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Prevalence, intensity and spatial co-distribution of schistosomiasis and soil transmitted helminths infections in Ogun state, Nigeria

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Abstract

A cross-sectional survey was carried out in primary schools to determine prevalence, intensity and spatial co-distribution of Schistosomiasis and soil transmitted helminths (STH) infections in Ogun State, Nigeria. A total of 2148 pupils from 42 schools were examined for *Schistosoma* and STH infections from urine and fresh fecal samples respectively. Ethyl ether concentration method prepared in sodium acetate – acetic acid – formalin ether was used to concentrate parasites' ova before microscopic examination. The overall prevalence of schistosomiasis and STH infections were 4.0% (95% CI = 3.21–4.92) and 34.64% (95% CI = 32.62–36.69) respectively. *Schistosoma haematobium* and *Ascaris lumbricoides* were the most prevalent across the study area among the *Schistosoma* and STH species respectively. Overall, intensity of infection was higher in males than in females for all *Schistosoma* and STH infections, but with no significant difference ($P > 0.05$), except for *Trichuris trichiura* ($\chi^2 = 6.490$, $P < 0.05$). Infection intensity was significantly inversely correlated ($\chi^2 = 12.953$, $P < 0.05$) with an increase in age group. Co-distribution of *Schistosoma* and STH infections occurred in 15 (35.7%) out of 42 schools, and only 30 children (1.4%) had co-infection of *Schistosoma* and STH. This study provides information on the prevalence and spatial risk of schistosomiasis and STH in Ogun State. This will serve as decision-support tool for Ogun State programme managers to help facilitate integration of schistosomiasis and STH control.

Introduction

Schistosomiasis and soil-transmitted helminthiasis (STH) are among the top ten neglected tropical diseases (NTD) targeted for control/elimination by 2020 (WHO, 2012*a*). Schistosomiasis is endemic in 78 countries, affecting almost 240 million people worldwide, and more than 700 million people are at risk (Bruun and Aagaard-Hansen, 2008). On the other hand, more than a billion people or 24% of the world's population is infected with STH infections worldwide (Pullan *et al.* 2014). Both diseases cause severe and subtle morbidity, including significant educational and nutritional effects in children (Mwinzi *et al.* 2012). These parasitic diseases are prevalent in areas with favourable climatic and environmental conditions, unhygienic eating habits, poor water supply, poor sanitation and personal hygiene conditions which facilitate their transmission (Midzi *et al.* 2014).

The World Health Organization's 2020 Roadmap on Neglected Tropical Diseases (WHO, 2012*a*) and the London 2012 declaration to combat the NTD disease (WHO, 2012*b*) are major driving forces that have led to the recent international commitment to escalate the control of NTDs. School-based de-worming programmes using anti-helminths therapy is the adopted strategy for prevention and control of schistosomiasis and STH infections in school children (WHO, 2006). However, identifying areas where both diseases occur singly or co-distributed will increase the efficiency of integrated control programming required in the implementation of the preventive chemotherapy treatment (Hanson *et al.* 2012). Therefore, maps of the co-geospatial distribution of at-risk population and disease burden at national and district levels will ensure a cost-effective planning and delivery of control activities (Schur *et al.* 2011).

Although, high resolution spatial risk maps for mono distribution of schistosomiasis and STH have been provided at country level respectively (Ekpo *et al.* 2013; Oluwole *et al.* 2015), operationally, co-distribution maps of schistosomiasis and STH are required at district levels for integrated control of both diseases in the context of preventive chemotherapy. This study contributes to the design of such maps for Ogun State, Nigeria.

Materials and methods

Study area

Ogun State is one of the 36 states of the Federal Republic of Nigeria, located in the south-western part of the country within longitude 2°45′E and 3°55¹E and latitude 7°01′N and 7°18′N. The state is divided into 20 administrative areas known as the local government areas (LGAs) with an estimated population of 5 million inhabitants. There are 1314 public primary schools in Ogun State with an average of 100 pupils enrolled in each school. The health system is decentralized, comprising PHC (Primary Health Care) facilities in the community and General hospitals at District headquarters. Tertiary health institutions are in the State capital, Abeokuta and in some major cities in the State.

Selection of schools and survey for schistosomiasis and STH infection

The study was carried out between February and December 2013. Systematic point sampling method was used to select the schools. This was done by placing a 15 km by 15 km grid on the GIS map of Ogun State and geo-referencing the centres of the grids. The ArcGIS version 10.1. software was used to extract the geographical coordinates and with the aid of Google Map (https://www.google.com.ng/maps/), the closest primary school to the centroid of each grid were selected for the study. A total of 46 schools were selected, but only 42 schools participated in the study due to logistic and accessibility constraints.

Using the WHO guideline on the survey for helminthiasis in schools, a minimum of 50 and a maximum of 60 children submitted stool and urine samples per school (WHO, 2002). Selection of children in each school was carried out after stratification by class grade from Primary 1 to 6. A quota was then allocated to each class grade with proportional allocation according to the number of students in each grade. Finally, the participating children were randomly selected in each grade. In schools were pupils were not up to 50 students, the entire pupils were recruited into the study.

Each pupil submitted a single stool and urine sample which were taken to the laboratory and processed for microscopic examination. Ten ml of each urine sample were centrifuged for 5min at 5000 revolutions per minute (RPM), and the sediment examined for ova of *Schistosoma haematobium* under the microscope. One gram of each stool sample was processed using ethyl ether concentration method prepared in sodium–acetate–acetic acid–formalin solution (SAF) (Endriss *et al.* 2005). The processed stool samples were then examined for ova of STH and *Schistosoma mansoni*. The ova of *Schistosomes* and each of the STH parasite observed in samples were counted. The intensity of *S. haematobium* was expressed as the number of ova per 10 ml of urine while the intensity of each STH parasite and *S. mansoni* were expressed as number of ova per gram of stool sample. We used SAF solution method to process the stool sample because it helps in sample fixation, thereby preserving the morphology of STH species eggs in the stool sample for up to 40 days; an advantage that is not possible with the Kato Katz method (Glinz *et al.* 2010). This was important as most of the study sites were quite far from the Laboratory and processing of stool samples on the day of collection was not feasible if the quality is to be assured. More importantly, this approach (formol-ether/acetyl-acetate concentration method prepared in SAF) has been proven to be more sensitive than the Kato Katz method (Glinz *et al.* 2010) especially in areas where transmission is low (Knopp *et al.* 2008; Nikolay *et al.* 2014). Besides, urine filtration kit and Kato-Katz kit recommended by WHO are not readily available in Nigeria market and can only be obtained by special request from WHO.

Geo-coordinates of study locations

The geo-coordinate location (latitude and longitude) of each school was verified using a handheld Global Positioning System (GPS) Garmin 12XL (Garmin Corp, USA). Coordinates were obtained and recorded in decimal degree unit.

Ethical approval and inform consent form

Ethical clearance for the study was given by the Federal Ministry of Health, Abuja and the Ogun State Ministry of Health, Abeokuta. Approval for the study was also obtained from the Ogun State Ministry of Education, Science and Technology with an approval reference number ESS.1/382/99. Permission and approval were also obtained from the Zonal Educational Officers, Educational Secretaries of each LGA and Head teachers of each school visited. Verbal and written informed consent was obtained from parents of the students of the selected schools after explaining the aim and objective of the study to them. Only students that agreed to participate in the study and whose parent consented by signing the informed consent forms or gave verbal consent were allowed to

Table 1. Prevalence of schistosomiasis and soil-transmitted helminth species in Ogun State in 2013

Categories	Prevalence of SCH (95% CI) *n*	Prevalence of STH (95% CI) *n*
Sex		
Male	3.6 (2.6–4.9) 1114	36.4 (33.5–39.3) 1114
Female	4.4 (3.2–5.8) 1034	32.8 (29.9–35.7) 1034
Age group		
5–7 years	3.2 (1.9–5.2) 495	35.2 (30.9–39.5) 495
8–10 years	3.7 (2.5–5.2) 867	35.1 (31.9–38.3) 867
11–13 years	4.4 (3.0–6.2) 663	35.1 (31.5–38.9) 663
≥14 years	6.5 (2.9–12.4) 123	26.8 (19.2–35.6) 123
LGAs		
Odeda	0 (0) 125	31.2 (23.2–40.1) 125
Abeokuta South	1.7 (0.04–8.9) 60	16.67 (8.29–28.52) 60
Abeokuta North	0.8 (0.02–4.2) 130	33.1 (25.1–41.9) 130
Imeko Afon	2.9 (1.2–5.9) 240	10.8 (7.2–15.5) 240
Egbado North	8.2 (4.8–12.8) 208	20.2 (15.0–26.3) 208
Egbado South	0 (0) 60	58.3 (44.9–70.9) 60
Obafemi/Owode	6.32 (3.2–11.0) 174	37.4 (30.2–45.0) 174
Sagamu	0 (0) 55	34.6 (22.2–48.6) 55
Remo North	0 (0) 60	63.3 (49.9–75.4) 60
Ijebu North	1.7 (0.20–5.9) 120	49.2 (39.9–58.5) 120
Ijebu North East	0 (0) 60	46.7 (33.7–60.0) 60
Ado Odo/Ota	0 (0) 142	52.1 (43.6–60.6) 142
Ijebu East	9.2 (5.2–14.6) 164	38.4 (30.9–46.3) 164
Ifo	0.8 (0.02–4.6) 115	14.8 (8.9–22.6) 115
Ogun Waterside	1.0 (0.02–5.2) 104	60.6 (50.5–70.0) 104
Ikene	0 (0) 118	33.1 (24.7–42.3) 118
Ewekoro	32.3 (22.9–42.8) 93	34.41 (24.9–44.) 93
Ipokia	0 (0) 60	23.3 (13–4–36.04) 60
Odogbolu	0 (0) 60	63.3 (49.9–75.4) 60
Overall	4.0 (3.2–4.9) 2148	34.64 (32.6–36.7) 2148

**n*, Number examined.

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participate in the study. All children in the schools selected for the survey were treated by the Schistosomiasis and STH control unit of the Ogun State Ministry of Health.

Data analysis

Data were entered using Microsoft excel, cleaned for error and analysis were executed using STATA version 12 (Stata Corp LP, USA). Descriptive statistics were used to compute prevalence and mean intensity of *Schistosoma* and STH infections by sex, age group and LGA. The Chi-square test using the complex samples crosstabs procedure was used to explore the relationship between prevalence of infections and sex, age groups and LGAs. The Kruskal–Wallis test was used to compare the differences in geometrical mean intensity of infection.

Spatial analysis

Co-ordinate of schools sampled and their prevalence data for *Schistosoma* and STH infections collected were entered using Microsoft excel 2007 and then imported into ArcGIS 9.3. This was then used to display the prevalence and distribution of each *Schistosoma* and STH parasite infections in Ogun State, Nigeria.

Results

Demographics

A total of 2148 pupils submitted both urine and stool samples for examination, 1114 (51.9%) of them were males while 1034 (48.1%), were females. The age distribution of the pupils that participated in the study were 495 (23.0%), 867 (40.4%), 663 (30.9%) and 123 (5.7%) for age groups 5–7 years, 8–10 years, 11–13years and ≥14 years respectively. The standard deviation of the mean age of participants was 9.7 ± 2.0 with no significant difference between boys and girls

Prevalence of Schistosoma and STH infections

Of the 2148 pupils examined, the overall prevalence of *Schistosoma* infections (at least one of *S. haematobium* or *S. mansoni*) was 4.0%

Table 2. Prevalence of *Schistosoma* and STH parasite in Ogun State in 2013

Categories	Prevalence of *S. haematobium* (95% CI) *n*	Prevalence of *S. mansoni* (95% CI) *n*	Prevalence of *Ascaris lumbricoides* (95% CI) *n*	Prevalence of *T. trichuira* (95% CI) *n*	Prevalence of Hookworm (95% CI) *n*
Sex					
Male	3.0 (2.1–4.1) 1114	0.6 (0.3–1.3) 1114	29.1 (26.43–31.85) 1114	3.2 (2.27–4.4) 1114	9.2 (7.5–11.0) 1114
Female	4.2 (3.0–5.6) 1034	0.5 (0.2–1.1) 1034	29.2 (26.73–32.38) 1034	1.3 (0.67–2.1) 1034	4.9 (3.7–6.4) 1034
Age group					
5–7 years	2.4 (1.3–4.2) 495	0.8 (0.2–2.1) 495	31.3 (27.3–35.6) 495	3.2 (1.9–5.2) 495	6.5 (4.5–9.0) 495
8–10 years	3.5 (2.4–4.9) 867	0.2 (0.03–0.8) 867	29.2 (26.2–32.3) 867	2.4 (1.5–3.7) 867	6.9 (5.3–8.8) 867
11–13 years	4.1 (2.7–5.9) 663	0.8 (0.3–1.8) 663	29.4 (26.0–33.0) 663	1.4 (0.623–2.56) 663	7.8 (5.9–10.2) 663
≥14 years	5.7 (2.32–11.37) 123	0.8 (0.02–4.5) 123	21.1 (14.3–29.4) 123	2.4 (0.5–7.0) 123	7.3 (3.4–13.4) 123
LGAs					
Odeda	0 (0) 125	0 (0) 125	16.0 (10.05–23.62) 125	0 (0.00) 125	24.0 (16.8–32.5) 125
Abeokuta South	1.7 (0.04–8.9) 60	0 (0) 60	16.7 (8.3–28.5) 60	0 (0.00) 60	1.7 (0.04–8.9) 60
Abeokuta North	0.8 (0.02–4.2) 130	0 (0) 130	20.0 (13.5–27.9) 130	0 (0.00) 130	18.5 (12.2–26.2) 130
Imeko Afon	2.9 (1.2–5.9) 240	0 (0) 240	6.3 (3.5–10.1) 240	0 (0.00) 240	11 (4.58 (2.3–8.1) 240
Egbado North	6.7 (3.7–11.0) 208	1.4 (0.3–4.2) 208	10.6 (6.8–10.6) 208	0.5(0.01–2.7) 208	11.1 (7.1–16.1) 208
Egbado South	0 (0) 60	0 (0.00) 60	55.0 (41.61–67.88) 60	0 (0.00) 60	5.0 (1.04–13.9) 60
Obafemi/Owode	6.3 (3.2–11.0) 174	0 (0.00) 55	32.2 (25.3–39.7) 174	0 (0.00) 174	8.6 (4.9–13.8) 174
Sagamu	0 (0) 55	0 (0.00) 55	25.5 (14.7–39.0) 55	0 (0.00) 55	9.1 (3.02–19.95) 55
Remo North	0 (0) 60	0 (0.00) 60	61.7 (42.2–73.9) 60	13.3 (5.9–24.6) 60	1.7 (0.04–8.9) 60
Ijebu North	1.7 (0.20–5.9) 120	0 (0.00) 120	46.7 (37.5–56.0) 120	3.3 (0.9–8.3) 120	0 (0.00) 120
Ijebu North East	0 (0) 60	0 (0.00) 60	46.7 (33.7–60.0) 60	0 (0.00) 60	0 (0.00) 60
Ado Odo/Ota	0 (0) 142	0 (0.00) 142	47.9 (39.4–56.4) 142	7.0 (3.4–12.6) 142	9.2 (5.0–15.2) 142
Ijebu East	8.5 (4.8–13.9) 164	0.6 (0.02–3.4) 164	37.2 (29.8–45.1) 164	0.6 (0.02- 3.4) 164	1.2 (0.2–4.3) 164
Ifo	1.0 (0.02–4.8) 115	0 (0.00)	5.8 (2.7–10.7) 115	1.7 (0.21–6.1) 115	8.7 (4.3–15.4) 115
Ogun Waterside	1.0 (0.02–5.24) 104	0 (0.00)	58.7 (48.58–68.23) 104	18.27 (11.37–27.05) 104	0 (0.00) 104
Ikene	0 (0) 118	0 (0.00)	32.20 (23.89–41.43) 118	0 (0.00) 118	2.5 (0.53–7.25) 118
Ewekoro	26.9 (18.2–37.1) 93	8.6 (3.8–16.2) 93	29.0 (20.1–39.4) 93	0 (0.00) 93	7.5 (3.1–14.9) 93
Ipokia	0 (0) 60	0 (0.00) 60	18.3 (9.52–30.44) 60	0 (0.00) 60	8.3 (2.76–18.4) 60
Odogbolu	0 (0) 60	0 (0.00) 60	61.7 (48.21–73.93) 60	6.7 (1.85–16.20) 60	0 (0.00) 60
Overall	3.6 (2.84–4.5) 2148	0.6 (0.3–1.0) 2148	29.3 (27.4–31.3) 2148	2.3 (1.7–3.0)	7.1 (6.1–8.3) 2148

**n*, Number examined.

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(95% CI = 3.2–4.9) with prevalence ranging from 1.7 to 32.3% in LGAs and 1.6 to 32.6% in schools. Prevalence of *Schistosoma* infection by sex and age group is shown in Table 1. *Schistosoma* infections were higher in females than in males, but it was not statistically significant ($\chi^2 = 0.8179$, $P > 0.05$). We observed an increase in the number of infected students with *Schistosoma* infections as the age increases with the highest prevalence observed in age group ≥14 years, but these differences were not statistically significant ($\chi^2 = 3.2486$, $P > 0.05$). Aggregated prevalence of *Schistosoma* parasites per LGAs in Ogun State (Table 1) shows that prevalence of *Schistosoma* infections was highest in Ewekoro LGA (32.3%, 95% CI = 22.9–42.8).

On the other hand, the overall prevalence of STH infections (at least one infection of *Ascaris lumbricoides* or hookworm or *Trichuris trichiura*) was 34.6% (95% CI = 32.6–36.7) with prevalence ranging from 10.8 to 63.3% in LGAs and 3.3 to 72.01% in schools. Prevalence of STH infections by sex and age group is shown in Table 2. STH infections were higher in male school children than in females, but the difference was not statistically significant ($\chi^2 = 3.0191$, $P > 0.05$). STH infections among the age group seem to decrease with increasing age, although this was not statistically significant ($\chi^2 = 3.5145$, $P > 0.05$). Aggregated prevalence of STH parasites per LGAs in Ogun State shows that the highest prevalence of STH infections was observed in Odogbolu and Remo North LGAs both having (63.3%, 95% CI = 49.9–75.4) while the least was in Imeko Afon LGA with (10.8%, 95% CI = 7.2–15.5) (Table 1)

Prevalence and intensity of Schistosoma and STH parasites in Ogun State

Schistosoma haematobium infection was the most common (3.6%, 95% CI = 2.8–4.5) *Schistosoma* spp among school children in Ogun state. Prevalence of *S. mansoni* was low (0.6%) (Table 2). There was no significant difference ($P > 0.05$) in infection with *S. haematobium and S. mansoni* in both sex and age group. The prevalence of each species of *Schistosoma* parasite per LGA is shown in Table 2. Among the STH parasites, *A. lumbricoides* was the most common (29.3%, 95% CI = 27.4–31.3), while *T. trichiura* has the least prevalence of (2.3%, 95% CI = 1.7–3.0). Infection was significantly higher in males than in females for both hookworm ($\chi^2 = 14.4621$, $P < 0.05$) and *T. trichiura* infection

Table 3. Arithmetic mean intensity (AMI) of *Schistosoma* and STH parasites in Ogun State in 2013

Categories	*S. haematobium AMI* eggs 10 mL^{-1} of urine (95% CI)	*S. mansoni AMI* eggs 10 mL^{-1} of urine (95% CI)	*Ascaris lumbricoides* AMI eggs 1 g^{-1} of feces (95% CI)	*T. trichuira* AMI eggs 1 g^{-1} of faeces (95% CI)	Hookworm AMI eggs 1 g^{-1} of faeces (95% CI)
Sex					
Male	0.7 (0.3–1.2)	0.01 (0.002–0.02)	36.6 (24.7–48.5)	0.2 (0.1–0.2)	0.6 (0.4–0.8)
Female	0.6 (0.2–1.0)	0.03 (−0.01–0.1)	27.7 (16.9–38.7)	0.02 (0.008–0.03)	0.3 (0.1–0.4)
Age group					
5–7 years	0.6 (−0.2–1.4)	0.02 (−0.002–0.05)	46.3 (24.1–68.4)	0.2 (0.1–0.3)	0.4 (0.1–0.7)
8–10 years	0.4 (0.1–0.6)	0.003 (−0.002–0.008)	36.1 (22.5–49.7)	0.05 (0.02–0.07)	0.3 (0.2–0.5)
11–13 years	0.9 (0.3–1.4)	0.04 (−0.01–0.08)	22.0 (12.2–31.8)	0.1 (0.001–0.1)	0.6 (0.2–0.9)
≥14 years	1.9 (−1.3–5.1)	0.01 (−0.02–0.05)	6.3 (2.27–10.3)	0.2 (−0.09–0.4)	0.3 (−0.01–0.6)
LGAs					
Odeda			4.6 (1.3–7.9)		0.9 (0.4–1.5)
Abeokuta south	0.02 (−0.02–0.05)		19.8 (−15.0–54.6)		0.03 (−0.03–0.1)
Abeokuta North			11.3 (2.9–19.7)		1.1 (0.4–1.84)
ImekoAfon	0.1 (0.01–0.09)		0.9 (−0.4–2.1)		0.3 (−0.02–0.7)
Egbado North	0.9 (0.2–1.7)	0.02 (−0.004–0.04)	1.8 (0.2–3.5)	0.08 (−0.07–0.2)	0.8 (0.3–1.4)
Egbado south			21.2 (9.6–32.7)		1.5 (−0.8–3.7)
Obafemi/Owode	0.40 (0.07–0.7)		22.3 (11.5–33.1)		0.4 (0.1–0.7)
Sagamu			4.2 (0.4–7.9)		0.2 (−0.003–0.3)
Remo North			354 (139.7–568.6)	0.4 (0.06–0.6)	0.01 (−0.02–0.05)
Ijebu North	0.5 (−0.4–1.5)		25.8 (12.5–39.2)	0.04 (−0.001–0.08)	
Ijebu North East			30.35 (12.2–48.6)		
Ado Odo/Ota			43.2 (28.6–57.8)	0.3 (0.05–0.6)	0.5 (0.1–0.9)
Ijebu East	3.5 (0.7–6.3)	0.01 (−0.01–0.04)	24.5 (4.7–44.3)	0.01 (−0.01–0.02)	0.02 (0.008–0.05)
Ifo	1.8 (−1.7–5.2)		2.9 (0.2–5.6)	0.02 (0.01–0.04)	1.0 (−0.6–2.5)
Ogun waterside	0.02 (−0.02–0.07)		61.6 (38.4–84.7)	0.8 (0.3–1.2)	
Ikene			25.8 (4.6–46.9)		0.03 (−0.003–0.05)
Ewekoro	3.4 (1.0–5.9)	0.4 (0.03 0.7)	7.4 (1.0–13.8)		0.3 (−0.008–0.63)
Ipokia			3.9 (0.7–7.0)		0.4 (−0.07–0.8)
Odogbolu			222.2 (89.4–355.1)	0.2 (−0.04–0.4)	

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($\chi^2 = 9.3773$, $P < 0.05$) but there was no significant difference ($\chi^2 = 0.0441$) in the prevalence of *A. lumbricoides* infection between sexes. Prevalence of STH infection was not statistically different ($P > 0.05$) between age groups. The prevalence of each parasite species per LGA is also shown in Table 2.

The Arithmetic and Geometric mean intensity of infections for the schistosomes and STH parasites by sex, age and LGA is provided in Tables 3 and 4, respectively. The intensity of infection was observed to be higher in males than in females for all parasites (Tables 3 and 4), but only in *T. trichiura* was there a significant difference in infection intensity ($\chi^2 = 6.490$, $P < 0.05$). Between the age groups, the intensity of infection was highest in 5–7 years than other age groups. The intensity of infection significantly reduces ($\chi^2 = 12.953$, $P < 0.05$) with an increase in age.

Spatial co-distribution of schistosomiasis and STH infections in Ogun State

Schstosoma haematobium was the most geographically spread infection, observed in 15 (35.7%) locations in 10 LGAs, whereas *S. mansoni* was seen in four (9.5%) locations in three LGAs. Co-occurrence of the two *Schistosoma* species was observed only in four locations in three LGAs (Fig. 1). Prevalence map for *Schistosoma* parasites in Ogun State based on WHO prevalence threshold for Preventive Chemotherapy is shown in Figs 2 and 3.

Ascaris lumbricoides infection was the most geographically spread of the STH parasites, observed in 40 (95.2%) locations in 19 LGAs. Hookworm was seen in 28 (66.7%) locations in 15 LGAs and *T. trichiura* was found in 10 (23.8%) locations in eight LGAs (Fig. 4) Co-distribution of hookworm and *A. lumbricoides* infections were observed in 21 (50%) locations in 13 LGAs, *A. lumbricoides* and *T. trichiura* co-existed in four locations in three LGAs. Co-occurrence of all three STH species was observed in six (14.3%) locations in five LGAs. Figures 5–7 shows the prevalence of each species of STH parasite in Ogun State using WHO prevalence threshold.

Spatial co-distribution of *Schistosoma and* STH infections in Ogun State is shown in Fig. 8. The two infections were observed in 15 (35.7%) of the 42 sampled schools. Aggregating by LGAs, 10 LGAs were identified to be endemic for both Schistosomiasis and STH (Table 2). These include Abeokuta South, Abeokuta North, Imeko Afon, Yewa North, Obafemi Owode, Ijebu North, Ijebu East, Ifo, Ogun waterside and Ewekoro.

Table 4. Geometric mean intensity (GMI) of *Schistosoma* and STH parasites in Ogun State in 2013

Categories	*S. haematobium GMI* eggs 10 mL^{-1} of urine (95% CI)	*S. mansoni GMI* eggs 10 mL^{-1} of urine (95% CI)	*Ascaris lumbricoides* GMI eggs 1 g^{-1} of faeces (95% CI)	*T. trichuira* GMI eggs 1 g^{-1} of faeces (95% CI)	Hookworm GMI eggs 1 g^{-1} of faeces (95% CI)
Sex					
Male	2.2 (1.7–2.7)	1.2 (0.04–2.4)	3.2 (3.0–3.4)	1.1 (0.8–1.4)	1.1 (0.9–1.3)
Female	1.7 (1.3–2.1)	0.6 (0.2–1.0)	2.93 (2.7–3.1)	0.3 (0.1–0.5)	1.0 (0.8–1.3)
Age group					
5–7 years	2.1 (1.3- 2.9)	0.9 (0.1–1.6)	3.3(3.0–3.6)	1.2 (0.8–1.7)	1.2 (0.8–1.5)
8–10 years	1.6 (1.2–2.1)	0.4 (−0.4–1.1)	3.2 (3.0–3.4)	0.5 (0.2–0.7)	1.0 (0.8–1.3)
11–13 years	2.1 (1.5–2.70)	1.1 (−0.1–2.2)	2.8 (2.6–3.0)	0.9 (0.3–1.6)	1.2 (0.8–1.5)
⩾14 years	1.8 (0.5–3.2)	0.69	2.3 (1.7–2.9)	1.5 (0.24–2.8)	0.7 (0.1–1.4)
LGAs					
Odeda			2.1 (1.4 –2.9)		0.85 (0.51–1.20)
Abeokuta South			2.6 (1.4–3.8)		0.69
Abeokuta North			2.7 (2.0–3.5)		1.2 (0.8–1.8)
Imeko Afon	0.6 (0.2–0.9)		1.2 (0.5–2.0)		1.4 (0.7–2.0)
Egbado North	1.8 (1.1–2.6)	0.2 (−0.3–0.7)	1.8 (1.3–2.4)	2.8	1.5 (1.1–1.9)
Egbado South			2.6 (2.1–3.2)		2.6 (0.6- 4.7)
Obafemi/Owode	1.4 (0.8–2.0)		2.9 (2.5–3.4)		1.0 (0.5–1.5)
Sagamu			1.9 (1.2–2.6)		0.4 (−0.1–1.0)
Remo North			4.7 (4.1–5.4)	0.7 (0.2–1.2)	
Ijebu North	03.1 (1.3–4.9)		2.9 (2.4–3.3)	0.17 (−0.2–0.5)	
Ijebu North East			3.3 (2.8–3.9)		
Ado Odo/Ota			3.6 (3.2–4.0)	1.2 (0.6–1.8)	1.2 (0.7–1.8)
Ijebu East	3.1 (2.5–3.8)	0.7	3.0 (2.6–3.3)		0.3 (0.3–1.0)
Ifo	5.3		2.9 (1.8–3.9)		0.9 (−0.1–1.8)
Ogun waterside	0.7		3.6 (3.2–4.0)	1.0 (0.6–1.4)	
Ikene			3.0 (2 .5–3.5)		
Ewekoro	1.7 (1.2–2.2)	1.09 (0.4–1.8)	2.0 (1.4–2.6)		1.0 (0.2–1.7)
Ipokia			2.4 (1 .687–3.2)		1.0 (0.1–1.9)
Odogbolu			4.3 (3.6–5.0)	0.6 (−0.2–1.5)	

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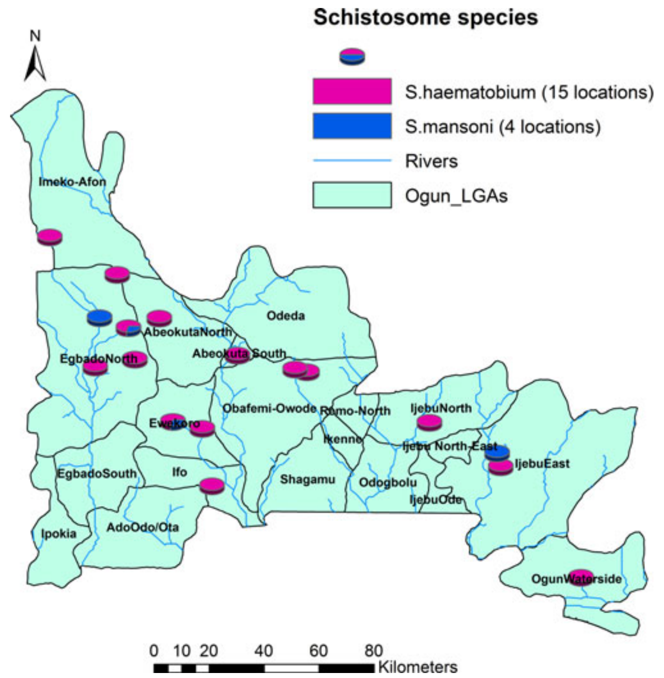

Fig. 1. Spatial distribution of the two *Schistosoma* parasites in Ogun State.

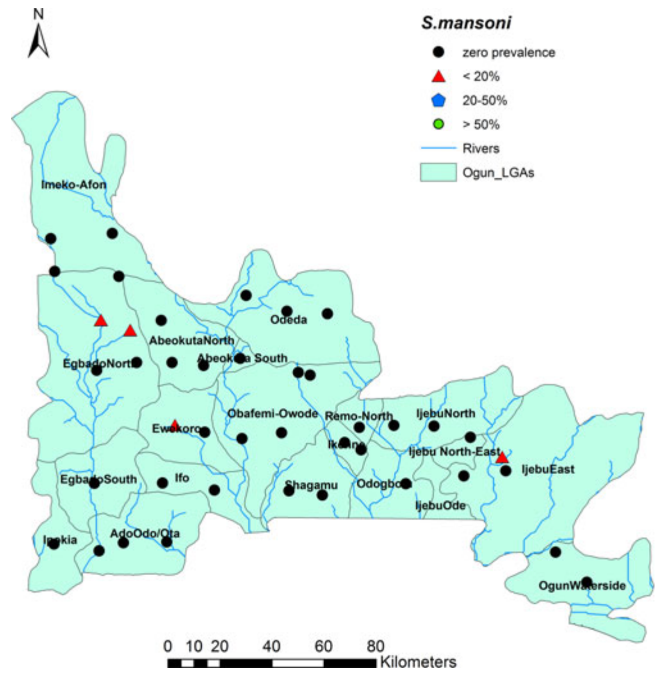

Fig. 3. Observed prevalence of *Schistosoma mansoni* in Ogun State.

Discussion

Map of co-distribution of schistosomiasis and STH infections and the number of people infected or at risk are essential for the implementation of cost-effectively integrated control programme (Magalhães *et al.* 2011; Schur *et al.* 2011; Chammartin *et al.* 2014). Here, we present for the first time the co-spatial distribution maps of schistosomiasis and STHs at LGA (implementation unit) for Ogun State to support integrated control like other studies in Kenya, Uganda, Cameroon and Zimbabwe (Handzel *et al.* 2003; Kabatereine *et al.* 2012; Tchuem Tchuente *et al.* 2013).

The prevalence and intensities of both diseases point out the fact that Schistosomiasis/STH infection remains a major public health problem in Ogun State (Ekpo *et al.* 2012, 2013; Oluwole *et al.* 2015). Schistosomiasis is a focal disease, prevalent in areas where there are high human–water contact practices with water bodies such as dams, rivers or irrigation canals, poor sanitation and poor access to potable water (Ekpo *et al.* 2013)

Schistosoma haematobium was the most widely distributed and most prevalent among the two species of *Schistosoma* found in this study. The finding also corroborates the recent mapping of schistosomiasis in Nigeria using compiled survey data from 1950 to 2010 which revealed that *S. haematobium* is the most spatially distributed of three *Schistosoma* species in Nigeria (Ekpo *et al.* 2013). The reason for wider distribution of *S. haematobium* than *S. mansoni* may be due to the ecology and distribution of

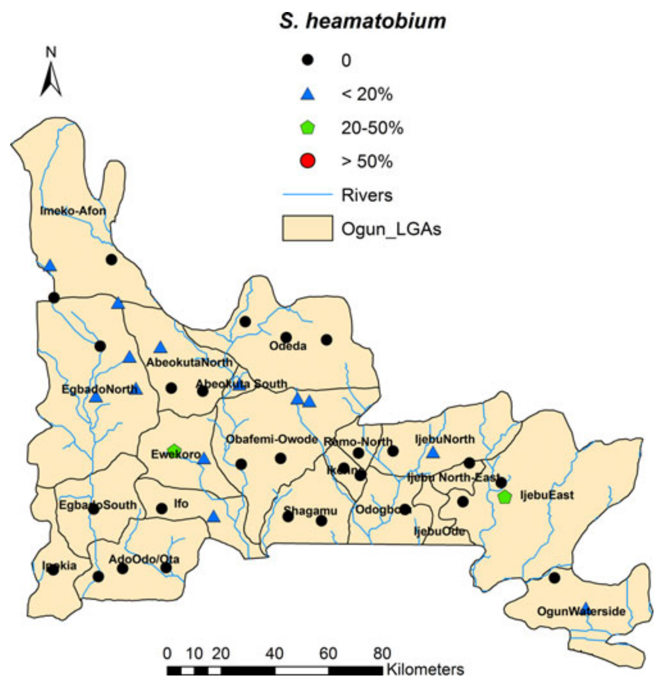

Fig. 2. Observed prevalence of *Schistosoma haematobium* in Ogun State.

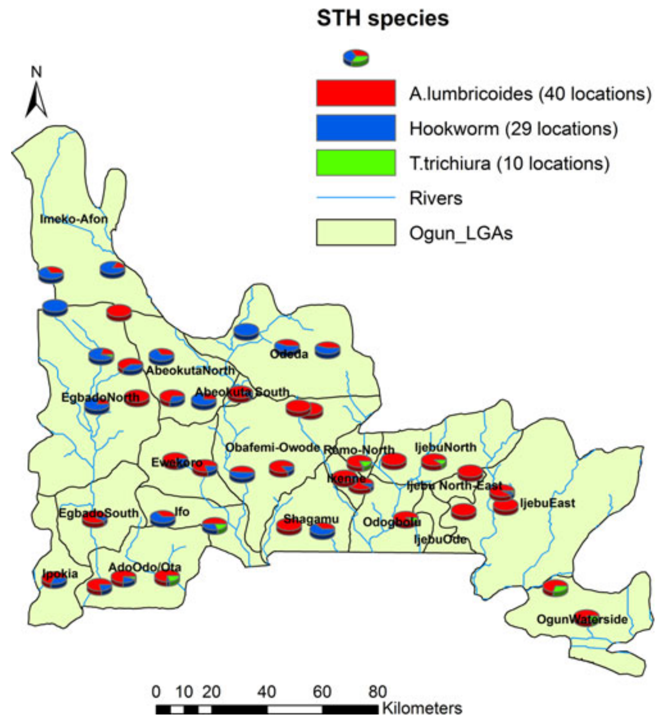

Fig. 4. Spatial distribution of STH parasite in Ogun State.

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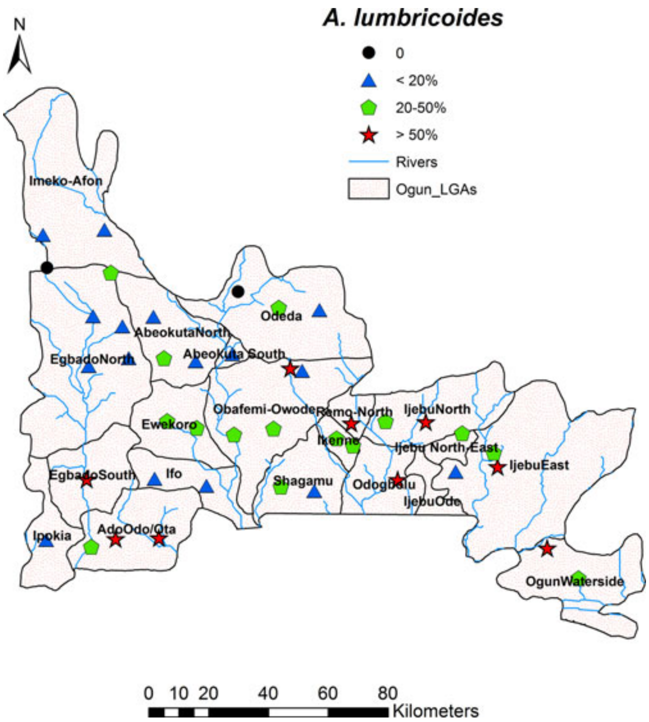

Fig. 5. Observed prevalence of *Ascaris lumbricoides* in Ogun State.

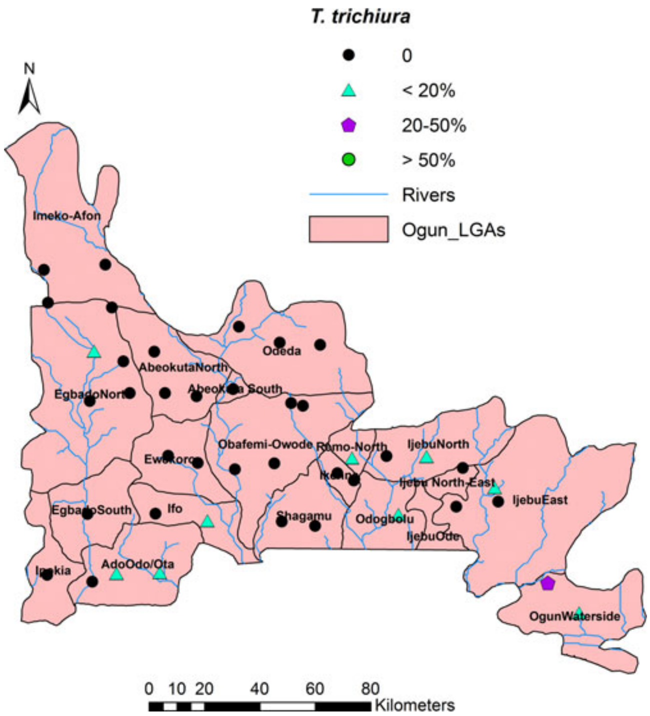

Fig. 7. Observed prevalence of *Trichuris trichiura* in Ogun State.

their snail intermediate host (Madsen *et al.* 1987; Madsen, 1992) which indirectly influenced the distribution of the parasites (Opisa *et al.* 2011).

Schistosoma mansoni was prevalent in four locations. These locations are not far from perennial water bodies which permit the sustained transmission of *S. mansoni* in these places and are similar to other observations of *S. mansoni* infection among people living close to a permanent water body (Lwambo *et al.* 1999; Handzel *et al.* 2003; Woodhall *et al.* 2013; Nagi *et al.* 2014). This may be due to inability of *S. mansoni* to develop in the snail intermediate host at high water temperature (>15 °C) (Pflüger, 1980) that may occur in seasonal water bodies.

Our findings show that prevalence of schistosomiasis increase as the age increases from age group 5–7 peaking at age group >14. This observation corroborates earlier findings which show that prevalence of shistosomiasis is highest among age group 10–15 years (Agnew-Blais *et al.* 2010; Senghor *et al.* 2014). This age group is known to be very active and are involved in recreational activities like swimming in schisto-infested water which made them at higher risk than the lower age group.

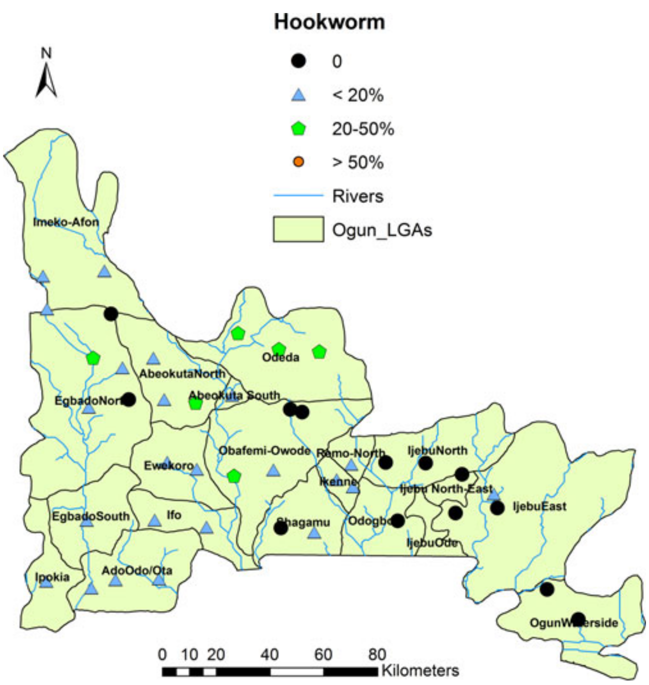

Fig. 6. Observed prevalence of hookworm in Ogun State.

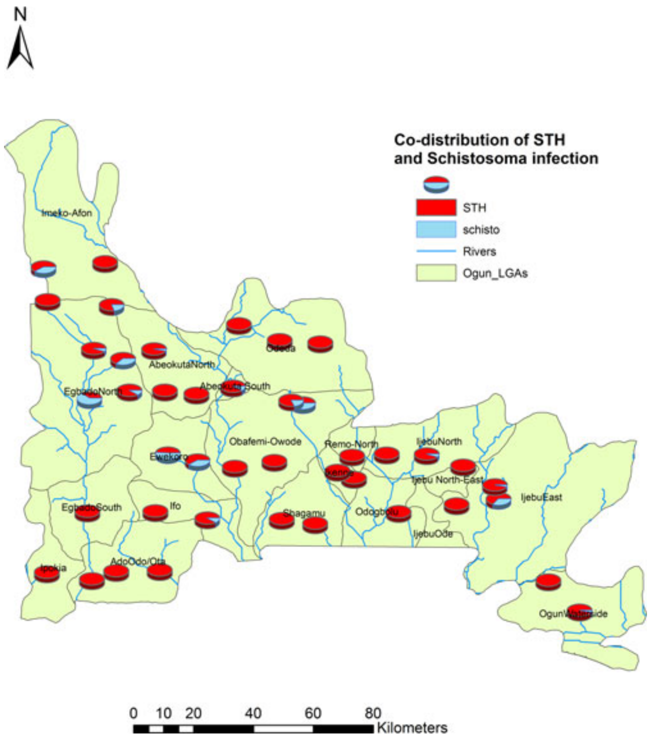

Fig. 8. Map of co-distribution of STH and *Schistosoma* infections in Ogun State.

The prevalence of schistosomiasis in Ewekoro LGA is higher than what is observed in other LGAs. This finding may be a reflection of their high level of exposure to infested water than other study sites in other LGAs. As shown in the map the selected study sites in Ewekoro LGA are very close to the river system. In addition, personal interaction with the school teachers and parents of the pupils during data collection shows that pupils from the selected schools come from a community where they do not have access to pipe borne water but depend solely on the river for their domestic activities. They also confirm that most of the children do engage in recreational activities especially swimming in the river

Ascaris lumbricoides was the most spatially distributed and prevalent among the STH, followed by hookworm and *T. trichiura*. This pattern of infection has been observed in earlier studies on STH infections in the south-western part of the country (Ibidapo and Okwa, 2008; Ekpo *et al.* 2012). Most studies on STH infections in endemic countries, both in sub-Sahara Africa and other continents have identified *A. lumbricoides* as the most common of the STH infections in the world (Pullan *et al.* 2011; Chammartin *et al.* 2013; Lai *et al.* 2013; Schule *et al.* 2014). Hence, this observation corroborates findings from other researches that incriminate *A. lumbricoides* as the main parasite in most STH infections. This is due to the ability of the ova of *A. lumbricoides* to withstand harsh environmental condition in the soil until a favourable condition for its embryonation is available

Ascaris lumbricoides was found in 19 LGAs, with increasing prevalence, from the western to the eastern part of the state. Hence, higher prevalence of *A. lumbricoides* is observed in Ogun waterside, Ijebu East, Ijebu North, Remo North, Odogbolu and Ijebu North East LGAs. The current study shows that hookworm is widely distributed in Ogun State, as we have earlier reported (Oluwole *et al.* 2015). The distribution of hookworm infection in Ogun State is due to its geographical location in the equatorial zone. This zone is known to be suitable for the development of hookworm larvae (Lai *et al.* 2013). However, the low prevalence of hookworm observed in Ogun Waterside, Ijebu East, Ijebu North, Remo North, Odogbolu and Ijebu North East LGAs of the state, may reflect the unfavourable environmental conditions for the survival of eggs and larvae of hookworm (Brooker *et al.* 2006) rather than improvement in the socioeconomic status of the people living in this area, when compared with Odeda, Abeokuta North, Ewekoro, Egbado North, Egbado south, Ifo and Ipokia LGAs with higher prevalence of hookworm. The high prevalence of STH (>20% WHO prevalence threshold) observed in the study, established the prerequisite for mass drug administration (MDA) for STH in Ogun State. However, studies have shown that there is a high level of re-infection among school-age children within 6 months after MDA (Ekpo *et al.* 2012; Jia *et al.* 2012; Yap *et al.* 2013). Hence, there is need to compliment deworming programme with other interventions such as health education on good hygienic practice and environmental sanitation. This will help reduce transmission of the disease (Campbell *et al.* 2014; Echazú *et al.* 2015)

Limitation of the study

In the selection of study sites, potentially high-risk areas for schistosomiasis disease (areas close to water bodies) was not given special consideration since the focus of the study was to model the co-distribution of schistosomiasis and STH across Ogun State using geostatistical methods. Hence, the prevalence of schistosomiasis in each LGA may have been underestimated.

Concluding remarks

This study provides information on the distribution and prevalence of *Schistosoma* and STH infections in Ogun State. Based on our results, integrated control of both diseases will be required in 10 LGAs of the state while STH control only is required in 10 LGAs. These evidence-based data may be useful for donors to allocate resources for supporting deworming activities in the State. The prevalence and spatial risk map of the two diseases are useful for state program managers as decision-support tools to help facilitate integrated control of the two diseases.

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Conflict of interest. None.

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