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High prevalence of *Plasmodium falciparum* and soil-transmitted helminth co-infections in a periurban community in Kwara State, Nigeria

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ABSTRACT

Prevalence of malaria and soil-transmitted helminth infections, and the burden of disease are enormous in sub-Saharan Africa. Co-infections aggravate the clinical outcome, but are common due to an overlap of endemic areas. A cross-sectional survey was conducted to assess prevalence, intensity of infection and association between malaria and soil-transmitted helminth infections in a typical periurban community in Kwara State. Fresh blood and faecal samples were examined using thick blood film and Kato-Katz smear techniques.

A total of 383/471 study participants (81.3%) were infected with at least one parasite species, with the following prevalences and mean infection intensities: *Plasmodium falciparum* 63.7% (2313.6 parasites/μl); *Ascaris lumbricoides* 63.1% (3152.1 epg); *Trichuris trichiura* 53.3% (1043.5 epg); and hookworms 30.1% (981.7 epg). Sixty-three percent of the study population were co-infected with two or more parasite species. The prevalence of ascariasis was significantly higher in individuals infected with *P. falciparum* (adjusted OR: 5.87; 95% CI: 3.30–10.42). Heavy *A. lumbricoides* and *T. trichiura* infections were associated with high *P. falciparum* parasitaemia. Co-endemicity of malaria and soil transmitted helminth infections is an important public health problem in the study area. Multi-target integrated approaches focusing on disease intervention are essential to mitigate morbidity caused by multiple infections.

Introduction

Despite intensive control measures performed worldwide, malaria still causes a serious health burden in many tropical and subtropical countries, with the Democratic Republic of the Congo and Nigeria accounting for more than 35% of global malaria deaths [1]. Commonly, there is a geographical overlap of regions with high malaria endemicity, and the occurrence of Neglected Tropical Diseases (NTDs), such as soil-transmitted helminth infections. As a consequence, co-infections are expected to be a common phenomenon, rather than an exception, mainly in resource-poor communities [2–5].

While single malaria infections are often serious and even fatal especially in children, intestinal helminth infections may also result in serious clinical outcomes. Consequently, social and clinical consequences of multiple infections are heavily increased, as compared to single infections [5–8].

In Nigeria, soil-transmitted helminth infections and malaria are recognized major public health problems [3,9]. Endemic areas are mostly sustained by ecological, behavioral and socio-environmental conditions that favor parasite development and transmission, and include highly vulnerable populations [5,9,21].

Previous studies in schoolchildren revealed antagonistic effects in helminth-schistosome coinfection [5]. However, epidemiological surveillance and spatial congruence of both malaria and helminthiases remain poorly defined in Nigeria. This baseline information is necessary for cost-effective control measures that rather target multiple diseases than a single infections. The present study investigated malaria and soil-transmitted helminth infections in a community in north central Nigeria.

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Materials and methods

Study area and population

A community-based study was conducted in Ogele, a typical peri-urban area. Ogele is a small linear settlement, located along the old Ogbomosho road, about 13 km from Ilorin, the state capital of Kwara State. The climate is tropical, with well-defined wet (April–October) and dry (November–March) seasons (mean annual precipitation of >1.100 mm). The community is located in the transitional zone between rainforest and savannah grassland.

The inhabitants belong mainly to the Yoruba ethnic group, with a small proportion of Hausa, Nupe and Fulani ethnic groups. The vast majority (95%) are Muslims with a few Christians and members of traditional religions [10]. People are mainly peasant farmers, and grow crops such as cassava, maize, vegetables and yam.

Generally, sanitation status is poor. Most houses are devoid of toilets and adequate ventilation, with dumpsites located close to human habitations. The community is inadequately provided with essential amenities, such as electricity and portable water supply. There is one primary school, a secondary school and a primary health care centre.

Data collection and laboratory procedures

First, we performed a census in the community, consisting of a house-to-house survey. The population in Ogele was estimated to amount 619. Individuals with history of anthelminthic and antimalarial treatment (past three weeks) and those living for less than three months in the study area were excluded. History of treatment was confirmed by examination of drugs and/or medical prescriptions.

The recruitment of participants and data collection were conducted between January and May 2015 (end of dry season and beginning of rainy season).

During house visits, participants were instructed on how and when the samples (stool and blood) were to be taken. Pre-tested questionnaires were administered to obtain socio-demographic variables.

Thick and thin blood smears were prepared on a different slide from capillary blood obtained from the 3rd finger of left hand by finger prick using a sterile lancet. Blood smears were stained with Giemsa and examined under the oil immersion microscope objective. Thick smear was used to diagnose presence of malarial infection and parasitaemia load, and thin smear was used to identify the type of *Plasmodium* species. The number of parasites per microliter of blood was calculated as described in Cheesbrough [11]. At least one hundred fields were examined before a negative result was reported.

Stool samples were collected in labeled wide-mouth screwed-capped containers and processed for microscopic examination, using Kato-Katz thick smear method [12]. Kato-Katz slides were examined at the Parasitology Laboratory of University of Ilorin for the presence of helminth eggs, within a week after preparation. To estimate intensity of infection, egg counts per slide were converted to egg per gram of faeces (epg) by multiplying number of eggs on the slide by 24. The mean density of the epg of faeces was used to classify the pattern of infection as light, moderate and heavy infection, as defined by WHO [13]. All blood and stool slides were examined by two investigators who were blinded to the results, and where positive/negative discrepancy occurred, slides were counter-read by a third experienced parasitologist (USU), who was blinded regarding the two previous results.

Table 1
Demographic characteristics of the study population (n = 471).

Characteristic	No (%)
Gender	
Male	228 (48.4)
Female	243 (51.6)
Age (years): median (range)	23 (3–64)
Toilet facilities	
Cesspit/pit	114 (24.2)
None	357 (75.8)
Main source of water supply	
Borehole/well	233 (49.5)
Stream/pond	238 (50.5)
Education	
Primary education completed	208 (44.1)
Primary education not completed	263 (55.9)
Bed net (ITN) use	
Yes	140 (29.7)
No	331 (70.3)
Parasite infection pattern	
Single infection	118 (25.1)
Double infection	54 (11.5)
Multiple infection	211 (44.8)

Data analysis

Categorical variables are presented as ratios (%), and continuous variables with means and their standard deviations (SD). Differences in the prevalence and intensity of infection between ages and sexes were tested using the Chi squared (categorical variables) and one way ANOVA tests (continuous variables). As stratified analyses have shown a considerable influence of age and sex regarding and infection intensities were stratified by sex and age. Statistical analyses were performed using Excel (Windows Corporation, Redmond, WA, USA) and SPSS version 16 (SPSS Inc., Chicago, IL, USA). Prevalence, simple logistic regression analysis was applied to determine association between the parasites species adjusted with age and sex.

Results

A total of 508 people were eligible (70.6% of target population); 25 had a history of anthelminthic and antimalarial treatment in the past three weeks, and 12 had been living for less than three months in the study area and were excluded; resulting in a study population of 471 individuals. Of these 228 (48.4%) were males and 243 (51.6%) females, with a median age of 23 years. More than half of the population were illiterate; only about 1/4 had access to ITN bed nets, and the vast majority had not received any anthelminthic treatment within the last 3 weeks. Detailed demographic characteristics of the study population are summarized in Table 1.

Prevalence of *Plasmodium falciparum* infection was highest (64%), followed by ascariasis (63%), trichuriasis (53%) and hookworm infection (30%, Table 2). A low prevalence of *Plasmodium vivax* (0.03%) was recorded in the study area. A total of 383 (81.3%) were co-infected with one or more parasite species.

The prevalence and intensity of each of the four parasite species followed similar patterns, and varied significantly with age (Tables 2 and 3). With the exception of hookworm infection, which showed a significant steady increase with age, highest prevalences were observed in 11–20 year-olds.

Infection densities are detailed in Table 3. Soil-transmitted helminth infections were more prevalent and showed significantly higher infection intensity among males. Infection density of malaria reduced gradually with age (Table 3).

Table 2
Prevalence of *Plasmodium falciparum* and of soil-transmitted helminth infections, stratified by age and sex (n = 471).

	Parasite species				
	N	*Plasmodium falciparum* (%)	*Ascaris lumbricoides* (%)	*Trichuris trichiura* (%)	Hookworms (%)
Age group (years)					
≤5	58	42 (72.4)	19 (51.5)	13 (22.4)	1(1.7)
6–10	45	39 (64.4)	34 (75.4)	32 (71.1)	1 (2.2)
11–20	110	77 (70.0)	86 (78.2)	71 (64.5)	5 (4.5)
21–30	112	75 (67.0)	83 (74.1)	72 (64.3)	32 (28.6)
31–40	40	11 (27.5)	24 (60.0)	20 (50.0)	26 (65.0)
40+	106	66 (62.3)	51 (48.1)	43 (40.6)	77 (72.6)
p Value		<0.0001	<0.0001	<0.0001	<0.0001
Sex					
Male	228	148 (64.9)	167 (73.2)	141 (61.8)	81 (35.5)
Female	243	152 (62.6)	130 (53.5)	110 (45.3)	61 (25.1)
p value		0.595	<0.0001	<0.0001	0.014
Total	471	300 (63.7)	297 (63.1)	251 (53.3)	142 (30.1)

Table 3
Mean intensity (±standard deviation) of *Plasmodium* species and soil-transmitted helminths, stratified by age and sex.

	N	*Plasmodium* spp.	*A. lumbricoides*	*T. trichiura*	Hookworms
Age					
≤5	58	2948.36 ± 2280.64	724.28 ± 1375.78	280.66 ± 675.76	13.24 ± 100.84
6–10	45	2579.51 ± 2804.84	3856.67 ± 3474.93	1013.42 ± 1278.45	47.47 ± 318.42
11–20	110	2374.95 ± 2339.08	4461.18 ± 3886.44	1457.95 ± 1294.59	123.65 ± 638.46
21–30	112	2114.12 ± 2495.29	3795.48 ± 3508.36	1373.48 ± 1427.96	1003.86 ± 1757.14
31–40	40	1099.20 ± 2133.38	2423.92 ± 2664.21	1072.82 ± 1222.95	2248.30 ± 1976.55
41+	106	1664.45 ± 1910.17	2418.09 ± 3351.76	821.66 ± 1170.32	2297.05 ± 2141.84
p Value		0.018	<0.0001	<0.0001	<0.0001
Sex					
Male	228	2376.91 ± 5582.36	4055.90 ± 3733.42	1254.81 ± 1338.44	1236.28 ± 1896.90
Female	243	2254.28 ± 4908.77	2304.16 ± 3056.20	845.27 ± 1214.01	742.74 ± 1578.62
Total	471	2313.64 ± 5240.38	3152.14 ± 3508.45	1043.52 ± 1290.76	981.65 ± 1755.55
p Value		0.890	0.001	0.001	0.002

About 23% of individuals were infected with two parasite species, and 52% of those with multiple infections were infected with three parasite species, with the most prominent combination of *P. falciparum*, *Ascaris lumbricoides* and *Trichuris trichiura*. Out of 300 subjects positive for *P. falciparum*, 3 (1%), 49 (16.3%) and 158 (52.7%) were not co-infected with *A. lumbricoides*, *T. trichiura* and hookworms, respectively. 57%, 30.3% and 11.7% of participants had light, moderate and heavy *Ascaris* infection. Similarly, 8.7%, 25% and 13% had light, moderate and heavy hookworm infection respectively.

Logistic regression analysis on the independent association between co-infections, controlled by sex and age is detailed in Table 4. A highly significant association was observed between increasing parasite loads of ascariasis and trichuriasis. Parasitaemia load of *P. falciparum* also increased (Table 5).

Discussion

Our study evidenced a high prevalence of co-infection of malaria and soil transmitted helminth infections in a typical periurban community in Nigeria. Malaria, ascariasis, trichuriasis and hookworm infections were very common. Prevalence and intensity of ascariasis and trichuriasis were associated with severe malaria. The data reiterate the World Health Organization's insistence for an integrated approach to improve tropical disease surveillance and control [14].

Co-infections with different species were the rule—more than 4/5 of the participants had infections by two or more parasite species. The occurrence of *A. lumbricoides*, *T. trichiura* and hookworms has been reported previously in children and adults, and these infections indeed are considered some of the most common parasitic diseases of mankind [5,21,22]. Clinical implications are tremendous—for example, children with parasitic co-infections and high parasite loads tend to suffer more commonly from reduced cognitive functions, malnutrition, growth retaradation and iron-deficiency anemia [5–8]. Previous surveys among schoolchildren in resource-poor communities in sub-Saharan Africa showed that polyparasitism is indeed a common phenomenon in many areas, with vulnerable populations exposed to highest risks. Similar to many infectious diseases, high risk populations for co-infections usually share low socio-economic characteristics [2,4,5,15].

Our findings of children being a high risk group for malaria infection have been widely reported previously from endemic regions [16,17]. Distribution by sex was as previously reported in the southwest of Nigeria [18,19] and other malaria-endemic regions [20]. The parasite density of *P. falciparum* in respect to sex and age followed a similar pattern; within the younger age group there was a consistently higher prevalence and parasite density than in the adult group. This observation has earlier been reported by Raso et al. [20] in a study of multiple parasite infections in rural Côte d'Ivoire and other studies in malaria endemic regions, and reasons were attributed mainly to higher exposure and immunological factors [2,14]. Males were twice likely to be infected with *A. lumbricoides* than their female counterparts. These predictions were consistent with reports from other endemic regions [5,34,35].

The high prevalence in *A. lumbricoides* and *T trichiura* are indicative of the similar transmission pattern reported by different authors [5,23–25]. The occurrence of ascariasis and trichuriasis was observed to peak in the young age group of 11–20 years, and it was peculiar to other studies in several localities [26,27]. This might be a result of development of protective immunity due to repeated exposure since infancy, social behavior reducing risk of infection,

Table 4
Logistic regression analysis of interaction of *Plasmodium species* and soil-transmitted helminths, adjusted by age and sex.

Outcome parasite species	Exposure variables	N (%)	Adjusted odds ratio	95% CI	p Value
Plasmodium falciparum	*A. lumbricoides*	232 (77.3)	5.867	3.304–10.418	<0.0001
	T. trichiura	192 (64.0)	1.630	0.826–2.474	0.201
	Hookworm	86 (28.7)	0.973	0.538–1.761	0.928
	Male sex	148 (64.9)	1.282	0.820–2.007	0.276
	Age 11–20 years	115 (69.7)	1.089	0.392–3.026	0.870
A. lumbricoides	*T. trichiura*	230 (77.4)	1.747	0.027–0.082	<0.0001
	Hookworm	98 (33.0)	0.347	0.164–0.733	0.005
	Male sex	167 (73.3)	1.721	1.029–2.879	0.039
	Age 11–20 years	124 (75.2)	3.704	1.079–12.71	0.037
T. trichiura	Hookworm	79 (55.6)	0.523	0.296–0.925	0.026
	Male sex	141 (61.8)	1.669	1.134–2.458	0.009
	Age 11–20 years	105 (63.6)	9.089	2.985–27.67	0.037
Hookworm	Sex (male)	81 (35.5)	2.567	1.498–4.400	0.001
	Age 11–20 years	20 (12.1)	0.063	0.002–0.048	<0.0001

Table 5
Association between parasite intensity of soil-transmitted helminths and *Plasmodium falciparum* in co-infected individuals.

	N	Mean intensity (±SD) *Plasmodium falciparum*	95% CI	ANOVA (one-way)
A. lumbricoides				
Uninfected	174	1353.66 ± 2520.990	976.44–1730.87	
Light infection	171	2339.67 ± 2200.705	2007.46–2671.88	
Moderate infection	91	2556.92 ± 2349.732	2067.5–3046.28	
Heavy infection	35	2813.77 ± 2466.270	1966.58–3660.96	$p < 0.0001$
T. trichiura				
Uninfected	220	1672.37 ± 2495.251	1340.81–2003.92	
Light infection	55	2368.22 ± 2396.158	1720.45–3015.99	
Moderate infection	196	2390.86 ± 2304.659	2066.20–2715.52	
Heavy infection	0	–	–	$p = 0.006$
Hookworms				
Uninfected	329	2145.88 ± 2577.542	1866.33 ± 2425.44	
Light infection	26	2007.54 ± 2079.016	1167.81 ± 2847.27	
Moderate infection	77	1872.78 ± 2107.342	1394.47 ± 2351.09	
Heavy infection	39	1650.90 ± 1868.288	1045.27 ± 2256.53	$p = 0.577$

use of anthelminthic drugs and improved hygiene. Similar to other studies, hookworm prevalence increased with age; this also might due to a drop in immunity which might be due to aging [28]. There was remarkable statistical significance of occurrence of STHs with respect to sex; males tend to show higher prevalences, based on differing healthcare-seeking behavior and disease-related exposure, as demonstrated in previous studies conducted in different parts of the world [9,27–31]. Some authors suggested that a proportion of the elderly population is at high risk of very heavy hookworm infection, due to increased exposure or age-dependent immune mechanisms [32].

Our data revealed that intestinal helminth infections were associated to each other, and co-occurrence of parasitic diseases occurred frequently. Individuals co-infected with *P. falciparum* were significantly more likely to harbour *A. lumbricoides* and *T. trichiura* infections, as compared to individuals without malaria. Similarly, individuals co-infected with *A. lumbricoides* were twice likely to have *T. trichiura* than individuals without. In fact, the parasitic diseases under study share similar risk factors for transmission in such localities, and are linked to low socio-economic status. In addition, the parasites may interact directly in infected hosts—polyparasitism and parasite interactions have been reported previously from endemic communities [5,20,23,33]. Further, the distribution of malaria often overlaps geographically with the presence of NTDs, such as intestinal helminth infections. As a consequence, polyparasitism is a common phenomenon in high risk groups living in endemic areas [2,3]. The association has also been insinuated as result of impaired immunological status of individuals with multiple infections [36].

Another important aspect of our findings was the interaction of severity of soil-transmitted helminth infections and the severity of malaria infection. Nacher et al. [37] reported that *A. lumbricoides* and other soil-transmitted infections suppressed cerebral malaria, renal failure, jaundice and protected against high body temperature. The likelihood of *P. falciparum* infection was observed to increase in patients with helminth infections in a low transmission area [38]. In contrast, in our study, heavy ascariasis and trichuriasis infections were associated with higher *Plasmodium* parasitaemia; while on the other side those with light hookworm infection presented high *Plasmodium* parasitaemia. Increase in *Plasmodium* density was found to be related to the number of helminth species, rather the intensity of helminth infection. According to the report of Mwangi et al. [39] from a high malaria transmission area, helminth infections were most likely leading to an increased risk of disease for non-severe malaria, while decreasing the risk for severe malaria.

Our study is subject to limitations. As infections, especially malaria, show seasonal variations, interpretation of results should consider the cross-sectional study design. Specifically, data collection covered the dry season and terminated at the onset of the rainy season. Thus, malaria prevalence and coinfection rates are supposed to be underestimated. For logistic reasons, only one faecal sample was collected, which may have caused underestimation of prevalences of intestinal helminth infections. In addition, the intensities of parasites encountered may be underestimated because of relatively low sensitivity of Kato-Katz diagnostic method employed. For this same reason, human pinworm infection was not reported, but may be present.

It was not the focus of our study, to investigate climatic, environmental and socio-economic determinants of parasite infections, but rather to provide a data baseline for planning of intervention measures, and for future research, including systematic studies on risk factors for disease and co-infection. Our results can be considered representative for the population, and for similar communities in the region.

Conclusions

Co-endemicity of malaria and soil transmitted helminth infections is an important health problem in the study area, perpetuating health problems particularly of highly vulnerable groups in the population.

The study provides evidence for the positive impact of multi-target approaches focusing on integrative disease intervention. Interventions targeting a single helminth infection should include simultaneously include malarial infection, and focus on the reduction of co-infections. For example, combining vector control strategies (e.g. by use of long-lasting insecticidal nets) with the administration of anthelminthic drugs will significantly improve the well-being of the entire population.

Author's contributions

BOA collected data, participated in the design and statistical analysis. USU conceived and designed the study, performed statistical analysis and drafted the manuscript. JH conceived and designed the study, assisted with statistical analysis and helped to draft the manuscript. All authors read and approved the final manuscript.

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Competing interests

None declared.

Ethical approval

This study was approved by the Ethical Review Board of Ilorin University, Ilorin, Kwara State. Prior to the study, we visited the community leaders to seek for their consent. Written consent was obtained from study participants or in the case of minors from their guardians.

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