggests that the male gender and children are more likely to interact with potential risks of *G. intestinalis* infection. This is probably related to poor hygienic practices such as handwashing after toilet visit and before eating. Additionally, adventurous lifestyles such as hunting, gardening, hiking and grazing can lead to increased exposure with potential risks of *G. intestinalis* infections (28). Furthermore, the higher rates of physical activities among younger people, and the fact that children frequently play with soil and surface waters which are often contaminated with giardia parasites predisposes them to acquiring the disease. Consistent with this findings, a cross-sectional school-based study in South West Ethiopia indicated that male children were two times at risk of intestinal parasitic infections (29). In addition, school-based correlation study in North East of Ethiopia showed that male students had higher odds of having intestinal parasitic infections (30). On the contrary, previous studies in Western Kenya in an area with similar environmental conditions as the present study showed that females had higher rates of giardiasis (8). Furthermore, the study findings are consistent with epidemiological studies on intestinal parasites in the community and in informal settlements in Kenya indicating higher rates of infection among children (31,32). Interestingly, breast-fed children had a low prevalence of giardiasis (33,34), suggesting a protective value of breast milk during early childhood.

The low body weight and body mass index of the giardiasis patients, suggests that *G. intestinalis* infection triggers gastrointestinal inflammation leading to malabsorption, maladigestion, loss of nutrients such as ADEK vitamins, and

competition for nutrients especially micronutrients (copper, zinc and iron) with the host resulting in malnutrition (35). In agreement with these results, a number of studies showed higher rates of weight loss, underweight and muscle wasting among children presenting with giardiasis (36–39). In addition, increased levels of protein energy malnutrition was associated with giardiasis in children (40,41). However, the finding of higher prevalence of overweight individuals among giardiasis patients can be ascribed to the malabsorption and constipation state in the patients. On this premise, *G. intestinalis* infection can modulate metabolism via changing the gut microbiome composition, promoting local intestinal inflammation, and altering appetite, food intake and the body mass index (42,43). Subsequently, these changes can cause fat deposition over time leading to obesity (44). These assertions are further supported by results of a survey in a Mexican population showing that an increase in the body mass index of 0.6 kg/m^2 was associated with intestinal parasitic infections (45).

The results of having more individuals with primary or less education, more individuals engaging in small scale business and subsistence farming in the cases, suggests that poor health education practices among this predominantly subsistence population is a critical factor in increasing the risk of *G. intestinalis* infections. Consistent with the findings, school-based cross-sectional studies in two primary schools in Northeast Ethiopia reported high prevalence of parasitic infections among children with uneducated parents (30). In addition, children of uneducated or primary level educated mothers had greater risk of presenting with giardiasis in Ghana (46), Tanzania (47) and Cuba (48). This is further supported by results indicating that individuals with formal employment were about two times less likely to have giardiasis. This means that possessing at least secondary education and being in stable formal employment are associated with appropriate health practices such as good health seeking behavior, access to health finances and good hygiene practices. This preposition is supported by results among school-going children in informal settlements of Nakuru town, Kenya indicating that having a parent practicing business was linked to a higher probability of intestinal infections (49). Likewise, studies among children hospitalized with diarrhea in Goiânia, Brazil, revealed that children who lived on a farm were likely to get infected with *G. intestinalis* (13). Equally important are observations that sugarcane chewing is connected to high infection rates among primary school children in North East Ethiopia (49,50). On the contrary, studies among school-going children in informal settlements in Nakuru, Kenya showing that children from families practicing farming were less likely to be infected with intestinal parasites or geohelminths (49), suggest that farming is not a risk factor of intestinal parasitic infections.

A peri-urban residence was associated with higher odds of having *G. intestinalis*, suggesting that peri-urban settings have higher sources of giardiasis. The possible underlying reasons include poor water quality, inappropriate sewage disposal and sanitation facilities, unhygienic eateries and high population densities which promote contamination and transmission of giardia cysts. Consistent with this results, previous studies in Ethiopia indicated high prevalence of intestinal parasites among urban residents relative to inhabitants from rural areas (30). Similarly, higher rates of giardiasis were reported in the informal settlements of urban and peri-urban regions in Kenya (32,49). These hypotheses are further supported by the results of the present study showing that fewer rural residents had *G. intestinalis*.

Dwelling in mud-walled or grass-thatched houses, houses with unscreened windows or in households with more than three people was associated with higher rates of giardiasis, suggesting increased indoor contamination leading to infection. Mud-walled crevices harbor giardiasis transmission agents like small rodents, lizards and cockroaches (48,49,50), and the practice of geophagy in which pregnant women eat soil from the mud walls (9). Given that soil harbors giardia cyst for longer periods, it represents a critical source of infection in pregnant women craving for soil, and children contaminating their hands and objects that they ingest (9,54). Besides, unscreened windows let contaminated dust in the dry season to enter the house and contaminate food and water resulting in infection (6). Additionally, this findings, partly

concur with a study in Nakuru, Kenya reporting higher prevalence of intestinal parasites among children from families with few rooms (49). Similarly, case-control studies in England and Brazil showed that children from households with more than four children had higher odds of having giardiasis (55,56).

A history of travel and eating at hotels, funerals or from food vendors was associated with higher likelihood of giardiasis, suggesting increased ingestion of foods and water contaminated with the infectious giardia cysts. Consistent with the current study, a history of travel to endemic regions was associated with giardiasis in the developed countries (28,57,58). For instance, a prospective cohort study in the Netherland among long-term (3-12 months) travelers to Sub-Saharan Africa, reported high incidence of *G. intestinalis* infection (12). Similarly, individuals with a history of travelling in England were three times at risk of giardiasis (55). Furthermore, a history of eating from outdoor food outlets is an important predictor of intestinal infections. This observation is consistent with previous studies among children from an informal settlement in Kenya indicating that eating from school was associated with the likelihood of intestinal protozoal infection (49). Likewise, studies among pregnant women in Ghana showed that intestinal parasitic infections were more prevalent in women consuming cooked food from vendors (54).

Presenting history. The presenting complains of fever, headache and gastrointestinal symptoms were associated with giardiasis, indicating that *G. intestinalis* presents with both gastro-intestinal and systemic manifestations. The gastrointestinal symptoms are due to duodenal and ileal giardia infection releasing parasite metabolic products and toxins that cause local inflammation. In addition, endogenous mediators with pyrogenic effect such as interleukin (IL)-1β, IL-6 and tumor necrosis factor-α secreted from leukocytes and other cells during giardia infection stimulate fever and headache (59). Furthermore, similar symptoms have been reported in children presenting with giardiasis in Rwanda (60), Ethiopia (61) and Egypt (19). On the contrary, genetic variability of the *G. intestinalis* parasite is associated with differences in the clinical presentation of the disease. For instance, studies in the Southwest of London, England among giardiasis cases showed that both assemblages A and B caused similar illnesses, but assemblage A was more frequently associated with fever than assemblage B (62). Similarly, among children less than 5 years of age in Spain, sub-assemblage AII was associated with symptomatic infection, while assemblage B was correlated with asymptomatic infection (63). Thus, genetic diversity influences the virulence and clinical outcomes of *G. intestinalis* infection.

Stool analysis. Stool examination results showing that passing stools that are semi-formed, loose or that are containing pus cells, mucus, greasy or foul smelling is associated with the likelihood of *G. intestinalis* infection, suggests that local parasite induced inflammation underlies the mechanism of gastrointestinal manifestations. Consistent with this results, previous studies reported that voiding semi-formed or loose stools, presence of mucus, steatorrhea and foul smelling stool were frequent features of symptomatic giardiasis (64,65). However, assemblage A *G. intestinalis* infection was associated with steatorrhea in children from Canada, suggesting that stool characteristics depends on parasite virulence (66). The basic mechanisms leading to semi-formed, loose or diarrheagenic stools is due to enterocyte damage and loss of brush border of the epithelial cells, consequently shortening the microvilli and modulating epithelial barrier functions (17). Besides, steatorrhea and mucus release result from decreased activity of lipases and increased release of mucin from goblet cells (67,68). Additionally, the presence of pus cells and foul smelling stools is attributable to intestinal epithelial cell apoptosis (4). The results of a median number of trophozoites of 7.0 with higher rates of scanty and few levels of trophozoites, suggest a more acute or recent infection. This results are similar to previous studies reporting scanty and few levels of trophozoites in children with acute giardiasis in western Kenya (69,70). On the contrary, previous studies indicating scanty and few levels of trophozoites in patients with history of nitroimidazole use, suggest refractory disease due to treatment failure (71).

Water sources, treatment storage and hygienic practices. Results showing that the major water sources (boreholes, shallow well, stream, spring

and pipetted water) are associated with *G. intestinalis* infection, suggest presence of the infective giardia cysts. However, boiling is an effective method of water treatment compared to chlorination. In addition, storage using super drums appears to be a risky means of water storage. Altogether, these results suggest higher rates of water contamination especially at sources and during storage. The possible reason includes contamination via collecting vessels, dust and soil particles, surface run-off water and farm animal excreta. Consistent with these results, giardia parasites have been detected in well water in Mexico (72). Similarly, a high prevalence of giardiasis was observed in children from Nakuru Kenya, using borehole water sources (49). Although piped water sources seem to be associated with lower odds of giardiasis in the current study, some studies showed that these water sources can also be contaminated (56,73). With regard to water treatment, boiling was associated with reduced odds, whereas chlorination was correlated with the likelihood of giardiasis. This is attributable to the use of sub-optimal chlorine dose, pH and temperature rendering chlorination ineffective. Additionally, contamination of water treatment plants with cysts from technical complications of coagulation, filtration, disinfection or broken pipes may result in *G. intestinalis* infection. These results also correspond with the CDC guidelines stipulating that boiling is the most effective method of drinking water treatment, while chemical chlorination is ineffective against giardia cysts (74). Storage of water in super drums is ineffective in sustaining safety over a long period as it may allow dust particles and other contaminants to enter open drums. Likewise, stored water can be contaminated through use of dirty collecting vessels, whereas rainfall water can be contaminated by washing of dust particles on the roof into the collecting reservoirs. Consistent with these observations, rain water and spring water have been associated with intestinal parasitic infections, which was attributed to contamination of the storage facilities (18).

The hygienic practices comprising hand washing before meals and after visiting the toilet were associated with low possibility of giardiasis, suggesting a reduction in the load of viable infective cysts of *G. intestinalis*. However, a subset of individuals who practiced hand washing also had giardiasis, and this is probably due to poor hand washing practices like not using soap and safe water during hand washing. In agreement with these results, a lack of or poor hand washing techniques have been associated with transmission of intestinal parasites among children inmates (75–77). On the contrary, a randomized trial in Kenya among children who practiced handwashing as a strategy to control giardiasis, was ineffective in reducing the infection (76), suggesting that other risk factors are involved either directly or indirectly in the transmission of giardiasis.

Association of domesticated and common pet animals with giardiasis. Giardiasis seems to have a zoonotic link in this rural community as evidenced by the higher rates of *G. intestinalis* infections in individuals residing in homes keeping cattle, goats, poultry and cats. This could be attributed to the fact that a majority of people interact with cattle dung, goat pellets and poultry excreta plus their pet companions that predisposes them to infection. In addition, a number of households co-inhabit with animals in their dwellings, especially earthen kitchens with weaning calves, kids and poultry, thus increasing the risk of contamination. Furthermore, use of cattle and goat excreta as manure, eating of raw fruits and vegetable like sweet potatoes and carrots, and the habit of chewing sugarcane without proper washing are potential sources of infections in this rural area. Although, cats are regarded as clean animals, it is possible that they can carry the giardia cysts in their furs, particularly during the dry season, and transmit the parasite during interaction with their owners. Consistent with these results, epidemiological studies in Belgium (78), Canada, (79,80) and informal settlements in Kenya (81) have reported increased risk of zoonotic transmission of giardiasis. Furthermore, previous studies in Kisumu, Kenya, detected high *G. intestinalis* presence in stool samples of animals roaming the city (82). However, studies in Nakuru, Kenya among school-going children failed to show any association of goat rearing with the likelihood of intestinal infections (49). Additionally, previous studies among children in Brazil, implicated cats

in the transmission of giardiasis (50), while in the Pacific Region, cats were linked to increased odds of *G. intestinalis* infection in children (83). Moreover, having cat pets was associated with intestinal protozoan parasites among school children from informal settlements in Nakuru, Kenya (49).

Conclusion

The results of this study indicated that demographic (age, gender, education, occupation, residence, house type, household size, history of travel and history of eating (at a funeral, hotel, or food vendor in the preceding two weeks), gastrointestinal complains, stool examination, environmental (domestic water sources, water treatment, water storage, hygienic practices, and anthropozoonotic (domestic animals and pets) factors are important in defining clinical presentation and acquisition of giardiasis. This study has implications on the epidemiology, as well as control and prevention of the disease in resources limited rural settings.

Limitations of the Study

Although the current cross-sectional study provides important information on the factors defining giardiasis in a rural setting, a longer prospective study design will provide additional insights into the dynamics of *G. intestinalis* transmission. Even though information on travel and history of eating was obtained by recording recall in the preceding fortnight, generalization of the results is valid as most of the patients had at least high school education and could discern the details about their prior health history. The use of microscopic stool examination for defining *G. intestinalis* positive cases is appropriate as this is the "gold-standard" clinical stool analysis, including examination of the stool specimens on three occasions by experienced microscopists. However, molecular identification can be a complementary investigation to provide additional information about the isolates, assemblages and sub-assemblages.

Data Availability

The data used to support the findings of the current study are available from the corresponding author upon request.

Competing Interest

None of the authors have a commercial relationship or financial conflict of interest as part of this study.

Funding for Statement

The research was in part supported by the Kenya National Council for Science and Technology (NRF/PHD/02/116), Busia County Referral Hospital and Masinde Muliro University of Science and Technology.

Authors' Contributions

TW and RI conceived and designed the study. RI, NS and EB performed the experiments. EB and TW performed statistical analyses, interpreted the results, and co-drafted and revised the manuscript together with NS. All authors have read and approved the manuscript.

Acknowledgements

We are grateful for the study participants, staff and management of Busia County Referral Hospital for ensuring the success of this study.

References

1. Samie A, Tanih NF, Seisa I, Seheri M, Mphahlele J, ElBakri A, et al. Prevalence and genetic characterization of Giardia lamblia in relation to diarrhea in Limpopo and Gauteng provinces, South Africa. Parasite Epidemiol Control. 2020 May;9:e00140.
2. Kirk MD, Pires SM, Black RE, Caipo M, Crump JA, Devleesschauwer B, et al. World Health Organization Estimates of the Global and Regional Disease Burden of 22 Foodborne Bacterial, Protozoal, and Viral Diseases, 2010: A Data Synthesis. PLoS Med. 2015 Dec;12 (12):e1001921.
3. Torgerson PR, Devleesschauwer B, Praet N, Speybroeck N, Willingham AL, Kasuga F, et al. World Health Organization Estimates of the Global and Regional Disease Burden of 11 Foodborne Parasitic Diseases, 2010: A Data Synthesis. PLOS Med. 2015 Dec 3;12(12): e1001920.
4. Troeger. Estimates of the global, regional, and national morbidity, mortality, and aetiologies of diarrhoea in 195 countries: a systematic analysis for the Global Burden of Disease Study 2016. Lancet Infect Dis. 2018 Nov;18(11):1211–28.

5. Ma JY, Li MY, Qi ZZ, Fu M, Sun TF, Elsheikha HM, et al. Waterborne protozoan outbreaks: An update on the global, regional, and national prevalence from 2017 to 2020 and sources of contamination. Sci Total Environ. 2022 Feb 1;806(Pt 2):150562.
6. Benjamin-Chung J, Crider YS, Mertens A, Ercumen A, Pickering AJ, Lin A, et al. Household finished flooring and soil-transmitted helminth and Giardia infections among children in rural Bangladesh and Kenya: a prospective cohort study. Lancet Glob Health. 2021 Mar 1;9(3):e301–8.
7. Kimosop RJ, Langat G, Ngeiywa MM, Mulambalah CS. Epidemiology of intestinal parasitic infections among suspected patients attending a referral hospital in Kenya. Afr J Health Sci. 2021 Dec 3;34(5):566–76.
8. Mutsami AN, Omondi V. Point Prevalence of Giardia Lamblia among Out- Patients Attending Sioport Sub-County Hospital, Busia County, Kenya. 2016;4.
9. Alula GA, Munshea A, Nibret E. Prevalence of Intestinal Parasitic Infections and Associated Risk Factors among Pregnant Women Attending Prenatal Care in the Northwestern Ethiopia. BioMed Res Int. 2021;2021:3387742.
10. Aschale A, Adane M, Getachew M, Faris K, Gebretsadik D, Sisay T, et al. Water, sanitation, and hygiene conditions and prevalence of intestinal parasitosis among primary school children in Dessie City, Ethiopia. PloS One. 2021;16(2):e0245463.
11. Fan YM, Oikarinen S, Lehto KM, Nurminen N, Juuti R, Mangani C, et al. High prevalence of selected viruses and parasites and their predictors in Malawian children. Epidemiol Infect. 2019 Jan;147:e90.
12. Soonawala D, van Lieshout L, den Boer MAM, Claas ECJ, Verweij JJ, Godkewitsch A, et al. Post-travel screening of asymptomatic long-term travelers to the tropics for intestinal parasites using molecular diagnostics. Am J Trop Med Hyg. 2014 May;90(5):835–9.
13. Colli CM, Bezagio RC, Nishi L, Bignotto TS, Ferreira ÉC, Falavigna-Guilherme AL, et al. Identical Assemblage of Giardia duodenalis in Humans, Animals and Vegetables in an Urban Area in Southern Brazil Indicates a Relationship among Them. PLoS ONE. 2015 Mar 11;10(3):e0118065.
14. Graczyk TK, Bosco-Nizeyi J, Ssebide B, Thompson RCA, Read C, Cranfield MR. Anthropozoonotic Giardia duodenalis genotype (assemblage) a infections in habitats of free-ranging human-habituated gorillas, Uganda. J Parasitol. 2002 Oct;88(5):905–9.
15. Roshidi N, Mohd Hassan NH, Abdul Hadi A, Arifin N. Current state of infection and prevalence of giardiasis in Malaysia: a review of 20 years of research. PeerJ. 2021 Nov 11; 9:e12483.
16. Escobedo AA, Almirall P, Alfonso M, Cimerman S, Chacín-Bonilla L. Sexual transmission of giardiasis: a neglected route of spread? Acta Trop. 2014 Apr;132:106–11.
17. Vivancos V, González-Alvarez I, Bermejo M, Gonzalez-Alvarez M. Giardiasis: Characteristics, Pathogenesis and New Insights About Treatment. Curr Top Med Chem. 2018;18(15):1287–303.
18. Moyo SJ, Kommedal Ø, Blomberg B, Hanevik K, Tellevik MG, Maselle SY, et al. Comprehensive Analysis of Prevalence, Epidemiologic Characteristics, and Clinical Characteristics of Monoinfection and Coinfection in Diarrheal Diseases in Children in Tanzania. Am J Epidemiol. 2017 Nov 1;1 86(9):1074–83.
19. Nasr DS, Yousof HASA, Tyler K, El-Badry A, Rubio JM, El-Dib N a. E. GIARDIA INTESTINALIS ASSEMBLAGES AMONG EGYPTIAN SYMPTOMATIC/ASYMPTOM ATIC CASES IN CAIRO. J Egypt Soc Parasitol. 2018 Aug 1;48(2):465–74.
20. Argüello-García R, Leitsch D, Skinner-Adams T, Ortega-Pierres MG. Drug resistance in Giardia: Mechanisms and alternative treatments for Giardiasis. Adv Parasitol. 2020; 107:201–82.
21. Lopes-Oliveira LAP, Fantinatti M, Da-Cruz AM. In vitro-induction of metronidazole-resistant Giardia duodenalis is not associated with nucleotide alterations in the genes involved in pro-drug activation. Mem Inst Oswaldo Cruz. 2020;115: e200303.
22. Omusotsi OG, Dennis AT, Kilimo CJ, Alex M, Kipchirchir KK, Cynthia J, et al. Assessing the Social, Cultural, Economic and Environmental Conditions of Nambale Town

in Busia County, Kenya. Urban Reg Plan. 2019 May 7;4(1):16.
23. Busia County Department of Health and Sanitation. Busia County Integrated Development Plan Busia County Health sector strategic and investment plan 2020-2021. Busia County Government. [Internet]. 2020 [cited 2022 Mar 28]. Available from: https://www.busiacounty.go.ke/index.php/downloads/send/13-annual-development-plans/9-health-and-sanitation-annual-work-plan
24. KNBS. Kenya Population and House Census: Population by County and Sub- County: Vol. I. Kenya National Bureau of Statistics. [Internet]. 2019 [cited 2022 Jun 6]. Available from: https://www.knbs.or.ke/?wpdmpro=2019-kenya-population-and-housing-census-volume-i-population-by-county-and-sub-county
25. WHO. World Health Organization (WHO) classification of nutritional status of infants and children [Internet]. World Health Organization; 2022 [cited 2022 Sep 12]. Available from: https://www.ncbi.nlm.nih.gov/books/NBK487900/table/fm.s1.t1/
26. CDC. Laboratory identification of parasites of public health concern [Internet]. 2022 [cited 2022 Sep 12]. Available from: https:// www. cdc.gov/dpdx/index.html
27. Cheesebrough M. Medical Laboratory Manual for Tropical Countries Vol. I, 2nd edition, 1987,Tropical Health Technology/Butterworth-Heinsmann [Internet]. 2006 [cited 2022 Mar 28]. Available from: https://www.weather-atlas.com/en/ kenya/busia-climate
28. Espelage W, an der Heiden M, Stark K, Alpers K. Characteristics and risk factors for symptomatic Giardia lamblia infections in Germany. BMC Public Health. 2010 Jan 28;10:41.
29. Jejaw A, Zemene E, Alemu Y, Mengistie Z. High prevalence of Schistosoma mansoni and other intestinal parasites among elementary school children in Southwest Ethiopia: a cross-sectional study. BMC Public Health. 2015 Jul 2;15(1):600.
30. 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. Pediatr Health Med Ther. 2020;11: 179–88.
31. Kipyegen CK, Shivairo RS, Odhiambo RO. Prevalence of intestinal parasites among HIV patients in Baringo, Kenya. Pan Afr Med J. 2012;13:37.
32. Mbae C, Mulinge E, Guleid F, Wainaina J, Waruru A, Njiru ZK, et al. Molecular Characterization of Giardia duodenalis in Children in Kenya. BMC Infect Dis. 2016 Mar 22;16:135.
33. Bilenko N, Ghosh R, Levy A, Deckelbaum RJ, Fraser D. Partial breastfeeding protects Bedouin infants from infection and morbidity: prospective cohort study. Asia Pac J Clin Nutr. 2008;17(2):243–9.
34. Muhsen K, Levine MM. A systematic review and meta-analysis of the association between Giardia lamblia and endemic pediatric diarrhea in developing countries. Clin Infect Dis Off Publ Infect Dis Soc Am. 2012 Dec;55 Suppl 4:S271-293.
35. Abou-Shady O, El Raziky MS, Zaki MM, Mohamed RK. Impact of Giardia lamblia on growth, serum levels of zinc, copper, and iron in Egyptian children. Biol Trace Elem Res. 2011 Apr;140(1):1–6.
36. Akech S, Ayieko P, Gathara D, Agweyu A, Irimu G, Stepniewska K, et al. Risk factors for mortality and effect of correct fluid prescription in children with diarrhoea and dehydration without severe acute malnutrition admitted to Kenyan hospitals: an observational, association study. Lancet Child Adolesc Health. 2018 Jul 1;2(7):516–24.
37. Akkad T, Kirchgatterer A, Kranewitter W, Aschl G, Höbling W, Knoflach P. [Fever and weight loss as leading symptoms of infection with giardia lamblia]. Z Gastroenterol. 2002 Feb;40(2):73–6.
38. Pickering AJ, Njenga SM, Steinbaum L, Swarthout J, Lin A, Arnold BF, et al. Effects of single and integrated water, sanitation, handwashing, and nutrition interventions on child soil-transmitted helminth and Giardia infections: A cluster-randomized controlled trial in rural Kenya. PLoS Med. 2019 Jun;16(6):e1002841.

39. Tickell KD, Pavlinac PB, John-Stewart GC, Denno DM, Richardson BA, Naulikha JM, et al. Impact of Childhood Nutritional Status on Pathogen Prevalence and Severity of Acute Diarrhea. Am J Trop Med Hyg. 2017 Aug 21;97(5):1337–44.
40. Al-Mekhlafi MSH, Azlin M, Nor Aini U, Shaik A, Sa'iah A, Fatmah MS, et al. Giardiasis as a predictor of childhood malnutrition in Orang Asli children in Malaysia. Trans R Soc Trop Med Hyg. 2005 Sep;99(9):686–91.
41. Muniz-Junqueira MI, Queiroz EFO. Relationship between protein-energy malnutrition, vitamin A, and parasitoses in living in Brasília. Rev Soc Bras Med Trop. 2002 Apr;35(2):133–41.
42. Bäckhed F, Ding H, Wang T, Hooper LV, Koh GY, Nagy A, et al. The gut microbiota as an environmental factor that regulates fat storage. Proc Natl Acad Sci U S A. 2004 Nov 2;101(44):15718–23.
43. Sanchez M, Panahi S, Tremblay A. Childhood Obesity: A Role for Gut Microbiota? Int J Environ Res Public Health. 2015 Jan;12(1): 162–75.
44. Hanson MA, Gluckman PD. Developmental origins of health and disease – Global public health implications. Best Pract Res Clin Obstet Gynaecol. 2015 Jan 1;29(1):24–31.
45. Zavala GA, Doak CM, Portrait F, Seidell JC, García OP, Rosado JL, et al. Are intestinal parasites associated with obesity in Mexican children and adolescents? Parasitol Int. 2019 Aug;71:126–31.
46. Anim-Baidoo I, Narh CA, Oddei D, Brown CA, Enweronu-Laryea C, Bandoh B, et al. Giardia lamblia infections in children in Ghana. Pan Afr Med J [Internet]. 2016 Dec 7 [cited 2022 Jun 26];24(217). Available from: https://www.panafrican-med-journal.com/content/article/24/217/full
47. Tellevik MG, Moyo SJ, Blomberg B, Hjøllo T, Maselle SY, Langeland N, et al. Prevalence of Cryptosporidium parvum/hominis, Entamoeba histolytica and Giardia lamblia among Young Children with and without Diarrhea in Dar es Salaam, Tanzania. PLoS Negl Trop Dis. 2015;9(10):e0004125.
48. Bello J, Núñez FA, González OM, Fernández R, Almirall P, Escobedo AA. Risk factors for Giardia infection among hospitalized children in Cuba. Ann Trop Med Parasitol. 2011 Jan;105(1):57–64.
49. Chege NM, Ondigo BN, Onyambu FG, Kattam AM, Lagat N, Irungu T, et al. The prevalence of intestinal parasites and associated risk factors in school-going children from informal settlements in Nakuru town, Kenya. Malawi Med J J Med Assoc Malawi. 2020 Jun;32(2):80–6.
50. Pereira M das GC, Atwill ER, Barbosa AP. Prevalence and associated risk factors for Giardia lamblia infection among children hospitalized for diarrhea in Goiânia, Goiás State, Brazil. Rev Inst Med Trop São Paulo. 2007 Jun;49:139–45.
51. Conan A, O'Reilly CE, Ogola E, Ochieng JB, Blackstock AJ, Omore R, et al. Animal-related factors associated with moderate-to-severe diarrhea in children younger than five years in western Kenya: A matched case-control study. PLoS Negl Trop Dis. 2017 Aug 4;11(8): e0005795.
52. Hailegebriel T. Undernutrition, intestinal parasitic infection and associated risk factors among selected primary school children in Bahir Dar, Ethiopia. BMC Infect Dis. 2018 Aug 13;18:394.
53. Hamu H, Debalke S, Zemene E, Birlie B, Mekonnen Z, Yewhalaw D. Isolation of Intestinal Parasites of Public Health Importance from Cockroaches (Blattella germanica) in Jimma Town, Southwestern Ethiopia. J Parasitol Res. 2014;2014:186240.
54. Abaka-Yawson A, Sosu SQ, Kwadzokpui PK, Afari S, Adusei S, Arko-Mensah J. Prevalence and Determinants of Intestinal Parasitic Infections among Pregnant Women Receiving Antenatal Care in Kasoa Polyclinic, Ghana. J Environ Public Health. 2020;2020:9315025.
55. Minetti C, Lamden K, Durband C, Cheesbrough J, Platt K, Charlett A, et al. Case-Control Study of Risk Factors for Sporadic Giardiasis and Parasite Assemblages in North West England. J Clin Microbiol. 2015 Oct;53(10):3133–40.
56. Teixeira JC, Heller L, Barreto ML. Giardia duodenalis infection: risk factors for children living in sub-standard settlements in Brazil. Cad Saude Publica. 2007 Jun;23(6):1489–93.

57. Coffey CM, Collier SA, Gleason ME, Yoder JS, Kirk MD, Richardson AM, et al. Evolving Epidemiology of Reported Giardiasis Cases in the United States, 1995-2016. Clin Infect Dis Off Publ Infect Dis Soc Am. 2021 Mar 1;72(5):764–70.
58. Davies AP, Campbell B, Evans MR, Bone A, Roche A, Chalmers RM. Asymptomatic carriage of protozoan parasites in children in day care centers in the United kingdom. Pediatr Infect Dis J. 2009 Sep;28(9):838–40.
59. Zampronio AR, Soares DM, Souza GEP. Central mediators involved in the febrile response: effects of antipyretic drugs. Temp Multidiscip Biomed J. 2015 Oct 13;2(4):506–21.
60. Geus D, Sifft KC, Habarugira F, Mugisha JC, Mukampunga C, Ndoli J, et al. Co-infections with Plasmodium, Ascaris and Giardia among Rwandan schoolchildren. Trop Med Int Health TM IH. 2019 Apr;24(4):409–20.
61. Mohamed AMA, Bayoumy AM, Abo-hashim AH, Ibrahim AA, El-Badry AA. Giardiasis in symptomatic children from Sharkia, Egypt: genetic assemblages and associated risk factors. J Parasit Dis Off Organ Indian Soc Parasitol. 2020 Dec;44(4):719–24.
62. Breathnach AS, McHugh TD, Butcher PD. Prevalence and clinical correlations of genetic subtypes of Giardia lamblia in an urban setting. Epidemiol Infect. 2010 Oct;138(10): 1459–67.
63. Zajaczkowski P, Lee R, Fletcher-Lartey SM, Alexander K, Mahimbo A, Stark D, et al. The controversies surrounding Giardia intestinalis assemblages A and B. Curr Res Parasitol Vector-Borne Dis. 2021 Jan 1;1:100055.
64. Oboth P, Gavamukulya Y, Barugahare BJ. Prevalence and clinical outcomes of Plasmodium falciparum and intestinal parasitic infections among children in Kiryandongo refugee camp, mid-Western Uganda: a cross sectional study. BMC Infect Dis. 2019 Apr 1;19(1):295.
65. Rumsey P, Waseem M. Giardia Lamblia Enteritis. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2022 [cited 2022 Sep 11]. Available from: http://www.ncbi.nlm.nih.gov/books/NBK531495/
66. Almeida AA, Delgado ML, Soares SC, Castro AO, Moreira MJ, Mendonça CM, et al. Genotype analysis of Giardia isolated from asymptomatic children in northern Portugal. J Eukaryot Microbiol. 2006;53 Suppl 1:S177-178.
67. Pelaseyed T, Bergström JH, Gustafsson JK, Ermund A, Birchenough GMH, Schütte A, et al. The mucus and mucins of the goblet cells and enterocytes provide the first defense line of the gastrointestinal tract and interact with the immune system. Immunol Rev. 2014 Jul;260(1):8–20.
68. Allain T, Amat CB, Motta JP, Manko A, Buret AG. Interactions of Giardia sp. with the intestinal barrier: Epithelium, mucus, and microbiota. Tissue Barriers. 2017 Jan 3;5(1):e1274354.
69. Masaku J, Njomo DW, Njoka A, Okoyo C, Mutungi FM, Njenga SM. Soil-transmitted helminths and schistosomiasis among pre-school age children in a rural setting of Busia County, Western Kenya: a cross-sectional study of prevalence, and associated exposures. BMC Public Health. 2020 Mar 18;20(1):356.
70. Swierczewski BE, Odundo EA, Koech MC, Ndonye JN, Kirera RK, Odhiambo CP, et al. Surveillance for enteric pathogens in a case-control study of acute diarrhea in Western Kenya. Trans R Soc Trop Med Hyg. 2013 Feb;107(2):83–90.
71. Abdel-Azim. Egyptian Herbal Drug Industry: Challenges and Future Prospects [Internet]. 2020 [cited 2022 Apr 1]. Available from: https://scialert.net/abstract/?doi=rjmp.2011.136.144
72. Balderrama-Carmona AP, Gortáres-Moroyoqui P, Álvarez-Valencia LH, Castro-Espinoza L, Balderas-Cortés J de J, Mondaca-Fernández I, et al. Quantitative microbial risk assessment of Cryptosporidium and Giardia in well water from a native community of Mexico. Int J Environ Health Res. 2015;25(5):570–82.
73. Xiao G, Qiu Z, Qi J, Chen J an, Liu F, Liu W, et al. Occurrence and potential health risk of Cryptosporidium and Giardia in the Three Gorges Reservoir, China. Water Res. 2013 May 1;47(7):2431–45.
74. CDC. A Guide to Drinking Water Treatment and Sanitation for Backcountry and Travel Use | Camping, Hiking, Travel | Drinking Water | Healthy Water | CDC [Internet]. 2021

[cited 2022 Jul 21]. Available from: https://www.cdc.gov/healthywater/drinking/travel/backcountry_water_treatment.html

75. Ameya G, Zerdo Z, Tesfaye M, Jabesa C, Awaje A, Dejene K, et al. Intestinal parasite infections and associated factors among inmates of Arba Minch prison, southern Ethiopia: cross sectional study. BMC Infect Dis. 2019 Dec 30;19(1):1086.
76. Luby SP, Rahman M, Arnold BF, Unicomb L, Ashraf S, Winch PJ, et al. Effects of water quality, sanitation, handwashing, and nutritional interventions on diarrhoea and child growth in rural Bangladesh: a cluster randomised controlled trial. Lancet Glob Health. 2018 Mar 1;6(3):e302–15.
77. Rop DC, Nyanchongi BO, Nyangeri J, Orucho VO. Risk factors associated with intestinal parasitic infections among inmates of Kisii prison, Kisii county, Kenya. BMC Res Notes. 2016 Aug 2;9:384.
78. Geurden T, Geldhof P, Levecke B, Martens C, Berkvens D, Casaert S, et al. Mixed Giardia duodenalis assemblage A and E infections in calves. Int J Parasitol. 2008 Feb;38(2):259–64.
79. Appelbee AJ, Frederick LM, Heitman TL, Olson ME. Prevalence and genotyping of Giardia duodenalis from beef calves in Alberta, Canada. Vet Parasitol. 2003 Mar 25;112(4):289–94.
80. O'Handley RM, Cockwill C, Jelinski M, McAllister TA, Olson ME. Effects of repeat fenbendazole treatment in dairy calves with giardiosis on cyst excretion, clinical signs and production. Vet Parasitol. 2000 Apr 28;89(3):209–18.
81. Peter GS, Gitau GK, Mulei CM, Vanleeuwen J, Richards S, Wichtel J, et al. Prevalence of Cryptosporidia, Eimeria, Giardia, and Strongyloides in pre-weaned calves on smallholder dairy farms in Mukurwe-ini district, Kenya. Vet World. 2015 Sep;8(9):1118–25.
82. Kanyari P. Prevalence of endoparasites in cattle within urban and peri-urban areas of Lake Victoria Basin, Kenya with special reference to zoonotic potential. 2010;
83. De Santis-Kerr AC, Raghavan M, Glickman NW, Caldanaro RJ, Moore GE, Lewis HB, et al. Prevalence and risk factors for Giardia and coccidia species of pet cats in 2003-2004. J Feline Med Surg. 2006 Oct;8(5):292–301.

How to Cite: BARASA, E., Shaviya, N., Indieka, B., Shiluli, C., & Were, T. (2024). Clinical, Environmental and Anthropozoonotic Factors Associated with Giardiasis in A Kenyan Rural Setting . Jour Med Resh and Health Sci, 7(2), 2985–3004. https://doi.org/10.52845/JMRHS/2023-7-2-1