The burden of Vector-Borne and Soil-Transmitted Polyparasitism in a Nigerian Rural Community: A cross-sectional study

Akeem Abiodun Akindele¹³*, Taiwo Adetola Ojurongbe², Folasade Josephine Ojo⁴, Samuel Adeyinka Adedokun⁵, Olusola Ojurongbe¹³

¹College of Health Sciences, Ladoke Akintola University of Technology, Ogbomoso, Nigeria.
²Department of Medical Microbiology and Parasitology, UNIOSUN Teaching Hospital, Osogbo, Nigeria.
³Centre for Emerging and Re-Emerging Infectious Disease, LAUTECH, Ogbomoso, Nigeria.
⁴Department of Medical Microbiology and Parasitology, UNIOSUN Teaching Hospital, Osogbo, Nigeria.
⁵Department of Community Medicine, Osun State University, Osogbo, Nigeria.

*Correspondence should be addressed to Dr. Akindele A. A.: aaakindele@lautech.edu.ng
Received 10th June 2022; Revised 2th July 2022; Accepted 6th July 2022

© 2022 Akindele et al. Licensee Pan African Journal of Life Sciences an official publication of Faculty of Basic Medical Sciences, Ladoke Akintola University of Technology, Ogbomoso. This is an Open Access article distributed under the terms of the Creative commons Attribution License (https://creativecommons.org/licenses/BY/4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

ABSTRACT

Background: Concomitant parasitic infections are common in the developing world, yet most studies focused on a single parasite in a narrow age group. This study investigated the extent of polyparasitism and co-infections in a rural community in Osun State, Nigeria.

Methods: Two hundred and forty-seven consenting individuals consisting of 118 males and 129 females participated in this study. Faecal specimens, venous blood, and skin snips were collected from the participants. The Kato-Katz technique was used to screen the faecal samples for soil-transmitted helminth, while Giemsa-stained blood smears were used for Plasmodium falciparum detection. Skin snips microscopy and haematoxylin-stained blood smears were used to diagnose onchocerciasis and loiasis, respectively. Demographic information was collected from all the participants.

Results: The prevalence of P. falciparum, hookworms and Ascaris lumbricoides were 55.9%, 19.4% and 26.3%, respectively. The overall prevalence of the filarial infections was 4.5% for Loa loa microfilaraemia, 23.5% for Onchocerca volvulus microfilarial. Thirty-eight per cent of the population harbouring at least two parasites concurrently. Females (52.2%) were generally more infected with all the helminths than males (48.8%), but the difference was not statistically significant (p=0.128). For onchocerciasis prevalence, males (29.7%) were more infected than females (17.8%), and the difference was statistically significant (p=0.035). Co-infection of malaria and loiasis was observed in 1.2% of the population (p=0.051), while 13% were co-infected with malaria and onchocerciasis (p=0.903). Co-infection of malaria and hookworm was observed in 10.5% of the population. The overall mean Packed Cell Volume (PCV) of the population was 40.03±5.84, and no significant difference (p=0.224) was observed between PCV and infection status. Also, no significant association (p=0.051) was observed between the age group and infection status. The intensity of the parasites was classified into 1-9, 10-99, 100-149, and 150 and above. Almost all the helminths except Ascaris lumbricoides had a low grade of helminths (1-9). The intensity was more pronounced in Ascaris lumbricoides than in other helminths. A. lumbricoides + P. falciparum co-infection had a higher geometric mean parasites density (GMPD) value when compared with only P. falciparum infection. There was no significant difference in co-infection of P. falciparum + loa loa, P. falciparum + O. volvulus and P.falciparum + Hookworm with P. falciparum alone.

Conclusion: This study confirmed that polyparasitism is still common in rural communities in the study area. The findings can be used to design and implement appropriate intervention strategies to alleviate morbidity and comorbidity in rural communities.

Keywords: Parasitic diseases, Malaria, Filarial infections, Soil-transmitted helminth infections
1. INTRODUCTION

Parasitic diseases are a significant cause of morbidity and mortality worldwide [1] and significantly affect socioeconomic disadvantaged populations in sub-Saharan Africa [2]. Hundreds of millions of people in the developing world are at risk of parasitic diseases [3]. A more significant percentage of parasitic infections are vector-borne and soil-transmitted, with transmission cycles involving a range of reservoirs that can include the intermediate hosts that are majorly found in rural communities [4].

Vector-borne parasitic diseases are responsible for over 1 billion cases and 1 million deaths yearly, corresponding to at least 17% of all infectious diseases in human populations [5]. Among them, we can find malaria, onchocerciasis, lymphatic filariasis, loiasis, Chagas disease, and African trypanosomiasis. Some of these diseases have been newly reported in areas known to be free of those diseases before. They have become a subject of growing interest in public health and scientific agendas [4].

Several factors are responsible for the recurrent high burden of vector-borne parasitic diseases. For instance, the spread of resistance to drugs in pathogens has become a significant obstacle to effectively treating some vector-borne parasitic diseases. An increase in insecticide resistance threatens the sustainability of vector control programmes in several tropical regions. Additionally, the expansion of different vector populations due to climate change is becoming a growing concern in temperate countries, where vector control programs have been suspended for almost 50 years [6]. The scientific community has been trying to overcome these challenges by creating new strategies and tools to improve the diagnosis and treatment of vector-borne parasitic diseases and by developing new methodologies and targets for vector control campaigns [7].

The deadliest vector-borne parasitic disease is malaria [8], a life-threatening disease caused by Plasmodium species, transmitted to humans through the bites of infected female mosquitoes of the genus Anopheles [9]. Malaria is a significant public health problem, with more than 200 million cases causing up to 1 million deaths yearly. People in endemic areas with symptomatic and asymptomatic malaria are reservoirs for the infection. Malaria is the most common disease in Africa and some countries in Asia, but the burden it inflicts depends upon the scale of malaria control efforts in each country [10].

Malaria, Filarial infections and STHs infections are widespread. They have similar geographical and overlapping distribution in developing countries with the significant adverse consequence of the co-infection on the health of infected individuals [11].

Filarial nematodes dwell within the lymphatics and subcutaneous tissues of up to 170 million people worldwide and are responsible for notable morbidity, disability and socioeconomic loss [12]. Although eight filarial species infect humans, only five cause significant pathology: W. bancrofti, B. malayi and Brugia timori, Onchocerca volvulus, and Loa loa. Onchocerciasis and loiasis are endemic filarial parasites in the central and western African countries, including Nigeria [13]. Onchocerciasis (river blindness) is the second most important cause of infectious blindness worldwide after trachoma. It is endemic in 31 African, Arabian Peninsula and Latin America countries [14, 15]. More than 99% of infected people live in sub-Saharan Africa [15]. Nigeria probably has the highest burden of onchocerciasis globally, accounting for about a third of the global prevalence [16]. The disease has had a significant impact on the economic and social lives of the endemic communities. Loiasis is a neglected tropical disease that has recently emerged as a disease of public health importance due to its negative impact on the control of onchocerciasis in areas where both loiasis and onchocerciasis co-exist [17]. Individuals harbouring a heavy microfilarial load of L. loa develop neurological complications when ivermectin is given as part of mass treatment programmes for onchocerciasis [18]. It is an African disease restricted to the equatorial rainforest regions of Central and West Africa. L. loa is often referred to as the African eye worm because the adult worm can sometimes be seen moving through the eye’s sclera [13].

Soil-transmitted helminth (STH) infections are among the most common neglected tropical diseases (NTD) worldwide and affect the poor and most deprived communities [19]. They are transmitted by eggs in human faeces, contaminating soil in poor sanitation areas. Children co-infected with these parasites have been shown to have hindered cognitive and physical development, leading to poor academic performance [20]. They are also prone to increased susceptibility to other infections. Multiple parasitic infections could induce modifications of the specific immune response to each pathogen and thus modification of clinical expression. Helminths can ameliorate or exacerbate malaria severity, and young children from rural areas are the most affected [21].

Most research on parasitic disease-related morbidity focused on single species infections, while the health impact of polyparasitism remains poorly understood. For coun-
tries like Nigeria, where polyparasitism is still widespread, a deeper mechanistic understanding of multiple species parasite infections is crucial for disease control and reducing the burden of these (co-) infections. Hence, this study was conducted to identify human parasite co-infection and highlight the need for prevention.

2. MATERIALS AND METHODS

2.1 Study Area

The study area was Ajebamidele in Ife-South Local Government Area of Osun State, Nigeria. Ajebamidele is about 50km from Ifetedo, the local government’s headquarters. It is located in the rainforest zone between latitude 40341 and 40361E and Longitude 70561 and 70581N, with a population of about 1,268. The area is rural and lacks basic amenities such as good roads, standard hospitals and adequate refuse and sewage disposal facilities. There is a river which serves as a source of water for bathing and other domestic activities. Members of the community are predominantly farmers.

2.2 Ethics statement

Ethical approval was sought and obtained from the Osun State University Health Research Ethics Committee. Verbal consent of the guardian of participants below age eighteen was sought and obtained. The parasitological survey was preceded by a pre-survey contact, during which permission was obtained from the Director of the Primary Health Centre of the Local Government and the paramount ruler of the village.

2.3 Sample collection

The village head assisted in mobilising his subjects. Information on each individual was obtained using well-structured questionnaires. Information like: age, sex, occupation, clinical symptoms, history of treatment with mectizan, and duration of stay within the village was obtained. Venous blood samples, stool and skin snips were collected from consenting residents aged 5 to 80 years.

2.4 Parasitological Survey

Detection and quantification of malaria parasites: Blood samples were collected by finger prick to determine *P. falciparum* parasitemia. Thick blood films were prepared, air dried, Giemsa-stained, and observed under the microscope to identify and quantify malaria parasites. Malaria parasites were counted against 200 leukocytes, and counts were expressed as the number of parasites per microliter of blood, assuming an average leukocyte count of 8,000 cells/μl of blood.

Detection and quantification of helminths: Clean plastic containers were distributed for stool collection, and instructions were given for proper collection. Kato-Katz’s thick smear technique was used to determine helminths ova quantitatively. Stool samples were processed within 12 hours of collection and examined microscopically. The intensity of infection was expressed as the number of eggs per gram of faeces (EPG).

Detection and quantification of microfilariae: The blood sample was collected between 10.00 and 16.00 hours from each subject who gave their informed consent and used to make a thick smear. The smears were then stained with haematoxylin, and microscopic examinations of slides were done. Microfilariae were identified based on the specific morphological features described by Cheesbrough [22]. The prevalence of microfilaraemia was determined, and the intensity of infection was expressed as mg/mL. Blood sampling for the presence of *W. bancrofti* in the study area was also carried out, in which blood samples were collected in the night between 21:00 and 02:00. Microscopic examinations of thick blood smears were done. No microfilarae was observed at night.

Skin snip examination for Onchocerca volvulus: Bloodless skin biopsies were taken from each study participant under aseptic conditions using a disposable sterile prick- ing needle and a razor blade. Skin snips were then separately placed in flat-bottomed microtiter plate wells filled with 100μl of physiological saline and left at room temperature for 30 minutes, and 24 h for those negative at 30 minutes as recommended by the OCP. The identity of each participant was labelled on each microtitration plate. The entire content in an individual well was transferred onto a microscopic slide. The emerged microfilariae were counted under a 10x microscope objective.

2.5 Determination of packed cell volume

For packed cell volume (PCV, %), microhematocrit tubes filled with blood were centrifuged in a microhematocrit rotor for 5 min at 10,000g. PCV values ≤31% were considered anemia, which was further classified as mild (21–30%), moderate (15–20%), or severe (≤15%).

2.6 Data analysis

Data were entered into a Microsoft Excel spreadsheet and exported to IBM SPSS (version 26) (IBM Corp. Released 2019. IBM SPSS Statistics for Windows, Version 26.0. Armonk, NY: IBM Corp) for analysis. Statistical significance for all analyses was determined at a 5% level of
significance. Frequencies and percentages were calculated to show the distribution pattern of multiple parasites and single parasitic infections in the study area. Chi-squared test was used to test the effect of age and sex on the prevalence of parasitic infection. Due to some observations in the contingency table that are less than 5, Fisher’s exact test was employed to test the association between PCV and the parasites. The relative risk (RR) of co-infection was also calculated. The mean PCV of the infections was plotted to show their prevalence in the study area.

3. RESULTS

Table 2 Of the 247 participants (118 males and 128 females), the mean age was 35.64 ± 22.83, while the mean packed cell volume (PCV) was 40.03 ± 5.84. *Plasmodium falciparum* + *Ascaris lumbricoides* (15%) was the most prevalent co-infection in the study area, followed by *Plasmodium falciparum* + *Onchocerca volvulus* (13%), then *Plasmodium falciparum* + Hookworm (10.5%), *A.lumbricoides* + Hookworm (8.1%), *A. lumbricoides* + *O. volvulus* (7.3%), Hookworm + *O. volvulus* (6.5%), and the least was both *Plasmodium falciparum* + *Loa loa* (1.2%) and Hookworm + *Loa loa* (1.2%) (Table1).

<table>
<thead>
<tr>
<th>TABLE 1: Distribution Pattern of Multiple Parasites among the study area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parasites</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td><em>P. falciparum</em> + <em>A. lumbricoides</em></td>
</tr>
<tr>
<td><em>P. falciparum</em> + Hookworm</td>
</tr>
<tr>
<td><em>P. falciparum</em> + <em>O. volvulus</em></td>
</tr>
<tr>
<td><em>P. falciparum</em> + <em>Loa loa</em></td>
</tr>
<tr>
<td><em>A. lumbricoides</em> + Hookworm</td>
</tr>
<tr>
<td><em>A. lumbricoides</em> + <em>O. volvulus</em></td>
</tr>
<tr>
<td><em>A. lumbricoides</em> + <em>Loa loa</em></td>
</tr>
<tr>
<td>Hookworm + <em>O. volvulus</em></td>
</tr>
<tr>
<td>Hookworm + <em>Loa loa</em></td>
</tr>
</tbody>
</table>

The prevalence of *Plasmodium falciparum* (55.9%) was the highest among the parasites found from the collected samples, followed by *Ascaris lumbricoides* (26.3%), *Onchocerca volvulus* (23.5%) and Hookworm (19.4%), the least prevalent was *Loa loa* (4.5%). The distribution patterns of the single parasitic infections among the study population were not statistically significant. (Table2).

The prevalence rate of each parasite among rural communities by sex is shown in Table 3. *Onchocerca volvulus* shows high prevalence in male subjects (50.8%) than in the female counterparts (29.7%), and the difference was statistically significant (p=0.028). The other parasites recorded in the study showed high prevalence in female subjects than in their male counterparts, and there is no statistical difference between the sexes.

Table 4 shows the overall prevalence of each parasite among the rural populace by age *A. lumbricoides* show the highest prevalence among the age group 1-20 (34.5%), and *P. falciparum* showed the high prevalence among the age group 61-80 (63.6%), *O. volvulus* showed high prevalence among the age group 61-80 (33.3%) while *Loa loa* gave the high prevalence of 7.5% among the age group 61-80 and Hookworm showed high prevalence among the age group 41-60 (24.5%). The relationship is not statistically significant.

Table 5 shows the association between the packed cell volume (PCV) and the parasites. The study participants' mean packed cell volume (PCV) was 40.03, with a standard deviation of 5.84. *Plasmodium falciparum* (62.3%) and hookworm (62.5%) infected subjects were found to have low PCV. Similarly, low PCV was observed in malaria and hookworm co-infected subjects (76.9%) and *P. falciparum* and *Ascaris lumbricoides* co-infected subjects (62.2%). The association between PCV and parasites were not statistically significant since the p-value is greater than 0.05

The association between *Plasmodium falciparum* and helminthic infection among the study population is shown in Table 6. The prevalence of *Ascaris lumbricoides* was slightly higher in *P. falciparum* positive subjects (26.8%) than in *P. falciparum* negative subjects (25.7%). Also, the prevalence of hookworm was higher in *P. falciparum* positive subjects (21.0%) than in *P. falciparum* negative subjects (17.4%). In the case of *Onchocerca volvulus* and *Loa loa*, prevalence rates were higher in *P. falciparum* negative subjects than in *P. falciparum* positive subjects. The association was not statistically significant (P > 0.05). Subjects infected with *Onchocerca volvulus* were almost approximately one time (RR=0.964) as likely to be infected with *P. falciparum* as those with no *O. volvulus* infection. Subjects with *Ascaris lumbricoides* (RR= 1.060) were also likely to be
Table 3: The overall prevalence of each parasite by sex among the rural community

<table>
<thead>
<tr>
<th>Sex</th>
<th>No Examined</th>
<th>No infected with Ascaris (%)</th>
<th>No infected with Hookworm (%)</th>
<th>No infected with P. falciparum (%)</th>
<th>No infected with O. volvulus (%)</th>
<th>No infected with Loa loa (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>118</td>
<td>29 (24.6)</td>
<td>23 (19.5)</td>
<td>60 (50.8)</td>
<td>35 (29.7)</td>
<td>4 (3.4)</td>
</tr>
<tr>
<td>Female</td>
<td>129</td>
<td>36 (27.5)</td>
<td>25 (19.4)</td>
<td>78 (60.5)</td>
<td>23 (17.8)</td>
<td>7 (5.4)</td>
</tr>
<tr>
<td>Total</td>
<td>247</td>
<td>65 (26.3)</td>
<td>48 (19.4)</td>
<td>138 (55.9)</td>
<td>58 (23.5)</td>
<td>11 (4.5)</td>
</tr>
<tr>
<td>p-value</td>
<td></td>
<td>0.553</td>
<td>0.982</td>
<td>0.128</td>
<td>0.028</td>
<td>0.438</td>
</tr>
</tbody>
</table>

Table 4: The overall prevalence of each parasite by age

<table>
<thead>
<tr>
<th>No Examined</th>
<th>A. lumbricoides (%)</th>
<th>Hookworm (%)</th>
<th>P. falciparum (%)</th>
<th>O. volvulus (%)</th>
<th>Loa loa (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-20</td>
<td>84</td>
<td>29 (34.5)</td>
<td>16 (19.0)</td>
<td>42 (50.0)</td>
<td>20 (23.8)</td>
</tr>
<tr>
<td>21-40</td>
<td>77</td>
<td>15 (19.5)</td>
<td>12 (15.6)</td>
<td>45 (58.4)</td>
<td>19 (24.7)</td>
</tr>
<tr>
<td>41-60</td>
<td>53</td>
<td>10 (18.5)</td>
<td>13 (24.5)</td>
<td>30 (56.6)</td>
<td>8 (15.1)</td>
</tr>
<tr>
<td>61-80</td>
<td>33</td>
<td>11 (33.3)</td>
<td>7 (21.2)</td>
<td>21 (63.6)</td>
<td>11 (33.3)</td>
</tr>
<tr>
<td>Total</td>
<td>247</td>
<td>65 (26.5)</td>
<td>48 (19.4)</td>
<td>138 (55.9)</td>
<td>58 (23.5)</td>
</tr>
<tr>
<td>P-value</td>
<td>0.068</td>
<td>0.068</td>
<td>0.641</td>
<td>0.409</td>
<td>0.538</td>
</tr>
</tbody>
</table>

Table 5: Associations between PCV and Parasites

<table>
<thead>
<tr>
<th>PCV (%)</th>
<th>No infected with P. falciparum</th>
<th>No infected with Ascaris</th>
<th>No infected with Hookworm</th>
<th>No infected with P. falciparum + Hookworm</th>
<th>No infected with P. falciparum + Ascaris</th>
</tr>
</thead>
<tbody>
<tr>
<td>21-30</td>
<td>7 (5.1)</td>
<td>1 (1.5)</td>
<td>1 (2.1)</td>
<td>1 (3.8)</td>
<td>1 (2.7)</td>
</tr>
<tr>
<td>31-40</td>
<td>86 (62.3)</td>
<td>38 (58.5)</td>
<td>30 (62.5)</td>
<td>20 (76.9)</td>
<td>23 (62.2)</td>
</tr>
<tr>
<td>41-50</td>
<td>40 (29.0)</td>
<td>22 (33.8)</td>
<td>16 (33.5)</td>
<td>5 (19.2)</td>
<td>10 (27.0)</td>
</tr>
<tr>
<td>&gt;50</td>
<td>40 (29.0)</td>
<td>22 (33.8)</td>
<td>16 (33.5)</td>
<td>5 (19.2)</td>
<td>10 (27.0)</td>
</tr>
<tr>
<td>P-value</td>
<td>0.121</td>
<td>0.778</td>
<td>0.679</td>
<td>0.224</td>
<td>0.794</td>
</tr>
</tbody>
</table>

Table 6: Association between P. falciparum and helminths infections among the study subjects

<table>
<thead>
<tr>
<th>Helminth</th>
<th>P. falciparum</th>
<th>RR</th>
<th>CI</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. lumbricoides</td>
<td>28 (25.7)</td>
<td>37 (26.8)</td>
<td>1.060</td>
<td>0.598-1.877</td>
</tr>
<tr>
<td>Hookworm</td>
<td>19 (17.4)</td>
<td>29 (24.5)</td>
<td>1.260</td>
<td>0.663-2.396</td>
</tr>
<tr>
<td>O. volvulus</td>
<td>26 (23.9)</td>
<td>32 (23.2)</td>
<td>0.964</td>
<td>0.533-1.742</td>
</tr>
<tr>
<td>Loa loa</td>
<td>8 (7.3)</td>
<td>2 (2.2)</td>
<td>0.281</td>
<td>0.073-1.084</td>
</tr>
</tbody>
</table>

Table 6: Association between P. falciparum and helminths infections among the study subjects

Figure 1 shows the mean PCV value of all the subjects. Subjects infected with *Onchocerca volvulus* have the highest mean PCV of 41%, followed by subjects with no infection 40.4%, subjects with *Ascaris lumbricoides* 40.3%, *Loa loa* 40.1%, *P. falciparum* and Hookworm subjects show lowest mean PCV of 39.5% and 39.6% respectively.

Figure 1: Mean PCV of the study participants
4. DISCUSSION

Malaria, STH and filariasis are among the Neglected Tropical Diseases (NTDs) responsible for major public health problems, particularly in Sub-Saharan Africa, where their occurrence as multiple species infections is regarded as a norm. Understanding the epidemiology and impact of these infections within the community is essential in policy makers' design and implementation of control strategies. Results from this study demonstrated that malaria, soil-transmitted helminths and filarial infections are still prevalent in some rural communities of Osun State, Nigeria and co-infections of these parasites are common.

The prevalence of *P. falciparum* parasitaemia was 55.9%. The high prevalence of asymptomatic malaria recorded in the study confirms previous reports that malaria is hyperendemic in Osun State [23]. It was previously observed that the majority of individuals infected with malaria parasites living in endemic regions do not show symptoms of this disease [24]. The high prevalence of malaria parasites could be a reflection of the poor socio-economic condition of the study area, which promotes the transmission of malaria, especially during the rainy season. Brooker and Micheal [25] had observed that *P. falciparum* is holo-endemic with year-round transmission and peak morbidity in the summer following the significant period of rains. The prevalence of *P. falciparum* was higher in females than males but was not statistically significant.

Like malaria, soil-transmitted helminths are highly prevalent in rural communities due to poor sanitary conditions prevailing in most of these areas. This study recorded 26.3% prevalence for *A. lumbricoides* and 19.4% hookworm prevalence, and they were the only soil-transmitted helminths observed. In earlier studies in Osun State, the prevalence of these two helminths was similar to the result obtained elsewhere [23, 26, 27]. The lower prevalence recorded in this study might reflect the increased awareness and improved sanitary conditions brought about by urbanisation.

Co-infection of *P. falciparum*, hookworm, *A. lumbricoides, O. volvulus* and L. loa were prevalent in the study area. A similar type of co-infections of malaria and intestinal helminths have been reported in North-western Tanzania [28] and other countries in Sub-Saharan Africa [29, 30] as well as Kajola in Osun state Nigeria [21]. Unlike in this study, where *P. falciparum + A. lumbricoides* and *P. falciparum + O. volvulus* were the most prevalent co-infection, in the Mvomero district, Tanzania, and *P. falciparum + W. bancrofti* were the most prevalent type of co-infection among the study populace [31]. This difference may result from the difference in the endemicity level of the parasites in the respective areas. The findings of this and other studies indicate that in most communities in Sub-Saharan Africa, multiple parasitic infections occur in the same geographical area [32]. It is therefore not uncommon that a considerable proportion of the population is polyparasitized with one or more intestinal helminths, malaria and filarial parasites.

Malaria-helminth co-infections are known to substantially impact children's physical health and social and intellectual development [33]. However, very little is known of their impact on the immunological response among infected individuals [34]. Studies using animal models suggest that helminth infections may increase susceptibility to malaria [35, 36], and therefore, helminth infection may adversely affect malaria intervention strategies [37]. Nonetheless, epidemiological studies have been limited and contradictory [38]. For instance, a recent study among residents of Kenya indicates no evidence that infection with gastrointestinal helminths increases susceptibility to *P. falciparum* malaria [39]. The high prevalence of *P. falciparum + O. volvulus* in the study area is likely to be attributed to the abundance of the mosquito vector (*Anopheles gambiae*) and *Simulium damnosum*[40].

In this study, it was observed that subjects with *Ascaris lumbricoides* (RR= 1.060) were also likely to be infected with *Plasmodium falciparum* as compared with uninfected subjects. This agreed with the work reported by Ojurongbe et al. [21], where *A. lumbricoides* infections were almost two times as likely to have *P. falciparum* infection as subjects without *A. lumbricoides* infection. The mechanism behind this association is not clearly understood. Still, it could be that the Th2 profile associated with immunoglobulin E production seen in Ascaris infection may down-modulate Th1 antimalarial immune responses, resulting in an increased risk of malaria infection [41]. There are, however, conflicting reports on how helminth infection affects malarial infection and vice versa. A similar association was previously observed among a cohort of pregnant women in Ghana. In Uganda, geo-helminth-positive children tended to be parasitaemic but were not statistically significant [42].

Anaemia is one of the most widespread health conditions afflicting individuals living in the tropics. It contributes to 23% of nutrition-related associated with impairments
in physical growth, cognition and school performance [43]. Although the aetiologies of anaemia is complex and multifactorial in origin, parasitic infections, including Plasmodium falciparum and hookworm, have reportedly played a role in contributing to anaemia in endemic areas [44]. However, relatively low hematocrit mean values were observed in subjects infected with Plasmodium falciparum and Hookworm. The non-anaemic stature of the infected individuals may be attributed to the feeding habit of the people in the studied area since they feed on fresh vegetables and fruits, which prevent them from being anaemic despite the fact that they were infected with malaria and hookworm.

The study has shown a prevalence rate of 23.5% for Onchocerca volvulus and 4.1% for Loa loa. The prevalence rate of Onchocerca volvulus was more pronounced in the study area than Loa loa and is far less than what was reported by other researchers [45, 46]. The low prevalence could be due to the control efforts already put in place in most of the states and local government areas across the nation since most subjects have been treated with mebendazol. Also, the low prevalence rate of Onchocerca volvulus could be due to the difference in a geographical location in the study area. The classification levels of onchocerciasis programmed according to McMahon et al. [47] are sporadic (<10%), hypoendemic (10-29%), mesoendemic (30-59%) and hyperendemic (64%). Therefore, based on the classification, the prevalence rate of 23.5% is deemed to be classified as hypodermic.

In conclusion, the results reveal that poly-parasitism exists in rural communities of Osun State, Nigeria. This point to the fact that epidemiological factors that enhance the susceptibility of individuals to multiple parasitic infections are still in existence in these communities. There are several adequate controls for improving or eradicating the menace of poly-parasitism, such as counseling mothers at clinics, health inspectors setting standards of hygiene, promoting better hygiene practices in schools and villages, budgeting to ensure that adequate resources are available for the building and maintenance of latrines within the rural communities and regular drug distribution to the affected villagers. Promising new alternative malaria control strategies are intermittent preventive treatment and the use of insecticide-treated nets regularly.

Acknowledgements

We express our gratitude to Osun State Ministry of Health for the permission and cooperation. In addition, the authors are sincerely grateful to all consenting participants and parents of participants for their co-operation.

Declaration of Conflict of Interest

The authors declare no conflict of interest.

Authors’ contributions

AAA participated in the collection of the sample, analysis of the sample and manuscript preparation. TAO participated in the study design and statistical analysis. FJO and SAA participated in the collection of the sample and analysis of the sample. OO designed and supervised the entire work. All authors read and approved the final manuscript.

REFERENCES

10. Akoniyon OP, Adewumi TS, Maharaj L, Oyegoke OO,
Akindele et al Pan African Journal of Life Sciences (2022); 6(2): 477-485


47. McMahon JE, Sowa SC, Maude GH, Hudson CM, Kirkwood BR. Epidemiological studies of onchocerciasis in forest villages of Sierra Leone. Tropical Medicine and Parasitology: Official Organ of Deutsche Tropenmedizinische Gesellschaft and of Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ). 1988 Sep 1;39