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Where will pediatric praziquantel be needed in Tanzania? Geographical variation in prevalence, and risk factors of *Schistosoma mansoni* in pre-school aged children in southern and north-western Tanzania

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ABSTRACT

Background: Pediatric schistosomiasis has been recognized as a public health concern in schistosomiasis endemic areas of sub-Saharan Africa, including Tanzania. However, there is limited epidemiological information relating to pediatric schistosomiasis in Tanzania. Therefore, this current focused on assessing the geographical prevalence of *S. mansoni* infection and its associated risk factors in pre-school children (PreSAC) in southern and north-western Tanzania.

Methods: A total of 1585 PreSAC aged 1–6 years were enrolled in a cross-sectional study. A single urine and stool sample were obtained from each child and processed using point-of-care circulating cathodic (POC-CCA) antigen and Kato Katz (K—K) technique. The overall prevalence of *S. mansoni* infection based on K—K technique and POC-CCA test were 18.6% (95%CI:16.7–20.6) and 28.3% (95%CI:26.1–30.6), respectively. The overall geometrical mean eggs per gram of faeces was 110.38epg (95% CI:97.3–125.3). The age group 4–6 years had the highest prevalence ($P < 0.01$) of *S. mansoni* in both diagnostic tests and infection intensity ($t = -2.8398$, $P < 0.005$) using K—K technique. On multivariable analysis, only Ukerewe district was associated with *S. mansoni* infection based on K—K technique (aOR = 2.8 (95%CI:2.1–3.9), $P < 0.001$). Based on POC-CCA test, age group (4–6 years), aOR = 1.7, 95%CI:1.3–2.2, $P < 0.001$), Nyasa (aOR = 6.2, 95%CI:3.0–12.5, $P < 0.001$), Geita (aOR = 4.2, 95%CI:2.1–8.2, $P < 0.001$) and Ukerewe (aOR = 28.9, 95%CI:15.0–55.8, $P < 0.001$) districts remained independently associated with *S. mansoni* infection.

Conclusion: Schistosoma mansoni is a public health concern among PreSAC in the study districts and its prevalence varies from one geographical setting to another. These findings strongly support the need to include pre-school aged in preventive chemotherapy.

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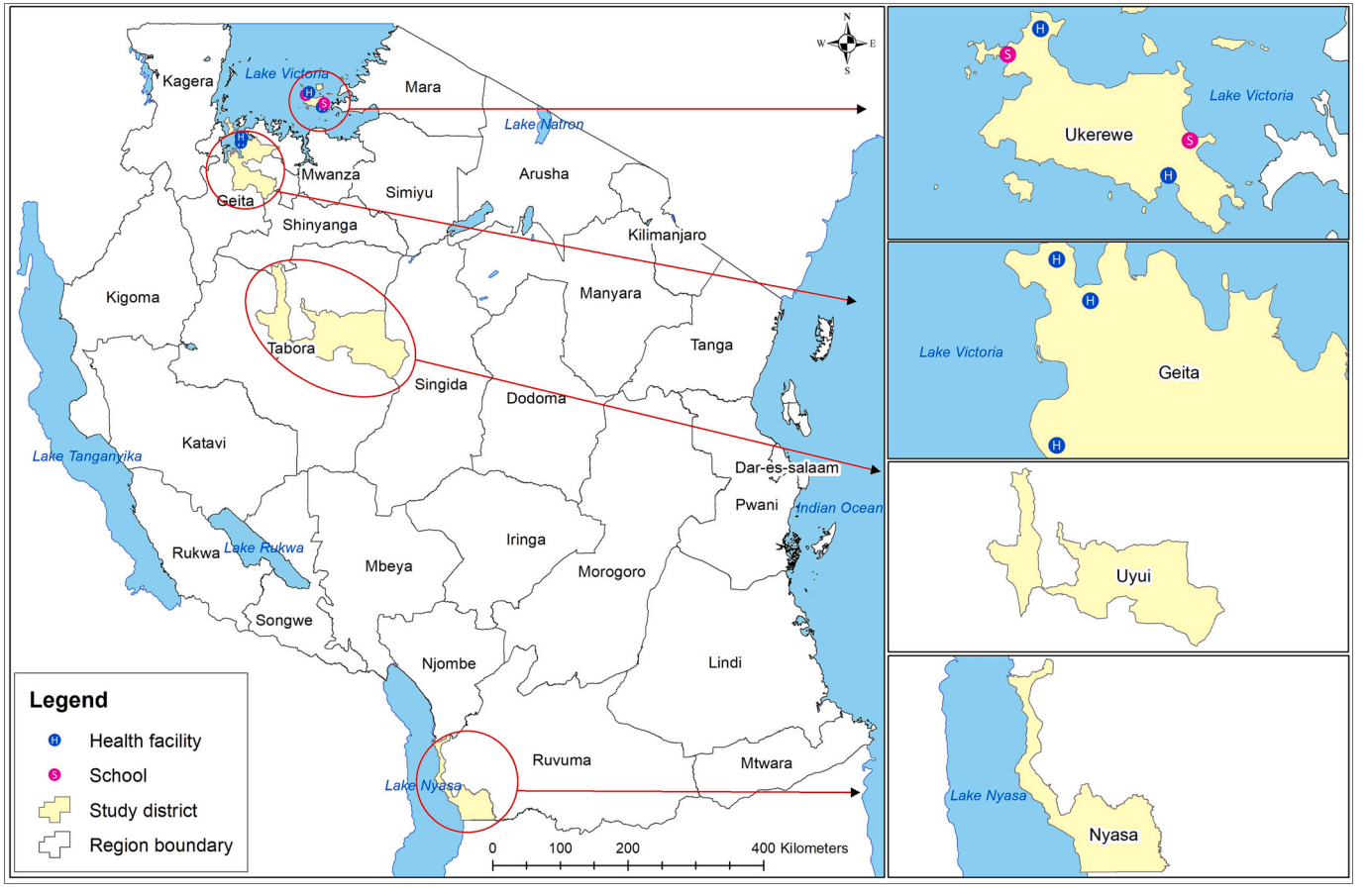

Fig. 1. Study districts in north-western and southern Tanzania.

1. Background

Schistosoma mansoni which cause intestinal schistosomiasis is endemic in Tanzania, with its prevalence varies from one geographical setting to another (Mazigo et al., 2012; Mazigo et al., 2022). The south-eastern and south-western sides of the Lake Victoria has been widely studied and evidence indicate that *S. mansoni* infection is widely distributed in these areas (Mazigo et al., 2012; Mazigo et al., 2022; Mueller et al., 2019; Mugono et al., 2014). There is limited information about the geographical distribution of *S. mansoni* infection in southern Tanzania, especially along the large water bodies. A recent survey along villages bordering Lake Nyasa shoreline reported the presence of *S. mansoni* infection at varying prevalence between studied villages (Mazigo et al., 2021). In Tanzania, studies on *S. mansoni* have been carried out mainly in school aged children (SAC) (Mazigo et al., 2012) and adult individuals (Malenganisho et al., 2008; Mazigo et al., 2014). For long time, Pre-school aged children (PreSAC) have been considered to have low risk of acquiring *S. mansoni* infection compared to SAC and adult individuals, (Mduluza and Mutapi, 2017). Partly, the use of the Kato Katz technique to estimate infection prevalence and intensity in this age group may have grossly under-estimated the infection levels (Ruganuza et al., 2015). This led to the belief that the PreSAC are at lower risk of the *S. mansoni* infection compared to other age groups. PreSAC are known to carry low intensity of infection and the Kato Katz technique is known to have low sensitivity in detecting individuals carrying low infection intensity (Ruganuza et al., 2015). Thus, the use of this technique in this age group needs to be complemented with other sensitive diagnostic test, such as Point-of-Care Circulating cathodic antigen (POC-CCA) test (Ruganuza et al., 2015).

In the past two decades, attention has focused on this age group (Mduluza and Mutapi, 2017; Osakunor et al., 2018b; Stothard et al., 2013). Data from epidemiological studies indicate that out of 120 million children affected by schistosomiasis worldwide, approximately 50 million are PreSAC (World Health Organization, 2002b, 2012). Evidence from epidemiological studies which focused on quantifying schistosomiasis morbidities in PreSAC have shown that *S. mansoni* infection is of clinical significance (Nalugwa et al., 2017; Osakunor et al., 2018a; Ruganuza et al., 2015). calling for the need to ensure that PreSAC are part of the mass drug administration (MDA) offered to SAC and other community members (World Health Organization, 2021a). The new guidelines for schistosomiasis control have recommended the inclusion of PreSAC from the age of two years ($\geq$2 years) using the currently available praziquantel drug (Mutapi, 2015; World Health Organization Expert Committee., 2002; World Health Organization, 2021a). However, this drug is licenced for individuals aged from $\geq$4 years of age. There is a global efforts to address this gap and a new praziquantel drug formulation for PreSAC population is expected to be available in the near future (Stothard et al., 2013). Pending the roll-out of the pediatric praziquantel formulation, it remains important to understand the level of infection in PreSAC living in different geographical settings in order to identify areas where treatment will be needed most. In that context, the present study focused in determining the prevalence and infection intensity of *S. mansoni* among PreSAC living in southern and north-western Tanzania, the areas surrounding the Lake Victoria and Lake Nyasa. Tanzania is expected to be among the first countries in sub-Saharan Africa to receive the pediatric formulation of PZQ, therefore it remains important for the country to understand which areas should be prioritized when the drug will be available.

2. Methods

2.1. Study sites

The study was conducted in four districts: Nyasa, Uyui, Ukerewe and Geita (Fig. 1). Nyasa district is located along the shoreline of Lake Nyasa (latitudes 10015′N and 1103′S and longitudes 34024′W and 350,228′E) in southern Tanzania. Ukerewe district is an island, part of the Mwanza region, located at 2°S and 33°E, at an altitude of 1100 m above the sea level. Uyui district is part of the Tabora region and is located at 4°55′0"S and 32°49′60″E, south-west side of the Lake Victoria. Lastly, Geita rural district is part of the Geita region located on the western side of the Lake Victoria. The main economic activities of the inhabitants of these districts are mainly subsistence farming growing cassava, livestock keeping, paddy, maize and sweet potatoes and fishing. Nyasa, Ukerewe, Uyui and Geita districts were purposively selected for this study because are known to be endemic for intestinal schistosomiasis (Mazigo et al., 2012). Preventive mass chemotherapies using PZQ in these districts are organized within the school environments and target SAC, while other community members including PreSAC outside the school environment, are not considered.

2.2. Study design, inclusion, and exclusion criteria

The current analytical cross-sectional study was conducted between September – October 2019 among PreSAC selected from purposively selected villages of Nyasa, Uyui, Geita and Ukerewe districts. The study included PreSAC aged 1–6 years old, born in the selected study villages, parents/guardians reported to have lived in the selected villages for more than two (2) years and provided informed consent for their children to participate in the study. The exclusion criteria were reported reported having a medical condition example sickle cell disease, cancer, febrile illness at the time of sample collection by parents/guardians which made children unfit to participate in the study.

2.3. Sample size and sampling procedures

A single proportion sample size formula for categorical variables (proportion outcome) was used to estimate the sample size (Cochran, 1963.). Considering the prevalence of intestinal schistosomiasis among PreSAC of 40% based on KK-technique (Ruganuza

et al., 2015), at 95% confidence interval and margin of error ± 3%, the minimum sample size required was 1024 children.

Based on POC-CCA test from the same study (Ruganuza et al., 2015), the prevalence of *S. mansoni* infection was 80%, at 95% confidence interval and precision error of ±3%, the estimated sample size was 683 PreSAC. We aimed at a large sample size based on KK-technique and a total of 1024 PreSAC were required to be enrolled into the study. However, the available resources supported recruitment and enrollment of 1585 pre-school children.

At each study village, a community leader was asked to invite caregivers with children aged 1–6 years by blowing a whistle/by using a loud speaker one day before the day of sample collection. Caregivers were asked to bring their children on the day of screening at the agreed site within the village. Participate who responded to the call and were willing to allow their children to participate in the study were included.

2.4. Data collection

2.4.1. Collection of study participants demographic information

A pre-tested questionnaire in Kiswahili language was used to collected demographic and anthelminthic treatment history from parents/guardians/caregivers. The questionnaire collected demographic information (age, sex) history of taking any anthelminthic in the past six months, any reported medical condition, and if the child had diarrhea on the day of sample collection.

2.4.2. Parasitological examination of stool sample for Schistosoma mansoni infection using Kato Katz technique

A single stool sample was collected from each child using a clean container from which, two KK thick smears were prepared from different sites of the stool sample using a template of 41.7 mg (Vestergaard Frandsen, Lausanne, Switzerland) following a standard protocol (Katz et al., 1972). Twenty four hours after preparation, all prepared KK-thick smears were examined by two independent laboratory technicians at the Parasitology laboratory of the Catholic University of Health and Allied Sciences (Katz et al., 1972). For quality assurance, 10% of all the negative and positive KK thick smears were re-examined by a third technician.

2.4.3. Examination of Circulating Cathodic Antigens using point-of-care Circulating Cathodic Antigens tests

All collected urine samples were examined for presence of Circulating Cathodic Antigens (CCA) using the POC-CCA urine cassette assay, (Rapid Medical Diagnostics, Pretoria, South Africa (http://www.rapid-diagnostics.com/) (Sousa-Figueiredo et al., 2013; Standley et al., 2010). The POC-CCA detect active infection by measuring the CCA produced by live worms in the blood vessels and excreted in urine of infected individuals (Van Dam et al., 2004). Preparation and examination of test results followed the manufacturer's instructions (Sousa-Figueiredo et al., 2013; Standley et al., 2010). All laboratory technicians involved in examining the POC-CCA cassettes, were not involved in preparation and examination of the KK thick smears.

2.5. Data analysis

Data were double entered in a Microsoft excel sheet (Microsoft cooperation, US), cleaned, and exported to Stata version 15 (Islam et al., 2017) for analysis. The focus of the analysis was to determine the prevalence of *S. mansoni* based on KK technique and POC-CCA test with their 95% confidence interval. Continuous (age, eggs intensities) variables were summarised using mean ± standard deviation (SD). Frequencies/proportions/categorical variables were compared using Chi-square (χ^2) or Fisher's exact tests and continuous variables were compared using *t*-test. For *S. mansoni* eggs, arithmetic mean egg counts were obtained from the counts of two KK thick smears and multiplied by 24 to obtain the individuals' eggs per gram of feaces. The mean egg counts for *S. mansoni* between sex and age groups were compared using either t-test (two groups) or ANOVA (for more than two groups). Intensity of infection was categorised according to WHO criteria, 1–99 epg, 100–399 epg and ≥ 400 defined as low, moderate and heavy intensities of infection (World Health Organization., 2002a). Bivariate and multivariate logistic regression models were used to assess the factors associated with *S. mansoni* infection based on the diagnostic test used. At bivariate analysis, all variables which had *P*-value of ≤0.2 were considered for multivariate analysis. The level of significant was set at *P*-value ≤0.05.

Table 1
Distribution of sex and age of the study participants from the four districts of southern and north-western Tanzania.

Variable	Study districts				χ2, P-value
	Geita	Nyasa	Ukerewe	Uyui	
Sex					
Female	257 (51.4%)	121 (44.3%)	277 (49.2%)	107 (49.2%)	$\chi^2 = 6.6379$
Male	243 (48.6%)	152 (55.7%)	286 (50.8%)	142 (57%)	$P = 0.08$
Age groups in years					
1–3	260 (52%)	104 (38.1%)	231 (41%)	121 (48.6%)	$\chi^2 = 20.0093$
4–6	240 (48%)	169 (61.9%)	332 (58.9%)	128 (51.45)	$P = 0.001$

3. Results

3.1. Demographic characteristics of study participants

A total of 1585 PreSAC from Geita, Uyui, Ukerewe districts and Nyasa districts were recruited into the study (Table 1). Of these, 48.1% ($n = 762/1585$) and 51.9% (823/1585) were female and male respectively. The mean age of the study participant was 3.58 ± 1.5 years. The distribution of age, sex and districts are shown in Table 1.

3.2. Prevalence of Schistosoma mansoni and infection intensity

Based on KK-technique, a total of 1544/1585 (97.4%) PreSAC had complete parasitological results. The overall prevalence of *S. mansoni* infection was 18.6% (95%CI: 16.7–20.6), with no sex difference (female = 18.2% *versus* male = 18.9%, $\chi^2 = 0.1658$, $P = 0.68$). In relation to age groups, the older age group, 4–6 years had the highest prevalence of *S. mansoni* infection compared to the youngest age group (1–3 years) ($\chi^2 = 6.0060$, $P = 0.014$). Table 2 shows the prevalence of *S. mansoni* infection based on KK-technique categorised by sex and age of the study participants.

The overall geometrical mean eggs per gram (epg) of faeces was 110.38epg of faeces (95%CI:97.3–125.3) with no sex difference in mean epg of feaces ($t = 0.7494$, $P = 0.4537$). Majority of the infected PreSAC had mild (49.8%) to moderate (39.4%) intensity of infection, with only 10% having heavy intensity of infection. In term of age, the age group 4–6 years had the highest geometrical mean eggs counts per gram of faeces compared to the youngest age group (51 GMepg *versus* 26.1GMepg, $t = -2.8398$, $P < 0.005$).

3.3. Prevalence of Schistosoma mansoni infection based on point-of-care Circulating Cathodic Antigen rapid test

A total of 1556/1585 (98.2%) of the study participants had complete results for POC-CCA test. The overall prevalence of *S. mansoni* infection was 28.3% (95%CI: 26.1–30.6). There was a significant difference in *S. mansoni* infection prevalence between the age groups, with the age group 4–6 years having the highest prevalence (64% *versus* 35.6%, $\chi^2 = 25.5823$, $P < 0.001$). In relation to sex of the study participants, there was no significant difference (47.4% *versus* 52.6% in female and males respectively, $\chi^2 = 0.1876$, $P = 0.66$). Overall, 56.9% of the PreSAC who had egg positive KK slides, were also positive on POC-CCA tests. In relation to intensity of infection, 57.8%, 55.8% and 58.1% of the children who had *S. mansoni* infection based on POC-CCA test had mild, moderate, and heavy intensity infection based on KK technique. Fig. 2 shows the prevalence of *S. mansoni* infection categorised by age groups using both POC-CCA and KK techniques.

3.4. Factors associated with Schistosoma mansoni infection among study participants

Based on the KK technique results, at bivariate level analysis, age group 4–6 years (OR = 1.4, 95%CI:1.1–1.8, $P < 0.02$) and Ukerewe district (OR = 2.9, 95%CI:2.2–4.1, $P < 0.001$) were associated with *S. mansoni* infection (Table 3). On multivariable analysis, only Ukerewe district (aOR = 2.8, 95%CI:2.1–3.9, $P < 0.001$) remained independently associated with *S. mansoni* infection. Table 3 shows factors which were associated with *S. mansoni* infection based the KK technique results.

Table 4 shows factors associated with *S. mansoni* infection based on POC-CCA test results. On bivariate analysis, age group 4–6 years (OR = 1.8, 95%CI = 1.4–2.3, $P < 0.001$) and study district, Nyasa (OR = 6.3, 95%CI:3.1–12.8, $P < 0.001$), Geita (OR = 4.0, 95% CI:2.0–7.9, $P < 0.001$) and Ukerewe (OR = 28.8, 95%CI:15.0–55.5, $P < 0.001$) compared to Uyui district were associated with *S. mansoni* infection. On multivariable analysis, the same factors remained independently associated with *S. mansoni* infection. Table 4 shows factors associated with *S. mansoni* infection based on POC-CCA tests results.

3.5. Variation in geographical prevalence of S.mansoni based on Kato Katz technique and Point-of-Care Circulating Cathodic Antigen test

Based on the POC-CCA test, Nyasa (20.9%) and Ukerewe districts had the highest prevalence of *S. mansoni* infection compared to Geita (14.4%) and Uyui (4%) districts ($\chi^2 = 319.7505$, $P < 0.001$). Similarly, based on KK technique, Nyasa (16.5%) and Ukerewe (31.9%) districts had the highest prevalence of *S. mansoni* infection compared to Geita (13.7%) and Uyui (0%) ($\chi^2 = 130.7971$, $P <$

Table 2
Prevalence of *S. mansoni* infection by Kato Katz technique categorised by age and sex.

Variable	*Schistosoma mansoni* infection status		χ^2, *P*-value
	Positive	Negative	
Sex			
Female	135 (18.2%)	608 (81.8%)	$\chi^2 = 0.1658$
Male	152 (18.9%)	649 (81%)	$P = 0.68$
Age in years (age groups)			
1–3	110 (15.9%)	582 (84.1%)	$\chi^2 = 6.0060$
4–6	177 (20.8%)	675 (79.2%	$P = 0.014$

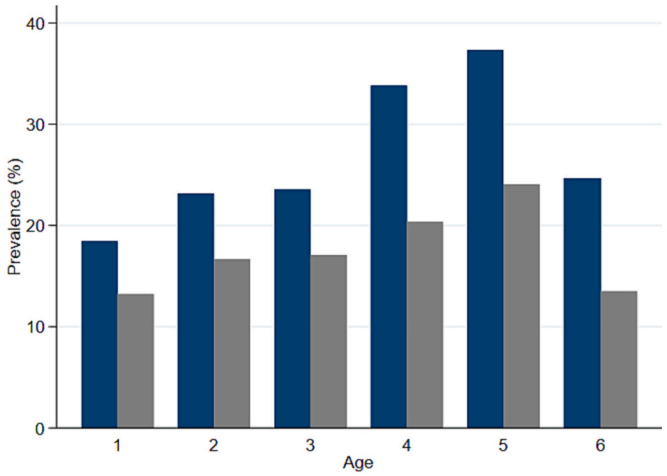

Fig. 2. Prevalence of *Schistosoma mansoni* infection based on KK (grey bars) and POC-CCA test (blue) categorised by age among pediatric population from Geita, Ukerewe, Nyasa, and Uyui, Tanzania. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 3
Factors associated with *S. mansoni* infection among PreSAC based on the KK technique results.

Variable	*S. mansoni* infection status		Unadjusted Odd Ratio			Adjusted Odd Ratio		
	Positive	Negative	OR	95%CI	*P*-value	aOR	95%CI	*P*-value
Age groups in years								
1–3	110(15.9%)	582(84.1%)	1			1		
4–6	177(20.8%)	675(79.2%)	1.4	1.1–1.8	0.02	1.2	0.9–1.6	0.1
Sex								
Female	135 (18.2%)	608(81.8%)	1			1		
Male	152(18.9%)	649(81%)	1.1	0.8–1.4	0.6	1.1	0.8–1.5	0.4
Study district								
Geita	63(13.7%)	398(86.3%)	1			1		
Nyasa	45 (16.5%)	228(83.5%)	1.2	0.8–1.9	0.3	1.2	0.8–1.8	0.4
Ukerewe	179(31.9%)	382(68.1%)	2.9	2.2–4.1	0.001	2.8	2.1–3.9	0.001

Table 4
Factors associated with *Schistosoma mansoni* infection among PreSAC using point-of-care circulating cathodic antigen test.

Variable	*S. mansoni* infection status		Unadjusted Odd Ratio			Adjusted Odd Ratio		
	Positive	Negative	OR	95%CI	*P*-value	aOR	95%CI	*P*-value
Age groups in years								
1–3	157(22.1%)	555(77.9%)	1			1		
4–6	284(33.7%)	560(66.3%)	1.8	1.4–2.3	0.001	1.7	1.3–2.2	0.001
Sex								
Female	209(27.8%)	542(72.2%)	1			1		
Male	232(28.8%)	573(71.2%)	1.1	0.8–1.3	0.6	1.1	0.8–1.5	0.3
Study district								
Uyui	10(4%)	239(95.9%)	1			1		
Geita	51(20.9%)	193(79.1)	6.3	3.1–12.8	0.001	6.2	3.0–12.5	0.001
Ukerewe	308(54.7%)	255(45.3%)	28.8	15.0–55.5	0.001	28.9	15.0–55.8	0.001
Nyasa	72(14.4%)	428(85.6%)	4.0	2.0–7.9	0.001	4.2	2.1–8.2	0.001

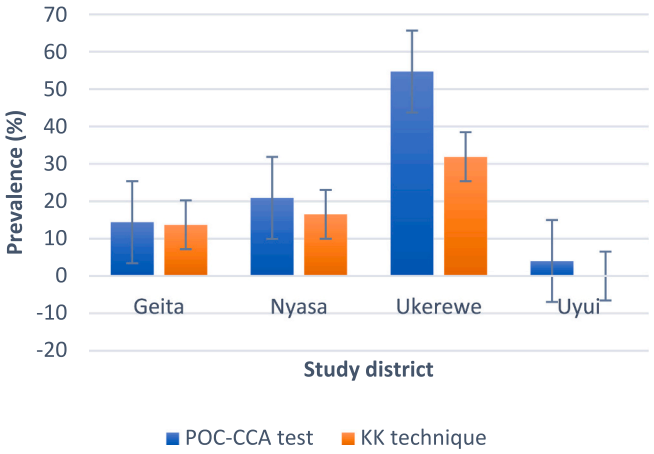

Fig. 3. Prevalence of *Schistosoma mansoni* among children underfives based on KK and POC-CCA techniques in each study districts.

0.001). Fig. 3 shows the prevalence of *S. mansoni* infection using KK technique and POC-CCA test in each district.

4. Discussion

The present study confirms that *S. mansoni* infection is common among PreSAC living in different geographical settings in Tanzania. The study noted a geographical variation in prevalence of *S. mansoni* infection using both KK- technique and POC-CCA tests. Considering the level of infection and intensity of infection observed in the current study population of PreSAC, our results support the WHO call of including children from the age of two years (≥2 years) into the treatment programme (Mutapi, 2015; World Health Organization., 2021).

The results of the present study confirms the result of the previous studies along the Lake Victoria in north-western Tanzania (Ruganuza et al., 2015), Uganda (Nalugwa et al., 2015) and Kenya (Chadeka et al., 2019; Sassa et al., 2020), which reported that intestinal schistosomiasis is a public health concern among PreSAC living in schistosomiasis endemic areas of East Africa region. At Ukerewe district, Ruganuza *et al* recorded the prevalence of 44.4% and 80.1% using KK technique and POC-CCA test in children aged 1–5 years (Ruganuza et al., 2015). Nalugwa *et al* in Uganda recorded a prevalence of 39.3% and 74.9% using KK technique in the same age group, (Nalugwa et al., 2017; Nalugwa et al., 2015). In Western Kenya, Sassa *et al* recorded a prevalence of 3.6% and 90.5% among PreSAC using both KK technique and POC-CCA test (Sassa et al., 2020) and Chadeka in the same area recorded a prevalence of 45.1% (Chadeka et al., 2019). In general, our findings and those of other authors clearly demonstrate that KK technique have reduced capacity to detect infection in young children who always carry low intensity of infection, this partly explain the low prevalence of *S.mansoni* infection in most of these studies compared to POC-CCA test. In addition, the observed variation in prevalence of *S. mansoni* between these studies partly can be explained by variation in risk factors and the level of exposure to risk areas among the population living in those study settings.

On the other hand, we noted a significant discordance between the KK technique and POC-CCA tests. This was consistent with our previous studies in adult (Mazigo et al., 2018), primary school children (Fuss et al., 2018) and PreSAC (Ruganuza et al., 2015). Similar studies elsewhere in sub-Saharan Africa have recorded similar discrepancies in PreSAC (Coulibaly et al., 2013; Dawson et al., 2013; Sassa et al., 2020). A number of factors have been described elsewhere to partly explain for the observed discrepancies between KK technique and POC-CCA tests (Coulibaly et al., 2013; Kittur et al., 2016).

In the current study, a significant number of PreSAC were moderately and heavily infected with *S. mansoni* parasite. In Uganda, 22.7% and 19.4% of the PreSAC were moderately and heavily infected respectively (Nalugwa et al., 2017). On ultrasonographical examination, liver fibrosis with distinct Symmer's pipe stems were noted in heavily-infected children (Nalugwa et al., 2017), indicating that *S. mansoni*-related morbidities does develop at very young age. Cumulatively, the current findings and that of other authors indicate that intestinal schistosomiasis is a serious public health problem in 1–5 years olds children living in different geographical settings with different level of *S. mansoni* transmission intensities. These findings support the WHO call which recommends for the need to include children from the age of two years and above (≥ 2 years) in treatment programme to prevent development of childhood chronic form of intestinal schistosomiasis which can have negative health impact on children.

In relation to age groups, the age group 4–6 years had the highest prevalence of *S. mansoni* infection. This observation was favourably compared with similar studies in the same age group in *S. mansoni* endemic settings (Coulibaly et al., 2013; Nalugwa et al., 2015; Ruganuza et al., 2015). In established *S. mansoni* endemic areas, the age-prevalence curve shows that prevalence and intensity infection peaks among children under the age of 15 years (Barakat et al., 2000). Alternatively, high exposure to risk environment among the age groups increases the likelihood of infection among children aged ≤5 years. Children age 1–6 years have been frequently reported by their caregivers to play in water (Kibira et al., 2019; Mutsaka-Makuvaza et al., 2019). Studies have noted the key role of older children and caregivers in exposing Pre-SAC to infested water bodies (Kibira et al., 2019; Poole et al., 2014). High exposure to risk environment and the fact that PreSAC are not part of the treatment programme could partly explain the high intensity of infection

observed in the age group, which is observed to be higher than that recorded among school aged children and adults in some communities (Nalugwa et al., 2015). Despite this fact, the long-term health impact of *S. mansoni* infection in PreSAC have received little attention compared to SAC (Mutapi, 2015), even the currently recommended praziquantel to be used to treat PreSAC is not recommended for children below 2-years of age. Considering the long-term health impact of *S. mansoni* infection observed in adult due to chronic nature of the disease, we recommend future studies to examine the cumulative health impact of intestinal schistosomiasis on PreSAC health.

Based on the two diagnostic tests used in the present study, a noted geographical variation in prevalence of *S. mansoni* infection was observed. Ukerewe and Nyasa districts recorded the highest prevalence of *S. mansoni* infection than Uyui and Geita districts. Ukerewe district is an island on the Lake Victoria in north-western Tanzania, the district has been repeatedly reported to be endemic for intestinal schistosomiasis (Kardorff et al., 1997; Mugono et al., 2014; Ruganuza et al., 2015), whereas Nyasa district is located along the Lake Nyasa in southern Tanzania, recent survey has noted the occurrence of *S. mansoni* infection in SAC (Mazigo et al., 2021). Part of the Geita rural district which borders the Lake Victoria to the north were involved in the study, however, the prevalence of *S. mansoni* infection was lower than what was observed at Ukerewe and Nyasa districts. Partly, the geographical location of these districts along the large water bodies which are preferred by the intermediate host of *S. mansoni* parasite (Handzel et al., 2003; Magendantz, 1972), the genus *Biomphalaria*, the degree of exposure of communities living close to these water bodies, high local population density around houses, and poor hygienic practices which is characterised by open defecation can explain the high *S. mansoni* prevalence observed in these districts (Chadeka et al., 2019; Handzel et al., 2003; Nagi et al., 2014). In north-western Tanzania, the prevalence of *S. mansoni* has been observed to decline with increase in distance from the shoreline of the Lake Victoria (Mazigo et al., 2012), with districts located more south of the lake recording very low prevalence of *S. mansoni* infection (Mazigo et al., 2012). This may partly explain the low prevalence of *S. mansoni* infection observed at Uyui district. These findings are compared favourably with what was observed in Western Kenya, in which prevalence of *S. mansoni* infection decreased with an increased in distance from the lakeshore line (Handzel et al., 2003). A recent study in Western Kenya noted a high degree of spatial heterogeneity in prevalence and intensity of *S. mansoni* infection in PreSAC (Nagi et al., 2014), with some villages recording low prevalence and others recorded unexpectedly high prevalence and intensity (Nagi et al., 2014).

On the other hand, on multivariable logistic regression, the geographical location of the study districts, specifically Ukerewe, Nyasa and Geita districts and age group 4–6 years remained as the main predictors of *S. mansoni* infection in the current study population. The geographical location of the district tends to determine the level of exposure of the population, with population living close to large water bodies such as Lakes Nyasa and Victoria remaining at high risk of being infected and in fact these population carries highest burden of the disease (Handzel et al., 2003; Mazigo et al., 2012). In our previous study among PreSAC, reported history of lake visits and the proximity to the lake shore were significantly associated with *S. mansoni* infection whereas reported lake visit frequency (4-7 days/week) was associated with heavy intensities of *S. mansoni* infection (Ruganuza et al., 2015). In the north-western Tanzania, most of the district bordering the Lake Victoria are known to be endemic for *S. mansoni* infection (Mazigo et al., 2012). High human population densities in fishing villages, poor sanitation and hygiene, high water contacts activities and high population densities of the intermediate hosts increases the risk for transmission of *S. mansoni* infection in all age structure in these districts (Mazigo et al., 2012). Cumulatively, the findings indicate that Geita, Nyasa and Ukerewe districts representing districts bordering the two large water bodies in Tanzania are geographical areas which needs to be given priority in term of schistosomiasis transmission especially in the pediatric population currently not considered for mass drug administration. In the future, when pediatric praziquantel will be available, high-risk areas such as Ukerewe, Geita and Nyasa districts should be given priorities.

We acknowledge that the study was not conducted without limitation. First, the study did not investigate other risk groups such as SAC and adult to allow comparison of infection and intensity, *S. mansoni* infection in intermediate hosts snails, human behaviours (water contacts behaviours), socioeconomic information and environmental factors associated with *S. mansoni* infection. Second, the results of POC-CCA test were not categorised and all trace results were classified as positive and this may have resulted into over-estimation of the *S. mansoni* infection prevalence. Irrespective of the mentioned limitation, these results add valuable evidence aiming at better understanding the epidemiology of *S. mansoni* infection among PreSAC living in different geographical settings in Tanzania and this contribute to further policy discussion.

In conclusion, we noted high prevalence of *S. mansoni* infection among PreSAC aged 1–6 years living in the four study districts. There was a geographical variation in the prevalence of *S. mansoni* infection with districts (Nyasa, Ukerewe and Geita) bordering the Lake Nyasa in the southern part and Lake Victoria in north-western part of the country having high prevalence as compared to others. These high-risk areas will require an immediate attention in term of implementation of intervention measures, which will include PreSAC in the treatment programme. In the future, when pediatric praziquantel will be available for use, these are some of the high-risk areas to be considered. Lastly, we recommend further research in this area, looking into the long-term health impact of schistosomiasis in pre-school aged children to add more evidence for policy discussion.

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Authors contribution

HDM, AEA and UM conceptualised the study and developed the protocol. AEA and HDM participated in training of the field data collection team and participated in data collection. HDM and UM, participated in data analysis and interpretation and wrote the first draft of the manuscript. All authors read and approved the final manuscript.

Ethical considerations

Ethics approval and consent to participate

Ethical approval for this study was provided by the National Ethical Committee, The National Institute for Medical Research, Tanzania (cert. NIMR/HQ/R.8a/Vol.1X/3061) and the methods used to collect the presented data followed the recommended standard operating procedures. The study was conducted according to Helsinki recommendations. The study received further permission from regional and districts authorities of the involved districts. The village authorities were also informed before data collection was done. Parents and guardians of pre-school children received information through the village government communication channels. Written informed consent form were received from children and parents/guardians before participation in the study. All children diagnosed with *S. mansoni* were treated with PZQ (40 mg/kg) according to WHO recommendation.

Consent for publication

Not applicable.

Declaration of competing interest

The authors declare that they have no competing interests.

Availability of data and materials

Data supporting the write-up and conclusion of this article are provided with the articles. Raw data are available for sharing upon reasonable request through the institutional review board/ethical review committee.

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References

Barakat, R., Farghaly, A., El Masry, A.G., El-Sayed, M.K., Hussein, M.H., 2000. The epidemiology of schistosomiasis in Egypt: patterns of *Schistosoma mansoni* infection and morbidity in Kafer El-Sheikh. Am. J. Trop. Med. Hyg. 62, 21–27.

Chadeka, E.A., Nagi, S., Cheruiyot, N.B., Bahati, F., Sunahara, T., Njenga, S.M., Hamano, S., 2019. A high-intensity cluster of *Schistosoma mansoni* infection around Mbita causeway, western Kenya: a confirmatory cross-sectional survey. Trop. Med. Health 47, 26.

Cochran, W.G., 1963. Sampling Techniques, 2nd ed. John Wiley and Sons, Inc, New York.

Coulibaly, J.T., N'Gbesso, Y.K., Knopp, S., N'Guessan, N.A., Silue, K.D., van Dam, G.J., N'Goran, E.K., Utzinger, J., 2013. Accuracy of urine circulating cathodic antigen test for the diagnosis of *Schistosoma mansoni* in preschool-aged children before and after treatment. PLoS Negl. Trop. Dis. 7, e2109.

Dawson, E.M., Sousa-Figueiredo, J.C., Kabatereine, N.B., Doenhoff, M.J., Stothard, J.R., 2013. Intestinal schistosomiasis in pre school-aged children of Lake Albert, Uganda: diagnostic accuracy of a rapid test for detection of anti-schistosome antibodies. Trans. R. Soc. Trop. Med. Hyg. 107, 639–647.

Fuss, A., Mazigo, H.D., Tappe, D., Kasang, C., Mueller, A., 2018. Comparison of sensitivity and specificity of three diagnostic tests to detect *Schistosoma mansoni* infections in school children in Mwanza region, Tanzania. PLoS One 13, e0202499.

Handzel, T., Karanja, D.M., Addiss, D.G., Hightower, A.W., Rosen, D.H., Colley, D.G., Andove, J., Slutsker, L., Secor, W.E., 2003. Geographic distribution of schistosomiasis and soil-transmitted helminths in Western Kenya: implications for anthelminthic mass treatment. Am. J. Trop. Med. Hyg. 69, 318–323.

Islam, T., Kabir, R., Nisha, M. 2017. Data Analysis with Stata A Comprehensive Guide for Data Analysis and Interpretation of Outputs First Edition Stata Version 13. ASA Publications; Dhaka, Bangladesh. ISBN: ISBN 978-984-35-3165-0.

Kardorff, R., Gabone, R.M., Mugashe, C., Obiga, D., Ramarokoto, C.E., Mahlert, C., Spannbrucker, N., Lang, A., Gunzler, V., Gryseels, B., Ehrich, J.H., Doehring, E., 1997. *Schistosoma mansoni*-related morbidity on Ukerewe Island, Tanzania: clinical, ultrasonographical and biochemical parameters. Tropical Med. Int. Health 2, 230–239.

Katz, N., Chaves, A., Pellegrino, J., 1972. A simple device for quantitative stool thick-smear technique in *Schistosomiasis mansoni*. Rev. Inst. Med. Trop. Sao Paulo 14, 397–400.

Kibira, S.P.S., Ssempebwa, J.C., Ssenyonga, R., Radloff, S., Makumbi, F.E., 2019. Schistosomiasis infection in pre-school aged children in Uganda: a qualitative descriptive study to identify routes of exposure. BMC Infect. Dis. 19, 165.

Kittur, N., Castleman, J.D., Campbell Jr., C.H., King, C.H., Colley, D.G., 2016. Comparison of *Schistosoma mansoni* prevalence and intensity of infection, as determined by the circulating cathodic antigen urine assay or by the Kato-Katz fecal assay: a systematic review. Am. J. Trop. Med. Hyg. 94, 605–610.

Magendantz, M., 1972. The biology of Biomphalaria choanomphala and B. Sudanica in relation to their role in the transmission of *Schistosoma mansoni* in Lake Victoria at Mwanza, Tanzania. Bull. World Health Organ. 47, 331–341.

Malenganisho, W.L., Magnussen, P., Friis, H., Siza, J., Kaatano, G., Temu, M., Vennervald, B.J., 2008. *Schistosoma mansoni* morbidity among adults in two villages along Lake Victoria shores in Mwanza District, Tanzania. Trans. R. Soc. Trop. Med. Hyg. 102, 532–541.
Mazigo, H.D., Nuwaha, F., Kinung'hi, S.M., Morona, D., Pinot de Moira, A., Wilson, S., Heukelbach, J., Dunne, D.W., 2012. Epidemiology and control of human schistosomiasis in Tanzania. Parasit. Vectors 5, 274.
Mazigo, H., Dunne, D.W., Kinung'hi, S.M., 2014. Praziquantel efficacy against *Schistosoma mansoni* among HIV-1 infected and uninfected adults living in fishing villages along Lake Victoria, Northwest Tanzania. Infect. Dis. Poverty 3, 47.
Mazigo, H.D., Kepha, S., Kinung'hi, S.M., 2018. Sensitivity and specificity of point-of-care circulating cathodic antigen test before and after praziquantel treatment in diagnosing *Schistosoma mansoni* infection in adult population co-infected with human immunodeficiency virus-1, North-Western Tanzania. Arch. Public Health 76, 29.
Mazigo, H.D., Uisso, C., Kazyoba, P., Nshala, A., Mwingira, U.J., 2021. Schistosomiasis among villages surrounding Lake Nyasa, southern Tanzania: prevalence, intensity of infection and geographical distribution among pre-school and school aged children. Sci 11, 295.
Mazigo, H.D., Zinga, M.M., Kepha, S., Yard, E., McRee-Mckee, K., Kabona, G., Ngoma, D.D., Nshala, A., 2022. Precision and geographical prevalence mapping of schistosomiasis and soil-transmitted helminthiasis among school-aged children in selected districts of North-Western Tanzania. Parasit. Vectors 15, 492.
Mduluza, T., Mutapi, F., 2017. Putting the treatment of paediatric schistosomiasis into context. Infect. Dis. Poverty 6, 85.
Mueller, A., Fuss, A., Ziegler, U., Kaatano, G.M., Mazigo, H.D., 2019. Intestinal schistosomiasis of Ijinga Island, North-Western Tanzania: prevalence, intensity of infection, hepatosplenic morbidities and their associated factors. BMC Infect. Dis. 19, 832.
Mugono, M., Konje, E., Kuhn, S., Mpogoro, F.J., Morona, D., Mazigo, H.D., 2014. Intestinal schistosomiasis and geohelminths of Ukara Island, North-Western Tanzania: prevalence, intensity of infection and associated risk factors among school children. Parasit. Vectors 7, 612.
Mutapi, F., 2015. Changing policy and practice in the control of pediatric schistosomiasis. Pediatrics 135, 536–544.
Mutsaka-Makuvaza, M.J., Matsena-Zingoni, Z., Katsidzira, A., Tshuma, C., Chin'ombe, N., Zhou, X.N., Webster, B., Midzi, N., 2019. Urogenital schistosomiasis and risk factors of infection in mothers and preschool children in an endemic district in Zimbabwe. Parasit. Vectors 12, 427.
Nagi, S., Chadeka, E.A., Sunahara, T., Mutungi, F., Justin, Y.K., Kaneko, S., Ichinose, Y., Matsumoto, S., Njenga, S.M., Hashizume, M., Shimada, M., Hamano, S., 2014. Risk factors and spatial distribution of *Schistosoma mansoni* infection among primary school children in Mbita District, Western Kenya. PLoS Negl. Trop. Dis. 8, e2991.
Nalugwa, A., Olsen, A., Tukahebwa, M.E., Nuwaha, F., 2015. Intestinal schistosomiasis among preschool children along the shores of Lake Victoria in Uganda. Acta Trop. 142, 115–121.
Nalugwa, A., Nuwaha, F., Tukahebwa, E.M., Olsen, A., 2017. *Schistosoma mansoni*-associated morbidity among preschool-aged children along the shores of Lake Victoria in Uganda. Trop. Med. Infect. Dis. 2.
Osakunor, D.N.M., Mduluza, T., Midzi, N., Chase-Topping, M., Mutsaka-Makuvaza, M.J., Chimponda, T., Eyoh, E., Mduluza, T., Pfavayi, L.T., Wami, W.M., Amanfo, S. A., Murray, J., Tshuma, C., Woolhouse, M.E.J., Mutapi, F., 2018a. Dynamics of paediatric urogenital schistosome infection, morbidity and treatment: a longitudinal study among preschool children in Zimbabwe. BMJ Glob. Health 3, e000661.
Osakunor, D.N.M., Woolhouse, M.E.J., Mutapi, F., 2018b. Paediatric schistosomiasis: what we know and what we need to know. PLoS Negl. Trop. Dis. 12, e0006144.
Poole, H., Terlouw, D.J., Naunje, A., Mzembe, K., Stanton, M., Betson, M., Lalloo, D.G., Stothard, J.R., 2014. Schistosomiasis in pre-school-age children and their mothers in Chikhwawa district, Malawi with notes on characterization of schistosomes and snails. Parasit. Vectors 7, 153.
Ruganuza, D.M., Mazigo, H.D., Waihenya, R., Morona, D., Mkoji, G.M., 2015. *Schistosoma mansoni* among pre-school children in Musozi village, Ukerewe Island, North-Western-Tanzania: prevalence and associated risk factors. Parasit. Vectors 8, 377.
Sassa, M., Chadeka, E.A., Cheruiyot, N.B., Tanaka, M., Moriyasu, T., Kaneko, S., Njenga, S.M., Cox, S.E., Hamano, S., 2020. Prevalence and risk factors of *Schistosoma mansoni* infection among children under two years of age in Mbita, Western Kenya. PLoS Negl. Trop. Dis. 14, e0008473.
Sousa-Figueiredo, J.C., Betson, M., Kabatereine, N.B., Stothard, J.R., 2013. The urine circulating cathodic antigen (CCA) dipstick: a valid substitute for microscopy for mapping and point-of-care diagnosis of intestinal schistosomiasis. PLoS Negl. Trop. Dis. 7, e2008.
Standley, C.J., Lwambo, N.J., Lange, C.N., Kariuki, H.C., Adriko, M., Stothard, J.R., 2010. Performance of circulating cathodic antigen (CCA) urine-dipsticks for rapid detection of intestinal schistosomiasis in schoolchildren from shoreline communities of Lake Victoria. Parasit. Vectors 3, 7.
Stothard, J.R., Sousa-Figueiredo, J.C., Betson, M., Bustinduy, A., Reinhard-Rupp, J., 2013. Schistosomiasis in African infants and preschool children: let them now be treated! Trends Parasitol. 29, 197–205.
Van Dam, G., Wichers, J., Ferreira, T.F., Ghati, D., Van Amerongen, A., Deelder, A., 2004. Diagnosis of schistosomiasis by reagent strip test for detection of circulating cathodic antigen. J. Clin. Microbiol. 42, 5458–5461.
World Health Organization, 2002a. Prevention and control of schistosomiasis and soil-transmitted helminthiasis. World Health Organ. Tech. Rep. Ser. 912, i.
World Health Organization, 2002b. Prevention and Control of Schistosomiasis and Soil-Transmitted Helminthiasis. World Health Organization, Geneva.
World health Organization, 2012. Report of a Meeting to Review the Results of Studies on the Treatment of Schistosomiasis in Pre-School-Age Children. World Health Organization, Geneva.
World Health Organization, 2021. WHO Guideline on Control and Elimination of Human Schistosomiasis. World Health Organization, Geneva, Switzerland.
World Health Organization, 2021a. Schistosomiasis. World Health Organization. https://wwwwhoint/news-room/fact-sheets/detail/schistosomiasis. Accessed March, 2021.
World Health Organization Expert Committee, 2002. Prevention and control of schistosomiasis and soil-transmitted helminthiasis. World Health Organ. Tech. Rep. Ser. 912, 1–57.