EPIDEMIOLOGY OF *SCHISTOSOMA HAEMATOBIUM* INFECTION AMONG SCHOOLCHILDREN IN NORTHERN SUDAN

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Abstract. Schistosomiasis is a major public health problem in endemic regions, particularly among school-aged children exposed to contaminated freshwater. In this study, we aimed to determine the prevalence of and sociodemographic factors associated with *Schistosoma haematobium* infection among primary school students in Alhafeer, Northern State, Sudan in order to inform efforts to control *S. haematobium* infection in the study population. Study subjects were randomly selected from 4 randomly selected study schools in the study area. Inclusion criteria for study subjects were being aged 7-14 years, attending a study school during the study period and being willing to participate in the study. Exclusion criteria for study subjects were not meeting inclusion criteria, failing to complete the study questionnaire or failing to provide the required study sample. The minimum number of subjects determined to be needed for the study was 365. Each subject was asked to complete the study questionnaire asking about demographics, paternal education and occupation, contact with bodies of water, toileting habits and the presence of a toilet at home. Each subject was also asked to provide a urine sample for microscopy to detect *S. haematobium*. All subjects positive for *S. haematobium* infection were treated. Chi-square and multivariate logistic regression analysis were used to determine associations between positive cases and selected independent variables, with statistical significance set at p-value ≤0.05. A total of 463 subjects were included in the study, 52.6% (n = 244) males. 202 subjects (43.6%) tested positive for *S. haematobium* infection. Of the subjects who tested positive, 135 (66.8%) were male. 109 subjects aged 7-10 years (54.0%) and 93 subjects aged 11-14 years (33.5%) tested positive for *S. haematobium* infection. 235 subjects (50.8%) swam in the canal and of these 135 (57.0%) tested positive for *S. haematobium* infection. 176 subjects (38.0%) urinated in the canal and among these 94 (53.4%) tested positive for *S. haematobium* infection. 130 subjects (28.1%) did not have a toilet in the house and among these 115 (88.5%) tested positive for *S. haematobium* infection. 333 subjects (71.9%) did have a toilet in the house and among these 87 (26.1%) tested positive for *S. haematobium* infection. The factors significantly associated with *S. haematobium* infection on the Chi-square test were swimming in the canal (p<0.0001), urinating in the canal (p<0.0001) and not having a toilet in the house (p<0.0001). The factors significantly positively associated with *S. haematobium* infection on multivariate logistic regression analysis were male gender (adjusted odds ratio (aOR) = 2.78; 95% confidence interval (CI): 1.90-4.06, p=0.0001) and a paternal education level of university level (aOR = 2.75; 95%CI: 1.40-5.40, p=0.010). In summary, the prevalence of *S. haematobium* infection among study subjects was high and more common among swimming in the canal, urinating in the canal, not having a toilet in the house, being a male and having a father with a university level education. We conclude, efforts to control *S. haematobium* infection should focus on preventing swimming and urinating in the canal, having a toilet in the house and should target males and those with a father with a university level education. Further studies are needed to determine what types of programs are needed to make these changes and reduce the proportion of subjects with *S. haematobium* infection in the study population.

Keywords: prevalence, schistosomiasis haematobium, schoolchildren, Northern Sudan

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INTRODUCTION

Schistosomiasis is a parasitic disease caused by blood flukes (trematodes) of the genus *Schistosoma* (CDC, 2024b). *Schistosoma haematobium* and *S. mansoni* are the most common species of *Schistosoma* causing infection in humans (CDC, 2024a). *S. haematobium* and *S. mansoni* are the causes of urinary and intestinal schistosomiasis, respectively (CDC, 2016). Infection occurs when free-swimming *Schistosoma* cercariae penetrate the skin of the person during their contact with contaminated freshwater (WHO, 2022). The World Health Organization (WHO) has estimated during 2021 there were 205.4 million people worldwide who required regular administration of antiparasitic medication (typically praziquantel) to prevent schistosomiasis (WHO, n.d.). Schistosomiasis is more common in poor rural communities, particularly where fishing, agriculture and domestic water-related activities expose individuals, especially women and children, to infested water sources (WHO, 2011).

Schistosomiasis is widely distributed throughout Sudan, with both *S. haematobium* and *S. mansoni* having been reported from multiple areas (Abou-Zeid *et al*, 2013; Ahmed *et al*, 2009). The first case of schistosomiasis reported in northern Sudan was in 1919 (Mohamed and Hamad, 2020). Large-scale irrigation for agriculture, such as is used in Gezira, Managil and Rahad, Sudan contributes to transmission of *Schistosoma haematobium* and *Schistosoma mansoni* in the irrigation canals (Mohamed *et al*, 2020). In Northern State (Sudan), the estimated prevalence of *Schistosoma haematobium* among school-aged children was 0.5% (95% CI: 0.3-0.7; 17/3,762 examined), with a state-weighted population prevalence of 0.2% (95% CI: 0.1-0.4) (Cha *et al*, 2019).

S. haematobium transmission occurs via intermediate snail hosts (WHO, 2010). In sub-Saharan Africa, *Bulinus* spp is the intermediate snail host for *S. haematobium* (Manyangadze *et al*, 2016).

S. haematobium infection causes chronic anemia and organ damage among school-aged children (CDC, 2024b). Despite efforts to control schistosomiasis, preventive chemotherapy coverage continues to be inadequate in Sudan (Ismail *et al*, 2023). Control requires integrated strategies and sustained surveillance. Since man-made water bodies, such as irrigation canals and reservoirs, are the habitats for intermediate-host snails (WHO, 2010), prevention of *S. haematobium* infection requires a change in human behavior regarding water related activities, especially among school children who are exposed to *S. haematobium* during frequent contact with bodies of water and because of poor sanitation and among males because of agricultural occupational activities (Gbalégba *et al*, 2017; Houmsou *et al*, 2016). The WHO has recommended surveys to detect factors associated with *S. haematobium* infection in order to inform control efforts (WHO, 2010).

WHO (2022) recommends prevention of *S. haematobium* infection with praziquantel for high-risk groups who are exposed through recreational or occupational activities, but there is not a praziquantel formulation for preschoolers, preventing large-scale population-based prophylaxis. In high transmission areas, annual treatment and ongoing monitoring are essential to assess intervention impact (Hamad *et al*, 2019; WHO, 2011).

Despite control efforts, schistosomiasis is still a public health problem in Sudan. Few studies from Sudan have evaluated the epidemiology of *S. haematobium* infection in semi-urban canal-adjacent communities, such as Alhafeer, Sudan. There is limited data regarding factors associated with *S. haematobium* infection among school-aged children in Alhafeer, Northern State, Sudan. We selected Alhafeer for our study because of the large number of irrigation canals, high student density and high infection rates in this area of Northern State, Sudan.

In this study, we aimed to determine the prevalence of and sociodemographic factors associated with *S. haematobium* infection among primary school students in Alhafeer, Northern State, Sudan in order to inform efforts to control *S. haematobium* infection in the study population.

MATERIALS AND METHODS

Study setting and design

The study was conducted in Alhafeer area, Dongola Locality, one of the 7 localities of Northern State, Sudan. Dongola Locality is divided into 3 administrative units, comprising 75 villages and 5 islands. According to the 5th Sudan Population and Housing Census conducted in April 2008 (priority results released 2009), Dongola Locality had 150,161 residents (CBS, 2009).

The locality contains 8 hospitals, 8 health centers and 44 health care units. There is a river in the study area and the land adjacent to the river and on the islands is predominantly clayey, while areas farther from the river have sandy soil.

We conducted this cross-sectional study during November 2022 - July 2023.

Study population

The study population is primary school children aged 7-14 years attending a study school.

Subject selection

We used probability sampling with a multi-stage approach to randomly select study subjects. Schools were treated as clusters and children as sampling units. A simple random sampling method was then applied to identify the final sample units. To ensure representation of schools in the study area, we used the probability proportional to size (PPS) method. The selection of subjects consisted of 2 stages. During the first stage, schools (clusters) were randomly selected and since we used PPS, larger schools with more students had a greater chance of being included in the study. During the second stage, subjects were selected by simple random sampling.

Sample size

In our study, we assumed a large population size ($N \to \infty$), the minimum required sample size was calculated using the Raosoft calculator (http://www.raosoft.com/samplesize.html) at a 95% confidence level, 5% margin of error, and an expected proportion (p) of 0.50; this yielded a minimum sample size of 384.

We based the assumed prevalence on the 2016–2017 Sudan nationwide school survey, which found <1% *S. haematobium* prevalence in Northern State; we therefore set a conservative planning prevalence of 1% for sample-size calculations (Cha *et al*, 2019). We used a 95% confidence level and a 5% margin of error. We estimated a 10% difference in prevalence among the 4 study schools due to differences in water contact habits and sanitation. This gave an estimated statistical power of >80%. Based on the above, the minimum number of study subjects calculated to be needed for was 365 among the 4 randomly selected study schools.

Data collection

Each subject was asked to complete a pilot-tested Arabic questionnaire asking about demographics, paternal education and occupation, contact with bodies of water, urination and defecation habits and the presence of a toilet in the home. Each subject was also asked to provide a terminal urine sample obtained after physical activity to enhance egg excretion and obtained between 10 AM and 2 PM. Samples were immediately placed in a box maintained at 4-8°C and kept in the cold box during transport to the Dongola Locality Health Center for microscopic examination to detect the presence and concentration (number of eggs/10 ml water) of *S. haematobium* eggs (CDC, 2016; WHO, 2002). A dipstick urine test was performed to detect the presence of microscopic hematuria, which could aid in the detection of *S. haematobium* eggs among subjects with low egg counts.

Statistical analysis

Descriptive statistics have been used to summarize demographic, behavioral and clinical data. Categorical and continuous variables are reported as frequencies, percentages, means and standard deviations. Chi-square tests and multivariate logistic regression analysis were used to determine associations between finding *S. haematobium* eggs (dependent variable) and selected independent variables. A p-value <0.05 was considered statistically significant.

Ethical approval

This study was approved by the Ministry of Health, Northern State, Sudan on 2 January 2023 (Ref. No. 11-2023). Informed consent was obtained from subject parents or guardians and verbal consent was obtained from each subject prior to being included in the study. Those who tested positive for *Schistosoma haematobium* eggs were referred to local health authorities for appropriate treatment.

RESULTS

A total of 463 subjects were included in the study, 52.6% (244) males. 202 subjects (43.6%) tested positive for *Schistosoma haematobium* eggs. Of the subjects with a positive test, 135 (66.8%) were male and 67

(33.2%) were female (p<0.0001). 109 subjects aged 7-10 years (54.0%), 63 subjects aged 11-12 years (31.2%) and 30 subjects aged 13-14 years (14.9%) tested positive for *S. haematobium* eggs (p<0.0001) (Table 1).

Paternal occupation was not significantly associated with testing positive for *S. haematobium* eggs (p = 0.160). 120 farmers (47.6%), 61 self-employed fathers (40.1%) and 20 government employees (34.9%) tested positive for *S. haematobium* eggs (p>0.05) (Table 1).

198 subjects (42.8%) had a father who was illiterate and of these, 72 (36.4%) had a positive test for *S. haematobium* eggs. 46 (9.9%) had a father who had a college level education and of these, 28 (60.9%) tested positive for *S. haematobium* eggs (Table 1).

There were no statistically significant differences in positivity rates (p = 0.910) by area of residence.

235 subjects (50.8%) swam in the canal and among these 135 (57.0%) tested positive *S. haematobium* eggs. 228 subjects did not swim in the canal and among these 67 subjects (29.4%) tested positive (p<0.0001). The most common age group of subjects who visited the canal were those aged 7-10 years and among these 83 (67.2%) tested positive *S. haematobium* eggs (p<0.0001) (Table 2).

Of the 235 subjects who swam in the canal, 176 (74.9%) urinated in the canal and of these, 94 (53.4%) tested positive for *S. haematobium* eggs. Of the 235 subjects who swam in the canal, 59 (25.1%) denied urinating in the canal but of these, 108 (67.8%) tested positive for *S. haematobium* eggs (Table 2).

130 subjects (28.1%) did not have a toilet in the house and among these, 115 (88.5%) tested positive for *S. haematobium* eggs. 333 subjects (71.9%) had a toilet in the house and among these 87 (26.1%) tested positive for *S. haematobium* eggs (p<0.0001) (Table 3).

Of the 130 subjects who did not have a toilet at home, 130 reported where they defecated. Of these

Table 1

Sociodemographic factors among study subjects and their association with testing positive for *Schistosoma haematobium* infection

Variables	Number of subjects	Positive for *Schistosoma haematobium* infection n (%)	p-value
Gender			<0.0001
Male	244	135 (55.3)	
Female	219	67 (30.5)	
Ages group			<0.0001
7-10 years	202	109 (54.1)	
11-12 years	142	63 (44.2)	
13-14 years	119	30 (25.0)	
Location/area			0.910
Alhafeer North	113	48 (42.6)	
Alhafeer East	104	46 (44.3)	
Alhafeer West	117	50 (42.9)	
Displaced persons area	129	57 (44.3)	
Paternal education level			0.015
Illiterate	198	72 (36.4)	
Basic	89	46 (52.1)	
Secondary	130	56 (42.9)	
University	46	28 (60.9)	
Paternal occupation			0.160
Government employee	59	20 (33.9)	
Farmer	252	120 (47.8)	
Self-employed	152	61 (40.2)	

Table 2

Exposure activities and schistosomiasis positivity among study subjects by age group

Variables	Total numbers by age			Total	Number of positive subjects by age			Total	p-value
	7-10 years	11-12 years	13-14 years		7-10 years	11-12 years	13-14 years		
Swam in the canal									<0.0001
Yes	139	68	28	235	83	44	8	135	
No	63	74	91	228	26	19	22	67	
Total	202	142	119	463	109	63	30	202	
Urinated in the canal									<0.0001
Yes	117	59	0	176	63	31	0	94	
No	85	83	119	287	46	32	30	108	
Total	202	142	119	463	109	63	30	202	

Table 3

Schistosomiasis positivity by presence of a toilet in the subject's house and where they defecated

Variables	Total number		Total	Number of positive subjects by gender		Total	p-value
	Male	Female		Male	Female		
Toilet in the house							<0.0001
Yes	163	170	333	63	24	87	
No	81	49	130	72	43	115	
Total	244	219	463	135	67	202	
Usual place of defecation							0.004
In the canal	57	35	92	54	31	85	
Near the Nile River	19	9	28	17	9	26	
In the school or mosque	5	5	10	1	3	4	
In the house (toilet)	163	170	333	63	24	87	
Total	244	219	463	135	67	202	

130 subjects, 92 (72.1%) reported defecating in the canal and of these, 85 (91.4%) had a positive test for *S. haematobium* eggs. Twenty-eight subjects (21.7%) reported defecating near the Nile River and of these, 26 (92.9%) had a positive test for *S. haematobium* eggs. 10 subjects (6.9%) reported defecating in a toilet at school or at the mosque and of these 4 (44.4%) had a positive test for *S. haematobium* eggs (p = 0.004) (Table 3).

Logistic regression analysis revealed the factors associated with schistosomiasis infection were being male aged 7-10 years (Table 4)

Table 4

Logistic regression analysis of associations between selected factors and schistosomiasis positivity (n = 463)

Selected factors	Odds ratio (exp(β))	p-value
Male gender	2.51	0.0001
Aged 7-10 years	2.18	0.001
Aged 11-13 years	1.52	0.030
Residence: Alhafeer North	0.86	0.450
Residence: Alhafeer East	0.90	0.520
Residence: Alhafeer West	0.89	0.500
Paternal education: basic	1.73	0.020
Paternal education: secondary	1.52	0.040
Paternal education: university	2.41	0.010
Paternal occupation: farmer	1.25	0.180
Government employee	1.11	0.300

Note: Coefficients (β) represent the log odds of schistosomiasis positivity being associated with each selected factor. Odds ratios (exp(β)) indicate the multiplicative change in odds relative to the reference category.

On multiple logistic regression analysis, the factors significantly positively associated with testing positive for *S. haematobium* infection were male gender (adjusted odds ratio (aOR) = 2.78; 95% confidence interval (CI): 1.90-4.06, p=0.001), having a father with a university level education (aOR = 2.75; 95%CI: 1.40-5.40, p=0.003) and being aged 7-10 years compared with being aged 13-14 years (aOR = 3.45; 95% CI: 2.10-5.65, p<0.001) (Table 5).

DISCUSSION

In our study, 43.6% of subjects tested positive for *Schistosoma haematobium* infection. A previous meta-analysis nation-wide estimate study from Sudan (Alsaafin *et al*, 2024) reported an estimated prevalence of 24.8%. This difference is likely due to more irrigational canals in our study area than exist nationwide. A previous study from northern Sudan with better sanitation and a lower reliance on open freshwater sources reported a prevalence of 8.6% (Ismail *et al*, 2023), showing the epidemiological heterogeneity of schistosomiasis in Sudan.

Regional variation in the prevalence of *S. haematobium* infection has been reported from Ethiopia, (reported prevalence ranged from 11% to 39%) due to differences in water access and snail ecology (Gebrehana *et al*, 2024). A study from Ghana, Nigeria and Côte d'Ivoire (Wang *et al*, 2024) also reported variations in prevalence rates (15-48%), with the highest rates being in communities lacking integrated sanitation. A study from Ghana (Opare *et al*, 2025) reported persistent transmission of schistosomiasis despite mass drug administration, attributing reinfection to environmental and behavioral factors. These studies show the limitations of mass drug administration and suggest the need for behavioral change to improve the prevalence of schistosomiasis. These findings also show ecological and socioeconomical risk factors need to be addressed to control schistosomiasis (Chen *et al*, 2025).

Table 5

Multivariate logistic regression analysis of predictors associated with schistosomiasis infection among school-aged children (n = 463)

Selected factors (reference)	aOR (95% CI)	p-value
Gender		
Male (*versus* Female)	2.78 (1.90 - 4.06)	0.001
Age group in years		
7-10 (*versus* 13-14)	3.45 (2.10 - 5.65)	0.001
11-12 (*versus* 13-14)	2.20 (1.30 - 3.72)	0.003
Residence location/area		
Alhafeer East (*versus* North)	1.08 (0.65 - 1.80)	0.760
Alhafeer West (*versus* North)	1.02 (0.62 - 1.70)	0.910
Displaced Area (*versus* North)	1.05 (0.64 - 1.72)	0.840
Paternal education level		
Basic (*versus* Illiterate)	1.75 (1.10 - 2.80)	0.019
Secondary (*versus* Illiterate)	1.35 (0.85 - 2.15)	0.190
University (*versus* Illiterate)	2.75 (1.40 - 5.40)	0.003
Father's occupation		
Farmer (*versus* Government employee)	1.75 (0.90 - 3.40)	0.095
Self-employed (*versus* Government employee)	1.40 (0.70 - 2.80)	0.280

aOR: adjusted odds ratio; CI: confidence interval

In our study, inadequate sanitation was significantly associated with a higher prevalence of *S. haematobium* infection, consistent with another study from Sudan (Ismail *et al*, 2023).

In our study, frequent contact with infested water was significantly associated with a higher likelihood of *S. haematobium* infection. This finding is consistent with regional data reported by the Ministry of Health Northern State, which identified water exposure as a key risk factor in endemic areas (Ismail *et al*, 2023). Their surveillance reported daily exposure to contaminated water contributes to sustained transmission. These results highlight the need for targeted behavioral and environmental interventions.

In our study, male subjects had a higher prevalence of testing positive for schistosomiasis than female subjects. This is likely due to male subjects having more outdoor activities and water exposure (Ahmed and Alharbi, 2025).

In our study, younger subjects were more likely to have a positive test for schistosomiasis than older subjects, similar to a previous study that reported the same findings and linked these findings to younger subjects being more likely to play in contaminated water and less likely to understand the risks of this kind of play (Dong *et al*, 2025).

In our study, subjects who swam in an irrigation canal were more likely to test positive for *S. haematobium* infection. A meta-analysis of previous studies found contact with infested water is the most common route of transmission, especially in rural and sub-urban areas (Wang *et al*, 2024).

In our study, subjects who reported urinating in canals were significantly more likely to test positive for *S. haematobium* infection. This behavior contributes to environmental contamination and sustains transmission in endemic areas. A previous study also reported unsafe water practices, including urination near or in water bodies, were linked to higher infection rates in Sudanese communities (Alsaafin *et al*, 2024). These findings reinforce the need for targeted behavioral interventions along with infrastructure improvement.

In our study, subjects without a toilet in the house were significantly more like to test positive for *S. haematobium* infection than subjects with a toilet in the house, similar to the findings of a previous study that reported open defecation and poor hygiene are significantly associated with endemic schistosomiasis (Chen *et al*, 2025). This suggests the need for community-level sanitation.

In our study, subjects whose father had a university level education were significantly more likely to test positive for *S. haematobium* infection than subjects whose fathers were illiterate. This may reflect regional clustering, reporting bias, differences in knowledge about risk for schistosomiasis and differences in exposure (Dong *et al*, 2025). This shows that socio-economic determinants alone cannot be used to determine risk.

Our study had several limitations. First, it had a cross-sectional design which prevents determination of causality. Second, it relied on self-reported data obtained from children, which is subject to recall and social desirability bias. Third, we evaluated only Alhafeer, limiting its generalizability to other regions of Sudan, which have differences in ecology and infrastructure. Prospective, longitudinal studies are needed to compensate for these deficiencies. Snail vector mapping and genetic parasitical genetic evaluations would also enhance our understanding of transmission ecology.

In summary, the prevalence of *S. haematobium* infection among study subjects was high and more common among swimming in the canal, urinating in the canal, not having a toilet in the house, being a male and having a father with a university level education. We conclude, efforts to control *S. haematobium* infection should focus on preventing swimming and urinating in the canal, having a toilet in the house and should target males and those with a father with a university level education. Further studies are needed to determine what types of programs are needed to make these changes and reduce the proportion of subjects with *S. haematobium* infection in the study population.

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CONFLICTS OF INTEREST DISCLOSURE

The authors declare no conflicts of interest.

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