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Asymptomatic *Giardia* infection and adverse nutritional outcomes among rural schoolchildren in Sana'a Governorate, Yemen

Mohammed A. K. Mahdy[1, *], Sami A. Al-Haidari[1,2], Rashad Abdul-Ghani[1, 3] and Abdulsalam M. Al-Mekhlafi[1]

[1]**Department of Parasitology, Faculty of Medicine and Health Sciences, Sana'a University, Yemen,**
[2]**Diseases Control & Surveillance, Ministry of Public Health and Population, Sana'a, Yemen,**
[3]**Tropical Disease Research Center, Faculty of Medicine and Health Sciences, University of Science and Technology, Sana'a, Yemen.**

*Corresponding author: alsharaby9@yahoo.com

Abstract

Background and Aim: The association between infection with Giardia lamblia and malnutrition in school-age children is well documented. Because both conditions are common among Yemeni schoolchildren, this study aimed to determine the prevalence of Giardia infection and its associated factors and to assess its association with adverse nutritional outcomes among rural schoolchildren in Sana'a Governorate, Yemen.

Subjects and Methods: A school-based, cross-sectional study was conducted among 445 schoolchildren aged 6–15 years. Giardia lamblia and other intestinal protozoa were detected by microscopic examination of stool specimen sediments after concentration with the formal-ether technique. Sociodemographic, behavioral, and environmental data were collected using a structured questionnaire through face-to-face interviews, and nutritional status was assessed using anthropometric measurements. Univariate analysis was used to test the significance of the associations, and multivariable binary logistic regression was employed to identify the independent predictors of Giardia infection.
Results: Giardia infection was prevalent among 20.2% [95% confidence interval (CI): 16.6, 23.8] of schoolchildren. Age 11 years (adjusted odds ratio [AOR] = 1.9, 95 % CI: 1.05, 3.31; textitp= 0.029), farmland ownership by children's families (AOR = 2.4, 95% CI: 1.30, 4.34; p = 0.014), and not washing hands after playing with soil (AOR = 3.1, 95% CI: 1.05, 8.89; p = 0.047) were independent predictors of Giardia infection. In terms of adverse nutritional outcomes, Giardia infection was significantly associated with stunting among children aged 6–11 years (OR = 1.9, 95% CI: 1.10, 3.22; p = 0.022) but was not associated with wasting or underweight.

Conclusion: One in five rural schoolchildren in Sana'a Governorate is infected with G. lamblia. Younger age, not practicing handwashing after playing with soil, and belonging to families owning farmland can independently predict infection. Giardia infection is associated with stunting among schoolchildren. Therefore, improving the nutritional status of rural schoolchildren warrants the prevention and control of Giardia infection.

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INTRODUCTION

Giardia lamblia, also called G. duodenalis or G. intestinalis, is a protozoan parasite that infects the small intestine and is typically transmitted through the fecal-oral route, often involving contaminated food, drinks or hands. Transmission can be anthroponotic or zoonotic [1, 2].

Globally, it is responsible for an estimated 28.8 million cases of foodborne diarrheal illness each year [3], and 250 water-borne outbreaks of the parasite were documented from 2017 to 2020 [4]. Although infection can be asymptomatic, giardiasis may cause diarrhea[5, 6, 7], pediatric wasting [8, 9], and stunting [9, 10, 11, 12]. In addition, it has been linked to long-term health issues, including irritable bowel syndrome, chronic fatigue, and pediatric cognitive impairment [13, 14].
In addition to being heavily burdened by neglected tropical diseases (NTDs) [15], Yemen is among the world's least developed nations, ranking 183rd out of 191 countries and territories in the 2022 Human Development Index (HDI) [16]. The ongoing conflict since 2015 has further exacerbated the situation, resulting in one of the most severe global humanitarian crises. Reports indicate that the prevalence of *Giardia* infections in the country varies from 9.7% to 35.3% across various population groups and study settings[17, 18, 19, 20, 21, 22, 23, 24, 25]. Factors linked to higher infection rates include being male [19, 23], consuming unsafe water, and poor hygiene practices such as not washing hands after using the toilet, having infected family members, and close contact with animals [19]. *Giardia* infection has been widely linked to malnutrition among school-age children (SAC) [9, 26]. Nevertheless, there is limited information regarding how this parasite affects the nutritional health of children in Yemen, although both *Giardia* infection [18] and malnutrition [18, 27, 28, 29] are highly prevalent among schoolchildren in the country. Yemen's national nutritional strategy aims to reduce the incidence of infectious diseases affecting the nutritional status of schoolchildren [30]; *Giardia* infection has been neglected in national control strategies against parasitic infections in the country. This neglect may be attributed to the prioritization of soil-transmitted helminth infections and schistosomiasis, along with insufficient data on the nutritional consequences of *Giardia* infection. Therefore, the present study aimed to determine the prevalence of *Giardia* infection and its associated factors and to assess its association with adverse nutritional outcomes among rural schoolchildren in Sana'a Governorate, Yemen.

SUBJECTS AND METHODS

Study design, area and subjects

This school-based, cross-sectional study was conducted among schoolchildren aged 6–15 years in rural areas of Sana'a Governorate, Yemen, in 2018. This Governorate surrounds the capital city of Sana'a and is located at 15°21'N and 44°12'E, covering an area of 13, 850 km². It is divided into 16 districts and inhabited by 1,311 million people according to the 2017 projections [31], with over 97% being residents in rural areas and mainly engaged in agricultural activities.

Sample size and sampling strategy

To estimate the prevalence of *Giardia* infection, a minimum sample size of 416 schoolchildren was calculated using Open Epi Info, version 3.01 (accessible at www.openepi.com). This calculation was based on the following parameters: anticipated prevalence of 16.1% [18], 95% confidence level, 5% margin of error, and design effect of 2. A total of 445 schoolchildren were recruited for this study. A multistage cluster sampling method was employed, in which two districts (Bani Matar and Al-Haimah Al-Dakheliah) were randomly selected from the 16 districts of the governorate (Figure 1). One school was selected randomly from each district. School children were then selected by simple random sampling, using the student records as a sampling frame and replacing absent, unwilling, and ineligible students with the next in the record.

Data collection and anthropometric measurements

Sociodemographic, behavioral, and environmental data were collected using a structured questionnaire via face-to-face interviews. To assess anthropometric status, children's body weight was recorded to the nearest 0.1 kg using a digital scale, their standing height was recorded to the nearest 0.1 cm using a stadiometer, and their age was obtained from school records. These measures were used to compute the height-for-age Z-score (HAZ), weight-for-age Z-score (WAZ), and body mass index (BMI)-for-age Z-score (BAZ), using the WHO AnthroPlus software, which has been designed to assess the growth and nutritional status of children and adolescents aged 5 to 19 years.[32] Children were categorized as stunted if their HAZ was below -2 standard deviations (SD) from the WHO Growth Standards median. Similarly, underweight and wasting were defined by WAZ and BAZ scores below -2 SD, respectively, [32].

Stool examination

G. lamblia and other protozoan species were detected by microscopic examination of the sediment of a single stool sample per child after concentration by the formal-ether concentration technique [33].

Data analysis

D Data analysis was conducted using IBM SPSS Statistics software, version 23.0 (IBM Corp., Armonk, NY, USA). To evaluate household wealth, principal component analysis (PCA) was applied to variables such as ownership of durable goods, livestock, and agricultural land [34]. Based on the resulting PCA scores, the households were classified into five wealth quintiles. These were further consolidated into three categories: low (bottom 40%), medium (middle 40%), and high (top 20%) wealth [34].

Pearson's chi-square test was employed in a univariate analysis to examine the relationship between individual independent variables and *Giardia* infection, along with calculating odds ratios (ORs) and their corresponding 95% confidence intervals (CIs). Subsequently, a binary logistic regression model was used for multivariate analysis to determine the predictors of *Giardia* infection in schoolchildren, reporting the adjusted ORs (AORs) and 95% CIs. Statistical significance was defined as a p-value less than 0.05.

Ethical considerations

This study adhered to the ethical standards of the Declaration of Helsinki for research involving human participants. The study proposal was approved by the Postgraduate Committee of the Faculty of Medicine and Health Sciences at Sana'a University. Authorization was also secured from administrators of the selected schools after explaining its purpose and importance. Written informed consent was obtained from the parents or guardians of the participating children who were informed of their right to decline their children's participation. Meanwhile, the children's assent was obtained after providing them with easy-to-understand information and clarifying that participation was voluntary. Anonymity and confidentiality of the children and their families were guaranteed.

RESULTS

Prevalence of *Giardia* and other protozoan species

Of the 445 schoolchildren, 248 (55.7%) were infected with at least one species of intestinal protozoa. Most schoolchildren were infected with *Entamoeba histolytica/dispar* (43.8%; 95% CI: 39.1, 48.8), followed by *G. lamblia* (20.2%; 95% CI: 16.6, 23.8) and *Entamoeba coli* (9.9%; 95% CI: 7.4, 12.8). Mixed infection with *E. histolytica/dispar* and *G. lamblia* was observed in 8.3% of schoolchildren (Table 1).

Factors associated with *Giardia* infection

Table 2 shows that age ≤11 years (OR = 1.7; 95% CI: 0.99, 3.00; p = 0.052), belonging to farmland-owning families (OR = 3.1; 95% CI: 1.19, 7.83; p = 0.002), and not washing hands after contact with soil (OR =2.1; 95% CI: 1.31, 3.38; p = 0.015) were significantly associated with *Giardia* infection. Moreover, age ≤11 years (AOR = 1.9, 95% CI: 1.05, 3.31; p = 0.029), belonging to farmland-owning families (AOR = 2.4, 95% CI: 1.30, 4.34; p = 0.014), and not washing hands after contact with soil (AOR = 3.1, 95% CI: 1.05, 8.89; p = 0.047) were confirmed as independent predictors of *Giardia* infection among school children.

Age-adjusted association between *Giardia* infection and adverse nutritional outcomes

All adverse nutritional outcomes were higher among *Giardia*-infected children than among their counterparts, but only stunting was significantly associated with *Giardia* infection among children aged 6-11 years (OR = 1.9, 95% CI: 1.10, 3.22; p = 0.022). Conversely, no association was found between *Giardia* infection and wasting or being underweight across all age categories (Table 3).

DISCUSSION

Neglecting intestinal parasitic infections in rural communities in Yemen may be further affected by the repercussions of the ongoing humanitarian crisis in the country. In this context, more than half of the schoolchildren in the rural districts of Bani Mater and Al-Haimah Al-Dakheliah in Sana'a Governorate were infected with at least one species of intestinal protozoa. This finding agrees with that (54.8%) reported among rural schoolchildren in three other districts of Sana'a in a study conducted before the escalation of armed conflict and humanitarian crisis in the country [18].

The present study revealed a prevalence of E. histolytica/dispar (43.8%) compared with earlier reports in Yemen, which found rates of 16.4–27.8% among schoolchildren [17, 18, 35], 17.1% among patients attending health facilities [21], and 13.8% among immunocompromised patients [22]. In contrast, it is lower than that (53.6%) reported for the Entameba complex among rural communities in the four governorates of Yemen, including Sana'a [36]. The dominance of E. histolytica/dispar infections observed in this study aligns with findings from previous research involving schoolchildren in Yemen [17, 18, 35] and African countries [37]. However, the relative proportion of pathogenic E. histolytica to non-pathogenic E. dispar could not be determined by microscopic examination because of the morphological similarities between the two species, and approximately 90% of Entamoeba infections are asymptomatic and are caused by E. dispar [38].

In this study, G. lamblia emerged as the second most frequently detected protozoan, affecting approximately 20% of the rural schoolchildren. This finding corresponds with similar findings reported for school-aged children in Yemen and elsewhere [17, 18, 37]. Age was an independent predictor of infection, with children aged 11 years or younger more likely to be infected—a trend that mirrors observations from other districts within the same governorate [18], where higher infection rates were observed in children aged ≤10 years.

Table 1. Prevalence of G. lamblia and other intestinal protozoa among schoolchildren in Sana'a Governorate, Yemen (2018)*

Types of infection	*n*	(%; 95% CI)
Overall prevalence	**248**	**(55.7; 51.1, 60.3)**
Single infections		
E. histolytica/dispar	195	(43.8; 39.1, 48.8)
G. lamblia	90	(20.2; 16.6, 23.8)
E. coli	44	(9.9; 7.4, 12.8)
Mixed infections		
G. lamblia and *E. histolytica/dispar*	37	(8.3; 6.1, 11.3)
G. lamblia and *E. coli*	7	(1.6; 0.4, 2.9)
E. histolytica/dispar and *E. coli*	7	(1.6; 0.4, 2.9)

This finding is consistent with previous reports [39, 40, 41, 42, 43]. Poor personal hygiene can partially explain the significantly higher risk of infection among younger children.

Children from families that owned farmland were found to be at a higher risk—approximately twice as likely—of contracting *Giardia* infection, making farmland ownership a significant independent predictor of infection. This finding could be attributed to the involvement of children in agricultural activities that expose them to infection from contaminated soil or irrigation water. In this regard, involvement in agricultural activities was found to predispose Colombia, Egypt, and Nepal to textitGiardiainfection [44, 45, 46]. Meanwhile, the spread of infection to children from other family members engaged in agriculture cannot be ruled out. The transmission of *G. lamblia* between individuals is well established [47, 48], with several studies indicating that having family members infected with *Giardia* increases the risk of contracting the infection [19, 49, 50].

Not practicing handwashing after playing with soil was an independent predictor of *Giardia* infection among schoolchildren in the present study, which is consistent with the findings of Yemen et al. [18, 19, 43, 51]. Soil can become contaminated with *G. lamblia* cysts as a result of unsanitary sewage disposal in rural areas, serving as a potential environmental source of infection [52, 53, 54] and facilitating the soil-to-mouth transmission of infection in children with poor personal hygiene. In contrast, no significant association was observed between *G. lamblia* infection and either the source of drinking water or availability of improved sanitation facilities. This finding is inconsistent with that reported for rural communities in Yemen, where drinking from unsafe water sources was significantly associated with *Giardia* infection [19].

Giardia infection, even if asymptomatic, can adversely affect the growth of children during early childhood [12]. In line with this assumption, in the present study, *Giardia*infection was significantly associated with stunting among schoolchildren aged 5–11 years, with *Giardia*-infected children being twice as likely to be severely stunted as non-infected children. Similarly, *Giardia* infection has been reported as a determinant of stunting in SAC [9, 26, 55, 56] and preschool-age children [11, 57, 58, 59]. A recent cohort study across seven resource-limited settings showed that *Giardia* infection had a greater impact on linear growth during early childhood than other types of intestinal infection [12]. It is noteworthy that stunting causes morbidity and is a predictor of low cognitive functioning during school-age [60], underpinning the need for interventions to reduce the *Giardia* burden among children. The lack of association between *Giardia* infection and nutritional status in older children could be explained by cumulative immunity due to repeated exposure to *Giardia* with increasing age [61], reducing the adverse effects of infection [62].

One limitation of this study is its reliance on microscopic analysis of a single stool sample per child, possibly overlooking some infections due to the sporadic nature of cyst excretion. Nonetheless, the use of the formal ether concentration technique may enhance the sensitivity of detection. However, this study focused only on asymptomatic cases, because children with diarrhea often stay at home. This exclusion may have underestimated the prevalence and impact of symptomatic giardiasis on the study population. Therefore, community-based studies are recommended to investigate the association between symptomatic giardiasis and adverse nutritional outcomes in SAC patients.

CONCLUSION

Giardia infection ranks second after infection with E. histolytica among rural schoolchildren in Sana'a Governorate, infecting approximately one in five children. The younger age of children, not practicing handwashing after playing with soil, and belonging to families owning farmlands can independently predict infection among children.

Table 2. Factors associated with *Giardia* infection among rural schoolchildren in Sana'a Governorate, Yemen (2018)

Variable	*N*	*Giardia* infection						
		n	(%)	OR	(95% CI)	AOR	(95% CI)	*p*-value
Gender								
Male	230	45	(19.6)	Reference				
Female	215	45	(20.9)	1.1	(0.69, 1.73)	1.2	(0.74, 1.69)	0.464
Age (years)								
>11	131	19	(14.5)	Reference				
≤11	314	71	(22.6)	1.7	(0.99, 3.00)	1.9	(1.07, 3.39)	0.029
District								
Bani Mater	218	36	(16.5)	Reference				
Al-Haimah Al-Dakheliah	227	54	(23.8)	1.6	(0.99, 2.53)	1.7	(0.51, 5.86)	0.384
Household size (members)								
≤ 5	79	15	(19.0)	Reference				
>5	366	75	(20.5)	1.1	(0.59, 2.04)	0.8	(0.43, 1.62)	0.602
Father's education								
Educated	295	59	(20.0)	Reference				
Uneducated	150	31	(20.7)	1.0	(0.64, 1.70)	1.2	(0.69, 1.92)	0.597
Socioeconomic status (wealth index)								
High	89	16	(18.0)	Reference				
Medium	178	42	(23.6)	1.4	(0.74, 2.68)	1.3	(0.62, 2.58)	0.517
Low	178	32	(18.0)	1.0	(0.51, 1.94)	1.1	(0.51, 2.41)	0.789
Sanitation [a]								
Improved	208	36	(17.3)	Reference				
Unimproved	237	54	(22.8)	1.4	(0.88, 2.26)	0.5	(0.16, 1.58)	0.240
Source of drinking water								
Piped	113	21	(18.6)	Reference				
Unpiped	332	69	(20.8)	1.2	(0.67, 1.98)	1.4	(0.72, 2.51)	0.347
Family ownership of farmlands								
No	233	34	(14.6)	Reference				
Yes	212	56	(26.4)	2.1	(1.31, 3.38)	2.3	(1.18, 4.49)	0.014
Washing hands before eating								
Yes	429	86	(20.0)	Reference				
No	16	4	(25.0)	1.3	(0.42, 4.22)	2.1	(0.61, 7.50)	0.235
Washing hands after playing with soil								
Yes	426	82	(19.2)	Reference				
No	19	8	(42.1)	3.1	(1.19, 7.83)	3.0	(1.02, 8.59)	0.047
Washing hands with soap								
Yes	357	68	(19.0)	Reference				
No	88	22	(25.0)	1.4	(0.82, 2.50)	0.9	(0.44, 1.84)	0.752

OR, odds ratio; AOR; adjusted odds ratio; CI, confidence interval.

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Table 3. Age-adjusted association of *Giardia* infection with clinical and nutritional outcomes among rural schoolchildren in Sana'a Governorate, Yemen (2018)

Giardia infection status	N	Adverse nutritional outcomes											
		Stunting				Wasting				Underweight [a]			
		n	(%)	OR	(95% CI)	*n*	(%)	OR	(95% CI)	*n*	(%)	OR	(95% CI)
Schoolchildren aged 6–11 years													
Non-infected	243	74	(30.5)	Reference		36	(14.8)	Reference		46	(25.4)	Reference	
Infected	71	32	(45.1)	1.9	(1.10, 3.22)*	12	(16.9)	1.2	(0.57, 2.39)	17	(34.0)	1.5	(0.77, 2.97)
Schoolchildren aged 12–15 years													
Non-infected	112	86	(76.8)	Reference		57	(50.9)	Reference					
Infected	19	12	(63.2)	0.5	(0.19,1.45)	6	(31.6)	0.5	(0.16, 1.26)	NA		NA	
Schoolchildren aged 5–15 years													
Non-infected	355	160	(45.1)	Reference		93	(26.2)	Reference					
Infected	90	44	(48.9)	1.2	(0.73,1.85)	18	(20.0)	0.7	(0.40, 1.24)	NA		NA	

OR, odds ratio; CI, confidence interval; NA, not applicable. * p = 0.022; a Calculated for 181 non-infected and 50 infected children, as the WHO AnthroPlus software uses WAZ reference data applicable only to children aged 10 years or younger.

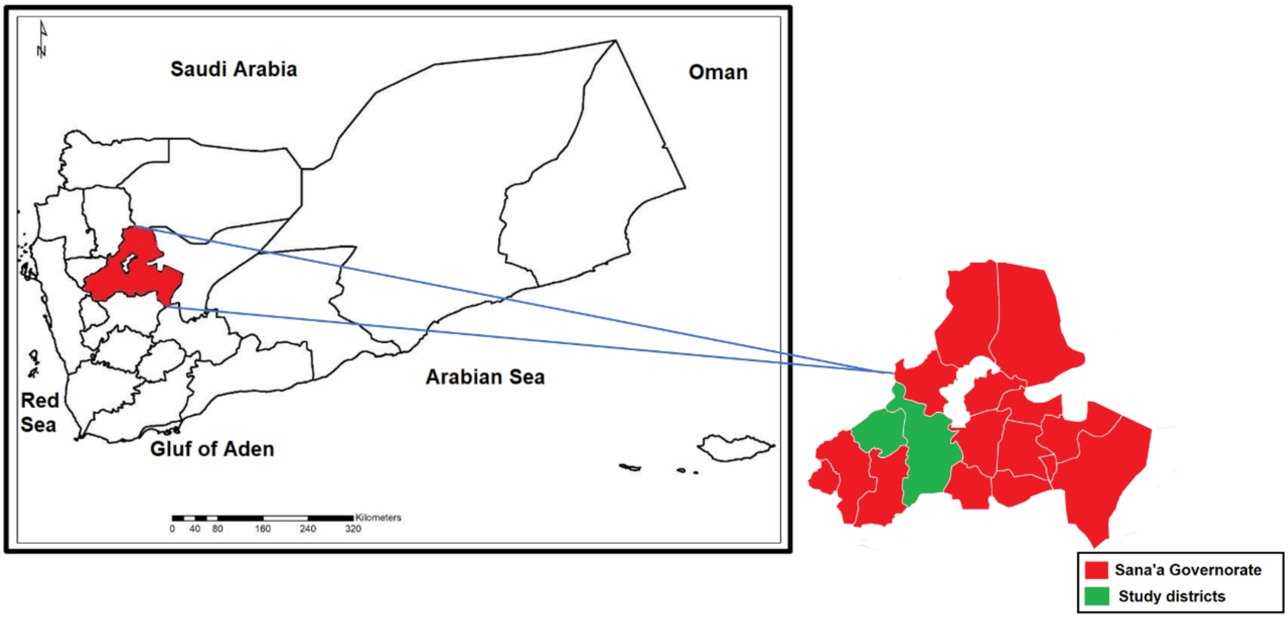

Figure 1. Map of Yemen showing the location of Sana'a governorate and study districts

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CONFLICT OF INTERESTS

The authors declare no conflicts of interest associated with this study.

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