Co-infection of urogenital schistosomiasis and malaria and its association with anaemia and malnutrition amongst schoolchildren in Dutse, Nigeria

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Schistosomiasis is a neglected tropical disease. Sub-Saharan Africa accounts for 93% of the world's 207 million schistosomiasis cases. Urogenital schistosomiasis and malaria are both public health problems in Nigeria, where they are endemic. We determined the co-prevalence of urogenital schistosomiasis and malaria in schoolchildren and assessed its implication on anaemia and malnutrition. This cross-sectional study was conducted amongst primary schoolchildren in the Warwade, Saya Saya and Jigawar Daha villages of Nigeria. Urine samples were collected to detect *Schistosoma haematobium* eggs, and finger prick blood was used for haemoglobin concentration and malaria diagnosis. Nutritional status was assessed using anthropometric measurements and a pre-tested questionnaire. The overall prevalence and density of *S. haematobium* were 27.7% and 9 eggs/10 mL, respectively, with significant differences between villages and sexes. The prevalence of malaria and infection density was 10.4% and 330 mps/μL, respectively. Co-infection prevalence was 3.3%. Anaemia prevalence was 66%, with significant variation across villages and between sexes. Prevalence of stunting, underweight, and wasting was 41.7%, 46%, and 29.7%, respectively. Mean haemoglobin concentrations in *Plasmodium* and children co-infected with urogenital schistosomiasis were significantly lower than those who were negative for the infection. No significant association was observed between malnutrition and single or co-infection of urogenital schistosomiasis and malaria. After adjusting for variables associated with anaemia, village of residence remained a significant predictor of anaemia. Water contact activities, such as fishing, swimming, and irrigation, emerged as independent risk factors of *S. haematobium* infection.

Significance:

Urogenital schistosomiasis and malaria infections are prevalent in communities around Warwade dam in Dutse, Nigeria, and cause anaemia. Continuous monitoring, proper treatment and regular intervention is desirable in the communities.

Introduction

The two most common tropical parasitic diseases in sub-Saharan Africa are schistosomiasis and malaria, with both being a serious public health problem.[1] The co-infection of malaria and helminth parasites in Africa is as a result of their high proportions, overlapping distribution, transmission methods and other risk factors.[2] There are three prevalent forms of schistosomiasis in Nigeria: *Schistosoma haematobium, S. mansoni*, and *S. intercalatum*.[3] Approximately two-thirds of the schistosomiasis cases are due to infection caused by *S. haematobium*, which represents an important cause of severe urinary tract disease.[4] Previous studies have confirmed that urogenital schistosomiasis and malaria infections are endemic in Nigeria.[5] Co-infections of these parasites lead to reduced learning, reduced school achievements and poor development in children.[6] Epidemiological studies have highlighted that individuals co-infected with more than one parasite species are at risk of increased morbidity, increased severity of the infecting parasite species and increased susceptibility to other infections.[7] In sub-Saharan Africa, anaemia and malnutrition are the most frequent conditions encountered in field surveys and parasitic infections are among the major causes of these conditions.[8] Mechanisms through which parasitic infections cause anaemia and malnutrition include damage to intestinal mucosa which results in impaired digestion and absorption of nutrients, intestinal blood loss, interference with processes leading to production of blood cells in the bone marrow, and impaired immune development.[9] The control of schistosomiasis and malaria infections has become a concern for many governments and has the support of donors (including international organisations) following the London Declaration of 2012.[10] Identifying areas where these infections occur, and studying their co-infection, risk factors and implication on anaemia and nutritional status will increase the efficiency and proper implementation of control or elimination programmes.[11] Based on previous studies, urinary schistosomiasis is prevalent in Jigawa State[12], and work has been done on its co-infection with malaria and its effect on anaemia and nutritional status. In this study, we sought to determine whether there is a significant co-infection of urogenital schistosomiasis and malaria and its risk of anaemia and malnutrition amongst schoolchildren in the areas around Dutse in Jigawa State, Nigeria.

Materials and methods

Study area

The study was conducted from June to August 2021 in Dutse, northwestern Nigeria. The study areas were Warwade, Saya Saya and Jigawar Daha rural localities about 15–19 km south of Dutse. Warwade lies between latitude 11˚44′3″ N and longitude 9˚13′38″ E; Saya Saya lies between latitude 11˚44′50″ N and longitude 9˚12′2″ E; and Jigawar Daha lies between latitude 11˚45′28″ N and longitude 9˚11′39″ E (Figure 1). The communities were purposely selected because of their closeness to the major dam in the area (Warwade Dam). The Dam is used for irrigation, fishing, recreation and other domestic purposes. The relief of the area is flat with little undulation. The average annual temperature in Dutse is 26.8 °C. The warmest month, on average, is April, which has an average temperature of 31 °C. The coolest month on average is January, with an average temperature of 21.7 °C. The annual average precipitation in Dutse is 729 mm.[13]

Study population, sample size estimation and sampling technique

The study population consisted of primary schoolchildren of the selected communities. The children were selected from class 1–6 and within the age range of 5–15 years, using stratified random sampling. The sample size (n) was estimated using the formula[14]:

$$n = Z^2 \times Pq \div d^2$$

where n is the sample size required, d is the acceptable margin of error (5%), Z is the standard normal deviate of 1.96 at the 95% confidence level, P is the prevalence of urogenital schistosomiasis reported in Dutse[15] (10.0%) or prevalence of malaria (43.7%)[16]. The proportion of negative urogenital schistosomiasis or malaria (q) is given by (q = 1-p). A minimum sample size of 258 was obtained from the average (138+378/2) of the calculated sample size of urogenital schistosomiasis (138) and malaria (378). However, due to the incidence of non-compliance and loss of samples, 300 samples were analysed in the study.

Sample collection and analysis

In the field, the middle finger of each enrolled pupil was cleaned with an alcohol swab and pricked with a sterile lancet to obtain a thick blood film on a labelled clean glass slide for the determination of malaria parasites. Haemoglobin levels were determined from another drop of blood on a Hb(Haemoglobin) test strip and Bioaid haemoglobin meter (Hangzhou Bosure Biotech Co. Ltd, China). The Hb value displayed was recorded to the nearest 0.1 g/dL. According to the World Health Organization (WHO), children of 5 to 11 years of age have a normal haemoglobin concentration with values of ≥11.5 g/dL and mild, moderate or severe anaemia with haemoglobin concentrations of 11.4–11.0 g/dL, 10.9–8.0 g/dL and ≤8.0 g/dL, respectively. Children of 12 to 14 years of age have a normal haemoglobin concentration with values of ≥12.0 g/dL and mild, moderate or severe anaemia with values of 11.9–10.9 g/dL, 10.9–8.0 g/dL and ≤8.0 g/dL, respectively. People of 15 years and older have a normal haemoglobin concentration with values of ≥13.0 g/dL and mild, moderate or severe anaemia with values of 12.9–11.0 g/dL, 10.9–8.0 g/dL and ≤8.0 g/dL, respectively.[17] Each of the enrolled children was provided with a clean, labelled, screw-capped plastic container and instructed to urinate into the container between 10:00 and 14:00[18] and to close the cap tightly.

Urine analysis

Urine samples with gross haematuria were observed visually while micro-haematuria was detected using Medi-Test Combi 9 urinalysis test strips (Macherey-Nagel, Germany). Fltration was used to determine the presence or absence of *S. haematobium* eggs in the urine samples. About 10 mL of urine was transferred into a beaker after gentle shaking of the urine sample container. With the aid of a pipette dropper, 2 to 3 drops of eosin were added to the beaker and mixed. The mixture was drawn up using a 10 mL syringe. A labelled Whatman® Nucleopore filter was inserted into a Millipore and fitted tightly. Keeping the syringe and the Millipore in a vertical direction, the plunger of the syringe containing the urine was depressed. Thereafter, 20 mL of Lugol's iodine was also flushed through the filter holding the filter paper. The filter unit was then unscrewed and the filter allowed to air dry. The whole filter was viewed under a microscope at low objective power (objective x4). Infection was recorded as the number of eggs per 10 mL of urine.[18,19] The intensity of infection was categorised as either heavy (>50 eggs/10 mL of urine) or light (<50 eggs/10 mL of urine).[7,18]

Malaria parasite diagnosis

Thick blood films were dehaemoglobinised in water and stained with 10% Giemsa solution for 10 min, rinsed in water and air dried. The

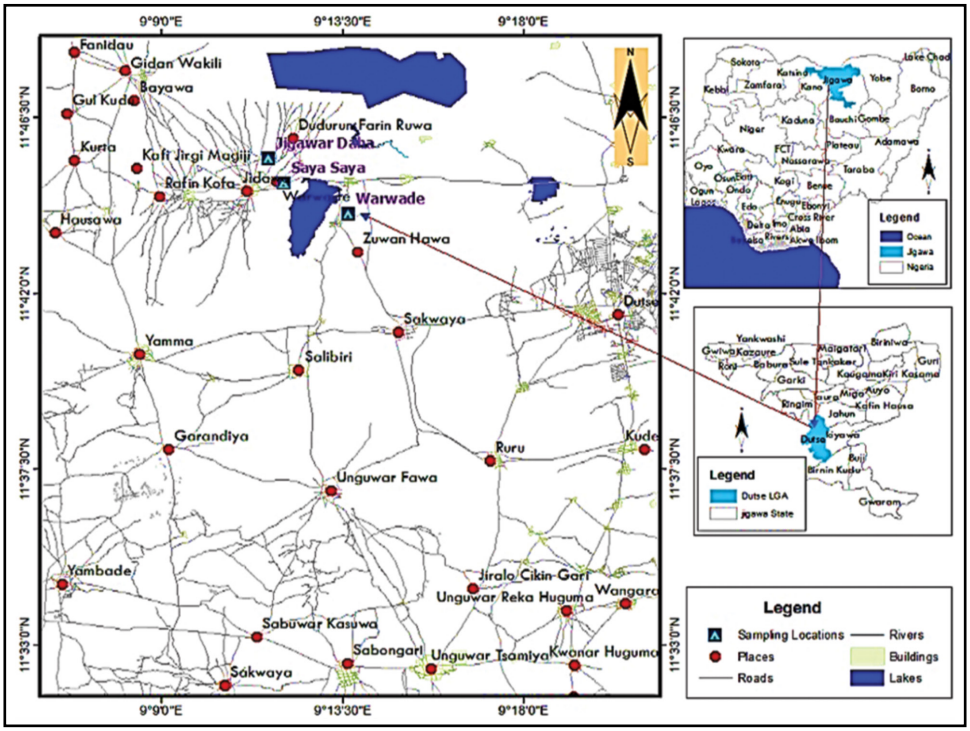

Figure 1: Map of Dutse local government area (LGA) in Jigawa State showing the sampling location.

stained films were viewed using 100 immersion oil objective. Slides were termed positive when asexual forms (trophozoites) and/or gametocytes of *Plasmodium* spp. were observed. The malaria parasites per microlitre of blood was determined by multiplying the average number of parasites per high power field (100x objective and 10x eye piece) by a factor of 500. Between 30 and 50 fields were examined.[20,18] Parasitaemia was classified as low (≤ 500 parasites/μL of blood), moderate (501–5000 parasites/μL of blood) or high (>5000 parasites/μL of blood).[7]

Questionnaire administration and anthropometric measurements

Using a simple pre-tested questionnaire, we interviewed the enrolled children, with the help of the schoolteachers, to obtain their sociodemographic data and associated risk factors for urogenital schistosomiasis and malaria. Age, height, weight and mid-upper arm circumference (MUAC) were recorded to determine participants' anthropometric indices. Height and weight were measured to the nearest 0.1 cm and 0.5 kg using a stadiometer and scale, respectively. MUAC was measured to the nearest 0.1 cm using a graduated tape. These parameters were used to calculate nutritional indices for stunting (height-for-age), wasting (body mass index (BMI)-for-age) and underweight (weight for age). The indices were computed as z-scores based on the WHO growth reference curves.[21] Height-for-age z-score (HAZ), BMI-for-age z-score (BAZ) and weight-for-age z-score (WAZ) were calculated. Children whose HAZ, BAZ and/or WAZ were more than two standard deviations below normal were considered stunted, wasted and/or underweight, respectively.[22]

Data analysis

All collected data were entered into Microsoft Excel (MS Excel 2016) and were checked manually for their completeness. The data were further analysed using the IBM-statistical package for the social sciences (SPSS) version 25 (IBM—SPSS, Inc, Chicago, IL, USA). Descriptive measures such as the mean, standard deviation (SD), median (interquartile), frequencies, and proportions were used to summarise the data. Differences in proportions between populations were obtained using the chi-square (χ^2) test and one-way analysis of variance (ANOVA). Median (interquartile) parasite density of *S. haematobium* and *Plasmodium falciparum* by village, sex and age group were compared using the Kruskal–Wallis test, Fisher's exact test and Mann–Whitney test. Mean (SD) Hb levels were compared using a one-way ANOVA and independent t-test where appropriate. Multivariate logistic regression analysis was used to obtain the predictors of anaemia, while both bivariate and multivariate regression analyses were used in determining risk factors associated with the transmission of *Plasmodium* sp. and *S. haematobium.*

Ethical approval

The protocol of the study was reviewed and approved by the Health Research Committee of the Ministry of Health, Jigawa State (JHREC/2021/038). The State Universal Basic Education Board (SUBEB) of Jigawa State gave administrative approval to conduct the research (reference number SUBEB/ADM/23/vol.1). Participation was voluntary, and a participant could decide to halt their participation in the study at any time without any penalty. The study complied with the institutional guidelines, rules and regulations of the Nigerian National Code for Health Research Ethics.

Results

A total of 300 schoolchildren from three communities – Jigawar Daha (115; 38.3%), Warwade (114; 38%) and Saya Saya (71; 23.7%) – were examined during the study. The demographic characteristics of the schoolchildren are presented in Table 1. More than half (57%) of the participants were female. Jigawar Daha had the highest proportion of female children, while male children were significantly higher in Warwade Primary School (p=0.006). The mean age of all participants was 9.8±2.6 years and the predominant age group was 8 to 11 years (57.3%). Principal water contact activities are depicted in Figure 2. The overall sociodemographics of the study participants are shown in Table 1.

Table 1: Sociodemographic characteristics of the study participants (*n* (%))

Variable	All participants	Warwade	Saya Saya	Jigawar Daha	*p*-value
Sex					0.006*
Female	171 (57)	52 (45.6)	43 (60.6)	76 (66.1)	
Male	129 (43)	62 (54.4)	28 (39.4)	39 (33.9)	
Age (years)					< 0.001*α
mean ± SD	9.8 ± 2.6	9.7 ± 2.0	8.2 ± 2.5	11.0 ± 2.4	
5–7	53 (17.7)	18 (15.8)	29 (40.8)	6 (5.2)	
8–11	172 (57.3)	76 (66.7)	34 (47.9)	62 (53.9)	
12–15	75 (25)	20 (17.5)	8 (11.3)	47 (40.9)	
Educational level					0.28
Primary 1	47 (15.7)	16 (14)	17 (23.9)	14 (12.2)	
Primary 2	50 (16.7)	17 (14.9)	13 (18.3)	20 (17.4)	
Primary 3	47 (15.7)	20 (17.5)	10 (14.1)	17 (14.8)	
Primary 4	52 (17.3)	20 (17.5)	8 (11.3)	24 (20.9)	
Primary 5	45 (15)	21 (18.4)	12 (16.9)	12 (10.4)	
Primary 6	59 (19.7)	20 (17.5)	11 (15.5)	28 (24.3)	
Parent occupation					0.15
Farmer	224 (74.7)	79 (69.3)	50 (70.4)	95 (82.6)	
Trader	47 (15 7)	20 (17.5)	14 (19.7)	13 (11 3)	
Artisan	20 (6.7)	12 (10.5)	5 (7.0)	3 (2.6)	
Civil servant	9 (3.0)	3 (2.6)	2 (2.8)	4 (3.5)	

**Significant at p<0.05; chi-square test and one-way ANOVA*α*

Prevalence, parasite density, single and co-infection of urogenital schistosomiasis and malaria

The prevalence of single infection with *S. haematobium* or *Plasmodium* spp. and co-infection were 27.7% (95% CI = 22.6–32.8%), 10.3% (95% CI = 6.7–13.7%) and 3.3% (95% CI = 1.3–5.3%), respectively (Table 2). The prevalence of single infection with *S. haematobium* in schoolchildren varied significantly from village to village (p<0.001) and between sexes (p=0.001), but not among age groups (p=0.45). The prevalence of single infection with *S. haematobium* was higher among male schoolchildren (37.2%). Also, the prevalence at Warwade (50.9%) was about three times that at Saya saya (16.9%), and 4.5 times that at Jigawar Daha (11.3%). Regarding single infection with *Plasmodium* spp. and co-infection with *Plasmodium* spp. and *S. haematobium*, there was no significant variation with sex or age, or across villages (Table 2). Out of 300 schoolchildren, 75 (25%) had light infection of *S. haematobium*, while only 8 (2.7%) had heavy infections. The median (interquartile) of *S. haematobium* parasite density was 9 (4 to 21), with significant difference among the villages (p<0.001) but not between sex (p=0.27) or among age groups (p=0.49). *Plasmodium* spp. parasitaemia was low (≤ 500 parasites/μL of blood) in 26 (8.7%) children and moderate (501–5000 parasites/μL of blood) in 5 (1.7%) children. Parasite density ranged from 50 to 3250 parasites per microlitre of blood, with a median (interquartile) of 330 (175 to 465).There was no significant variation in infection intensity across villages (p=0.68), between sexes (p=0.21) or among age groups (p=0.93).

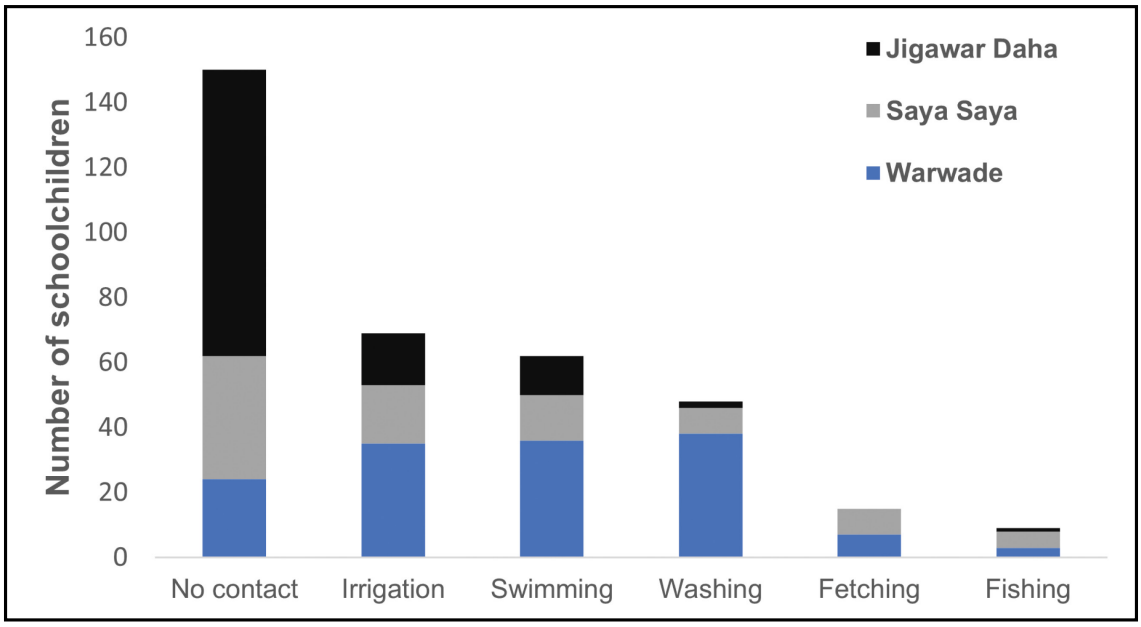

Figure 2: Water contact activities in schoolchildren stratified by villages.

Table 2: Prevalence, parasite density, single and co-infection of urogenital schistosomiasis and malaria in schoolchildren by village, sex and age

Variable	N	Single *S. haematobium* infection			Single *Plasmodium* spp. infection			Co-infection prevalence
		Prevalence *n* (%)	Parasite density (eggs/10 mL urine)		Prevalence *n* (%)	Parasite density (eggs/10 mL urine)		
			Range	Median (IQR)		Range	Median (IQR)	*n* (%)
Village	300	83 (27.7)	1 to 68	9 (4–21)	31 (10.4)	50–3250	330 (175–465)	10 (3.3)
Warwade	114	58 (50.9)	2 to 68	14.5 (6–26.5)	7 (6.1)	90–475	335 (190–465)	4 (3.5)
Saya Saya	71	12 (16.9)	2 to 27	6.5 (4.5–14.8)	7 (9.9)	135–430	325 (170–335)	2 (2.8)
Jigawar Daha	115	13 (11.3)	1 to 7	2 (1.5–4.0)	17 (14.8)	20–3250	395 (155–535)	4 (3.5)
p-value		< 0.001*		< 0.001*[c]	0.1		0.68[c]	0.96
Sex								
Female	171	35 (20.5)	1 to 64	7 (3–17)	19 (11.1)	50–3250	335 (220–5325)	6 (3.5)
Male	129	48 (37.2)	1 to 68	9 (4.3–25.8)	12 (9.3)	80–475	210 (145–430)	4 (3.1)
p-value		0.001*		0.27[e]	0.61		0.21[e]	0.85
Age group								
5–7	53	11 (20.8)	1 to 28	17 (8–23)	9 (17.0)	130–535	335 (182.5–470)	1 (1.9)
8–11	172	51 (29.7)	1 to 68	9 (4–21)	17 (9.9)	50–3250	330 (152.5–452.5)	9 (5.2)
12–15	75	21 (28.0)	1 to 64	6 (3 to 26)	5 (6.7)	135 to 560	230 (155–477.5)	0
p-value		0.45		0.49[c]	0.16		0.93[c]	0.07[d]

*p-value was obtained using chi-square test, Kruskal–Wallis test[c], Fisher's Exact test[d] and Mann–Whitney test[e]; *significant at p<0.05*

Prevalence of anaemia and malnutrition

The overall prevalence of anaemia was 66% (95% CI = 60.6–71.4%). For severe, moderate and mild anaemia the prevalence was 5.7% (95% CI = 3.1–8.3%), 40.3% (95% CI = 34.7–45.9%) and 20% (95% CI = 15.5–24.5%), respectively (Figure 3). The prevalence of anaemia differed significantly among villages ($p<0.001$), between sexes ($p=0.03$) and among age groups ($p=0.003$). The anaemia prevalence was highest in Warwade, while Saya Saya had the lowest prevalence (Table 3). A higher prevalence of anaemia was observed in male and older children (12–15 years).

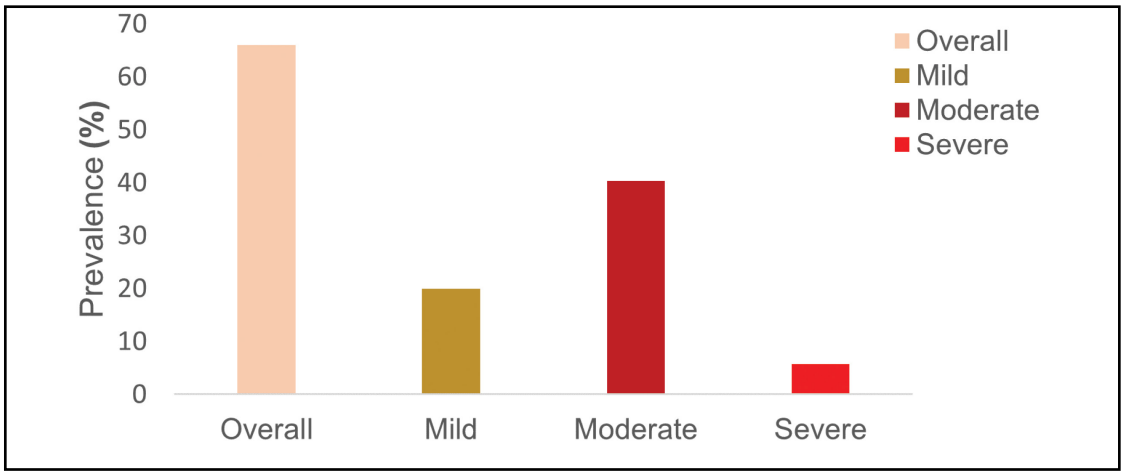

Figure 3: Prevalence of anaemia amongst schoolchildren in the studied areas.

Table 3: Prevalence of anaemia and malnutrition in schoolchildren by village, sex and age

Variable	N	Anaemia			Prevalence of malnutrition n (%)		
		Prevalence	Hb concentration, g/dL		Stunting	Underweight	Wasting
		n (%)	Range	Mean (SD)	*n* (%)	*n* (%)	*n* (%)
Village	300	198 (66)	3.6–19.9	10.9 (1.8)	125 (41.7)	138 (46.0)	89 (29.7)
Warwade	114	85 (74.6)	7.3–14.6	10.9 (1.2)	53 (46.5)	63 (55.3)	41 (36.0)
Saya Saya	71	33 (46.5)	3.6–14.7	11.5 (1.9)	33 (46.5)	26 (36.6)	16 (22.5)
Jigawar Daha	115	80 (69.6)	3.6–19.9	10.6 (2.2)	39 (33.9)	49 (416)	32 (27.8)
p-value		<0.001*		0.01*[a]	0.10	0.03*	0.13
Sex							
Female	171	104 (60.8)	3.6–19.9	10.9 (2.0)	65 (38.0)	79 (46.2)	52 (30.4)
Male	129	94 (72.9)	3.6–14.7	10.9 (1.5)	60 (46.5)	59 (45.7)	37 (28.7)
p-value		0.03*		0.95[b]	0.14	0.94	0.75
Age group							
5–7	53	29 (54.7)	7.3–14.7	11.4 (1.2)	13 (24.5)	6 (11.3)	8 (15.1)
8–11	172	108 (62.8)	3.8–14.4	10.9 (1.8)	70 (40.7)	76 (44.2)	44 (25.6)
12–15	75	61 (81.3)	3.6–19.9	10.7 (2.3)	42 (56.0)	56 (74.7)	37 (49.3)
p-value		0.003*		0.06[a]	0.002*	<0.001*	<0.001*

*p-value obtained using chi-square test, one-way ANOVA[a] and independent t-test[b]; *significant at p<0.05*

Hb, haemoglobin; SD, standard deviation

Urinary schistosomiasis and malaria co-infection and association with anaemia and malnutrition

The proportion of anaemic schoolchildren with *S. haematobium* or *Plasmodium* spp. or co-infection with both parasites was not significantly higher than in those without these infections (Table 4). No significant variation in haemoglobin levels was observed between children with and without *S. haematobium* infection (10.9 vs 10.9 g/dL; p=0.91); however, mean haemoglobin levels in children with malaria infection were significantly lower than in uninfected children (9.7 vs 11.0 g/dL; p=0.004). Also, as shown in Figure 4, haemoglobin concentrations decreased significantly with increasing malaria parasite density (p<0.001). Regarding co-infection, mean haemoglobin levels were significantly lower in children infected with both parasites (9.6 vs 10.9 g/dL; p=0.03). There was no significant association between single infection with schistosomiasis or malaria or with co-infection and nutritional status. The results in Table 4 indicate that cases of malnutrition did not significantly differ between infected and non-infected children in the study areas.

Predictors of anaemia

Variables that showed significant associations (p<0.05) with anaemia were considered for multivariate logistic regression analysis. The results in Table 5 indicate that only village of residence remained a significant predictor of anaemia among schoolchildren. The odds of anaemia among schoolchildren was 3.4 times higher at Warwade and 2.6 times higher at Jigawar Daha compared to Saya Saya. Moreover, male children were 1.7 times more likely to be anaemic than female children, and children aged 12–15 years and 8–11 years were, respectively, 1.6 and 1.4

Table 4: Urinary schistosomiasis, malaria and co-infection association with anaemia and malnutrition

Variable	N	Anaemia			Prevalence of malnutrition *n* (%)		
		Prevalence	Hb concentration, g/dL		Stunting	Underweight	Wasting
		n (%)	Range	Mean (SD)	*n* (%)	*n* (%)	*n* (%)
S. haematobium							
Negative	217	138 (63.6)	3.6–19.9	10.9 (1.9)	86 (39.6)	95 (43.8)	63 (29.0)
Positive	83	60 (72.3)	5.5–14.7	10.9 (1.5)	39 (47.0)	43 (51.8)	26 (31.3)
p-value		0.16		0.91[b]	0.25	0.21	0.69
Plasmodium spp.							
Negative	269	175 (65.1)	3.6–19.9	11.0 (1.7)	112 (41 .6)	127 (47.2)	81 (30.1)
Positive	31	23 (74.2)	3.8–13.0	9.7 (24)	13 (41.9)	11 (35.5)	8 (25.8)
p-value		0.31		0.004*[b]	0.97	0.22	0.62
Co-infection							
Negative	290	191 (65.9)	3.6–19	10.9 (1.8)	121 (41.7)	135 (46.6)	86 (29.7)
Positive	10	7 (70.0)	5.5–12.3	9.6 (2.5)	4 (40.0)	3 (30.0)	3 (30.0)
p-value		0.79		0.03*[b]	0.91	0.30	0.98

*p-value obtained using chi-square test and independent t-test[b]; *significant at p<0.05*

Hb, haemoglobin

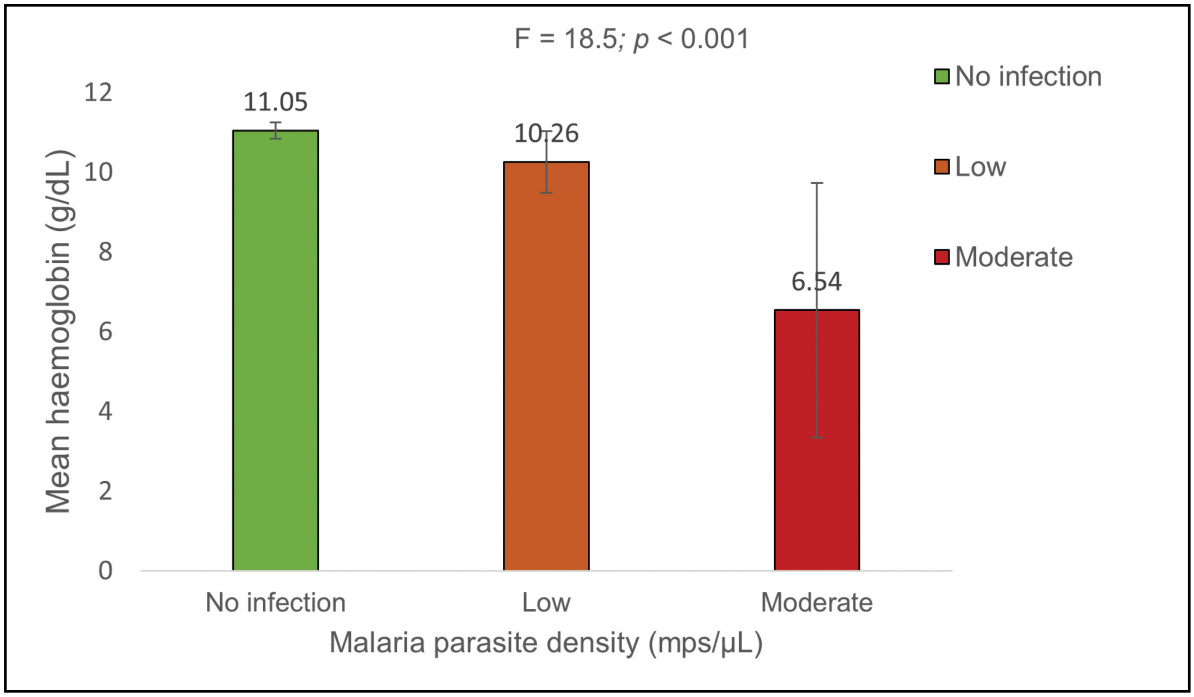

Figure 4: Association between haemoglobin levels and malaria parasite density.

times more likely to be anaemic than the 5–7-year cohort. Stunted and underweight children had almost 2 times the risk of being anaemic when compared to non-stunted children in the studied population (Table 5).

Risk factors associated with the transmission of urogenital schistosomiasis and malaria

At bivariate level, water contact activities (except for fetching) showed significant association (irrigation: p=0.01; swimming: p<0.001; washing: p=0.002, fishing; p=0.01) with the transmission of *S. haematobium* infection (Table 6). After adjusting for village of residence, sex and age, water contact activities that emerged as independent significant risk factors of *S. haematobium* infection included fishing, swimming and irrigation. Engaging in fishing activities was associated with an 8.3-fold increased likelihood of *S. haematobium* infection relative to those who did not fish. Also, the odds of *S. haematobium* infection among schoolchildren who engaged in swimming was 4.5 times greater than in those children who did not swim. In addition, schoolchildren engaged in irrigation activities were 2.3 times more likely to be infected with *S. haematobium* compared to those who did not (Table 6). Regarding *Plasmodium* spp. infection, the use of insecticides and insecticide treated nets decreased the odds of

Table 5: Predictors of anaemia in schoolchildren in the studied communities

Predictor	Bivariate analysis			Multivariate analysis		
	cOR	95% CI	*p*-value	aOR	95% CI	*p*-value
Area						
Saya Saya (ref.)	1.0			1.0		
Jigawar Daha	2.6	1.4 – 4.9	0.002*	2.3	1.2 – 4.7	0.02*
Warwade	3.4	1.8 – 6.3	<0.001	3.1	1.6 – 6.2	0.001*
Sex						
Female (ref.)	1.0			1		
Male	1.7	1.1 – 2.8	0.03*	1.6	0.95 – 2.8	0.08
Age group (years)						
5–7 (ref.)	1.0			1.0		
8–11	1.4	0.75 – 2.6	0.29	1.1	0.52 – 2.2	0.83
12–15	3.6	1.6 – 8.0	0.002*	2.5	0.94 – 6.8	0.07
S. haematobium						
Negative (ref.)	1.0			–		
Positive	1.5	0.86 – 2.6	0.16	–	–	–
Plasmodium sp.						
Negative (ref.)	1.0			–		
Positive	1.5	0.67 – 3.6	0.31	–	–	–
Co-infection						
Negative (ref.)	1.0			–		
Positive	1.2	0.31 – 4.8		–	–	–
Haematuria						
Negative (ref.)	1.0			–		
Positive	1.5	0.52 – 4.2	0.47	–	–	–
Stunted						
No (ref.)	1.0			1.0		
Yes	1.8	1.1 – 3.0	0.02*	1.7	0.92 – 3.0	0.09
Underweight						
No (ref.)	1.0			1.0		
Yes	1.7	1.1 – 2.8	0.03*	1.01	0.55 – 1.9	0.98
Wasted						
No (ref.)	1.0			–		
Yes	0.83	0.49 – 1.4	0.47	–	–	–

*cOR, crude odds ratio; aOR, adjusted odds ratio; ref., reference; CI, confidence interval; *significant at p<0.05*

Table 6: Risk factors associated with urogenital schistosomiasis infection in schoolchildren

Risk factors	Bivariate analysis			Multivariate analysis		
	cOR	95% CI	*p*-value	aOR	95% CI	*p*-value
Village						
Saya Saya (ref.)	1.0			1.0		
Jigawar Daha	0.63	0.27 – 1.5	0.28	1.04	0.40 – 2	0.94
Warwade	5.1	2.5 – 10	<0.001*	5.5	2.4 – 12.5	< 0.001*
Sex						
Female (ref.)	1.0			1.0		
Male	2.3	1.4 – 3.9	0.001*	1.1	0.60 – 2.1	0.72
Age group (years)						
5–7 (ref.)	1.0			–		
8–11	1.6	0.77 – 3.4	0.21	–	–	–
12–15	1.5	0.65 – 3.4	0.35	–	–	–
Irrigation						
No (ref.)	1.0			1.0		
Yes	2.2	1.2 – 3.9	0.01*	2.3	1.2 – 4.6	0.01*
Swimming						
No (ref.)	1.0			1.0		
Yes	5.6	3.1 – 10.2	< 0.001*	4.5	2.3 – 9.1	< 0.001*
Washing						
No (ref.)	1.0			1.0		
Yes	2.6	1.4 – 5.0	0.002*	1.4	0.68 – 3.0	0.35
Fetching						
No (ref.)	1.0			–		
Yes	1.3	0.44 – 4.0	0.62	–	–	–
Fishing						
No (ref.)	1.0			1.0		
Yes	5.6	1.4 – 22.8	0.01*	8.3	1.6 – 43.0	0.01*

*cOR, crude odds ratio; aOR, adjusted odds ratio; ref., reference; CI, confidence interval; *significant at p<0.05*

Plasmodium spp. infection among schoolchildren (Table 7). However, these risk factors (use of insecticides and treated nets) did not attain statistical significance in the studied population, in both bivariate and multivariate analyses (Table 7).

Discussion

Schistosomiasis and malaria have an adverse effect on cognitive development, leading to diminished educational performance and absenteeism.,[2324] Both urogenital schistosomiasis and malaria lead to anaemia and growth retardation in children.[25] From the findings in this study, urogenital schistosomiasis is highly prevalent (≥50%) in Warwade, whereas it is moderately prevalent (≥10%) in Saya Saya and Jigawar Daha. This is because Warwade is the closest community to the Warwade Dam, followed by Saya Saya and Jigawar Daha and the closer the children are to the water body the higher the probability of being infected with schistosomiasis. This shows that there is a high transmission of urogenital schistosomiasis around the Warwade Dam in Dutse. The high prevalence and infection intensity in schoolchildren in the area is an indicator that the rest of the population are at high risk of infection. The 50.9% prevalence of urogenital schistosomiasis in Warwade is greater than the prevalence reported by Alhaji et al.[26] who found a 12.3% prevalence in the Warwade community using a sedimentation technique. This difference is because we sampled primary schoolchildren and adolescents and employed a filtration technique. The overall prevalence of *S. haematobium* (27.7%) in the studied villages is also greater than the prevalence found in a recent study by Dogara et al.[15] who reported a 10% prevalence of *S. haematobium* in the Dutse metropolis using a sedimentation method. This difference is due to the prximity of our studied villages to Warwade Dam and because we employed a filtration technique which is more sensitive than a sedimentation method.[19]

Moreover, the 27.7% prevalence of *S. haematobium* in the studied communities is higher than the prevalence reported by David et al.[27] in Gwaram, Jigawa State. However, the overall prevalence of *S. haematobium* in this study is lower than the overall prevalence found by Awosolu et al.[28] in southwestern Nigeria. Amaechi et al.[29] recorded an

Table 7: Risk factors associated with malaria infection in schoolchildren

Risk factor	Bivariate analysis			Multivariate analysis		
	cOR	95% CI	*p*-value	aOR	95% CI	*p*-value
Village						
Saya Saya (ref.)	1.0			1.0		
Jigawar Daha	1.6	0.62 – 4.0	0.33	3.3	1.1 – 10.0	0.04*
Warwade	0.60	0.20 – 1.8	0.36	0.92	0.28 – 3.0	0.88
Sex						
Female (ref.)	1.0				1.0	
Male	0.82	0.38 – 1.8	0.61	0.80	0.35 – 1.8	0.60
Age group (years)						
5–7 (ref.)	1.0			1.0		
8–11	0.54	0.22 – 1.3	0.16	0.34	0.12 – 0.94	0.04*
12–15	0.35	0.11 – 1.1	0.08	0.15	0.04 – 0.59	0.01
Use of ITN						
No (ref.)	1.0			1.0		
Yes	0.64	0.30 – 1.4	0.21	0.85	0.38 – 1.9	0.69
Use of insecticide						
No (ref.)	1.0			1.0		
Yes	0.65	0.31 – 1.4	0.26	0.54	0.24 – 1.2	0.13

*cOR, crude odds ratio; aOR, adjusted odds ratio; ref., reference; CI, confidence interval; ITN, insecticide-treated net; *significant at p<0.05*

overall prevalence of 50.8% in southeastern Nigeria. The prevalence and infection intensity of *S. haematobium* varied by village. This is probably due to the level of exposure and the distance of the communities to the main water body (Warwade Dam) in the area. However, the prevalence and intensity also varied by sex; being more prevalent in male than female children; this is due to water contact activity/behaviour and susceptibility to infection in relation to sex. This is consistent with the work in Ondo State[30] in southeastern Nigeria[31] and in The Gambia.[32] However this is contrary to the findings of Otuneme et al.[33] and Hassan et al.[34] who recorded higher prevalence in female participants in southwestern Nigeria. Although there is no significant difference between prevalence and infection intensity among age groups, children of 8–11 years and 11–15 years have relatively higher prevalence and intensity when compared to the 5–7-year cohort. This is comparable to the research in Côte d'Ivoire where higher prevalence was found in 8–15-year-olds.[35] Uweh et al.[36] also reported higher prevalence in the 11–15-year age group in Benue State and another higher prevalence was found in a fishing community in Kebbi State within the age group of 8–10 years.[37]

The total prevalence of malaria of 10.3% reported in this study was lower than the prevalence (51%) reported by Dogara and Ocheje[38] in Dutse General Hospital. However, the relatively low prevalence of malaria in the studied villages may be attributed to the season in which the research was conducted; high prevalence of malaria in northern Nigeria usually occurs in the rainy season (August–November). Also, our low prevalence is because ours was not a hospital-based study; many of the infections are asymptomatic with moderate parasitaemia. A very low co-infection (3.3%) was detected between *S. haematobium* and *Plasmodium* spp., showing no significant association between urogenital schistosomiasis and malaria infection in our study. Co-infection prevalence in this research is lower when compared to other studies in Nigeria. Morenikeji et al.[39] reported 57.1% co-infection prevalence in a rural community in southwestern Nigeria; Oladele et al.[40] found 16% co-infection prevalence in Ogun State. However, co-infection is lower than that reported by Nyarko et al.[41] in Ghanian schoolchildren and Deribew et al.[42] in Ethiopian schoolchildren (0.9% and 2.84%, respectively). Notwithstanding this, in a recent study by Sumbele et al.[7] in Cameroon, a relatively higher 8.3% co-infection prevalence of *S. haematobium* and *P. falciparum* was reported. Moreover, *S. haematonium* and *Plasmodium* may modulate the effect of each other within their host. According to Lyke et al.[43] *S. haematobium* exerts a persistent stimulatory effect on the host immune system, protecting children against uncomplicated *P. falciparum.* Conversely, schistosomiasis can have a negative effect on host response to malaria, including increased susceptibility to *Plasmodium* infection and increased severity of disease, especially among children.[44] Oladele et al.[40] found most co-infected school-aged children had malnutrition, impaired cognitive development, splenomegaly and fatigue, resulting in poor school performance and reduced overall physical work capacity.

Our study revealed that an overall 66% of the schoolchildren were anaemic. Warwade, Saya Saya and Jigawar Daha had an anaemia prevalence of 74.6%, 46.5% and 69.6%, respectively. This showed that the schoolchildren in the villages were severely anaemic – an indication of a huge public health problem.[17] The higher prevalence of anaemia in schoolchildren is comparable to the findings o Nyarko et al.[41] in Ghana, Deribew et al.[42] in Ethiopia and Sumbele et al.[7] in Cameroon who reported an anaemia prevalence of 59.9%, 81.8% and 74.4%, respectively. However, in northwestern Nigeria, a lower anaemia prevalence of 11.7% was reported by Oladele et al.[40] Although there are many causes of anaemia, the high prevalence of anaemia in Warwade, Saya Saya and Jigawar Daha is probably due to the high prevalence and infection intensity of *S. haematobium* and *Plasmodium.* Therefore, this study provides further evidence that parasitic infections are associated with anaemia. Results of this research revealed a mean haemoglobin concentration of 10.9±1.8 g/dL. This is because the prevalence of moderate anaemia is greater than that of severe and mild anaemia. Although in this study there was no significant difference in haemoglobin levels in children with and without *S. haematobium* infection, the mean

haemoglobin level in children with malaria was significantly lower than that in uninfected children, and haemoglobin concentration decreased significantly with increasing malaria parasite density. This result is consistent with the findings of Konaté et al.[45] in Mali, Starck et al.[46] in Burkina Faso and Ehiem et al.[47] in Ghanaian schoolchildren. Moreover, mean haemoglobin levels were significantly lower in children co-infected with *S. haematobium* and *Plasmodium.* This is due to the combined loss of red blood cells (erythrocytes) as a result of *S. haematobium* and *Plasmodium* infections. This result is also comparable to the findings of Kinung'hi et al.[48] in Tanzania, Sumbele et al.[7] in Cameroon and Edosomwan et al.[49] in Nigeria. We also found a higher prevalence of anaemia in male children than in female children. This is probably due to the higher prevalence and intensity of *S. haematobium* in the male participants in the study. Nevertheless, Warwade (village of residence) was the only significant predictor of anaemia. This is likely due to the severe and prolonged burden of *S. haematobium* infection (>50% prevalence) and malnutrition in Warwade. Being stunted and underweight increased the risk of anaemia in the schoolchildren.

Accordance to the WHO classification of the severity of malnutrition, malnutrition (stunting, underweight and wasting) is highly prevalent in the studied population.[50] Millions of children in the world suffer from malnutrition; although the causes of malnutrition are multifactorial, studies have indicated that malaria and urogenital schistosomiasis increase the risk of malnutrition[51]. Thus *S. haematobium* and *Plasmodium* infections are detrimental to growth and development of children, which could lead to attention deficit, school absenteeism and reduced cognitive ability.[50] Other studies in Nigeria have found lower prevalence of stunting, underweight and wasting: Ayogu et al.[52] in southeastern Nigeria, Umeokonkwo et al.[53] in Abakaliki metropolis and Ajakaye and Ibukunoluwa[54] in Edo State. The prevalence of malnutrition (stunting, underweight and wasting) detected in this study is also higher when compared to the findings in Angola[55], in northwestern Tanzania[48] and in Cameroon[7].

Underweight varied significantly from village to village, while stunting, underweight and wasting varied significantly by age group. This finding is probably due to nutritional and environmental stress, as older children (12–15 years) are more hyperactive than those much younger (5–7 years). We did not discern a significant association between single or multiple parasite infections (*S. haematonium* and *Plasmodium*) and malnutrition. Although an association between single and multiple parasite infections and malnutrition have been reported in Kenya and Angola[56,55], some studies in Nigeria and Tanzania reported no association[57,49]. The lack of association between *S. haematobium, Plasmodium* sp. or co-infection of the parasites and malnutrition is likely due to other factors that are associated with undernutrition, maybe socio-economic factors and other infections.

Water contact activities that aided the transmission of urogenital schistosomiasis in this study were fishing, swimming and irrigation. This is line with the research of Singh et al.[58] in Sokoto, Mafiana et al.[59] in Ogun State and N'Guessan et al.[60] in Mauritania. In this study, children who were engaged in fishing had a 8.3-fold greater likelihood of urogenital schistosomiasis infection relative to those who did not fish. Also, the odds of *S. haematobium* infection among schoolchildren who engaged in swimming was 4.5 times greater than those who did not swim. In addition, schoolchildren engaged in irrigation activities were 2.3 times more likely to be infected with *S. haematobium* compared to those who did not engage in irrigation. Again, children in Warwade are 5.5 times more likely to have *S. haematobium* infection when compared to children in Saya Saya and Jigawar Daha. The use of insecticides and insecticide-treated nets decreased the odds of *Plasmodium* sp. infection among schoolchildren but not statistically significantly in the studied population, in both bivariate and multivariate levels of analyses.

Conclusions

Schistosomiasis is a neglected tropical disease; the largest burden of which is found in sub-Saharan Africa, which accounts for ~93% of the world's ~207 million schistosomiasis cases. In Nigeria, both schistosomiasis and malaria are diseases of public health concern which affect mainly schoolchildren. *S. haematobium* and *Plasmodium* spp infections were prevalent in the schools in our study. Although a low co-infection was observed, a high prevalence of anaemia and malnutrition was found in the studied areas. Despite the fact that the parasite infections (*S.haematobium, Plasmodium* sp. and co-infection) were not significantly correlated with malnutrition (stunting, underweight or wasting), there was, however, a significant difference in *Plasmodium* spp. single infection as well as co-infection with anaemia. Village of residence (Warwade and Saya Saya) was an independent significant predictor of anaemia, while being in the 12–15-year age group, being male, stunted and underweight increased the odds of anaemia. Swimming, irrigation and fishing were independent significant risk factors of urogenital schistosomiasis infection, while the use of insecticide and insecticide-treated nets decreased the odds of malaria infection. In view of the findings of this study, there is need for large-scale interventions in the communities within and around the Warwade Dam area via mass drug administration.

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Competing interests

We have no competing interests to declare.

Authors' contributions

J.B.B.: Conceptualisation, writing – initial draft, data collection, parasitological analysis, writing – final draft. B.A.: Conceptualisation, writing – initial draft. H.M.: Writing – initial draft, data collection, parasitological analysis, nutritional analysis, writing – final draft. M.M.D.: Writing – initial draft, parasitological analysis. C.B.O.: Data collection, parasitological analysis. A.A.I.: Nutritional analysis. G.J.: Writing – final draft.

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