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Impact of Helminth Co-Infections on Clinical Malaria Severity Among Febrile School-Age Children: A Study from Mvomero, Tanzania

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Abstract

Helminths may influence clinical malaria severity. The current study examined the impact of helminth infections on malaria severity among children in Mvomero, Tanzania. This was a hospital-based cross-sectional study conducted from 2018-2019. Blood, stool and urine specimens from febrile subjects attending four health facilities in Mvomero were examined for malaria and helminth infection. Overall, 326 febrile children were enrolled. The range and mean ages were 5-17 and 10.2 years, respectively. Of 326 children, 46.8% (n = 153) had *Plasmodium falciparum* malaria, with prevalence being higher in males than females (p = 0.03). Among positive *P. falciparum* -infected children, 59.5% had malaria alone, and 40.5% were co-infected with helminths. *Schistosoma haematobium* was the most common parasite in malaria-positive children (p = 0.04), with the highest prevalence amongst the 11-13-year-olds (18.3%, p = 0.02). The prevalence of anemia among malaria malaria-positive individuals was 28%. Anemia was more common in children between 8 -10-year-old (p = 0.013). Malaria-positive children co-infected with hookworm and *haematobium* exhibited a reduced mean Hb concentration and an increased *P. falciparum* parasitaemia (p < 0.05). To conclude, co-infection with hookworm and schistosoma increases the severity of clinical malaria. An integrated malaria and helminth management strategy for all individuals in Mvomero is crucial.

Keywords: Clinical malaria; helminths-coinfection; anemia; hookoworms; *Schistosoma hematobium*; *Ascaris lubricoides*

Introduction

In the past 15 to 20 years, the World Health Organization has recorded a global decrease in malaria-attributed death, mortality and incidence (WHO 2021). This reduction in death due to malaria has been attributed to the scale-up of malaria intervention, including Insecticide Treated Nets (ITN) and effective malaria treatment. The nationwide distribution of long insecticide-treated nets ITN through mass replacement campaigns has decreased malaria incidence and transmission in Tanzania (Bhatt et al. 2015, WHO 2020, Koenker et al. 2022, URT and NBS 2022). However, since 2020, there has been a remarkable increase in the incidence and malaria-attributable mortality, particularly in Sub-Saharan Africa (WHO 2020). Studies show that the malaria burden is concentrated in the segment of the population where poverty is at the greatest (Wafula et al. 2023) and where utilization of LINs is lower than the target set by National and Global Malaria control initiatives, as well as poor access to care (Khatib et al. 2018). According to Mboma et al. (2018), by 2013, only 20 % of the households in Tanzania had enough nets for each family member, and only 40% used

ITNs. Accordingly, recentNational surveys suggest that malaria prevalence in Tanzania has increased from 9.2% in 2011/2012 to 14.4% in 2015/2016 (Mboma et al. 2018, URT-NBS, 2017),contributing to 5% of the global malaria burden (WHO 2022). One significant contributing factor to this rebound could be the prevalence of insecticide resistance, malaria vector behavioural change (Matiya et al. 2019), and poor utilization of ITNs. Recent data suggest that both *Anopheles gambiae* and *An. fenustus* are the most important malaria vectors. Apart from biting outdoors, *An. fenustus* has demonstrated resistance to pyrethroids, resulting in residual malaria transmission (Killeen and Ranson, 2018, Msugupakulya et al. 2020, Tungu et al. 2023).

Residual malaria transmission may change the epidemiology of malaria in endemic areas in Tanzania, including Mvomero. For instance, Khatib et al. (2018) reported changing malaria risks in endemic areas, demonstrating shifting malaria incidence to older children. Recent studies in Mvomero by Rumisha 2019 reported a clinical malaria prevalence of 34%, with a high infection rate attributed to school children aged 6-9 years. In addition, the high prevalence rate of asymptomatic malaria among the 11-13 years of age group (Kisiringo and Kidima 2020) and anemia, mild (28%) and severe (4.5 %) among children aged 10 -15 years (Rumisha et al. 2019) has been reported in the same area. Fewer studies have investigated the determinants of anemia among individuals in endemic areas, limiting the development of effective interventions that address context-specific causes of anemia and subsequent monitoring of anemia control programs. Anemia is a common cause of stunting (Wang et al., 2020), impaired cognitive development (Ssemata et al. 2020) and mortality among children in many parts of the world, including Tanzania. Surveys such as those conducted by Kisiringo and Kidima (2020) showed a high helminth infection rate among school-going children in Mvomero. However, the impact of parasite infection on the prevalence of anemia is understudied, particularly for symptomatic malaria-helminth co-infection among school-aged children in Mvomero. In addition, the current age distribution pattern of clinical malaria and clinical manifestation of severe malaria among school-going children has not been established. This study sought to investigate the current age pattern of clinical malaria and establish the relationship between *P. falciparum* malaria parasitaemia and helminth infection on the burden and prevalence of anemia among school-going children in Mvomero. Understanding the variation in the clinical manifestation of severe malaria by age and establishing the role of parasitic helminth infection on anemia is essential in planning and implementing effective control strategies targeting anemia, the most critical clinical condition among school-age children in malaria-endemic areas.

Materials and Methods

Study area and population

This study was conducted in the Mvomero district, located between 6–7°Sand 37–38°E in central eastern Tanzania (Figure 1). This study area lies in the Wami River, characterized by wetlands, temporary rain puddles, and paddy and sugar cane irrigation schemes, which are suitable habitats for vectors for malaria and schistosomiasis (Rumisha et al. 2019). Moreover, as in other parts of the country, Mvomero is also endemic to Soil-Transmitted Helminths (Mboera et al. 2011). Four health centres serving five villages near the wetlands or irrigation schemes were selected to investigate clinical malaria in children with *P. falciparum* helminths co-infection (double infection). The selected health centres include Chazi, Mtibwa Sugar Estate, and Turiani.

Study design and sampling

This hospital-based cross-sectional study was conducted from 2018 to 2019. It was designed to enrol febrile school-aged children who are in health centres. Furthermore, children showing severe malaria were included. Severe malaria in this study was defined as malaria associated with signs of vital organ dysfunction and severe syndromes such as shock, severe body weakness, and convulsion (Mohapatra 2009). Inclusion criteria included febrile school-aged children

attending the hospital whose parents /guardians had consented and who had assented to be enrolled. Individuals with a history of diabetes, chronic liver diseases, autoimmune diseases, sickle cell anemia, and urinary infection were excluded from the study.

Clinical and socio-demographic data collection

Trained clinicians of the selected health centre recorded demographic information, including age and gender, through questionnaires. The clinical diagnosis was also performed by trained physicians who assessed variables associated with clinical malaria among school-aged children who attended health facilities. Such variables of clinical malaria include body temperature, convulsion, vomiting, haemoglobin (Hb) concentration, severe body weakness and diarrhoea.

Biological sample collection and processing for parasite and haemoglobin level detection

A total of 150 µL of finger prick blood was collected, 50µL each for Malaria Rapid Diagnostic Test (mRDT), microscopic slide and Hb levels. The mRDT were performed using SD Bioline malaria *P. falciparum* antigen dipstick (HRP2/pLDH-German) to detect the presence of malaria parasite antigen. On the other hand, the thick blood smear and observation using a microscope were done to identify malaria parasite and their quantification. Malaria parasites were quantified by counting the number of malaria parasites against 200 leukocytes (WHO 2015, Cheesbrough 2005).

For STH and schistosomiasis diagnosis, stool and urine samples were collected into special plastic vials. The membrane filtration technique was used to determine the presence of intensities of *S. haematobium* in urine samples from positive malaria children. The presence and intensity of helminth infection in stool samples were analyzed by the Mac Master counter method as described by (Cheesbrough 2005, Levecke et al. 2011). Haemoglobin concentration was determined using a portable haemoglobin spectrophotometer, and haemoglobin values were used to assess anemia status. Anemia was defined based on WHO guidelines (WHO 2011) using age cut-off thresholds. Additionally, the school-aged children were further categorized into early and late sub-groups within major age groups to capture subtle variations between groups. Young school-age children were divided into early (5-7 years) and late (8-10 years) sub-groups; likewise, adolescents were divided into early (11-13 years) and late (14-17 years) sub-groups.

Ethical consideration

The Institutional Review Board (Research Ethics Committee (UDSM-REC) approved the study, certificate No UDSM-REC/2018/02 of the University of Dar es Salam. The study was also approved by regional and district government authorities. Before data collection, consent and assent were sought from parents/guardians and children, respectively.

Data analysis

Data were entered into Microsoft Excel spreadsheets, checked for entry errors, and analyzed by using the IBM-Stastical Package for Social Sciences. Descriptive statistics was used to summarise independent and dependent variables. Multivariate logistic regression assessed the associations between parasites and associated risk factors, while proportions for categorical variables were compared using a chi-square test. Odds Ratios (OR) were used to show the strength of associations between determinants and burden of co-infection of schistosomiasis, malaria and soil helminths. Regression analysis analyzes the association between the intensity of the parasite and the severity of malaria, as well as between the type of species and the severity of a disease. For continued data, each sample's arithmetic mean of parasite intensity was calculated using the Montresor et al. (1998) formula. i.e.

Arithmetic mean = $\sum epg/n$. Where $\sum epg$ = Sum of individual *epg*, n = the number of subjects investigated. *P*-values less than 0.05 were considered statistically significant.

Results

Characteristics of the study population

Three hundred twenty-six 326 febrile school aged children between 5 and 17 years were recruited from four health facilities serving Kigugu, Mbogo, Komtonga, Turiani, Mkindo Mnazi mmoja, Kiwandani, Kunke, Kaole, Kisale and district council the Mvomero district from 2018 to 2019. This included the following health centres: Chazi, Mtibwa Sugar Estate andTuriani Hospital (Bwagala) were selected. Of the 326 Children recruited, 56.4% (n = 184) were boys and 43.6% (n =142) were girls. The mean age of children was 10.2 years (SD = 3.4); the mean body temperature was (38.0^{o}C, SD = 1.7). The majority of malaria-positive children significantly presented high fever (p = 0.022) and body weakness (p = 0.041), whereas few individuals presented with convulsion, vomiting and diarrhea (Table 1).

Table 1: Demographic Characteristics of *P. falciparum* malaria-positive children

Characteristic	Category	Total
Age	5 -7 yrs.	57
	8 - 10 yrs.	43
	11 - 13 yrs.	24
	14 - 17 yrs.	29
Sex		
	Female	64
	Male	89
	Total	153
Body temp.		
	37.5-38.0^{o}c	99
	≥ 38.5^{o}c	54

Prevalence of *P. falciparum* malaria and helminth infection among children attending different hospitals in Mvomero from 2018 to 2019

A total of 46.9% (n =153) of children recruited were positive for *Plasmodium falciparum*. The *P.falciparum*-infected children were predominantly males (58.2%) than females (41.8%) (p = 0.03). Among the *P.falciparum*-infected children, 59.5% (n = 91) had malaria alone, and 40.5% (n = 62) were co-infected with helminths. *Schistosoma haematobium* was the most prevalent parasite among *P. falciparum*-positive children (p = 0.04, Table 2). The prevalence of *S. haematobium* was higher among children of the 11 - 13 age group than in any other age group (p = 0.02, Table 2)**.** The infection rates were higher in boys than girls, although the difference was insignificant (p = 0.09). Among the STH, hookworm was the most prevalent (p = 0.043). The children aged 8 - 10 years were highly infected with hookworm. Girls had a higher prevalence of hookworm infection than boys, although the difference was not statistically significant (χ^2 = 11.6; p = 0.07, Table 2).

Table 2: Overall prevalence of *P. falciparum* malaria- helminth co-infection

Infection type	**N (%)**
Clinical malaria alone	91 (59.5)
Malaria and S. haematobium	28(18.3)
Malaria and hookworm	23(15)
Malaria and A. lumbricoides	11(7.2)
Total	**153 (100)**
Clinical symptoms of *P. falciparum* malaria-infected children	
Fever	65%

Vomiting	23%
Convulsion	4%
Diarrhea	17%
Body weakness	36%

Prevalence of anemia among children with clinical malaria

The overall prevalence of anemia (Hb conc < 6.9 g/dl) among children with clinical malaria was 28% (n = 43). The mean haemoglobin concentration of symptomatic *P. falciparum*-positive malaria in children was 9.2g/dl. Haemoglobin concentration significantly decreased with increasing age for malaria-positive children (p= 0.03). The rate of severe anemia (Hb conc < 7.0 g/dl) among malaria-positive individuals was 7.8% (n = 12), whereas those with moderate anemia (7.0 g/dl< Hb conc < 10 g/dl) were 20.3% (n = 31),. Overall, children aged 8 - 10 years had a higher prevalence of anemia than other age groups among the *P. falciparum*-infected children (χ^2 = 9.45; p = 0.013, Figure 1). Children with *P. falciparum*- helminth co-infection had a higher prevalence of anemia compared to children with *P. falciparum* infection alone (Fig. 2) (χ2 = 16.13; p = 0.04)

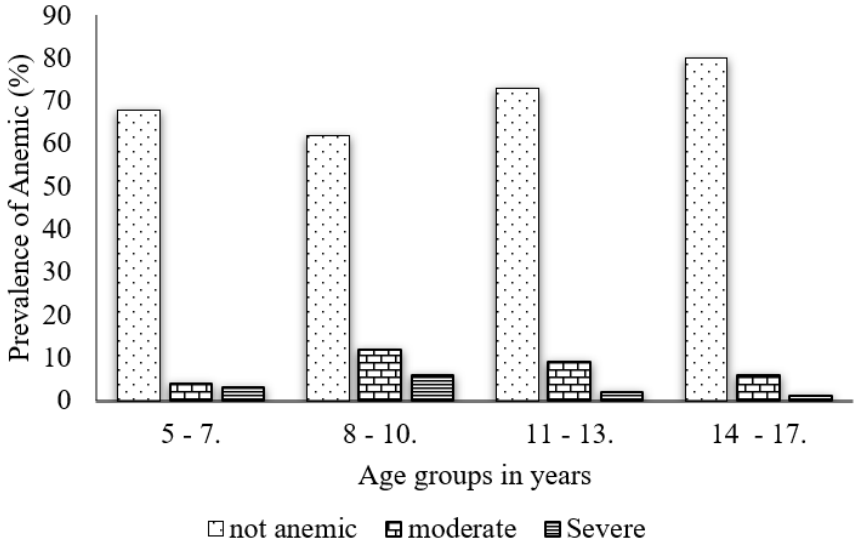

Figure 1: Prevalence of anemia among different age groups of *P. falciparum infected* children in Mvomero (n = 153)

Helminth co-infection accelerates *P . falciparum* parasitaemia in individuals with symptomatic malaria

A higher mean of *P. falciparum* parasite density was observed in children aged between 8 - 10 years that were *P. falciparum* positive. This observation coincides with a higher mean of *S. haematobium* and *hookworm* densities among the same age group (8 - 10 years of age (Table 6).

Although all individuals with *P. falciparum* malaria co-infected with helminth infection harboured light helminth infection (1 - 1999 epg for hookworm, 1-4999 epg for *A. lumbricoides* and 1-49 egg/10ml for *S. haematobium*)therae was an association between helminth intensity and mean *P. falciparum* density and lower mean haemoglobin concentrations (p = 0.021 and p = 0.034, respectively, Figure 2, Table 4 and 6).

Table 3: Association between type of infection and malaria parasitaemia in children with clinical malaria

Parasites			***Severity of malaria***		
P. falciparum alone	Covariate	Category	Malaria parasite density (parasites/µl)	Adjusted OR(95%Cl)	P-value
			3584	1	
	Age (years)	5-7	3976	0.8(0.5-2.6)	0.07
		8-10	**4574**	**1.6(1.2-4.8)**	**0.04**
		11-13	3657	0.9(0.6-1.8)	0.16
		14-17	3475	0.6(0.3-1.2)	0.09
	Sex		3953	1	
		Female	4173	0.6(0.4-1.4)	0.06
		Male	3223	0.9(0.6-1.5)	0.84
P. falciparum + S. haematobium	Age (years)		3998	1	
		5 - 7	4686	0.8(0.5-1.3)	0.6
		8 - 10	**4857**	**1.9(1.3-4.8)**	**0.03**
		11 -13	3885	0.7(0.5-1.6)	
		14-17	3747	0.8(0.5-2.4)	
	Sex		4185	1	
		Female	4885	0.7(0.4-1.8)	0.07
		Male	4672	0.9(0.6-2.5)	
P. falciparum+ hookworm	Age (years)		4579	1	
		5 -7 .	4789	0.9(0.4-2.4)	0.08
		8- 10	**4942**	**2.3(1.4-5.8)**	**0.01**
		11- 13	3966	0.9(0.6-2.5)	0.4
		14 -17	3832	0.8 (0.4-1.8)	0.6
	Sex		4161	1	
		Female	**4486**	**1.6(1.1-3.6)**	**0.03**
		Male	3974	0.8(0.5-1.9)	0.07
P. falciparum+ A. lumbricoides	Age(years)		3545	1	
		5 - 7	3589	0.5(0.3-1.7)	0.8
		8 - 10	3893	1.1(0.9-4.5)	0.06
		11 -13	3474	0.8(0.4-1.9)	0.12
		14 -17	3287	1.3(0.8-1.8)	0.08
	Sex		3863	1	
		Female	3995	1.2(0.9-4.6)	0.07
		Male	3783	0.9(0.6-1.8)	0.062

Children co-infected with *P. falciparum* and helminth had significantly higher mean *P. falciparum* density compared to children infected with malaria alone (t = 8.3, p = 0.04, Table 3 and Table 4) In addition, hookwormin fection significantly influenced mean *P. falciparum* densities compared to other helminth parasites (p < 0.001, Table 3). Co-infection with hookworm and *S. haematobium* correlated positively with *P. falciparum* parasitaemia among malaria-positive children (r = 0.96, p = 0.03 and r = 0.72, p = 0.042, respectively). However, co-infection with *A. lumbricoides* showed a medium negative correlation with malaria parasitaemia (r = -0.592; p = 0.042).

***Schistosoma hematobium* and hookworm infection increase the risk of developing severe anemia among children with symptomatic malaria**

In all infection types, children between 8 and 10 years had an increased risk of developing anemiaanemia compared to children in other age groups (adjusted OR = 2.3, 95% Cl 1.4-5.8, p = 0.01) (Table 3 and 4). Children with *P. falciparum* -helminths parasite co-infection had a higher prevalence of anemiaanemia compared to the children with *P. falciparum* alone (χ^2 = 16.13; p = 0.04, Figure 2 and Table 3).

Table: 4: Association between age and Hb level and *P. falciparum* infection among children

	Covariate	Category (yersrs)	Hb (g/dl)	Adjusted OR(95%Cl)	P-value
P. falciparum alone	Age	5-7 yrs.	11.9	1	
		8-10 yrs.	**9.8**	**1.6 (1.2-4.8)**	**0.04**
		11-13 yrs.	11.7	0.9 (0.6-1.8)	0.16
		14-17 yrs.	12.6	0.6 (0.3-1.2)	0.09
	Sex	Male	11.7	1	11.7
		Female	10. 9	0.6 (0.4-1.4)	0.06

Overall, *P.falciparum*-infected children who were co-infected with hookworm and *S. haematobium* had lower mean haemoglobin concentration compared to children infected with *P. falciparum* alone and co-infected with *A. lumbricoides* (t = 4.6, p = 0.04, Table 5). The highest prevalence of severe anemia was observed in children with *P. falciparum* co-infected with *hookworm*. . Children co-infected with hookworm contributed to 50% of children with severe malaria. In addition individuals with hookworm infection were at higher risk (RR = 6.65) of developing severe anemia compared to other helminths infection (p = 0.03, Figure 2). Using multivariate logistic regression analysis to identify predictors of severe anemia in individuals with symptomatic malaria, it was found that *P. falciparum* and hookworm co-infection are significant predictors of anemia (Table 5 and Figure 2).

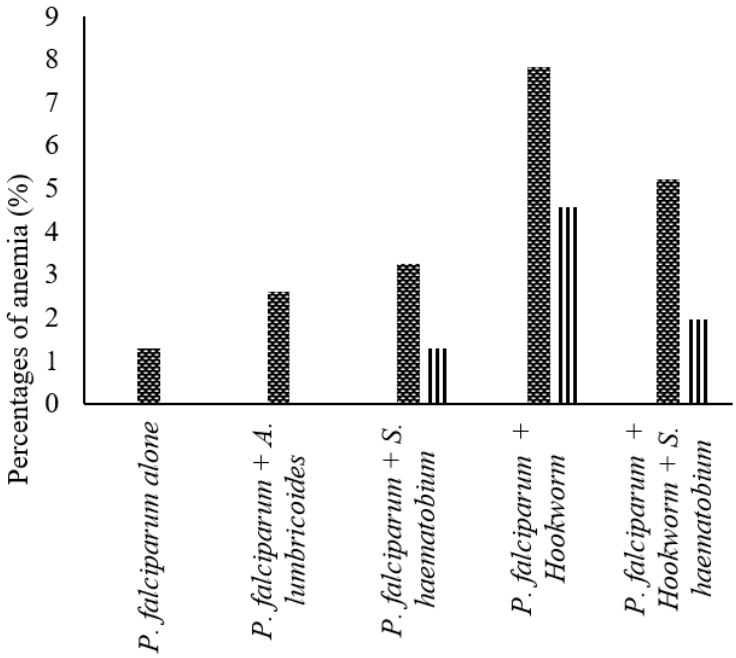

Figure 2: Contribution of helminth infection on the rate of anemia among individuals with symptomatic *P. falciparum* malaria in Mvomero

Table 5: Association between helminth infection and Hb level in children with *P. falciparum* malaria

Parasites			Severity of malaria		
	Covariate	Category	Hb g/dl	Adjusted OR(95%Cl)	P-value
P. falciparum + S. haematobium	Age (years)	5 - 7	10.6	1	0.6
		8 - 10	**8.3**	1.9(1.3-4.8)	**0.03**
		11 -13	10.4	0.7(0.5-1.6)	
		14-17	11.9	0.8(0.5-2.4)	
	Sex	Male	9.5	1	0.07
		Female	8. 8	0.7(0.4-1.8)	
P. falciparum + hookworm	Age(years)	5 -7	8.4	1	
		8- 10	**7.8**	2.3(1.4-5.8)	**0.01**
		11- 13	9.6	0.9(0.6-2.5)	0.4
		14 -17	10.2	0.8 (0.4-1.8)	0.6
	Sex	Male	8.5	1	
		Female	8. 3	1.6(1.1-3.6)	0.03
	Age(years)	5 - 7	11.4	1	

P. falciparum + *A. lumbricoides*		8 - 10	10.4	1.1(0.9-4.5)	0.06
		11 -13	11.5	0.8(0.4-1.9)	0.12
		14 -17	11.7	1.3(0.8-1.8)	0.08
	Sex	Male	10.2	1	
		Female	9. 7	1.2(0.9-4.6)	0.07

Table 6: Association between intensity of helminths and Hb level in children with *P. falciparum*infection

Parasites			**Severity of malaria**			
	Covariate	Category	Parasite Intensity	Hb	Adjusted OR(95%Cl)	**P-value**
			Egg/10ml	**g/dl**		
S. haematobium			24.6	10.6		
	Age (years)	5 - 7	32.7	9.4	1.0	
		8 - 10	**36.8**	**8.3**	**1.7(1.1-3.67)**	**0.03**
		11 - 13	28.5	10.4	0.8(0.5-2.32)	0.09
		14 - 16	25.2	11.9	0.9(0.7-2.84)	0.73
	Sex	Girls	28.9	10.5	1.0	
		Boys	32.4	8.8	1.2(0.8 - 3.2)	0.06
Hookworm			**Egg/gram**			
			647.56	9.8		
	Age (years)	5 - 7	643.56	8.2	1.0	
		8 - 10	**754.62**	**7.8**	**1.8(1.2-4.76)**	**0.018**
		11 - 13	606.48	9.6	1.1(0.9-1.84)	0.36
		14 - 16	555.27	10.2	0.8(0.54-1.8)	0.74
	Sex	Girls	**748.76**	**8.4**	**1.4(1.1-2.94)**	**0.04**
		Boys	584.48	9.4	1.0	
A. lumbricoides	Age (years)		574.57	10.9		
		5 - 7	475.8	11.3	1.0	
		8 - 10	659.27	10.4	0.9(0.4-1.97)	0.08
		11 - 13	587.65	11.5	0.9(0.6-1.76)	0.7
		14 - 16	514.43	11.7	0.67(0.4-1.8)	0.4
	Sex	Girls	517.32	11.4	1.0	
		Boys	693.64	10.2	0.7(0.4-1.95)	0.09

Discussion

This study investigated the role of helminth infection in the severity of clinical malaria in Mvomero. Using a hospital-based study, it is shown that clinical malaria is prevalent among younger below 11 years in Mvomero.These findings contradict with the 2019 Global Malaria Burden Report on malaria in other Sub-Saharan African states, which revealed that malaria cases were highest in children over 12 (Oshagbemi et al. 2023) and in Morogoro, where most infections were in children under five (Aikambe et al. 2020). It is possible that the disparity is related to the different study designs that were used and different malaria endemicity. Additionally, 3 out of 10 children with clinical malaria were anaemic.

Similarly, children aged 9-10 years had higher prevalence of anemia compared to other age groups among *P. falciparum* infected children. The rate of helminth infection among children with clinical malaria in Mvomero is higher, with *S. haematobium* co-infection being the highest among *P. falciparum*-infected individuals. Children with *P. falciparum* –helmith confection had a higher prevalence of anemia than children with *P. falciparum* alone. Overall, *P. falciparum*-infected children co-infected with hookworm and *S. haematobium* had significantly lower mean haemoglobin concentrations than children infected with *P. falciparum* alone or co-infected with *A. lumbricoides.* In this study, children co-infected with hookworm and *P. falciparum* had the highest frequency of severe anemia. The current findings call for an integrated approach to address coexisting parasite infections in endemic settings.

Children between the ages of 8 and 11 were more likely to present with clinical malaria in the current study. This finding is consistent with research by Coulibaly et al. (2021) that showed malaria at-risk groups in endemic areas were shifting to considerably older populations. Other studies indicates that asymptomatic *P. falciparum* cases are more common in children aged 12 years and above (Chacky et al., 2018). Therefore, specific regional malaria control approaches might be required to address changes in disease epidemiology. As noted by Pemberton-Ross et al. (2015) a lower deployment of malaria intervention in the older age group may be the cause of the high prevalence of clinical malaria in children aged 8 to 10. The high level of helminth infection in this group in the current study, which has been repeatedly observed in prior investigations in the same area, is another probable cause (Kisiringyo and Kidima, 2020; Mboera et al. 2011). Helminths infection induces T-helper cell 2 cytokines, which inhibit Th-1 immune responses that are important in cellular-mediated responses against *P. falciparum* infection (Salazar-Castañon et al. 2014). It follows that inhibition of Th-1 cytokines may increase susceptibility to infection and therefore, high *P. falciparum* parasitaemia, which was high among malaria-positive individuals coinfected with helminth infection in our study.

The current study shows children with clinical malaria alone did not experience severe anemia. On the contrary, those coinfected with hookworm and *S. haematobium*, despite being light infections, all have been shown to increase parasitaemia and anemia in all malaria–helminth co-infected children. The high frequency of anemia among clinical malaria-positive children co-infected with the helminth could be due to the effect of pro-inflammatory cytokines released by the host immune cells in response to *P. falciparum* infection, schistosome eggs and schistosomulae (Kotepui et al. 2023). Studies show that *P. falciparum* infection is associated with an increase in proinflammatory cytokines such as TNF-α and IFN-γ (Nasr et al. 2014, Mahittikorn et al. 2022, 2022, Ademola et al. 2023) which are linked to diserythropoiesis (Dumarchey et al. 2022; Thawani et al. 2006). Other potential mechanisms that could explain the association with anemia in individuals with malaria and helminth infection include the destruction of red blood cells (White 2018) intestinal blood loss (Tan et al. 2017) and malnutrition-induced anemia by hookworm infection (Darko et al. 2023).

Although the study has successfully demonstrated that hookworm and *S. haematobium* have an impact on *P. falciparum parasitaemia* and accelerate anemia in individuals with clinical malaria, the scope of this study is limited in terms of the inability to establish the role of nutrition with anemia in individuals in the study; inability to verify the status of helminth infection pathology and therefore immune response phenotype existed among the malaria positive individuals coinfected with helminths. Despite its exploratory nature, this study offers insight into the role of different types of helminths on the prevalence of anemia and malaria parasitaemia in Mvomero. The results has implications for the current helminth control strategies in all areas where helminth and malaria coexist. There is a need for establishment of comprehensive helminth infection treatment and improvements to existing surveillance startergies to eliminate these delibatating infection and, therefore morbidity in endemic areas.

Conclusion

The current hospital based data show that there is high rate of helminth infection among clinical malaria cases in Mvomero. Additionally, clinical malaria cases in Mvomero have shifted to the children aged 8-10 years. The 8-10 old children had high malaria parasite density and at risk of developing anemia. Hookworm and schistosoma infection increases severity of clinical malaria among children in Mvomero synergistically increase anemia rate. This study suggest use of an integrated approach to malaria and helminth control for all individuals in Mvomero.

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