

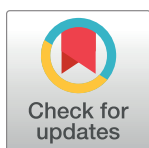
RESEARCH ARTICLE

Intestinal schistosomiasis among schoolchildren in Sana'a Governorate, Yemen: Prevalence, associated factors and its effect on nutritional status and anemia

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Abstract

Intestinal schistosomiasis is a neglected tropical disease, causing morbidity and mortality in tropical and subtropical countries. Despite the frequent implementation of mass drug administration with praziquantel, the reinfection with *Schistosoma mansoni* is still common in Yemen. In addition, there is a scarcity of information on the impact of *S. mansoni* on nutritional status and anemia among schoolchildren. The present study aimed to determine prevalence and risk factors of intestinal schistosomiasis and investigate its impact on nutritional status and anemia among schoolchildren in Sana'a Governorate, Yemen. It was conducted in 2018 on 445 schoolchildren aged 5–15 years. Biodata, socio-economic, demographic, behavioral and environmental data were collected using a standard questionnaire. *S. mansoni* was identified and quantified by microscopic examination of Kato-Katz fecal smear. Hemoglobin concentration and anthropometric measurements were estimated using standard methods. The prevalence of *S. mansoni* was higher in Al-Haimah Al-Dakheliah (33.9%) than Bani Mater (1.4%). Household without tap water (Adjusted Odds Ratio (AOR) = 2.9, 95% Confidence interval (CI): 1.12, 7.55, $P = 0.028$) was the independent risk factor of the infection. The prevalence of wasting and stunting was 25.0% (95%CI: 21.2%, 29.2%) and 45.8% (95%CI: 41.2%, 50.5%), respectively. The prevalence of underweight among schoolchildren aged 5–10 years was 27.3% (95%CI: 21.9%, 33.4%). The prevalence of anemia was 31.7% (95%CI: 27.5%, 36.2%) with 0.5%, 21.1% and 10.1% being severe, moderate and mild anemia, respectively. *S. mansoni* (AOR = 4.1, 95%CI: 2.16, 7.84, $P < 0.001$) and early adolescence (AOR = 6.8, 95%CI: 4.26, 10.82, $P < 0.001$) were independent predictors of stunting among schoolchildren. The early adolescent schoolchildren (AOR = 3.1, 95%CI: 1.86, 4.97, $P < 0.001$) and children from families with low (AOR = 2.1, 95%CI: 1.01, 4.15, $P = 0.046$) or moderate wealth (AOR = 2.3, 95%CI: 1.11, 4.77, $P = 0.026$) were significantly more wasted.

Early adolescence (AOR = 1.8, 95%CI:1.14, 2.78, $P=0.011$), female (AOR = 1.6, 95% CI: 1.03, 2.43, $P=0.038$) and Al-Haimah Al-Dakheliah District (AOR = 3.4, 95%CI: 1.20, 9.55, $P=0.021$) were independent risk factors for anemia. The study findings indicate highly focal prevalence of schistosomiasis in Sana'a Governorate with a public health significance that varies from low to high risk. Approximately half of schoolchildren were stunted, which was associated with *S. mansoni* infection and early adolescence. One quarter of schoolchildren were wasted with early adolescent schoolchildren and children from poor families being at high risk of wasting. Anemia was a moderate public health threat affecting the female and the early adolescent schoolchildren. The study suggests the implementation of control measures to combat schistosomiasis and integrated diseases control programmes to improve the health status of schoolchildren in Sana'a Governorate.

Author summary

The present study aimed to determine prevalence and risk factors of intestinal schistosomiasis and investigate its impact on nutritional status and anemia among schoolchildren in Sana'a Governorate, Yemen. It was conducted in 2018 on 445 schoolchildren aged 5–15 years. Information was collected using a standard questionnaire. *S. mansoni* was identified by microscopic examination of Kato-Katz fecal smear. Hemoglobin concentration and anthropometric measurements were estimated using standard methods. The prevalence of *S. mansoni* was highly focal (1.4–33.9%). Schoolchildren living in households without tap water had significantly high infection rate of *S. mansoni*. The prevalence of wasting, stunting, underweight and anemia among schoolchildren was 25.0%, 45.8%, 27.3% and 31.7%, respectively. Although *S. mansoni* was significantly associated with stunting, no significant association was found between *S. mansoni* and wasting, underweight or anemia. The stunting was higher among early adolescent than young schoolchildren. The early adolescent schoolchildren and children from families with low or moderate wealth were significantly more wasted than schoolchildren from families with high wealth. Schoolchildren in the early adolescence, being female or living in Al-Haimah Al-Dakheliah District were at high risk of anemia. The study suggests implementation of control measures to combat schistosomiasis and integrated diseases control programmes to improve the health status of schoolchildren in Sana'a Governorate.

Introduction

Human schistosomiasis is a neglected tropical disease caused by *Schistosoma* species and occurs mainly in tropical and sub-tropical countries [1]. It causes severe morbidity and mortality with an estimated global burden of 1.4 million disability-adjusted life-years (DALYs)[2]. *Schistosoma* species with high global prevalence include *S. haematobium* (urogenital schistosomiasis), *S. mansoni* and *S. japonicum* (intestinal schistosomiasis)[1]. Intestinal schistosomiasis in schoolchildren compromises growth, physical fitness, cognitive function and educational achievement and causes anemia [3–5].

In Yemen, schistosomiasis has been a public health problem since 1922[6] with a patchy distribution and different infection rates, ranging from 15% to 100% [7–14]. A combined Yemen-WHO project for controlling schistosomiasis was set up in 1973, which estimated that

25% of the population were infected with *S. mansoni* and/or *S. haematobium* [15,16]. After implementing several campaigns of school-based mass drug administration (MDA) with praziquantel, the prevalence of *S. mansoni* at country level dropped to 2.5% with a district-based prevalence ranging from 0.0 to 35.7% [17]. In the nationwide survey conducted in 2017, three years after the previous survey, the prevalence of *S. mansoni* increased to 7.4% [18]. Malnutrition and anemia are other threats affecting schoolchildren in Yemen where 59%, 47% and 18% of school-aged children were found stunted, underweight and anemic, respectively [19]. However, there is a paucity of information about the impact of *S. mansoni* on the nutritional status and anemia among schoolchildren in Yemen [20]. Thus, the present study aimed to determine prevalence of *S. mansoni*, identify factors associated with the infection and its impact on nutritional status and anemia among schoolchildren in rural communities of Sana'a Governorate, Yemen.

Methods

Study area, design and subjects

This is a cross-sectional study conducted in the rural areas of Sana'a Governorate, Yemen. Schoolchildren aged 6–15 years were the study population. Children who had taken iron, nutritional supplements or anti-parasitic drugs in the last six months prior to the study were excluded.

Sample size and sampling strategy

The minimum sample size required for the study was 358 schoolchildren which was calculated by Epi Info | CDC (<https://www.cdc.gov/epiinfo/index.html>) using the following parameters: 95% confidence interval, $\pm 5\%$ precision and the highest recently reported prevalence of *S. mansoni* (37%) [17]. However, 445 schoolchildren were enrolled in the study to replace participant for not providing fecal sample. A multistage sampling approach was used for selecting schoolchildren where two districts from rural areas of Sana'a Governorate were randomly selected, followed by random selection of one school from each district. Children from each school were selected by systematic random sampling from the students record until the required sample size was obtained. If a selected child refused to participate or was not eligible, he/she was replaced by the next student in the record. The number of students selected from each school was proportional to the size of the school.

The study questionnaire

Biodata, socio-economic, demographic, behavioral and environmental data were collected using a pre-designed, structured questionnaire through a face-to-face interview. The questionnaire included questions about durable items, animals and agricultural land owned by households; household's source of drinking water; sanitation coverage; father and mother education; and the number of household's members.

Parasitological investigations

A single fresh fecal sample was collected from each participant in a dry, clean plastic container, labeled with the child's name and identification number. At the field, a Kato-Katz thick fecal smear was prepared from each fecal sample and the rest of feces were preserved in 10% formalin. The Kato-Katz thick fecal smears were then transported to the Parasitology Laboratory in the Faculty of Medicine and Health Sciences, Sana'a University and examined for *S. mansoni* [21]. The intensity of *S. mansoni* was classified into light (1–99 EPG), moderate (100–399

EPG) and high intensity (≥ 400 EPG) [22]. The public health significance of the prevalence of *S. mansoni* was classified into high risk ($\geq 30\%$), moderate risk (≥ 10 and $< 30\%$) and low risk ($< 10\%$) as suggested by the national control strategy [17].

Hemoglobin estimation

A single measurement of hemoglobin concentration from each child was conducted using a portable hemoglobin analyzing system HB 301+ (HemoCue1 AB, Angelhome, Sweden) on blood collected by finger-prick following the manufacturer instruction. Children were classified into anemic or non-anemic ($Hb \geq 115$ g/l for children aged 5–10 years and $Hb \geq 120$ g/l for children aged 11–15 years), and subsequently as mild ($Hb = 110$ – 114 g/l for children aged 5–10 years and $Hb = 114$ – 119 g/l for children aged 11–15 years), moderate ($Hb = 80$ – 109 g/l) and severe anemia ($Hb < 80$ g/l) after adjusting the hemoglobin measurement for altitude according to WHO reference [23]. The public health significance of anemia prevalence was classified as normal ($\leq 4.9\%$), mild (5.0–19.9%), moderate (20.0–39.9%) and severe ($\geq 40\%$) [23].

Anthropometric measurements

For anthropometric measurements, standing height of each child was measured to the nearest 0.1 cm using a portable stadiometer (Seca, model 208) and his/her weight was measured to the nearest 0.1 kg using a digital weight scale. The age of each participant was retrieved from the birth certificate or school records. The collected measures were used for calculating height-for-age z-score (HAZ), weight-for-age z-score (WAZ) and BMI-for-age z-score (BAZ) using the WHO AnthroPlus software for the global application of the WHO reference 2007 for 5–19 years [24]. The WHO reference data for WAZ used by the WHO AnthroPlus software were for age ≤ 10 years; therefore, underweight was estimated for children aged 5–10 years old. The nutritional indicators for school-age children were defined as follows:

Nutritional indicator	Cut-off Z-score
Stunting (Height-for-age (HAZ))	
Stunting	Below– 2 SD of the WHO Growth Standards median for HAZ
Moderate stunting	–2 SD to– 3 SD of the WHO Growth Standards median for HAZ
Severe stunting	Below– 3 SD of the WHO Growth Standards median for HAZ
BMI (BMI for age (BAZ))	
Wasting	Below– 2 SD of the WHO Growth Standards median for BAZ
Moderate wasting	–2 SD to– 3 SD of the WHO Growth Standards median for BAZ
Severe wasting	Below– 3 SD of the WHO Growth Standards median for BAZ
Underweight (Weight-for-age (WAZ))	
Underweight	Below– 2 SD of the WHO Growth Standards median for WAZ
Moderate underweight	–2 SD to– 3 SD of the WHO Growth Standards median for WAZ
Severe underweight	Below– 3 SD of the WHO Growth Standards median for WAZ

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Statistical analysis

Data were analyzed using IBM SPSS Statistics for Windows, version 23.0 (IBM Corp., Armonk, NY, USA). The wealth indices were determined using the principal component analysis (PCA) of durable items, animals and agricultural land owned by households. The

constructed PCA-based scores of households were divided into five quintiles and three wealth categories, where households' residents with the lowest 40%, the middle 40% and the highest 20% of household wealth quintiles were classified as low, middle and high, respectively[25]. Categorical variables were presented in frequencies. The association between independent and dependent variables was tested using Pearson's chi-square with reporting odds ratio (OR) and its corresponding 95% confidence interval (CI). Multivariable analysis using entry binary logistic regression model was conducted including all predicting variables and the adjusted OR with its corresponding 95%CI were reported. *P*-value of <0.05 was considered significant.

Ethics statement

The study protocol was approved by Research and Ethics Committee (REC) of the Faculty of Medicine and Health Sciences, Sana'a University. Approval of school headmasters/ headmistresses was also taken after explaining the significance of the study. Each child was voluntary involved after receiving information in a way that the child can understand and give his/her assent. No informed consent was obtained from child's parents/guardians, although they were informed about the study and had the right to refuse the participation of their child. Anonymity, dignity and privacy of the child and his/her family were protected.

Results

Characteristic of study population

Table 1 summarizes the characteristics of participants. A total of 445 schoolchildren were enrolled in this study. Their age ranged between 5 and 15 years with a mean of 10 ± 2.54 . The majority of children (70.6%) were in the age group of 5–11 years. About 82% of the children belonged to families with more than 5 members. More than half of the children were living in houses without proper sanitation coverage (no toilet or flush/pour flush to open area) and about one-third had unimproved source of drinking water. Although no much difference in the characteristics of the study participants between the two districts, the majority of schoolchildren in Al-Haimah Al-Dakheliah District are living in houses without access to improved sanitation.

Prevalence and factors associated with *Schistosoma mansoni*

The prevalence of *S. mansoni* was higher in Al-Haimah Al-Dakheliah (33.9%) than in Bani Mater (1.4%). The intensity of *S. mansoni* was classified as heavy (4.1%), moderate (3.6%) and light intensity infection (10.3%) (Table 2).

Univariable analysis was restricted to Al-Haimah Al-Dakheliah District where the prevalence of schistosomiasis was high, which identified a significant association between *S. mansoni* infection and uneducated mother (OR = 3.0, 95% CI: 1.11, 8.21, *P* = 0.024) and households without tap water (OR = 3.5, 95% CI: 1.49, 8.29, *P* = 0.003). Multivariate analysis identified households without tap water (adjusted OR = 2.9, 95% CI: 1.12, 7.55, *P* = 0.028) as an independent risk factor of *S. mansoni* (Table 3).

Prevalence and factors associated with stunting, wasting and underweight

The prevalence of stunting among schoolchildren was 45.8% with 26.3% of the children being severely stunted while the prevalence of wasting was 25% with 9.7% of the children being severely wasted. Children aged 11–15 years had significantly higher rates of stunting and wasting than children aged 5–10 years. Among schoolchildren aged 5–10 years, 27.3% of them were diagnosed as underweight and 10.8% were classified as severe underweight (Table 4).

Table 1. Distribution of the study population by socio-demographic information, Sana'a Governorate, Yemen.

Characters	All children	Al-Haimah Al-Dakheliah (N = 227)	Bani Mater (N = 218)
	n (%)	n (%)	n (%)
Gender			
Male	230 (51.7)	128(56.4)	102(46.8)
Female	215 (48.3)	99(43.6)	116(53.2)
Age (Years)			
5–11	314 (70.6)	165(72.7)	149(68.3)
12–15	131 (29.4)	62(27.3)	69 (31.7)
Father Education			
Diploma and above	29 (6.5)	17(7.4)	12(5.5)
Secondary school	90 (20.2)	50(22.1)	40(18.4)
Primary school	176 (39.6)	86(37.9)	90(41.3)
Uneducated	150 (33.7)	74(32.6)	76(34.9)
Mother Education			
Diploma and above	5 (1.1)	0(0.0)	5(2.3)
Secondary school	17 (3.8)	3(1.3)	14(6.4)
Primary school	68 (15.3)	28 (12.3)	40(18.3)
Uneducated	355 (79.8)	196(86.3)	159(72.9)
Household's size			
≤ 5 members	79 (17.8)	24(10.6)	55(25.2)
> 5 members	366 (82.2)	203(89.4)	163(74.8)
Sanitation coverage			
Flush/pour flush toilet to piped sewer system or Pit latrine	208 (46.7)	7(3.1)	201(92.2)
Flush/pour flush toilet to open area	169 (38.0)	153(67.4)	16(7.3)
No toilet	68 (15.3)	67(29.5)	1(0.5)
Water coverage			
Improved*	282 (63.4)	149(65.5)	133(61.0)
Unimproved#	163 (36.6)	78(34.4)	85(39.0)
Wealth indices			
Rich	89 (20.0)	23(10.1)	66(30.3)
Middle	178 (40.0)	113(49.8)	65(29.8)
Poor	178 (40.0)	91(40.1)	87(39.9)

*, Piped water into dwelling/yard, public tap

#, Dug well, Tanker-truck, Surface water.

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Univariable analysis showed that schoolchildren resident in Al-Haimah Al -Dakheliah District (OR = 2.2, 95%CI:1.20, 4.06, $P = 0.011$) and living in houses with unimproved sanitation (OR = 1.9, 95%CI:1.02, 3.41, $P = 0.043$) or infected with *S. mansoni* (OR = 2.0, 95%CI: 1.01, 4.05, $P = 0.045$) were at high risk of developing underweight. However, underweight had negative association with educated fathers (OR = 0.5, 95%CI: 0.27, 0.98, $P = 0.041$). Multivariable analysis did not identify an independent risk factor of underweight (Table 5).

Stunting was significantly associated with children aged 11–15 years (OR = 5.6, 95%CI: 3.73, 8.44, $P < 0.001$), females (OR = 1.5, 95%CI: 1.01, 2.13, $P = 0.047$) and *S. mansoni* infection (OR = 4.0, 95%CI: 2.00, 8.01, $P = 0.002$). Multivariable analysis identified the infection with *S. mansoni* and early adolescence as independent risk factors of stunting (Table 6).

Wasting was associated with children aged 11–15 years (OR = 2.9, 95%CI: 1.86, 4.60, $P < 0.001$), households without tap water (OR = 1.9, 95%CI: 1.0, 3.28, $P = 0.021$) and children

Table 2. Distribution of *Schistosoma mansoni* infection among schoolchildren in the rural areas of Sana'a Governorate, Yemen (N = 445).

Type of infection	Prevalence	
	n (%)	95%CI
<i>S. mansoni</i> according to districts		
Al-Haimah Al-Dakheliah (N = 227)	77(33.9)	(28.1, 40.3)
Bani Mater (N = 218)	3(1.4)	(0.5, 4.0)
Intensity of <i>S. mansoni</i>		
Heavy intensity infection	18 (4.1)	(2.6, 6.3)
Moderate intensity infection	16 (3.6)	(2.3, 5.8)
Light intensity infection	46 (10.3)	(7.8, 13.5)

N, samples examined; n, samples positive for the infection; CI, Confidence interval

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Table 3. Factors associated with *Schistosoma mansoni* among schoolchildren in Sana'a Governorate, Yemen (N = 227)[&].

Variable	N	<i>S. mansoni</i> infection		AOR (95%CI)	P value
		n (%)	OR (95%CI)		
Gender					
Male	128	46 (35.9)	Reference		
Female	99	31 (31.3)	0.8(0.47, 1.42)	1.0(0.52, 1.98)	0.968
Age (Years)					
11–15	101	34(33.7)	Reference		
5–10	126	43(34.1)	1.0(0.59, 1.78)	1.1(0.59, 1.98)	0.794
Household's size					
≤ 5 members	24	8(33.3)	Reference		
> 5 members	203	72(34.0)	1.0(0.42, 2.53)	1.4(0.55, 3.68)	0.470
Father Education					
Educated	153	50 (32.7)	Reference		
Uneducated	74	27 (36.5)	1.2(0.66, 2.12)	1.0(0.54, 1.93)	0.961
Mother Education					
Educated	31	5 (16.1)	Reference		
Uneducated	196	72 (36.7)	3.0(1.11, 8.21)	2.5(0.84, 7.23)	0.102
Sanitation coverage[#]					
Improved sanitation	7	1 (14.3)	Reference		
Unimproved sanitation	237	76 (34.5)	3.2(0.37, 26.8)	2.2(0.24, 20, 87)	0.479
Source of drinking water[*]					
Tap water	46	7 (15.2)	Reference		
Other sources	181	70 (38.7)	3.5(1.49, 8.29)	2.9 (1.12, 7.55)	0.028
Wealth indices					
Rich	23	7(30.4)	Reference		
Middle	113	31(27.4)	0.9(0.32, 2.30)	0.7(0.25, 2.08)	0.540
Poor	91	39(42.9)	1.7(0.64, 4.57)	1.3(0.42, 3.78)	0.686
Swimming in ponds or dams					
No	69	20(29.0)	Reference		
Always/sometimes	158	57(36.1)	1.4(0.75, 2.55)	0.9(0.42, 1.99)	0.822

N, number of children examined; n, number of infected children; OR, Odds ratio; AOR; adjusted odds ratio CI, Confidence intervals

^{*}, Other sources of drinking water (Dug well + Tanker-truck + Surface water)

[#], Improved sanitation (Flush/pour flush toilet to piped sewer system or Pit latrine) and unimproved sanitation (no toilet or Flush/pour flush toilet to open area)

[&]; the analysis was restricted to Al-Haimah Al-Dakheliah District where the prevalence of schistosomiasis was high.

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Table 4. Prevalence of underweight, stunting and wasting among schoolchildren in Sana'a Governorate, Yemen*.

Variable	5–10 years (N = 231)		11–15 years (N = 214)		5–15 years (N = 445)	
	n (%)	95%CI	n (%)	95%CI	n (%)	95%CI
Underweight*						
Moderate/Severe (WAZ < - 2SD)	63 (27.3)	(21.9, 33.4)	NA	NA	NA	NA
Moderate (WAZ = - 3SD to -2SD)	38 (16.5)	(12.2, 21.8)	NA	NA	NA	NA
Severe (WAZ < - 3SD)	25 (10.8)	(7.4, 15.5)	NA	NA	NA	NA
Stunting						
Moderate/Severe (HAZ < - 2SD)	61 (26.4)	(20.8, 32.6)	143(66.9)	(60.1, 73.1)	204(45.8)	(41.2, 50.5)
Moderate (HAZ = - 3SD to -2SD)	40 (17.3)	(12.7, 22.8)	47 (22.0)	(16.6, 28.1)	87 (19.6)	(16.1, 23.5)
Severe (HAZ < - 3SD)	21 (9.1)	(5.7, 13.6)	96 (44.9)	(38.1, 51.8)	117(26.3)	(22.4, 30.6)
Wasting						
Moderate/Severe (BAZ < - 2SD)	36 (15.6)	(11.2, 20.9)	75 (35.1)	(28.7, 41.8)	111(25.0)	(21.2, 29.2)
Moderate (BAZ = - 3SD to -2SD)	24 (10.4)	(12.2, 18.9)	44 (20.6)	(15.4, 26.6)	68 (15.3)	(12.2, 18.9)
Severe (BAZ < - 3SD)	12 (5.2)	(6.7, 15.1)	31 (14.5)	(10.1, 19.9)	43 (9.7)	(7.3, 12.8)

N; number of children enrolled in the study, n; number of malnourished children, CI; confidence interval, NA; not applicable, WAZ; Weight-for-Age Z-score, HAZ; Height-for-age Z-score, BAZ; BMI-for-Age Z-score

*; The WHO reference data for WAZ used by the WHO AnthroPlus software were for age ≤ 10 years, therefore underweight was estimated for children aged 5–10 years (n = 231)

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from families placed in the middle category of wealth indices (OR = 2.2, 95%CI: 1.12, 4.15, $P = 0.022$). Multivariable analysis identified children aged 11–15 years, and the middle and poor categories of wealth indices as independent risk factors of wasting (Table 7).

Prevalence and factors associated with anemia

The prevalence of anemia among schoolchildren was 31.7% (95%CI: 27.5%, 36.2%) with 0.5%, 21.1% and 10.1% being severe, moderate and mild anemia, respectively. Univariable analysis showed that schoolchildren from Al-Haimah Al-Dakheliah District (OR = 3.9, 95%CI: 2.12, 6.97, $P < 0.001$), whose mothers were uneducated (OR = 2.5, 95%CI: 1.11, 5.69, $P = 0.023$), and those living in houses with unimproved sanitation (OR = 3.2, 95%CI: 1.11, 5.69, $P < 0.001$) and without tap water (OR = 2.2, 95%CI: 1.10, 4.52, $P = 0.024$) were at higher risk of anemia. Multivariable analysis using binary logistic regression model identified female (AOR = 1.6, 95% CI: 1.03, 2.43, $P = 0.038$), Al-Haimah Al-Dakheliah District (AOR = 3.4, 95%CI: 1.20, 9.55, $P = 0.021$) and early adolescence (11–15 years) (AOR = 1.8, 95%CI: 1.14, 2.78, $P = 0.011$) as independent risk factors of anemia among schoolchildren (Table 8).

Discussion

The present study indicated focal prevalence of *S. mansoni* among schoolchildren in Sana'a Governorate. At district level, the study placed Al-Haimah Al-Dakheliah and Bani Mater districts at high and low risk of schistosomiasis (33.9% and 1.4%, respectively). The presence of foci with high infection rates, although the pressure of MDA campaigns, can be explained by the high reinfection rate of *S. mansoni*. A recent study conducted in Ethiopia reported high reinfection rate of *S. mansoni* after 6 months of treatment with praziquantel[26]. The reinfection with *S. mansoni* was found to be affected by socioeconomic status, level of education of the household head and the baseline heavy infection[27], which may justify the variation in the prevalence of *S. mansoni* between the two districts. These findings, in turn, suggest that MDA campaigns should be integrated with additional measures to control schistosomiasis.

Table 5. Factors associated with underweight among schoolchildren, Sana'a Governorate, Yemen (N = 231).

Variable	N	Underweight			
		n(%)	OR (95%CI)	AOR (95%CI)	P value
Gender					
Male	124	34 (27.4)	Reference		
Female	107	29 (27.1)	1.0 (0.55, 1.76)	1.0(0.53, 1.85)	0.966
District					
Bani mater	105	20(19.0)	Reference		
Al-Haimah Al - Dakheliah	126	43(34.1)	2.2 (1.20, 4.06)	4.7(0.85, 26.29)	0.077
Household's size					
≤ 5 members	46	13 (28.3)	Reference		
>5 members	185	50 (27.0)	0.9 (0.46, 1.93)	0.8(0.37, 1.72)	0.561
Father Education					
Educated	148	47(31.8)	Reference		
Uneducated	83	16(19.3)	0.5 (0.27, 0.98)	0.5(0.25, 1.07)	0.077
Mother Education					
Educated	50	17 (34.0)	Reference		
Uneducated	181	46 (25.4)	0.7 (0.34, 1.30)	0.6(0.27, 1.38)	0.238
Sanitation coverage[#]					
Improved sanitation	102	21(20.6)	Reference		
Unimproved sanitation	129	42(32.6)	1.9 (1.02, 3.41)	0.5(0.08, 2.35)	0.340
Source of drinking water[*]					
Tap water	75	18 (24.0)	Reference		
Other sources	156	45 (28.8)	1.3 (0.68, 2.42)	1.0(0.49, 2.06)	0.992
Wealth indices					
Rich	41	9 (22.0)	Reference		
Middle	71	19 (26.8)	1.3 (0.52, 3.22)	0.9(0.31, 2.38)	0.764
Poor	119	35 (29.4)	1.5 (0.64, 3.43)	1.3(0.52, 3.34)	0.652
<i>S. mansoni</i>					
Not infected	188	46 (24.5)	Reference		
Infected	43	17 (39.5)	2.0 (1.01, 4.05)	1.5(0.67, 3.53)	0.309
<i>E. histolytica</i>					
Not infected	133	39 (29.3)	Reference		
Infected	98	24 (24.5)	0.8 (0.43, 1.41)	0.9(0.46, 1.61)	0.637
<i>G. lamblia</i>					
Not infected	181	46 (25.4)	Reference		
Infected	50	17 (34.0)	1.5 (0.77, 2.67)	1.5(0.71, 3.06)	0.294

N, number of children examined; n, number of malnourished children; OR, Odds ratio; AOR, Adjusted odds ratio; CI, Confidence intervals

*Other sources of drinking water (Dug well + Tanker-truck + Surface water)

#, Improved (Flush/pour flush toilet to piped sewer system or Pit latrine) and Unimproved (no toilet or Flush/pour flush toilet to open area)

[‡], underweight was measured for children aged 5–10 years.

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Multivariable analysis identified having no tap water at home as an independent risk factor of *S. mansoni* in Al-Haimah Al-Dakheliah District. This observation could be explained by the possibility of children's responsibility of bringing household's water, a common practice in Yemen, which increased their contact with unsafe water and made them prone to *S. mansoni* infection [28,29]. The result suggests an integration of MDA of praziquantel and the delivery of a community-based WASH programme as an effective approach for combating

Table 6. Factors associated with stunting among schoolchildren, Sana'a Governorate, Yemen (N = 445).

Variable	N	Stunted children			P value
		n(%)	OR (95%CI)	AOR (95%CI)	
Age (Years)					
5–10	231	61(26.4)	Reference		
11–15	214	143(66.8)	5.6(3.73, 8.44)	6.8(4.26, 10.82)	< 0.001
Gender					
Male	230	95 (41.3)	Reference		
Female	215	109 (50.7)	1.5(1.01, 2.13)	1.4(0.90, 2.13)	0.144
District					
Bani mater	218	107(49.1)	Reference		
Al-Haimah Al - Dakheliah	227	97(42.7)	0.8(0.53, 1.13)	0.4(0.13, 1.08)	0.070
Household's size					
≤ 5 members	79	40(50.6)	Reference		
>5 members	366	164(44.8)	0.8(0.49, 1.29)	0.7(0.38, 1.21)	0.187
Father Education					
Educated	295	145 (49.2)	Reference		
Uneducated	150	59 (39.3)	0.7(0.45, 1.00)	0.7(0.40, 1.06)	0.083
Mother Education					
Educated	90	43(47.8)	Reference		
Uneducated	355	161(45.4)	0.9(0.57, 1.44)	0.9(0.50, 1.60)	0.698
Sanitation coverage[#]					
Improved sanitation	208	99 (47.6)	Reference		
Unimproved sanitation	237	105 (44.3)	0.9(0.60, 1.27)	1.5(0.55, 4.20)	0.418
Source of drinking water[*]					
Tap water	113	44 (38.9)	Reference		
Other sources	332	160 (48.2)	1.5(0.94, 2.25)	0.8(0.49, 1.44)	0.529
Wealth indices					
Rich	89	42(47.2)	Reference		
Middle	178	87(48.9)	1.1(0.64, 1.78)	1.2(0.64, 2.19)	0.600
Poor	178	75(42.1)	0.8(0.49, 1.36)	1.3(0.71, 2.50)	0.379
S. mansoni					
Not infected	365	155(42.5)	Reference		
Infected	80	49 (61.3)	4.0(2.00, 8.01)	4.1(2.16, 7.84)	< 0.001
E. histolytica					
Not infected	250	120 (48.0)	Reference		
Infected	195	84 (43.1)	0.8(0.56, 1.20)	0.8(0.50, 1.19)	0.242
G. lamblia					
Not infected	355	160 (45.1)	Reference		
Infected	90	44 (48.9)	1.2(0.73, 1.85)	1.5(0.87, 2.55)	0.148

N, number of children examined; n, number of malnourished children; P, p value; OR, Odds ratio; AOR, Adjusted odds ratio; CI, Confidence intervals

*Other sources of drinking water (Dug well + Tanker-truck + Surface water)

[#], Improved (Flush/pour flush toilet to piped sewer system or Pit latrine) and Unimproved (no toilet or Flush/pour flush toilet to open area).

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schistosomiasis in these communities. The positive impact of WASH intervention on deworming programmes has been well evidenced [30,31].

The nutritional status of schoolchildren in Yemen has been neglected despite its significant impact on cognitive and educational achievement[5]. In the present study, the prevalence of

Table 7. Factors associated with wasting among schoolchildren, Sana'a Governorate, Yemen (N = 445).

Variable	N	Wasted children		AOR (95%CI)	P value
		n(%)	OR (95%CI)		
Age (Years)					
5–10	231	36(15.6)	Reference		
11–15	214	75(35.0)	2.9(1.86, 4.60)	3.1(1.86, 4.97)	<0.001
Gender					
Male	230	56 (24.3)	Reference		
Female	215	55 (25.6)	1.1(0.70, 1.64)	1.0(0.64, 1.60)	0.947
District					
Bani mater	218	53(24.3)	Reference		
Al-Haimah Al -Dakheliah	227	58(25.6)	1.1(0.70, 1.64)	0.9(0.31, 2.78)	0.898
Household's size					
≤ 5 members	79	22(27.8)	Reference		
>5 members	366	89(24.3)	0.8(0.48, 1.44)	0.8(0.42, 1.40)	0.389
Father Education					
Educated	295	75 (25.4)	Reference		
Uneducated	150	36 (24.0)	0.9(0.59, 1.46)	1.0(0.57, 1.58)	0.844
Mother Education					
Educated	90	19(21.1)	Reference		
Uneducated	355	92(25.9)	1.3(0.75, 2.29)	1.0(0.54, 1.93)	0.954
Sanitation coverage[#]					
Improved sanitation	208	50 (24.0)	Reference		
Unimproved sanitation	237	61 (25.7)	1.1(0.71, 1.69)	1.2(0.41, 3.30)	0.783
Source of drinking water[*]					
Tap water	113	19 (16.8)	Reference		
Other sources	156	92 (27.7)	1.9(1.10, 3.28)	1.4(0.77, 2.55)	0.270
Wealth indices					
Rich	89	14(15.7)	Reference		
Middle	178	51(28.7)	2.2(1.12, 4.15)	2.1(1.01, 4.15)	0.046
Poor	178	46(25.8)	1.9(0.96, 3.62)	2.3(1.11, 4.77)	0.026
S. mansoni					
Not infected	365	90(24.7)	Reference		
Infected	80	21 (26.3)	1.1(0.63, 1.89)	1.0(0.51, 1.85)	0.923
E. histolytica					
Not infected	250	65 (26.0)	Reference		
Infected	195	46 (23.6)	0.9(0.57, 1.36)	0.9(0.54, 1.35)	0.504
G. lamblia					
Not infected	355	93 (26.2)	Reference		
Infected	90	18 (20.0)	0.7(0.40, 1.24)	0.7(0.39, 1.30)	0.267

N, number of children examined; n, number of malnourished children; P, p value; OR, Odds ratio; AOR, Adjusted odds ratio; CI, Confidence intervals

*Other sources of drinking water (Dug well + Tanker-truck + Surface water)

[#], Improved (Flush/pour flush toilet to piped sewer system or Pit latrine) and Unimproved (no toilet or Flush/pour flush toilet to open area).

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stunting, underweight and wasting among schoolchildren aged 5–15 years was 45.8%, 27.3% and 25%, respectively. The study reported lower prevalence of stunting and underweight and five-times higher prevalence of wasting compared to stunting, underweight and wasting reported in previous studies conducted among schoolchildren in Al Mahweet and Sada'ah

Table 8. Factors associated with anemia schoolchildren in Sana'a Governorate, Yemen (N = 445).

Variable	Anemia				
	N	n (%)	OR (95%CI)	AOR (95%CI)	P value
Gender					
Male	230	64 (27.8)	Reference		
Female	215	77 (35.8)	1.5(0.96, 2.2)	1.6(1.03, 2.43)	0.038
Age (Years)					
5–10	231	62(26.8)	Reference		
11–15	214	79(36.9)	1.6(1.1, 2.5)	1.8(1.14, 2.78)	0.011
District					
Bani mater	218	48(22.0)	Reference		
Al-Haimah Al - Dakheliah	227	93(41.0)	2.5 (1.6, 3.7)	3.4(1.20, 9.55)	0.021
Household's size					
≤ 5 members	79	22(27.8)	Reference		
> 5 members	366	119(32.5)	1.3 (0.73, 2.1)	1.0(0.56, 1.81)	0.976
Father Education					
Educated	295	102 (34.6)	Reference		
Uneducated	150	39 (26.0)	0.7(0.44, 1.1 ⁺)	0.7(0.45, 1.17)	0.188
Mother Education					
Educated	90	27 (30.0)	Reference		
Uneducated	355	114 (32.1)	1.1(0.7, 1.8)	1.0(0.53, 1.70)	0.860
Sanitation coverage[#]					
Improved sanitation	208	46 (22.1)	Reference		
Unimproved sanitation	237	95 (40.1)	2.4 (1.6, 3.6)	1.0(0.37, 2.64)	0.975
Source of drinking water[*]					
Tap water	113	25 (22.1)	Reference		
Other sources	332	116 (34.9)	1.9 (1.2, 3.1)	1.6(0.94, 2.85)	0.084
Wealth indices					
Rich	89	25(28.1)	Reference		
Middle	178	56(31.5)	1.1(0.7, 2.0)	0.7(0.40, 1.39)	0.347
Poor	178	60 (33.7)	1.2(0.7, 2.0)	1.1(0.61, 2.15)	0.677
<i>S. mansoni</i>					
No	365	113(31.0)	Reference		
Yes	80	28 (35.0)	1.2(0.7, 2.1)	0.6(0.36, 1.14)	0.131
<i>E. histolytica</i>					
No	250	78 (31.2)	Reference		
Yes	195	63(32.3)	1.1(0.7, 1.6)	1.1(0.73, 1.72)	0.603
<i>G. lamblia</i>					
No	355	111 (31.3)	Reference		
Yes	90	30 (33.3)	1.1(0.7, 1.8)	1.0(0.60, 1.71)	0.970

N, number of children examined; n, number of malnourished children; OR, Odds ratio; AOR, adjusted odds ratio; CI, Confidence intervals

^{*}, Other sources of drinking water (Dug well + Tanker-truck + Surface water)

[#], Improved sanitation (Flush/pour flush toilet to piped sewer system or Pit latrine) and unimproved sanitation (no toilet or Flush/pour flush toilet to open area).

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governorates, Yemen[19,20]. The prevalence of stunting and wasting were higher among schoolchildren aged 11–15 years than those aged 5–10 years. These findings are consistent with previous studies conducted in Pakistan [32], Tanzania[33] and Madagascar[34]. The increased prevalence of stunting and wasting with age could be explained in part by the accumulated exposure of the older children to childhood diseases and inadequate diets [35].

Schistosoma mansoni is an independent risk factor of stunting among schoolchildren in Sana'a Governorate. The association between *S. mansoni* and stunting was reported in different studies [4,36,37].

Underweight takes into account both acute malnutrition (wasting) and chronic malnutrition (stunting). In the present study, a significant association between *S. mansoni* and underweight was found using univariable analysis although the multivariable analysis model did not confirm this association. Schoolchildren belonging to families with poor and middle wealth indices were at high risk of being acute malnourished. This finding is consistent with previous reports from Ethiopia [38] and India [39], which could reflect the inadequate feeding among children from families with low wealth indices.

The prevalence of anemia represents a moderate and severe public health problem among schoolchildren in Bani Matar and Al-Haimah Al -Dakheliah districts, respectively. Although the causes of anemia in the present study have not been identified, iron deficiency is one of the primary causes of anemia in the Yemeni communities [40]. The reason behind the high prevalence of anemia in Al-Haimah Al -Dakheliah District is not clear, although it may be attributed to socioeconomic status: 90% of the children belonged to families with moderate and poor wealth indices. Schoolchildren aged 11–15 years were at two times higher risk of being anemic compared to younger age group. This finding is consistent with previous studies conducted among children in different countries [41–46], which could be explained by the hyperactivity during this age together with high demand of micronutrient and limited consumption of a variety of food sources due to the household food insecurity [47], which can be reduced by school feeding [48,49]. The gender female was also an independent risk factor of anemia, which is in line with previous studies [50,51]. It is noteworthy that anemia among schoolchildren may lead to impaired cognitive function [52]. No significant association was found between *S. mansoni* and anemia, which is consistent with previous studies conducted elsewhere [28,33].

The present study is limited by the low number of districts and schools enrolled in the study, which prevents the conclusion about the overall prevalence of schistosomiasis at governorate level because the disease is highly focal, although study findings are consistent with the results of the latest nationwide survey. However, the study sample size and design are appropriate to assess the association between schistosomiasis and nutritional status of schoolchildren in Sana'a Governorate.

In conclusion, the study findings showed highly focal prevalence of schistosomiasis in Sana'a Governorate with a public health significance that varies from low to high risk. Schoolchildren living in houses without tap water are at high risk of the infection. Schoolchildren harboring the parasite and early adolescent children had high prevalence of stunting. Besides, early adolescent schoolchildren and children belonged to families with middle or poor wealth were wasted. Anemia is a moderate public health threat with early adolescent and female schoolchildren, being at higher risk. The study findings suggest adopting integrated control measures for the control of schistosomiasis such as MDA and WASH, and integrated diseases control programmes for improving the health status of schoolchildren.

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