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Prevalence of Urinary Schistosomiasis among Internally Displaced School-Age Children in Sudan: The Impact of Water Sources and Water-Contact Activities amid Armed Conflict

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Abstract

Background

Schistosoma haematobium is under research, particularly in school age displaced children living in displacement camps where they are exposed to potentially contaminated fresh water. The armed conflict in Sudan which started in 2023, has led to disruption of water, sanitation and healthcare infrastructure, which could have contributed to exposed to schistosomiasis transmission. This study aimed to determine the prevalence of *S. haematobium* infection among the displaced school age children in displaced camps near Wadelfadni, Gezira state, Sudan.

Methods

The study was a cross- sectional study carried out in the displaced camps near Wadelfadni, Gezira State, Sudan, from July to August 2026 that involved 302 school-age children. A structured questionnaire was used for collecting sociodemographic and water-contact information. Urine samples which were collected from the subject were tested for the presence of *S. haematobium eggs* using light microscopy.

Results

Among the 302 children enrolled, the mean ± SD age was 12.45 ± 3.0 years (range, 6–18 years), and 207 (68.5%) were male. Overall, *S. haematobium* infection was found in 143 children, which represents 47.4% (95% CI: 41.8%–53.0%). No statistically significant difference in prevalence of infection was found between males (49.8%) and females (42.1%) (PR 0.7, 95% CI 0.5–1.2, P = 0.133). Also, there was no significant difference between the age groups with regard to infection (P = 0.236). Hematuria was strongly associated with infection: 73 (97.3%) of 75 children with hematuria were infected compared with 70 (30.8%) of 227 children without hematuria (PR = 3.16, 95% CI: 2.6–3.8; P < 0.001). Water sources were found to be significant factors in the infection experienced as those who used canal water had 76.9% of the infection, while there was 62.6% among those who used both canal and borehole water. Swimming was strongly associated with infection, with 74 (89.2%) of 83 swimmers infected (PR = 17.9, 95% CI: 8.5–37.8; P < 0.001). Fishing was also significantly associated with infection (PR = 2.5, 95% CI: 1.3–4.9; P = 0.004).

Conclusion

The overall prevalence of urinary schistosomiasis among internally displaced school age children in the study area was high. The results underscore the importance of enhanced schistosomiasis control activities such as periodic screening and treatment, health education, access to safe water, and

aggressive action to internally displaced school age children at high risk for frequent exposure to freshwater.

Key message

What is already known on this topic:

The data on infection among internally displaced school-age children from Saudan are limited.

What this study adds:

This is the first study that was conducted among internally displaced school-age children in Sudan.

Overall, infection was found in 143 children, which represents 47.4% (95% CI: 41.8%–53.0%).

Hematuria was strongly associated with infection: 73 (97.3%) of 75 children with hematuria were infected compared with 70 (30.8%) of 227 children without hematuria (PR = 3.16, 95% CI: 2.6–3.8; P < 0.001).

Water sources were found to be significant factors in the infection experienced as those who used canal water had 76.9% of the infection, while there was 62.6% among those who used both canal and borehole water.

Swimming was strongly associated with infection, with 74 (89.2%) of 83 swimmers infected (PR = 17.9, 95% CI: 8.5–37.8; P < 0.001). Fishing was also significantly associated with infection (PR = 2.5, 95% CI: 1.3–4.9; P = 0.004).

How this study might affect research, practice, or policy:

The results underscore the importance of enhanced schistosomiasis control activities such as periodic screening and treatment, health education, access to safe water, and aggressive action to internally displaced school age children at high risk for frequent exposure to freshwater.

Introduction

Schistosomiasis is a neglected tropical disease (NTD), caused by parasitic trematodes of the genus Schistosoma (1, 2). It continues to be a significant public health issue in many tropical and subtropical countries, including where fresh water is a resource that is relied on for domestic, agricultural, recreational and occupational uses(3, 4). Urinary schistosomiasis is mostly due to *Schistosoma haematobium* and is mainly prevalent among children in endemic areas (5). When children contact with infected freshwater containing snails during various activities, such as swimming, fishing, washing, bathing and collecting water, and can be exposed to the cercariae (6). Chronic morbidity such as hematuria, urinary tract pathology, anemia, impaired physical development and lowered school performance is a potential risk of repeated exposure to schistosomiasis (7). Schistosomiasis has always

been reported in many parts of Sudan (8), in freshwater bodies, including irrigation schemes and canals, that associated with transmission, and the lack of access to safe water and sanitary facilities. Various environmental, socioeconomic, behavioural and health system factors affect the epidemiology of schistosomiasis(8). Communities that rely on surface water sources are particularly vulnerable and surface water can also provide suitable breeding habitats for intermediate snail hosts, and repeated contact with humans (9).

There has been significant impact on health services, water infrastructure, sanitation systems, population movements and disease control in many affected communities since the onset of armed conflict in Sudan in April 2023. These disturbances can render people, mainly internally displaced school age children, more vulnerable to locally transmitted diseases and hinder the prevention and treatment of diseases (10). If no safe water is available, then communities might be more dependent on other untreated freshwater sources, such as canals, which are potential sources for schistosomiasis. There is no recent data in Sudan, about the prevalence of schistosomiasis in internally displaced school-age children in conflict affected communities. This study aimed to determine the prevalence of *S. haematobium* infection among the school age displaced children in displacement camps near Wadelfadni, Gezira state, Sudan and the relationship of *S. haematobium* infection with age, sex, presence of blood in urine, water sources and water contact activities.

Subjects and Methods

Study design and setting

This cross-sectional study was conducted among internally displaced school-age children in the Wadelfadni area, Gezira State, Sudan, from 1 July to 30 August 2026. This study was conducted amid substantial disruptions to water supply and healthcare infrastructure caused by the armed conflict that began in Sudan in 2023. The required sample size for this study was calculated using the formula described by Charan and Biswas (11). By apply the formula; $n = Z^2 \times P (1 - P) / d^2$

Where:

- n = required sample size
- Z = standard normal deviation at the 95% confidence level (1.96)
- P = Expected prevalence based on a previous study conducted among school age children in Sudan was 12.9% (12)
- d = allowable margin of error (5%)

The sample size was calculated as follows:

$n = (1.96)^2 \times 0.129 (1 - 0.129) / (0.05)^2$

$n = 3.8416 \times 0.129 \times 0.871 / 0.0025$

n = 173.1

Therefore, the minimum calculated sample size was 174 school age children. To compensate for possible non-response, incomplete questionnaires, or missing laboratory data, an additional 15% was added:

n_ adjusted = 174/ (1 − 0.20)

n_ adjusted = 217.5 ~ = 218 school age children.

After rounding and considering the feasibility of the study, a total of 302 children were enrolled during the period of study.

Study population:

Definition of internal displacement people who have been forced to leave their home or habitual residence, particularly because of armed conflict, generalized violence, human-rights violations, disasters, or similar events (13).

Inclusion criteria

Internally displaced children aged 6–18 years who resided within the displacement camps near Wadelfadni, Gezira state, Sudan and their parents/guardians who provided informed consent were included.

Exclusion criteria

Internally displaced children whose parents or guardians refused to provide consent, as well as children who were unable to provide a urine sample or those over 18 years old, and non-internally displaced children, were excluded from the study.

Data collection

The data was collected using a predesigned structured questionnaire that used in previous study (14). The data included: age, sex, presence of hematuria, source of water and the main purpose for coming into contact with fresh water. Water contact activities were identified as domestic use, washing, swimming, fishing and other activities.

Laboratory Analysis

The collection of urine samples and laboratory testing were done in accordance with the standard laboratory procedures. A clean labeled leak proof urine specimen container was used to collect urine specimen. Ten milliliters of urine collected from each children participated, then collected urine was sent to the lab to be analyzed. Urine specimen were processed for the detection of *S. haematobium* infection by sedimentation method. In brief, a urine sample was centrifuged for five minutes to sediment the urine. The sediment was then examined with a light microscope for the presence of eggs with characteristic terminal spines of *S. haematobium* (15). The presence of *S. haematobium* was noted as positive in presence of eggs in Urine sediment. The participant/parent-reported visible/gross hematuria was used as the definition of hematuria.

Statistical analysis

The data was entered and analyzed using SPSS version 23.0. Participants' characteristics were summarized using descriptive statistics. The age of children was normally distributed quantitative data, thereby presented as mean and standard deviation (SD). Categoric variables were presented in terms of frequencies and percentages. The prevalence of *S. haematobium* infection was determined by the percentage of children with *S. haematobium* eggs found in the urine sample of all children examined. Prevalence ratios (PRs) and 95% confidence intervals (CIs) were computed to examine the associations between prevalence and demographic or exposure-related variables. A P value of < 0.05 was deemed to be statistically significant.

Results

There were 302 school-age displaced children in the study. The mean ± SD age was 12.45 ± 3.0 years, with a range of 6–18 years. Of the participants, 166 (55.5%) were aged > 12 years and 136 (45.5%) were aged ≤ 12 years. Most of the participants were males (207, 68.5%) and the females represent 95(31.5%). hematuria was reported among Seventy-five children (24.8%). Regarding water sources, 155 (51.3%) children reported using both borehole and canal water, while 121 (40.1%) used borehole water only and 26 (8.6%) used canal water only. Among the children who reported water-contact activities, 83 (27.5%) reported swimming and 84 (27.8%) reported other water-contact activities. Washing, fishing, and domestic water use were reported by 46 (15.2%), 45 (14.9%), and 44 (14.6%) children, respectively (Table 1).

Table 1
General characteristics of study subjects in displaced camps near Wadelfadni, Gezira state, Sudan (n = 302)

Item	Frequency (n)	Percent (%)
Age years (mean ± SD 12.45 ± 3.0 years)		
≤ 12 years	136	45.5
> 12 years	166	55.5
Sex		
Male	207	68.5
Female	95	31.5
Hematuria		
Yes	75	24.8
No	227	75.2
Source of water		
Canal water	26	8.6
Borehole	121	40.1
Both	155	51.3
Activity		
Domestic use	44	14.6
Washing	46	15.2
Swimming	83	27.5
Fishing	45	14.9
Others*	84	27.8
*Others: use of water for agriculture irrigation, local building materials and other activities such as animal drinking or clothes or car washing		

Of the 302-school age displaced children examined, 143 were positive for *Schistosoma haematobium*, giving an overall prevalence of 47.4% (95% CI: 41.8–53.0%) (Fig. 1).

Among children aged ≤ 12 years, 68 (50.0%) were positive for *S. haematobium*, compared with 75 (45.2%) among those aged > 12 years. The difference in prevalence between the two age groups was not statistically significant (PR = 1.2, 95% CI: 0.8–1.9; P = 0.236) (Table 2).

Table 2
The association between age of children and *Schistosoma haematobium* infection rates among school age displaced children in displaced camps near Wadelfadni, Gezira state, Sudan (n = 302)

Age group/years	*Schistosoma haematobium* infection				PR (95% CI)	P
	Negative		Positive			
	n	%	n	%		
≤ 12 years (n = 136)	68	50.0	68	50.0	1.2(0.8–1.9)	0.236
> 12 years (n = 166)	91	54.8	75	45.2		

Among male children, 103 (49.8%) were infected with *S. haematobium*, compared with 40 (42.1%) among female children. The difference in the prevalence of *S. haematobium* infection between males and females was not statistically significant (PR = 0.7, 95% CI: 0.5–1.2; P = 0.133) (Table 3).

Table 3
The association between sex of children and *Schistosoma haematobium* infection rates among school age displaced children in displaced camps near Wadelfadni, Gezira state, Sudan (n = 302)

Sex	*Schistosoma haematobium* infection				PR (95% CI)	P
	Negative		Positive			
	n	%	n	%		
Male (n = 207)	104	50.2	103	49.8	0.7(0.5–1.2)	0.133
Female (n = 95)	55	57.9	40	42.1		

There was significance association between *S. haematobium* and hematuria. The prevalence of infection was 73 (97.3%) out of 75 with hematuria and 70 (30.8%) out of 227 without hematuria. participants with hematuria had a significant increase in the prevalence of infection (PR = 3.16, 95% CI: 2.6–3.8; P < 0.001) (Table 4).

Table 4

The association between presence of hematuria and Schistosoma haematobium infection rates among school age displaced children in **displaced camps near** Wadelfadni, Gezira state, Sudan (N = 302)

Hematuria	*Schistosoma haematobium* infection				PR (95% CI)	P
	Negative		Positive			
	n	%	n	%		
Yes (n = 75)	2	2.7	73	97.3	3.16(2.6–3.8)	0.0001**
No (n = 227)	157	69.2	70	30.8		
** Fisher's Exact test applied						

Water sources were significantly associated with *S. haematobium* infection (P < 0.001). Among children who used canal water, 20 (76.9%) were infected, compared with 26 (21.5%) of those who used borehole water and 97 (62.6%) of those who used both canal and borehole water (Table 5). The risk of using canal water and both canal water and borehole was increased to more than four times and near four times (PR = 4.1 and 3.7, 95% CI: 1.6–10.6 and 2.3–5.9; P < 0.001 and 0.0001), respectively while use only borehole water was considered protective (PR = 0.15, 95% CI: 0.9 − 0.25, P < 0.0001) (Table 5).

Table 5

The association between water source types and Schistosoma haematobium infection rates among school age displaced children in displaced camps near Wadelfadni, Gezira state, Sudan (n = 302)

Item	***Schistosoma haematobium* infection**				**PR (95% CI)**	**P**
	Negative		**Positive**			
n	**%**	**n**	**%**			
Source of water						
Canal water (n = 26)	6	23.1	20	76.9	4.1(1.6–10.6)	0.001
Borehole (n = 121)	95	78.5	26	21.5	0.15(0.9 − 0.25)	0.0001
Both (n = 121)	58	37.4	97	62.6	3.7(2.3–5.9)	0.0001

Water-contact activities were significantly associated with *S. haematobium* infection. Swimming showed the strongest association, with 74 (89.2%) of the 83 children who reported swimming being infected. Children who reported swimming were significantly more likely to be infected (PR = 17.9, 95% CI: 8.5–37.8; P < 0.001). Fishing was also significantly associated with infection, with 30 (66.7%) of the 45

children who reported fishing being infected (PR = 2.5, 95% CI: 1.3–4.9; P = 0.004). In contrast, no statistically significant association was observed between infection and washing (20/46; 43.5%; P = 0.341) or domestic water use (18/44; 40.9%; P = 0.223) (Table 6).

Table 6
The association between water-contact activities and *Schistosoma haematobium* infection rates among school age displaced children in Wadelfadni, Gezira state, Sudan (n = 302)

Water-contact activities	***Schistosoma haematobium* infection**					
	Negative		Positive		PR (95% CI)	P
	n	%	n	%		
Domestic use (n = 44)	26	59.1	18	40.9	0.73(0.38–1.4)	0.223
Swimming (n = 83)	9	10.8	74	89.2	17.9(8.5–37.8)	0.0001
Washing (n = 46)	26	56.5	20	43.5	0.83(0.44–1.6)	0.341
Fishing (n = 45)	15	33.3	30	66.7	2.5(1.3–4.9)	0.004
Others* (n = 84)	83	98.8	1	1.2	0.006(0.001–0.047)	0.0001**
*Others: use of water for agriculture irrigation, local building materials and other activities such as animal drinking or clothes or car washing						
** Fisher's Exact test applied						

Discussion

The present study showed that the prevalence of urinary schistosomiasis in the displacement camps was 47.4%. This result was in accordance with a study conducted among Sudanese children that reported 44% of them had urogenital schistosomiasis(14). Research from Chad reported that 42.86% school children had *S. haematobium* infection(16). This finding was higher than the pooled prevalence of *S. haematobium* among school-aged children in another study in Sudan, 22.37%(17). In contrast, two studies conducted among Malian and Nigerian children noticed that 50.2% and 62% of children had urinary schistosomiasis, respectively(18, 19). This finding suggests that there is significant ongoing transmission and is a critical public health concern, especially for children, who are more susceptible to

repeated exposures to fresh water and are likely to impact disease-control activities in conflict settings(20, 21) and the potential disruption of disease-control activities in conflict-affected settings.

Our study revealed no statistically significant association between age and infection. It was observed that there was a slight increase in the prevalence of the infection in children ≤ 12 years compared to those > 12 years, but without significant differences. This could suggest that the contamination of water is affecting the school-age population and is not just affecting certain age groups.

The current study showed no significant difference between the sexes and urinary schistosomiasis, as was reported by Woldeyohannes and his colleagues (22). The prevalence of infection is relatively high for both males and females, suggesting that the risk of infection due to exposure to water is greater than that due to exposure to sex alone in this population.

A strong association between hematuria and *S. haematobium* infection was also noteworthy in this data. King reported a similar finding(23). Almost all children who had hematuria had an infection. One of the clinical presentations of urinary schistosomiasis was hematuria, which has been mainly associated with the passage and deposition of the parasite eggs in the urinary tract, resulting in inflammation of the mucosal surfaces and bleeding(24). Hematuria was strongly associated with S. haematobium infection in this study; however, infection was also detected among children who did not report hematuria, indicating that the absence of hematuria does not necessarily exclude infection(25).

The present study demonstrated a significant association and significant risk to infection among those children using only canal water and using both borehole and canal water (PR = 4.1 and 3.7, 95% CI: 1.6–10.6 and 2.3–5.9; P < 0.001 and 0.0001), respectively. It may be attributed to the recurrent contact of individuals with canal water compared to protected borehole water, resulting in a higher prevalence of schistosomiasis among those who use both sources and a lower prevalence among children who use borehole water exclusively(7).

Water contact was particularly important in terms of behavior. Almost 90% of children who reported that they had swam were infected. The high association between swimming and infections is biologically plausible because the cercariae of S. haematobium can infect humans while they are swimming in fresh water where it is present in the snails of its intermediate host(26). Likewise, the prevalence of infection was significantly higher among children who participated in fishing activities, which is similar to the reported study conducted among fishermen in the White Nile State, Sudan(27), due to multiple and extended exposure to potentially contaminated water.

These findings should also be interpreted in the context of the broader humanitarian situation in Sudan. In areas affected by armed conflict, communities may become increasingly vulnerable to the transmission of endemic diseases when essential water and sanitation infrastructure, healthcare services, disease surveillance systems, and preventive health programs are disrupted. Such disruptions can increase exposure to contaminated water and limit access to timely diagnosis, treatment, and disease-control interventions.(28). If access to the treated water is limited, populations might

increasingly rely on surface-water sources for domestic and recreational uses. These changes can lead to enhanced human–water contact and may allow for the maintenance of schistosomiasis transmission. The high prevalence of *S. haematobium* infection observed in this study highlights the need for an integrated approach to schistosomiasis control in endemic communities. Effective control should combine prompt treatment and preventive chemotherapy with praziquantel, together with health education, improved access to safe water and sanitation, and behavioral measures to reduce contact with potentially contaminated freshwater. Regular screening and timely treatment are also essential, particularly in communities affected by armed conflict and disruptions to water and healthcare infrastructure.

Strengths and limitations

This study has several strengths. Firstly, it provides novel and up-to-date epidemiological data regarding urinary schistosomiasis among this group of children in Sudan and Secondly, using adequate sample size, which is sufficient statistical power and reliability of the findings for determination of the prevalence of schistosomiasis and examining its associations with age, sex, presence of blood in urine, water sources and water contact activities.

It also has several limitations such as the cross-sectional type of study that prevents causal inference; therefore, the observed associations should be interpreted cautiously. In addition to, the results of this study, however, may not be extrapolatable to other geographic areas of Sudan, and the sensitivity of the infection detection method (urine sediment and light microscopy) might be less than more sensitive molecular or antigen-detection methods, particularly in patients with low intensity infections.

Conclusion

The prevalence of urinary schistosomiasis was high in school age displaced children compare to that reported in previous studies where nearly half of the children were infected with S. haematobium. Significant cofactors of infection were freshwater exposure particularly swimming in fresh water. Results suggest that there is a great need to intensify schistosomiasis prevention and control efforts in the affected communities. Access to safe water, reduced likelihood of children's exposure to potentially contaminated fresh water, strengthening health education and regular monitoring and provision of praziquantel should be considered priorities in the backdrop of ongoing disruption of health and water infrastructure in Sudan.

Declarations

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Ethics approval and consent to participate

The study was approved by the Ethics Committee of the Faculty of Medical Laboratory Sciences, University of Gezira (Ethical Approval No. 07/026). Permission to conduct the study was obtained from the relevant local health and education authorities. The study was performed in accordance with the principles of the Declaration of Helsinki Written informed consent was obtained from the parents or legal guardians of all participating children, and assent was obtained from the children when applicable. All participants' personal information was kept strictly confidential and was used solely for research purposes.

Consent for publication

.Not applicable

Availability of data

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request, subject to applicable ethical and institutional restrictions.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

A AT, supervised the study, and performed final manuscript editing. EAA contributed to data collection and manuscript drafting. ANMG, contributed to advanced statistical analysis, prepared the tables and figures and reference management. All authors read and approved the final manuscript.

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Figures

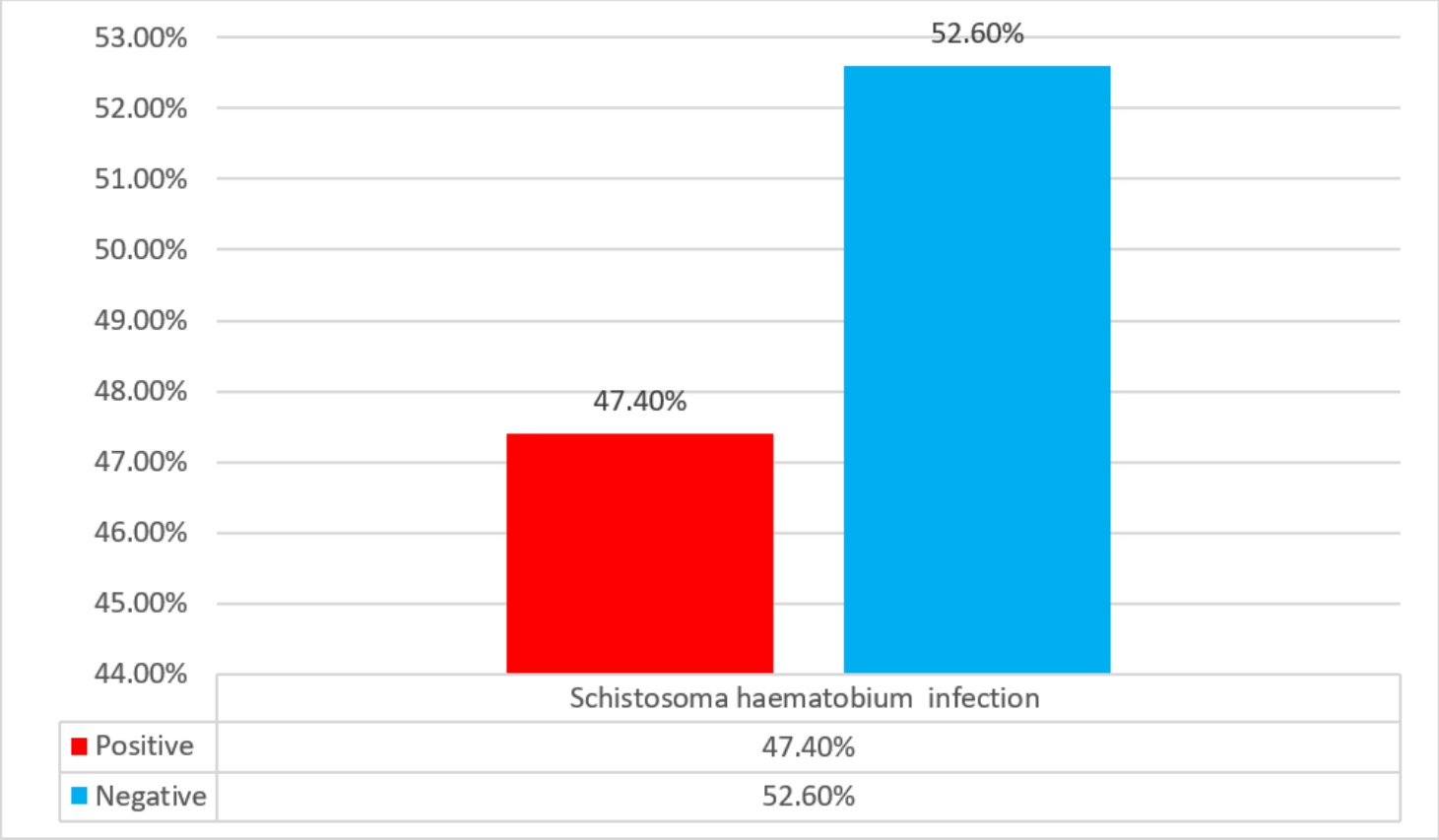


Figure 1

Prevalence of *Schistosoma haematobium* in school age displaced children in displaced camps near Wadelfadni, Gezira state, Sudan (n = 302)