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

Sami Ahmed Al-Haidari1,2, Mohammed A. K. Mahdy1* , Abdulsalam M. Al-Mekhlafi1, Walid M. S. Al Murisi1, Ahmed Ali Qaid Thabit3, Mohammed Abdullah Al-Amad4, Hassan Al-Shamahi5, Othman Saeed Bahashwan4, Abdulwahed Al Serouri4

1 Department of Parasitology, Faculty of Medicine, Sana’a University, Sana’a, Yemen, 2 Diseases Control & Surveillance, Ministry of Public Health and Population, Sana’a, Yemen, 3 Communicable Diseases Department, World Health Organization, Sana’a, Yemen, 4 Field Epidemiology Training Programme, Ministry of Public Health and Population, Sana’a, Yemen, 5 Department of Medical Microbiology, Faculty of Medicine, Sana’a University, Sana’a, Yemen

* alsharaby9@yahoo.com

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. Schistosoma 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 income (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 \( S. mansonii \) 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. \( S. mansonii \) was identified by microscopic examination of Kato-Katz fecal smear. Hemoglobin concentration and anthropometric measurements were estimated using standard methods. The prevalence of \( S. mansonii \) was highly focal (1.4–33.9%). Schoolchildren living in households without tap water had significantly high infection rate of \( S. mansonii \). The prevalence of wasting, stunting, underweight and anemia among schoolchildren was 25.0%, 45.8%, 27.3% and 31.7%, respectively. Although \( S. mansonii \) was significantly associated with stunting, no significant association was found between \( S. mansonii \) 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), \( S. mansonii \) 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, ± 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 (≥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+ (HemoCue AB, Angelhome, Sweden) on blood collected by finger-prick following the manufacturer instruction. Children were classified into anemic or non-anemic (Hb ≥ 115 g/l for children aged 5–10 years and Hb ≥ 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 (≤ 4.9%), mild (5.0–19.9%), moderate (20.0–39.9%) and severe (≥ 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/ headmisters 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).
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: 10, 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 |
|-------------------|------------|
| S. mansoni according to districts | n (%)     | 95%CI |
| Al-Haimah Al-Dakheilah (N = 227) | 77(33.9)   | (28.1, 40.3) |
| Bani Mater (N = 218) | 3(1.4)     | (0.5, 4.0) |

| Intensity of S. mansoni | Prevalence |
|-------------------------|------------|
| 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* infection among schoolchildren in Sana’a Governorate, Yemen (N = 227)*.

| Variable | N | n (%) | OR (95%CI) | AOR (95%CI) | P value |
|----------|---|-------|------------|-------------|---------|
| 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-Dakheilah District where the prevalence of schistosomiasis was high.

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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. Multi-variable 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 \textit{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 \textit{S. mansoni}. A recent study conducted in Ethiopia reported high reinfection rate of \textit{S. mansoni} after 6 months of treatment with praziquantel[26]. The reinfection with \textit{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 \textit{S. mansoni} between the two districts. These findings, in turn, suggest that MDA campaigns should be integrated with additional measures to control schistosomiasis.
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 5. Factors associated with underweight among schoolchildren, Sana’a Governorate, Yemen (N = 231).

| Variable                           | Underweight |
|------------------------------------|-------------|
|                                    | N  | n (%) | OR (95% CI) | AOR (95% CI) | P value |
| Gender                             |    |       |             |             |         |
| Male                               | 124 | 34 (27.4) | Reference   |             | 0.966   |
| Female                             | 107 | 29 (27.1) | 1.0 (0.55, 1.76) | 1.0(0.53, 1.85) |         |
| District                           |    |       |             |             |         |
| Bani mater                          | 105 | 20 (19.0) | Reference   |             | 0.077   |
| Al-Haimah Al–Dakheliah             | 126 | 43 (34.1) | 2.2 (1.20, 4.06) | 4.7(0.85, 26.29) |         |
| 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   |             | 0.340   |
| Unimproved sanitation               | 129 | 42 (32.6) | 1.9 (1.02, 3.41) | 0.5(0.08, 2.35) |         |
| Source of drinking water*          |    |       |             |             |         |
| Tap water                          | 75  | 18 (24.0) | Reference   |             | 0.992   |
| Other sources                      | 156 | 45 (28.8) | 1.3 (0.68, 2.42) | 1.0(0.49, 2.06) |         |
| Wealth indices                     |    |       |             |             |         |
| Rich                               | 41  | 9 (22.0)  | Reference   |             | 0.764   |
| Middle                             | 71  | 19 (26.8) | 1.3 (0.52, 3.22) | 0.9(0.31, 2.38) |         |
| Poor                               | 119 | 35 (29.4) | 1.5 (0.64, 3.43) | 1.3(0.52, 3.34) | 0.652   |
| S. mansoni                         |    |       |             |             |         |
| Not infected                       | 188 | 46 (24.5) | Reference   |             | 0.309   |
| Infected                           | 43  | 17 (39.5) | 2.0 (1.01, 4.05) | 1.5(0.67, 3.53) |         |
| E. histolytica                     |    |       |             |             |         |
| Not infected                       | 133 | 39 (29.3) | Reference   |             | 0.637   |
| Infected                           | 98  | 24 (24.5) | 0.8 (0.43, 1.41) | 0.9(0.46, 1.61) |         |
| G. lamblia                         |    |       |             |             |         |
| 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)

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

b, underweight was measured for children aged 5–10 years.

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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

| Variable               | N     | n(%)       | OR (95%CI)       | AOR (95%CI)       | P value |
|------------------------|-------|------------|------------------|-------------------|---------|
| Age (Years)            | N     | n(%)       | Reference        |                   |         |
| 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                 | N     | n(%)       | Reference        |                   |         |
| 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               | N     | n(%)       | Reference        |                   |         |
| 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       | N     | n(%)       | Reference        |                   |         |
| ≤ 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       | N     | n(%)       | Reference        |                   |         |
| 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       | N     | n(%)       | Reference        |                   |         |
| Educated               | 355   | 161(45.4)  | 0.9(0.57, 1.44)  | 0.9(0.50, 1.60)   | 0.698   |
| Uneducated             |       |            | Reference        |                   |         |
| Sanitation coverage²   | N     | n(%)       | Reference        |                   |         |
| 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 water³ | N     | n(%)       | Reference        |                   |         |
| 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         | N     | n(%)       | Reference        |                   |         |
| 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             | N     | n(%)       | Reference        |                   |         |
| 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         | N     | n(%)       | Reference        |                   |         |
| 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             | N     | n(%)       | Reference        |                   |         |
| 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
²Other sources of drinking water (Dug well + Tanker-truck + Surface water)
³Improved (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 7. Factors associated with wasting among schoolchildren, Sana’a Governorate, Yemen (N = 445).

| Variable                  | Wasted children |          |          |          |          |
|---------------------------|-----------------|----------|----------|----------|----------|
|                           | N               | n(%)     | OR (95%CI)| AOR (95%CI)| P value  |
| **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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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].

### 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   |
| **S. mansoni**                  |                      |    |       |            |             |         |
| 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   |
| **E. histolytica**              |                      |    |       |            |             |         |
| 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   |
| **G. lamblia**                  |                      |    |       |            |             |         |
| 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).
**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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Author Contributions

Conceptualization: Sami Ahmed Al-Haidari, Mohammed A. K. Mahdy, Abdulsalam M. Al-Mekhlafi.

Data curation: Sami Ahmed Al-Haidari.

Formal analysis: Sami Ahmed Al-Haidari, Mohammed A. K. Mahdy.

Investigation: Sami Ahmed Al-Haidari, Walid M. S. Al Murisi.

Methodology: Sami Ahmed Al-Haidari, Mohammed A. K. Mahdy.

Project administration: Mohammed A. K. Mahdy.

Supervision: Mohammed A. K. Mahdy, Abdulsalam M. Al-Mekhlafi.

Writing – original draft: Sami Ahmed Al-Haidari, Mohammed A. K. Mahdy.

Writing – review & editing: Mohammed A. K. Mahdy, Abdulsalam M. Al-Mekhlafi, Walid M. S. Al Murisi, Ahmed Ali Qaid Thabit, Mohammed Abdullah Al-Amad, Hassan Al-Shamahi, Othman Saeed Bahashwan, Abdulwahed Al Serouri.

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