One Health Bulletin 2024; 4(2): 76−84

johb.info

Original Article

One Health Bulletin

Gastrointestinal helminthiasis among Nigerian farmers in Delta North communities

Antonia Enudi✉, Onyebiguwa Nmorsi, Andy Egwunyenga

Department of Animal and Environmental Biology, Faculty of Science, Delta State University, Abraka, Nigeria

ABSTRACT

Objective: To investigate the prevalence of gastrointestinal helminth infections among farmers of different age groups and the risk factors influencing disease transmission in different geographic settings with intermittent treatment in Delta North Agricultural Zone in Nigeria.

Methods: This cross-sectional study was carried out among all age groups in some farming communities in freshwater swamp forest and lowland rainforest of Delta North Agricultural Zone. Kato Katz method was used to detect gastrointestinal helminth infections in stool samples. Study participants totalled 20 698 including 11 215 (54.2%) males and 9483 (45.8%) females. Additionally, diagnostic tests performance for *Schistosoma mansoni* using Kato Katz and PCR were compared.

Results: This study identified six parasites namely, *Schistosoma mansoni*, *Ascaris lumbricoides*, hookworm, *Trichuris trichiura*, *Enterobius vermicularis* and *Strongyloides stercoralis*, with a total prevalence of 21.6%. The freshwater swamp forest had a slightly higher prevalence (21.8%) with six parasite species than that of the lowland rainforest (21.0%) with five species, but the difference was not statistically significant ($P > 0.05$). Factors that influenced disease transmission include sex, age, behaviour, type of infection, culture and environment, with vulnerabilities higher among children and females ($P < 0.05$). Additional investigation comparing Kato Katz method and PCR using *Schistosoma mansoni* 121 bp primer on 120 samples showed prevalence of 0.0% for Kato Katz and 4.2% for PCR.

Conclusions: This study revealed persistent gastrointestinal helminth infections in areas where there is intermittent mass antihelminthic administration. This underscores the need for integrated control of gastrointestinal helminthiasis in farming communities.

KEYWORDS: Gastrointestinal helminthiasis; Delta North Agricultural Zone; Farmers; Risk factors

1. Introduction

Gastrointestinal helminthiasis is a major cause of morbidity, which may result in health complications and even death[1,2]. The disease, caused by different gastrointestinal helminths, impacts on the general wellbeing of individuals and families[3]. The common and globally distributed gastrointestinal helminths are soil-transmitted helminths (STHs) and *Schistosoma(S.) mansoni*. The STHs include *Ascaris(A.) lumbricoides*, hookworms, *Trichuris(T.) trichiura* and *Strongyloides stercoralis*[4,5], and parasites infections occur mostly through the faecal-oral route and skin penetration, depending on the parasite species. Helminthiasis is prevalent

Significance

Gastrointestinal helminthiasis is endemic in Delta State, Nigeria. While most studies on this disease focused on prevalence among children, this study focused on prevalence in communities under intermittent treatment. We observed the highest prevalence among children, found six parasites in freshwater swamp forest and five in lowland rainforest, and identified unavoidable risk factors that promote reinfection. Thus, the study underlines the need for integrated control of gastrointestinal helminthiasis in farming communities.

✉To whom correspondence may be addressed. E-mail: ebelenudi@hotmail.com

This is an open access journal, and articles are distributed under the terms of the Creative Commons Attribution-Non Commercial-ShareAlike 4.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.

For reprints contact: reprints@medknow.com

©2024 *One Health Bulletin* Produced by Wolters Kluwer- Medknow.

How to cite this article: Enudi A, Nmorsi O, Egwunyenga A. Gastrointestinal helminthiasis among Nigerian farmers in Delta North communities. One Health Bull 2024; 4(2): 76-84. doi: 10.4103/ohbl.ohbl_40_23

Article history: Received 21 December 2023 Revision 31 January 2024
Accepted 28 March 2024 Available online 7 April 2024

among the poor, particularly children in tropical and subtropical countries[6–10]. Worldwide, the estimated population infected with one or more STHs is about 1.5 billion (24.0%)[5], and Africa has the second highest burden of *A. lumbricoides*, *T. trichiura* and hookworms[11]. Intestinal schistosomiasis majorly caused by *S. mansoni* in Africa, occurs through contact with unsafe water and may lead to liver pathology[1].

Disease indicators include poor access to safe water, sanitation and hygiene. Globally, Nigeria ranks among the first three countries that lack access to clean water and sanitation, and the second among countries that practice open defecation[12], having the highest number of cases of common STHs in Africa[7,10,13]. In accordance with the World Health Organization (WHO) strategies to reduce morbidity, the Nigerian government initiated the National Schistosomiasis Control Programme in 1988, the Soil-Transmitted Helminths control programme in 2007[14,15], and improved the WASH (water, sanitation and hygiene) sector[12,16,17]. Despite government efforts, only 10.0% of Nigerians access WASH services[17,18]. In Delta State, about 23.0%-26.0% of the population use basic WASH[17].

Other factors that promote gastrointestinal helminth infections include environment such as soil type, rainfall, temperature, flooding and ensuing pools of stagnant water where children play[6,7,10,19,20], age, sex and occupation[4,7,10]. Additionally, diagnostic challenges result in underestimation of prevalence[11,20–23], while cultural bias affects participation in investigations[9,22,24].

The global and national goal to eliminate schistosomiasis and STHs as a public health problem by 2030[11], has yielded positive outcomes[25,26]. Of public health significance is still the persistence of infections in these areas including Delta State, Nigeria. This investigation aimed at providing data on prevalence of gastrointestinal helminth infections among farmers of different age groups in different geographic settings of Delta North Agricultural Zone, in areas with intermittent government control intervention. Also, the risk factors influencing the transmission of these neglected diseases are indicated in this study.

2. Materials and methods

2.1. Study design

A cross-sectional study was carried out from July 2019 to December 2021. Delta State has three agricultural zones, of which Delta North agricultural zone has nine local government areas (LGAs). Three LGAs were selected purposively, based on their common boundary with the Niger River on the east, and Slovin's formular was used to determine the sample size. The selected area is divided into two ecological zones[27], namely the freshwater swamp forest that comprised Ndokwa East and Oshimili South LGAs with a total land area of 2 120 sq km and a total population of 344 523, and the Oshimili North LGA in lowland rainforest, with 516 sq km land area and a population of 161 259. Nine farming communities were randomly selected and comprised seven communities in freshwater swamp forest and two in lowland rainforest. The number of recruited volunteers were 20 698 comprising 11 215 males and 9 483 females. Questionnaires administered on participants were used to collect socio-demographic information such as age, sex, education, occupation, water source, sanitation and hygiene practices.

2.2. Study area

The ecological zones have diverse water resources for domestic use, recreation, farming, fishing, transportation, other water related activities, while some communities are vulnerable to flooding[27]. The study locations are Abuator (5° 35'46.9N, 6° 31'05.8E), Onye-Uku (5° 39'02.9N, 6° 32'07.7E), Ise-Onukpor (5° 35'19.9N, 6° 34'21.8E), Iyede-Ame (5° 27'36.1N, 6° 25'01.6E), Ibrede (5° 33'29.9N, 6o23'31.4E), Oko-Anala (6° 05'49.1N, 6° 42'36.1E) and Oko-Amakom (6° 07'53.8N, 6° 44'25.7E) in the freshwater swamp forest, while Ugbolu (6° 18'39.8N, 6° 41'26.7E) and Ebu (6° 28'47.6N, 6° 36'23.3E) are in the lowland rainforest (Figure 1).

2.3. Study population

The study population was predominantly subsistence crop farmers but they also carried out fishing and hunting, as well as local food processing and petty trading. Their occupations exposed them to open water sources especially, those in freshwater swamps areas that are prone to annual flooding. Study participants from all ages and different occupations were selected at random from among community members who because of communitymobilization, volunteered as participants. Those recruited in the study were resident in the communities, who gave their consent to participate and were willing to produce stool samples. Nonresidents and those unable to produce stool samples were excluded.

2.4. Sample collection and parasitological analysis

Participants were instructed on the proper way to collect stool samples after which, each participant was given a 30 mL screw-

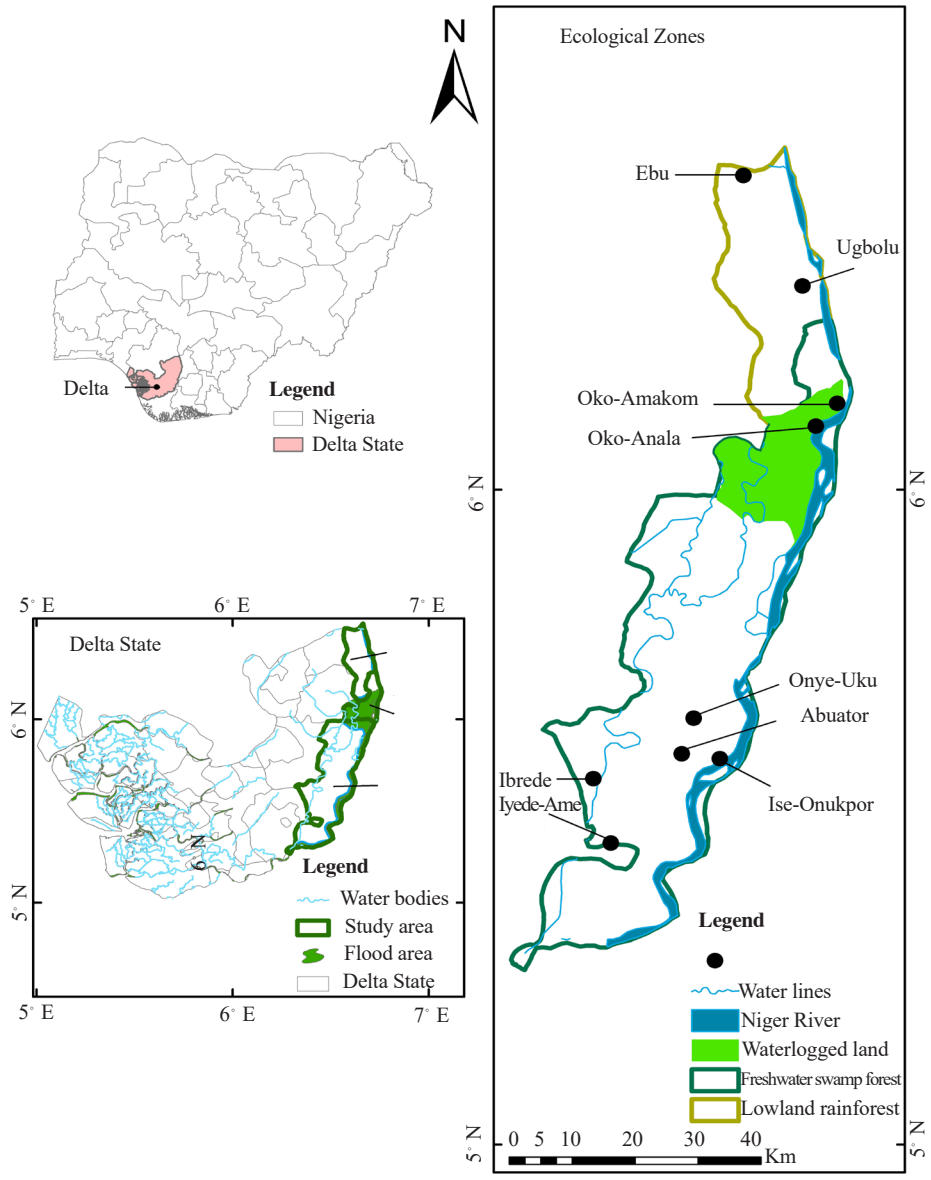


Figure 1. The ecological zones and study locations in three Local Government areas of Delta State in Nigeria.

covered plastic container bearing their identification number. Parents of younger children assisted in collecting their children's stool samples to avoid contaminating stool with urine. Stool samples were examined macroscopically for parasites, soil, colour, consistency, blood and mucus. Samples were preserved in ice boxes and transported to the laboratory for parasitological tests using direct smear method and Kato Katz technique prepared with templates that produce 41.7 mg of stool[28,29]. Samples were prepared and read within two hours for easy identification of hookworm eggs and other intestinal helminths, and later reread for easy identification of *S. mansoni* eggs. The intensities of infections were determined according to WHO guidelines[30].

2.5. Polymerase Chain Reaction (PCR) for Schistosoma mansoni

PCR was carried on 120 urine samples of randomly selected participants[23]. The 110 bp fragment from the 121-bp tandem repeat was amplified using forward primer 5' GATCTGAATCCGACCAACCG 3', and reverse primer 5' ATATTAACGCCCACGCTCTC 3' designed by Hamburger *et al.* (GenBank accession # M61098)[31]. Each tube had 20 µL reaction volume of made up of 4 µL firepole, 0.25 µL each of the forward and reverse primers, 5 µL of DNA and 10.5 µL of ddH_2O. The profile for amplification involved denaturation for 5 min at 95 ℃, then 40 cycles each for 30 s at 94 ℃, then annealing for 30 s at 60 ℃, followed by

elongation at 72 ℃ for 30 s and a final elongation step at 72 ℃ for 7 min.

The PCR amplifications were carried out using a Thermal Cycler (SimpliAmp). The amplified products were visualized on a 1.5% agarose gel stained with ethidium bromide (0.5 μg/mL). A 50 bp ladder was included in the gel during electrophoresis to estimate band sizes for *S. mansoni* and bands highlighted around the 110 bp was considered positive for S. mansoni. Photo documentation was carried out using Gel Documentation and Analysis System (Clinx Science instruments, USA) and positive tests were recorded.

2.6. Statistical analysis

Data were analysed using PAleontological STatistical Version 4.03 (PAST Øyvind Hammer, University of Oslo) MedCalc Version 20.115 (MedCalc Software, Belgium) was used to calculate odds ratio (*OR*) and 95% confidence interval (*CI*), Kappa's coefficient and test agreement between diagnostic tests, and to calculate sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), positive and negative likelihood ratio and accuracy. Categorical variables used were age groups and sex. Test of independence using Chi-squared test was used to determine the relationship between prevalence and categorial variables, to calculate risk factors and socio-demographic characteristics of participants. Statistical significance was determined at 5% significance level and at 95% *CI* .

2.7. Ethics approval and consent to participate

The Delta State University Ethical Review Committee gave ethical clearance (REC/FOS/17/02) and additionally, the Ministry of Health Research and Ethics Committee gave ethics approval (HM/596/T2/47) for this study to be carried out. Approval to use the facilities of the Primary Health Care Centers in study locations was obtained from the Delta State Primary Health Care Development Agency. Community leaders were visited and informed of the study. With their permission, community mobilization took place, where the purpose of the study was explained to community members and confidentiality with regards to information disclosed was assured. Participants comprised of volunteers who gave their consent by signing or thumb printing the consent form. Parents and guardians gave consent on behalf of their children and wards, while children gave consent by nodding.

3. Results

3.1. Socio–demographic profile of study participants

Study participants that submitted questionnaires and stool samples totalled 20 698, of which 11 215 (54.2%) were males and 9 483 (45.8%) were females. The socio-demographic characteristics are shown in Table 1. About half of the participants comprised children 0-9 years 5 358 (25.9%) and 10-19 years 5 089 (24.6%), while other age groups made up 49.5%. Most of the participants 14 913 (72.1%) depended on open water sources for household use, while 14 499 (70.1%) had contact with open water. Sanitation was poor as 14 456 (69.8%) practiced open defecation, while hygiene practices showed that 10 218 (49.4%) of participants walked barefoot.

Around 78.9% of participants in the freshwater swamp forest depended more on open water sources (11 529/14 619), while 66.1% in lowland rainforest had better access to pipe-borne water (4 017/6 079). Sanitation was poor in freshwater swamp forest, where 72.4% (10 585/14 619) defecated openly, while hygiene practices were similar in both forests, however, 19.3% children in the freshwater swamp forest played in puddles (2 815/14 619) compared to those in the lowland rainforest (8.4%, 509/6 079).

3.2. Prevalence of gastrointestinal helminth infections

The summary of prevalence is presented in Table 2. Participants totalled 20 698, comprising 14 619 from the freshwater water swamp forest and 6 079 from the lowland rainforest. Participants infected with gastrointestinal helminth infections totalled 4 462 with a prevalence of 21.6%, comprising 3 187 (15.4%) from freshwater swamp forest and 1 275 (6.2%) from the lowland rainforest. The differences observed in prevalence had no statistical significance with ecological zone (*OR* 1.05; 95% *CI*: 0.98-1.13; $P = 0.19$). This study observed six gastrointestinal helminths, namely *S.mansoni* (0.9%), *A. lumbricoides* (14.7%), hookworm (3.6%), *T. trichiura* (1.5%), *Strongyloides(S.) stercoralis* (0.4%) and *Enterobius(E.) vermicularis* (0.4%) which was observed only in the freshwater swamp forest. Intensity of infection was light for the observed helminths[30].

Gender prevalence showed that males in both forests were less likely to develop infections ($OR < 1$) however, the observed difference was statistically significant only in freshwater swamp forest ($P = 0.00$).

Prevalence of *A. lumbricoides* and *S. mansoni* had statistical significance in ecological zone ($P < 0.05$), and freshwater swamp forest participants had higher likelihood of developing infections

Table 1. Characteristics of freshwater swamp forest and lowland rainforest of Delta North agricultural zone [*n* (%)].

Category	Variable	Freshwater swamp forest (*n* = 14619)	Lowland rainforest (*n* = 6079)	Total (*n* = 20698)
Sex	Male	7993 (54.7)	3222 (53.0)	11215 (54.2)
	Female	6626 (45.3)	2857 (47.0)	9483 (45.8)
Age group (year)	0-9	3921 (26.8)	1437 (23.6)	5358 (25.9)
	10-19	3662 (25.0)	1427 (23.5)	5089 (24.6)
	20-29	1737 (11.9)	689 (11.3)	2426 (11.7)
	30-39	1637 (11.2)	596 (9.8)	2233 (10.8)
	40-49	1175 (8.0)	589 (9.7)	1764 (8.5)
	50-59	983 (6.7)	560 (9.2)	1543 (7.5)
	60-69	860 (5.9)	499 (8.2)	1359 (6.6)
	≥70	644 (4.4)	282 (4.6)	926 (4.5)
Household water	Lake, pond, river, stream	11529 (78.9)	3384 (55.7)	14913 (72.1)
	Piped water	7920 (54.2)	4017 (66.1)	11937 (57.7)
Water contact	Yes	11435 (78.2)	3064 (50.4)	14499 (70.1)
	No	3184 (21.8)	3015 (49.6)	6199 (29.9)
Sanitation	Pit	2848 (19.5)	1574 (25.9)	4422 (21.4)
	Water closet	1186 (8.1)	634 (10.4)	1820 (8.8)
	Open defecation	10585 (72.4)	3871 (63.7)	14456 (69.8)
Hygiene	Wash hands before eating	12596 (86.2)	5305 (87.3)	17901 (86.5)
	Wash fruits before eating	11349 (77.6)	4526 (74.5)	15875 (76.7)
	Wash hands after eating	13765 (94.2)	5837 (96.0)	19602 (94.7)
	Walk barefoot	7251 (49.6)	2967 (48.8)	10218 (49.4)
	Wash hands after defecating	11894 (81.4)	4983 (82.0)	16877 (81.5)
	Play in puddles	2815 (19.3)	509 (8.4)	3324 (16.1)

(*OR* > 1). Hookworm and T. trichiura infections equally depended on ecological zones ($P < 0.05$) however, lowland rainforest participants had higher likelihood of developing infections. The chances of developing Strongyloides stercoralis infections was higher in lowland rainforest, but the observed difference had no statistical significance ($P > 0.05$).

The prevalence of co-infection among gastrointestinal helminths was 0.9% (190/20698), and it was higher in the lowland rainforest of 1.3% (79/6079) than that in freshwater swamp forest of 0.8% (111/14619). Freshwater swamp forest volunteers had five types of co-infection with two parasites. In lowland rainforest, three types of co-infection with two parasites and one co-infection with three parasites were observed.

3.3. Prevalence of gastrointestinal helminthiasis according to age

Gastrointestinal helminthiasis cut across all age groups as presented in Table 3. The highest prevalence occurred among children 0-9 years in both forests, 31.4% (*OR* = 1.00; 95% *CI*: 0.88-1.14; $P = 0.97$), followed by children 10-19 years, 23.4% (*OR* = 1.05; 95% *CI*: 0.91-1.22; $P = 0.49$) and prevalence had no statistical significance in ecological zone. Prevalence of participants of age groups 20-29, 40-49, 50-59 and 60-69 years had statistical significance in ecological zone ($P < 0.05$), with freshwater swamp forest participants more vulnerable to infections (*OR* > 1). Participants 30-39 and ≥70 years in lowland rainforest had significantly higher likelihood of developing gastrointestinal helminthiasis ($P < 0.05$).

3.4. Comparison of diagnostic tests

Comparison of *S. mansoni* prevalence using Kato Katz method and PCR, for a subset of the study sample size made up of 120 participants, showed 0.0% prevalence using Kato Katz method, while 121 bp PCR showed amplification bands indicating *S. mansoni* infection as shown in Figure 2. Total PCR prevalence of 4.2% was observed and composed of 4.5% for freshwater swamp forest and 3.7% for lowland rainforest. The 121bp PCR had 100% (95% *CI*: 47.82-100.00) sensitivity compared to Kato Katz test that had 0.00% sensitivity as shown in Table 4.

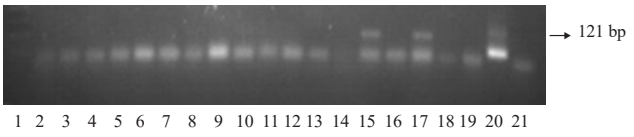


Figure 2. PCR amplification of a highly repeated 121 basepair sequence of *Schistosoma mansoni* as shown by agarose gel stained with ethidium bromide. Lane 1: 50 bp of molecular weight markers. Lanes 2-14, 16, 18 and 19: no amplifications. Lanes 15 and 17: amplifications. Lane 20: positive control; Lane 21: negative control. Amplifications below the base pair marker are primer dimers.

Table 2. Gastrointestinal helminthiasis prevalence in freshwater swamp forest and lowland rainforest according to species.

Parasites	Freshwater Swamp Forest			Lowland Rainforest			EZ	*OR* (95% *CI*)	*P*
	Male (*n*=7993)	Female (*n*=6626)	Total (*n*=14619)	Male (*n*=3222)	Female (*n*=2857)	Total (*n*=6079)	(*n*=20698)		
Mono-infection									
A. lumbricoides	1115 (13.9)	1099 (16.6)	2214 (15.1)	411 (12.8)	418 (14.6)	829 (13.6)	3043 (14.7)	1.13 (1.04-1.23)	0.01
Hookworm	261 (3.3)	220 (3.3)	481 (3.3)	135 (4.2)	133 (4.7)	268 (4.4)	749 (3.6)	0.74 (0.63-0.86)	0.00
T. Trichiura	113 (1.4)	89 (1.3)	202 (1.4)	56 (1.7)	53 (1.9)	109 (1.8)	311 (1.5)	0.77 (0.61-0.97)	0.03
S. mansoni	58 (0.7)	98 (1.5)	156 (1.1)	30 (0.9)	9 (0.3)	39 (0.6)	195 (0.9)	1.67 (1.17-2.38)	0.00
E. vermicularis	52 (0.7)	35 (0.5)	87 (0.6)	0 (0.0)	0 (0.0)	0 (0.0)	87 (0.4)		0.00
S. stercoralis	18 (0.2)	29 (0.4)	47 (0.3)	15 (0.5)	15 (0.5)	30 (0.5)	77 (0.4)	0.65 (0.41-1.03)	0.07
Total	1617 (20.2)	1570 (23.7)	3187 (21.8)	647 (20.1)	628 (22.0)	1275 (21.0)	4462 (21.6)	1.05 (0.98-1.13)	0.19
OR (95% *CI*)	0.82 (0.75-0.88)		0.89 (0.79-1.01)						
P	0.00		0.07						
Co-infection									
Sm + Al	10 (0.1)	10 (0.2)	20 (0.1)	10 (0.3)	2 (0.1)	12 (0.2)	32 (0.2)	0.69 (0.34-1.42)	0.31
Al + Hw	26 (0.3)	26 (0.4)	52 (0.4)	29 (0.9)	28 (1.0)	57 (0.9)	109 (0.5)	0.38 (0.26-0.55)	0.00
Al + Tt	11 (0.1)	6 (0.1)	17 (0.1)	0 (0.0)	0 (0.0)	0 (0.0)	17 (0.1)		
Al + Ev	9 (0.1)	4 (0.1)	13 (0.1)	0 (0.0)	0 (0.0)	0 (0.0)	13 (0.1)		
Hw + Tt	7 (0.1)	2 (0.0)	9 (0.1)	3 (0.1)	1 (0.0)	0 (0.0)	13 (0.1)	0.94 (0.29-3.04)	0.91
Al + Hw + Tt	0 (0.0)	0 (0.0)	0 (0.0)	4 (0.1)	2 (0.1)	6 (0.1)	6 (0.0)		
Total	63 (0.8)	48 (0.7)	111 (0.8)	46 (1.4)	33 (1.2)	79 (1.3)	190 (0.9)	0.58 (0.43-0.78)	0.00
OR (95% *CI*)	1.09 (0.75-1.59)		1.24 (0.79-1.94)						
P	0.66		0.35						

OR=odds ratio; *CI*=confidence interval; Sm=*Schistosoma mansoni*; Al=*Ascaris lumbricoides*; Hw=Hookworm; Tt=*Trichuris trichiura*; Ev=*Enterobius vermicularis*; EZ=Ecological Zones

Table 3. Gastrointestinal helminthiasis in freshwater and lowland rainforest according to age.

Age group (year)	Freshwater swamp forest participants	Prevalence [*n* (%)]	Lowland rainforest participants	Prevalence [*n* (%)]	Total [*n* (%)]	*OR* (95% *CI*)	*P*
0-9	3921	1230 (31.4)	1437	450 (31.3)	1680 (31.4)	1.00 (0.88-1.14)	0.97
10-19	3662	865 (23.6)	1427	324 (22.7)	1189 (23.4)	1.05 (0.91-1.22)	0.49
20-29	1737	244 (14.0)	689	51 (7.4)	295 (12.2)	2.04 (1.49-2.80)	0.00
30-39	1637	206 (12.6)	596	178 (29.9)	384 (17.2)	0.34 (0.27-0.42)	0.00
40-49	1175	187 (15.9)	589	68 (11.5)	255 (14.5)	1.45 (1.08-1.95)	0.01
50-59	983	181 (18.4)	560	54 (9.6)	235 (15.2)	2.11 (1.53-2.92)	0.00
60-69	860	165 (19.2)	499	62 (12.4)	227 (16.7)	1.67 (1.22-2.29)	0.00
≥70	644	109 (16.9)	282	88 (31.2)	197 (21.3)	0.45 (0.32-0.62)	0.00

Table 4. Evaluation of sensitivity, specificity, likelihood ratios, disease prevalence, predictive values and accuracy for schistosomiasis diagnostic tests.

Diagnostic test	Sensitivity (%)	Specificity (%)	Positive likelihood ratio	Negative likelihood ratio	Prevalence (%)	Positive predictive value (%)	Negative predictive value (%)	Accuracy (%)
Kato Katz (95% *CI*)	0.00 (0.00-52.18)	100.00 (95.55-100.00)		1.00 (1.00-1.00)	0.0		100.00	100.00 (95.80-100.00)
PCR (95% *CI*)	100.00 (47.82-100.00)	100.00 (95.55-100.00)		0.00	4.2	100.00	100.00	100.00 (95.80-100.00)

4. Discussion

The overall prevalence of 21.6% and light intensity infections documented in this study denotes that the ecological zones are low risk areas. This level of endemicity may be related to the existence of intermittent antihelminthic mass drug administration put in place by the Federal Government. However, it would have been expected that infection would have reduced significantly given the annual deworming programme.

This study showed that prevalence of gastrointestinal helminthiasis did not depend on ecological zones however, the relatively higher number of parasites and cumulative prevalence observed among the participants in freshwater swamp forest was most likely due to the presence of numerous water bodies, which create humid environment for parasites to thrive and serve as recreational centers for children[7,20].

In this investigation, females had higher prevalence than males, especially with *Ascaris*, hookworm and *S. mansoni* infections. This pattern could be attributed to female engagement in domestic activities such as cleaning their environment, food preparation, and walking on barefoot within and around the home environment that may be contaminated by parasite eggs and larvae[6]. Likewise, their role as caregivers exposes them to infection through caring for infants and children who play around the homes and environments[9,32,33]. Livelihood activities such as food processing and petty trading of fruits and vegetables, which may be contaminated with gastrointestinal parasites may be contributing factors. Cultural factors also played a role because girls often accompany and assist their mothers, take care of their younger siblings and acquire basic domestic skills.

In both ecological zones, children had the highest prevalence indicating the vulnerabilities of preschool-age and school-age children to gastrointestinal infections. This observation accords other numerous studies[4,32,34,35], while Bolaji *et al.*[36], observed higher prevalence among children 14-17 years. Although children had low prevalence of *S. mansoni* in this study, water contact activities such as bathing and swimming influenced transmission. Another important factor contributing to this pattern of infection is poor hygiene practices among children[6,9,37].

The freshwater swamp forest, where subsistence farming is practiced alongside fishing was the observed foci for *E. vermicularis* infection. Although *E. vermicularis* is associated with young children, in this study, infection cut across different age groups as observed by Pezzani *et al.*, in Argentina[38]. The low prevalence could be an underestimation of the actual prevalence because detection of eggs in stool is not a sensitive test for *E. vermicularis*, compared to the scotch tape technique. The observation of infection in only one ecological zone could be an indication of poor sanitation and hygiene practices of the participants, and because freshwater swamp forest is more humid.

The report on *S. stercoralis* infection has public health significance because it reproduces within its host, can autoinfect the host and infection may last a lifetime if not adequately treated[3,4]. The implication is the need for a sustained Strongyloides control in our study area. This low prevalence may be an underestimation due to the use of Kato Katz technique for parasitological analysis, which is not very sensitive to *S. stercoralis* and hookworm infections. Various studies reported poor sensitivity of diagnostic techniques to Strongyloides infection thus, the need for combining techniques for effective parasite detection[21,22,39,40]. A study carried out in Ifedore district of Nigeria[19], reported the presence of *Strongyloides* larvae in soil samples, and the negative correlation between high soil temperature and larvae. This finding supports that of our study on *S. stercoralis* occurrence at low prevalence.

Intestinal schistosomiasis had an overall low prevalence compared to findings from a study in Tanzania, where overall prevalence was 15.1%[41], and 90.6% in Nyamikoma village, Tanzania[42]. Parasitological methods have been reported to underestimate *S. mansoni* prevalence[23,43]. In this study, the observed low *S. mansoni* prevalence might be an underestimation based on the comparison of prevalence between the PCR using 121 bp primer and Kato Katz technique. PCR detected infection whereas, Kato Katz technique detected none. This observation could be compared to findings by Bolaji *et al.*[36], in Osun State, Nigeria, where *S. mansoni* prevalence was 3.6% using microscopy and 10.1% using PCR.

This study adopted the Kato Katz technique, thus a likely underestimation of prevalence. Secondly, study communities were not easily disposed to giving stool samples because of cultural beliefs and social malaise. Community mobilization helped to allay fears however, we cannot rule out the possibility of skepticism on the part of some residents.

The observed prevalence irrespective of the intermittent mass drug administration, underscores the need for disease monitoring using sensitive diagnostic tool such as the PCR to identify gastrointestinal helminthiasis foci for disease control, provision of pipe borne water and health education to improve household sanitation and hygiene.

Conflict of interest statement

The authors claim there is no conflict of interest.

Funding

This study receives no extramural funding.

Data availability statement

The data supporting the findings of this study are available from the corresponding author upon request.

Authors' contributions

Enudi A was involved in the conception, design, data collection, analysis and interpretation, manuscript drafting, revision and approval. Nmorsi O was involved in the conception, design, data interpretation, revision and approval for publication. Egwunyenga A was involved in the conception, design, data interpretation, revision and approval for publication.

References

[1] HAl Amin ASM, Wadhwa R. *Helminthiasis* [Online]. Available from: https://www.ncbi.nlm.nih.gov/books/NBK560525/ [Accessed on 12 September 2023].

[2] Hotez PJ, Bundy DAP, Beegle K, Brooker S, Drake L, de Silva N. et al. Helminth Infections: Soil-transmitted Helminth Infections and Schistosomiasis. In: Jamison DT, Breman JG, Measham AR, et al., editors. Disease Control Priorities in Developing Countries. 2nd edition. *Washington (DC): The International Bank for Reconstruction and Development / The World Bank; 2006.* Chapter 24 [Online]. Available from: https://www.ncbi.nlm.nih.gov/books/NBK11748/ [Accessed on 12 September 2023].

[3] Hotez PJ, Brindley PJ, Bethony JM, King CH, Pearce EJ, Jacobson J. Helminth infections: The great neglected tropical diseases. *J Clin Invest* 2008; **118**(4): 1311-1121.

[4] Montresor A, Mupfasoni D, Mikhailov A, Mwinzi P, Lucianez A, Jamsheed M, et al. The global progress of soil-transmitted helminthiases control in 2020 and World Health Organization targets for 2030. *PLoS Negl Trop Dis* 2020;**14**(8): e0008505.

[5] World Health Organization. *Soil Transmitted Helminth Infections*. [Online]. [18 January 2023]. Available from: https://www.who.int/news-room/fact-sheets/detail/soil-transmitted-helminth-infections#:~:text=More%20than%201.5%20billion%20people,Americas%2C%20China%20and%20East%20Asia. [Accessed on 5 October 2023].

[6] Delaluna JOC, Flores MJC, Belizario Jr. VY, Janairo JIB, Derick Erl P. Sumalapao DEP. Soil-transmitted helminth egg contamination from soil of indigenous communities in selected barangays in Tigaon, Camarines Sur, Philippines. *Asian Pac J Trop Med* 2020; **13**(9): 409-414

[7] Yaro, CA, Kogi, E, and Luka, SA. Spatial distribution and modelling of soil transmitted helminthes infection in Nigeria. *Res J Parasitol* 2018; **13**(2): 19-35.

[8] Hotez PJ and Kamath A. Neglected tropical diseases in sub-saharan Africa: review of their prevalence, distribution, and disease burden. *PLoS Negl Trop Dis* 2009; **3**(8):e 412. doi: 10.1371/journal.pntd.0000412.

[9] Ganguly S, Barkataki S, Sanga P, Boopathi K, Kanagasabai K, Devika S, et al. Epidemiology of Soil-Transmitted Helminth Infections among Primary School Children in the States of Chhattisgarh, Telangana, and Tripura, India, 2015-2016. *Am J Trop Med Hyg* 2022; **107**(1):122-129.

[10] Mogaji HO, Johnson OO, Adigun AB, Adekunle ON, Bankole S, Dedeke GA, et al. Estimating the population at risk with soil transmitted helminthiasis and annual drug requirements for preventive chemotherapy in Ogun State, Nigeria. *Sci Rep* 2022; **12**(1): 2027.

[11]World Health Organization. *Ending the neglect to attain the Sustainable Development Goals: A road map for neglected tropical diseases 2021–2030* [Online]. Available from: https://www.who.int/publications/i/item/9789240010352. [Accessed on 17 December 2022].

[12]UNICEF, Federal Government of Nigeria. *Evaluation of the UNICEF supported Federal Government of Nigeria Water, Sanitation and Hygiene Programme (2014–2017)* [Online]. Available from: https://www.unicef.org/nigeria/media/2986/file/Evaluation%20Report%20on%20WASH%20Programme%202014%20-%202017.pdf. [Accessed on 2 December 2022].

[13]Hotez PJ, Asojo OA and Adesina AM. Nigeria: "Ground Zero" for the high prevalence neglected tropical diseases. *PLoS Negl Trop Dis* 2012; **6**(7): e1600.

[14]Nigeria Federal Ministry of Health. *National protocol for integrated epidemiological mapping and baseline survey of schistosomiasis and soil transmitted helminths (version 1.2)* [Online]. Available from: https://health.gov.ng/doc/PROTOCOL-FOR-SCHISTO-STH-MAPPING-1.pdf. [Accessed on 28 November 2022].

[15]Federal Ministry of Health. *Neglected Tropical Diseases Nigeria Multi – Year Master Plan 2015–2020* [Online]. Available from https://espen.afro.who.int/system/files/content/resources/NIGERIA_NTD_Master_Plan_2015_2020.pdf. [Accessed on 28 November 2022].

[16]Federal Ministry of Water Resources, Government of Nigeria, National Bureau of Statistics, UNICEF. *Water, Sanitation and Hygiene: National Outcome Routine Mapping (WASH NORM) 2019: A report of findings* [Online]. Available from: https://www.unicef.org/nigeria/media/3576/file/WASH%20NORM%20Report%202019.pdf. [Accessed on 29 November 2023].

[17]Federal Ministry of Water Resources, Government of Nigeria, National Bureau of Statistics, UNICEF. Water, Sanitation and Hygiene: National Outcome Routine Mapping (WASHNORM) 2021: A Report of Findings [Online]. Abuja. Federal Ministry of Water Resources; 2022. Available from: https://www.unicef.org/nigeria/media/5951/file/2021%20WASHNORM%20Report%20.pdf. [Accessed on 28 November 2023].

[18]Mogaji H, Dedeke G, Jaiyeola O, Adeniran A, Olabinke D, Oluwole A, et al. A preliminary survey of school-based water, sanitation, hygiene (WASH) resources and soil-transmitted helminthiasis in eight public schools in Odeda LGA, Ogun State, Nigeria. *Parasitol Open* 2017; **3**: E16.

[19]Oyewole OE and Simon-Oke IA. Ecological risk factors of soil-transmitted helminths infections in Ifedore district, Southwest Nigeria. *Bull Natl Res Cent* 2022; **46**: 13.

[20]Dejon-Agobé JC, Honkpehedji YJ, Zinsou JF, Edoa JR, Adégbitè BR, Mangaboula A, et al. Epidemiology of Schistosomiasis and Soil-Transmitted Helminth Coinfections among Schoolchildren Living in Lambaréné, Gabon. *Am J Trop Med Hyg* 2020; **103**(1): 325-333.

[21]Hailu T, Amor A, Nibret E, Munshea A, Anegagrie M, Flores Chavez MD, et al. Evaluation of five diagnostic methods for Strongyloides stercoralis infection in Amhara National Regional State, northwest Ethiopia. *BMC Infect Dis* 2022; **22**: 297.

[22]Gyang VP, Chuang TW, Liao CW, Lee YL, Akinwale OP, Orok A, et al. Intestinal parasitic infections: Current status and associated risk factors among school aged children in an archetypal African urban slum in Nigeria. *J Microbiol Immunol Infect* 2017; **52**(1): 106-113.

[23]Lodh N, Shiff CJ, Mutengo MM, Mwansa JCL. Diagnosis of

Schistosoma mansoni without the stool: Comparison of three diagnostic tests to detect *Schistosoma mansoni* infection from filtered urine in Zambia. *Am J Trop Med Hyg* 2013;**89**(1):46-50.

[24]Bartlett AW, Sousa-Figueiredo JC, van Goor RC, Monaghan P, Lancaster V, Mugizi R, et al. Burden and factors associated with schistosomiasis and soil-transmitted helminth infections among school-age children in Huambo, Uige and Zaire provinces, Angola. *Infect Dis Poverty* 2022; **11**:73. https://doi.org/10.1186/s40249-022-00975-z.

[25]Chisango TJ, Ndlovu B, Vengesai A, Nhidza AF, Sibanda EP, Zhou D, et al. Benefits of annual chemotherapeutic control of schistosomiasis on the development of protective immunity. *BMC Infect Dis* 2019; **19**(1): 219.

[26]Kabatereine NB, Brooker S, Koukounari A, Kazibwe F, Tukahebwa EM, Fleming FM, et al. Impact of a national helminth control programme on infection and morbidity in Ugandan schoolchildren. *Bull World Health Organ* 2007; **85**: 91-99.

[27]Balogun VS, Onokerhoraye AG. Climate change vulnerability mapping across ecological zones in Delta State, Niger Delta Region of Nigeria. *Clim Serv* 2022; **27**: 100304.

[28] World Health Organization. *Bench aids for the diagnosis of intestinal parasites. 2nd ed* [Online]. Available from: https://www.who.int/publications/i/item/9789241515344. [Accessed on 14 December 2022].

[29]Cheesbrough M. *District Laboratory Practice in Tropical Countries[Online]*. Available from: https://medicallabtechno.weebly.com/uploads/7/5/1/5/7515789/monica-cheesbrough-district-laboratory-practice-in-tropical-countries-part-1.pdf. [Accessed 30 October 2022]..

[30]Montresor A, Crompton DWT, Gyorkos TW, Savioli L. *Helminth control in school–age children: A guide for managers of control programmes* [Online]. Geneva: World Health Organization; 2002. Available from: https://iris.who.int/bitstream/handle/10665/44671/9789241548267_eng.pdf?sequence=1. [Accessed on 14 October 2023].

[31]Hamburger J, Turetski T, Kapeller I, Deresiewicz R, 1991. Highly repeated short DNA-sequences in the genome of Schistosoma mansoni recognized by a species-specific probe. *Mol Biochem Parasitol* 1991; **44**: 73-80

[32]Gbonhinbor J, Abah AE, and Awi-Waadu G. Prevalence of intestinal parasitic infection and associated risk factors among primary school-aged children (5-15 years) in southern Nigeria. *Int J Infect* 2022; **9**(3): e123721. doi: 10.5812/iji-123721.

[33]Idowu OA, Babalola AS, and Olapegba T. Prevalence of soil-transmitted helminth infection among children under 2 years from urban and rural settings in Ogun state, Nigeria: implication for control strategy. *Gaz Egypt Pediatr Assoc* 2022; **70**: 5.

[34]Woldegerima E, Bayih AG, Tegegne Y, Aemero M, and Zeleke, AJ. Prevalence and reinfection rates of *Schistosoma mansoni* and praziquantel efficacy against the parasite among primary school children in Sanja Town, Northwest Ethiopia. *J Parasitol Res* 2019; **2019**: 3697216.

[35]Nmor, JC, Onojafe, JO, Omu, BA. Anthropogenic indices of soil-transmitted helminthiasis among children in Delta State, Southern Nigeria. *Iran J Public Health* 2009; **38**(3): 31-38.

[36]Bolaji OS, Awopetu OR, Akinleye AC, Bakare EO, Bolaji ES, Ukaga CN, et al. Detection by polymerase chain reaction of *Schistosoma mansoni* DNA in urine of school age children in parts of Osun State. *J Chem Bio Phy Sci Sec B* 2019; **9**(4): 521-534.

[37]Labana RV, Romero VA, Guinto AM, Caril AN, Untalan KD, Reboa AJC, et al. Prevalence and intensity of soil-transmitted helminth infections among school-age children in the Cagayan Valley, the Philippines. *Asian Pac J Trop Med* 2021; **14**(3): 113-121.

[38]Pezzani BC, Minvielle MC, de Luca MM, Cordoba MA, Apezteguia MC, Basualdo JA. Enterobius vermicularis infection among population of General Mansilla, Argentina. *World J Gastroenterol* 2004; **10**(17): 2535-2539.

[39]Hailu T, Nibret E, Amor A, & Munshea A. Strongyloidiasis in Africa: Systematic review and meta-analysis on prevalence, diagnostic methods, and study settings. *BioMed Res International* 2020; **2020**: 2868564.

[40]Forrer A, Khieu V, Schär F, Vounatsou P, Chammartin F, Marti H, et al. *Strongyloides stercoralis* and hookworm co-infection: Spatial distribution and determinants in Preah Vihear Province, Cambodia. *Parasit Vectors* 2018; **11**(1): 33.

[41]Mazigo HD, Uisso C, Kazyoba P, Nshala A, Mwingira UJ. Prevalence, infection intensity and geographical distribution of schistosomiasis among pre-school and school-aged children in villages surrounding Lake Nyasa, Tanzania. *Sci Rep* 2021; **11**: 295

[42]Mnkugwe RH, Minzi OS, Kinung'hi SM, Kamuhabwa AA, Aklillu E. Prevalence and correlates of intestinal schistosomiasis infection among school-aged children in North-Western Tanzania. *PLoS One* 2020; **15**(2): e0228770.

[43]Spencer SA, Penney JM, Russell HJ, Howe AP, Linder C, Rakotomampianina ALD, et al. High burden of *Schistosoma mansoni* infection in school-aged children in Marolambo District, Madagascar. *Parasites Vectors* 2017; **10**: 307.

Publisher' s note

The Publisher of the *Journal* remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Edited by Liang TC, Qi Y