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INTESTINAL PARASITIC INFECTIONS AMONG ADULT STAFF FROM A PUBLIC UNIVERSITY RESIDENTIAL HALLS IN BANGLADESH

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Abstract: Intestinal parasitic infestation (IPI) is a significant health problem around the world, affecting 3.5 billion people and causing 200,000 deaths annually. The objective of this study was to evaluate the prevalence of intestinal parasitic infestation among the staff of four residential halls of a public university in Bangladesh. Faecal samples (n=100) were collected from staff of four residential halls to detect parasite eggs and larvae. The Formal-Ether Concentration Technique was used to determine the parasite prevalence from the study samples. Each participant was interviewed with a detailed questionnaire to obtain sociodemographic and behavioral information. Seven intestinal parasite species were identified, including protozoa (*Blastocystis* spp. and *Cystoisospora* spp.), cestodes (*Diphyllobothrium latum* and *Hymenolepis* spp.), and nematodes (*Ascaris lumbricoides*, *Enterobius vermicularis*, and *Trichuris trichiura*). *Blastocystis* spp., *Ascaris lumbricoides,* and *Cystoisospora* spp. exhibited the highest prevalence, whereas *Enterobius vermicularis* and *Trichuris trichiura* were relatively uncommon. Cestodes *Diphyllobothrium latum* and *Hymenolepis* sp. showed varied prevalence. No statistically significant differences in parasitic infestation were observed regarding age, gender, toilet type, or education level ($p > 0.05$). The high parasitic prevalence observed among the university residential staff highlights the need for continuous screening to prevent faeco-oral transmission of parasites. These findings will provide guidelines for the authorities to develop effective control strategies for IPIs.

Key words: Intestinal parasitic infestation, prevalence, risk factors, faeco-oral transmission, diarrhea.

INTRODUCTION

IPI is one of the neglected tropical diseases that represents a significant global health challenge, especially in developing countries, with a prevalence rate of 30–60%, making IPIs common and seriously detrimental to both individual and public health (Taghipour *et al.,* 2021). As most research is centered on diarrheal diseases in children, studies on adult populations are scarce (Keusch *et al.*, 2016). The asymptomatic nature of

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the IPI also poses a problem, as they often serve as undetected reservoirs of community transmission. For working-class populations, even mild chronic infestations cause persistent abdominal discomfort and intensified malnutrition, causing incalculable socioeconomic loss (Braseth *et al.*, 2021; Hotez *et al.*, 2008).

One of the leading infections in humans, prevalent in low- and middle-income countries, is caused by soil-transmitted helminths and protozoan parasites (Haque *et al.,* 2007). Among these pathogens, *Ascaris lumbricoides*, *Trichuris trichiura*, and *Enterobius vermicularis* cause severe digestive disorders (Cheesbrough *et al.,* 2005). Simultaneously, protozoans like *Blastocystis* spp. remain highly prevalent yet clinically controversial due to immense genetic diversity and varied pathogenic traits among distinct subtypes (Osman *et al.,* 2016; Van Gestel *et al.,* 2019). Infections with hookworms and *A. lumbricoides* are estimated to cause 2000-10,000 annual deaths (Marie & Petri, 2025). Schistosomes, filarial worms, and soil-transmitted helminths (*A. lumbricoides*, *T. trichiura*, *N. americanus*, and *A. duodenale*) cumulatively affect more people than HIV and malaria combined at any given moment (Lustigman *et al.,* 2012). Co-infections with various parasites (such as hookworms and roundworms) are frequent, and their detrimental effects are often intensified by malnutrition or nutritional deficiencies (Lebu *et al.*, 2023).

In Bangladesh, parasitic illness is a serious public health crisis fueled by rapid urbanization, widespread poverty, poor living conditions, filthy surroundings, and inadequate sanitation infrastructure (Cox *et al.,* 1982; Cheng *et al.,* 1986). These interconnected environmental factors and socioeconomic vulnerabilities are the primary drivers of the high incidence of protozoa and helminths across all age groups. Some of them might induce serious clinical symptoms such as anemia, obstruction, and severe gastrointestinal complications (Cheng *et al.,* 1986). In Bangladesh, public universities usually have residence halls where residential students live. Often, staff and students live in close proximity, and they assist students in various ways. Residential hall staff, particularly those working in dining facilities, handle food and utensils regularly. Consequently, faeco-oral transmission of intestinal parasites is possible among staff and students. Therefore, continuous screening of IPI among staff is a vital epidemiological tool for assessing and monitoring the risk of faeco-oral transmission of intestinal parasites. Thus, this study aims to evaluate the prevalence and diversity of IPIs among hall staff across four university residential halls. We hypothesize that due to shared sanitary facilities and occupational exposures, hall staff would exhibit a notable baseline prevalence of IPIs and that specific behavioral or sociodemographic factors would correlate with higher infestation rates. The findings of this research will help bring awareness among both students and staff about IPIs, ultimately contributing to future prevention and control strategies.

The current study was carried out across four different residential halls of a public university in Bangladesh from September 2022 to September 2023. A convenient sampling strategy was employed to recruit adult support staff, focusing on frontline service roles including food handlers, dining staff, cleaners, and maintenance personnel. Eligible participants were adult staff members aged 18-59 years who are currently employed at the selected residential halls and provided explicit consent to participate. The target sample size of 100 participants (n = 100) was determined based on the logistical feasibility of collecting and rapidly processing fresh biological specimens under localized laboratory constraints, serving as an exploratory baseline for this institutional workforce.

Each participant was interviewed with a detailed questionnaire for the determination of the hygienic practices via face-to-face interviews to gather demographic data. Following the interview, participants were instructed on proper sample collection and provided with wide-mouth, leak-proof, sterile plastic bottles. Fresh faecal samples were collected and transported immediately to the Parasitology laboratory of the Department of Zoology, University of Dhaka for further analysis. A total of 100 faecal samples were collected for the determination of parasite eggs and larvae.

Formal-Ether Concentration Technique Concentration method was used to detect parasites (both protozoan and helminths) as it is the best overall technique for determining the concentration of the parasite's eggs, larvae and cyst in stool (Cheesbrough, 1987). Prevalence was calculated according to the standard epidemiological equation (Margolis *et al.* 1982).

$$\text{Prevalence (\%)} = \left(\frac{\textit{Number of individuals of a host species infected with a particular parasite species}}{\textit{Total number of host examined}}\right) \times 100$$

To investigate factors associated with parasite diversity, the outcome was converted into a binary variable based on the seven species investigated. Binary logistic regression was used to estimate Odds Ratios (OR) and 95% Confidence Intervals (CI) for factors associated with high parasite detection. To account for the modest sample size (n = 100) and potential sparse cell counts, three regression approaches were utilized. They are: univariate model, reduced multivariable model, and fully adjusted multivariable model. Statistical significance was defined as $p < 0.05$.

Ethical approval: Ethical approval was obtained from the Faculty of Biological Sciences, University of Dhaka, ethical review committee.

RESULTS AND DISCUSSION

This study assessed the intestinal parasitic infestations among adult staff members residing in four residential halls of University of Dhaka, Bangladesh. A total of 100 adult staff members participated in this study. All participants (100%) were infected with at least one intestinal parasite. Co-infection with multiple parasites was highly common. The mean age was 38 years (SD = 8), ranging from 18 to 59 years. The majority of participants were male (79%), married (98%), and had attained at least secondary education (62%). Most participants reported a monthly income above 11,000 BDT (84%). Additionally, they lived in a building-type housing (80%). Notably, 88% shared toilets, and only 12% had access to personal toilets (Table 1). Seven species of intestinal parasites were identified from 100 samples, of which two species were protozoan (*Blastocystis* spp. and *Cystoisospora* spp.); two were cestodes (*Diphyllobothrium latum*. and *Hymenolepis* spp.); and three were nematodes (*Ascaris lumbricoides, Enterobius vermicularis, and Trichuris trichiura*) (Table 2).

Table 1. Demographic Characteristics of Adult Staff Members

Variables	**N = 100**[1]
Age (years)	38 (8) [Range: 18-59]
Sex	
Female	21 (21%)
Male	79 (79%)
Marital Status	
Married	98 (98%)
Unmarried	2 (2.0%)
Education Level	
Illiterate	11 (11%)
Primary	27 (27%)
Secondary+	62 (62%)
Monthly Income (BDT)	
6,000-10,000	16 (16%)
11,000+	84 (84%)
House Type	
Building	80 (80%)
Tin-shed	20 (20%)
Toilet Type	
Personal	12 (12%)
Shared	88 (88%)

[1]Mean (SD) [Range: Min-Max]; n (%)

Table 2, Name of the identified parasites

Group	**Parasite**
Protozoa	*Blastocystis* spp. *Cystoisospora* spp.
Cestoda	*Diphyllobothrium latum* *Hymenolepis* spp.
Nematoda	*Ascaris lumbricoides* *Enterobius vermicularis* *Trichuris trichiura*

The sex-wise prevalence of seven intestinal parasites revealed that while some infections are nearly universal, others showed clear differences according to gender in their distribution. The most common organism was the protozoan *Blastocystis.* It reached 100% in both groups. *Ascaris* and *Cystoisospora* were both slightly more prevalent in females at 95.2%. On the contrary, the infection rates for helminths like *Hymenolepis*, *D. latum*, and *E. vermicularis* were notably lower. Furthermore, a clear trend emerges

Table 3. Prevalence of intestinal parasites among staff of residential halls of a public university in Bangladesh

Name of parasites	Total sample	Infected Individual	Prevalence
Blastocystis spp.		100	100%
Cystoisospora spp.		91	91%
Diphyllobothrium latum		29	29%
Hymenolepis spp.	100	41	41%
Ascaris lumbricoides		92	92%
Enterobius vermicularis		3	3%
Trichuris trichiura		6	6%

where males consistently show higher infection rates than females. For instance, the prevalence of *Hymenolepis* was numerically higher in males (44.3%) than in females (28.6%). Additionally, *D. latum* was present in 30.4% of males and 23.8% of females, while *Trichuris* appeared at 6.3% of males compared to 4.8% in females. Notably, *E. vermicularis* was only present in the male population at 3.8% (Figure 1).

Notably, the study observed a uniform prevalence of 100% for *Blastocystis* spp. Infections with *A. lumbricoides* (92%) and *Cystoisospora* spp. (91%) closely followed that rate. Other detected parasites included *Hymenolepis* spp. (41%), *D. latum* (29%), *T. trichiura* (6%), and *E. vermicularis* (3%) (Table 3).

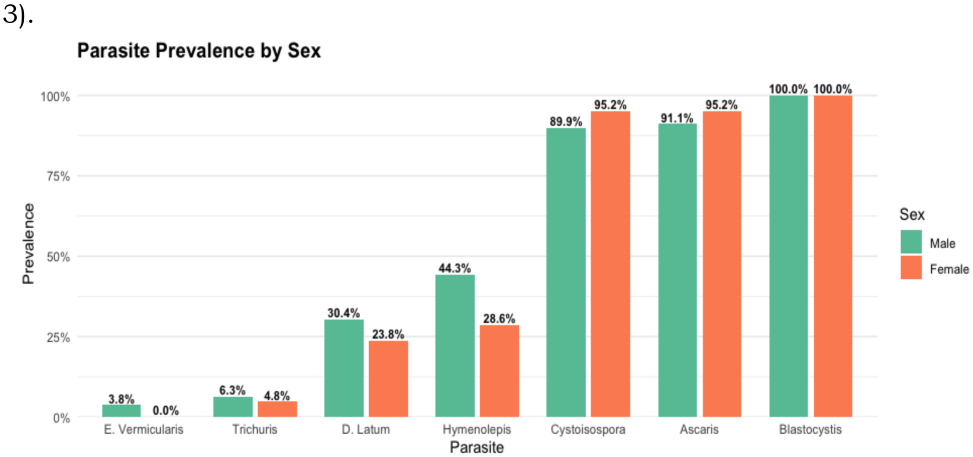

Fig. 1. Intestinal Parasite Prevalence by Sex of the Adult Staff.

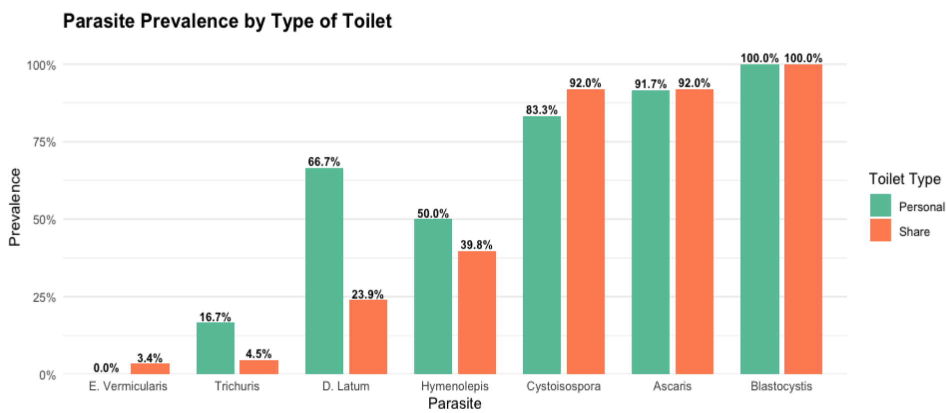

Fig. 2. Intestinal Parasite Prevalence by Type of Toilet.

Fig. 2. illustrates the prevalence of seven intestinal parasites based on whether sanitation facilities were personal or shared. *Blastocystis* (100%) showed equal distribution across both groups while *Cystoisospora* and *Ascaris* were slightly more common in shared environments (both at 92.0%). On the other hand, several helminths were significantly more prevalent among those using personal toilets. *D. latum* affected 66.7% of those with personal toilets compared to only 23.9% in the shared facility. Similarly, *Hymenolepis* and *Trichuris* rates were higher among those using a personal toilet, at 50.0% and 16.7%, respectively. *E. vermicularis* was the only species detected exclusively among individuals sharing facilities, appearing at a rate of 3.4%.

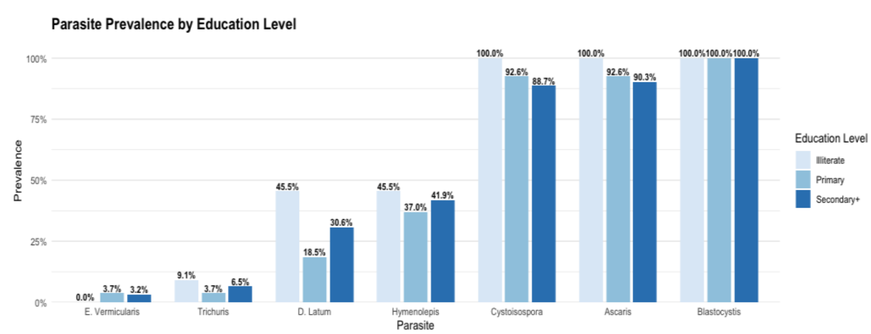

Fig. 3. Intestinal Parasite Prevalence by Education Level.

The prevalence of seven intestinal parasites according to three educational groups (illiterate, primary and secondary) suggested that higher educational qualification correlates with a slight reduction in common infections. *Blastocystis* remained constant at 100%, but both *Cystoisospora* and

Ascaris dropped from 100% in the illiterate group to 88.7% and 90.3% in the secondary groups. However, the distribution of helminths was less linear. The illiterate group exhibited the highest rates for *D. latum* (45.5%) and *Hymenolepis* (45.5%). *Trichuris* prevalence followed a similar pattern, peaking at 9.1% in the illiterate group. *E. vermicularis* was only detected in the primary (3.7%) and secondary (3.2%) groups, remaining absent in participants with no formal education (Fig. 3).

Table 4. Frequency of Multiple Parasite Infections

Number of Parasite types	Count
1	4
2	4
3	43
4	27
5	19
6	3

A total of six different levels of parasite multiplicity were observed in the study population. 43 individuals were simultaneously infected with three different parasite types. Infections involving four and five parasite types were also common. Only 4 individuals were infected with a single parasite type and 3 individuals with six types of parasites (Table 4).

Table 5. The Five Most Common Observed Parasite Coinfection Combinations Among Study Participants

Coinfection Combination	Count	Percentage (%)
Blastocystis + *Cystoisospora* + *Ascaris*	40	40
Blastocystis + *Cystoisospora* + *Ascaris* + *Hymenolepis* + *D. latum*	17	17
Blastocystis + *Cystoisospora* + *Ascaris* + *Hymenolepis*	16	16
Blastocystis + *Cystoisospora* + *Ascaris* + *D. latum*	7	7
Blastocystis	4	4

The five most common distinct parasite coinfection combinations are presented in Table 5. The most common combination was *Blastocystis*, *Cystoisospora*, and *Ascaris*. This combination was detected in 40% of participants. This was followed by combinations that included other parasites such as *Hymenolepis* and *Diphyllobothrium latum*. However, the frequency decreased in each combination. Notably, a small proportion of participants (4%) were infected with *Blastocystis* alone (Table 5). In terms of parasite diversity, *Blastocystis* spp. was detected in 100% of participants. Although this prevalence is substantially higher than that reported in many epidemiological investigations, previous studies have documented similarly elevated prevalence levels in highly endemic settings. A comprehensive review of *Blastocystis* epidemiology reported that prevalence in humans may reach 100% (Popruk *et al.,* 2021). Similarly, a study conducted among children in rural Senegal similarly documented a prevalence of 100% where poor hygiene and sanitation were one of the risk factors for transmission (Safadi *et al.,* 2014). Another study conducted on slum-dwelling malnourished adults found *Blastocystis* prevalence of 78.6% with crowding emerging as a significant risk factor (Fahim *et al.*, 2021). In Thailand, a longitudinal study at an orphanage in Bangkok highlighted the role of both person-to-person and environmental transmission. Age and proximity to infected caregivers were significant risk factors influencing *Blastocystis* transmission (Pipatsatitpong *et al.*, 2012). In Bangladesh, Khanum *et al.* (2014) reported an overall intestinal parasitic prevalence of 23.1% among students, staff, and teachers at the University of Dhaka, with the highest rate among staff (66.67%) in September 2009. *A. lumbricoides* was the most common parasite in that study. However, the total burden of infection was significantly lower (*A. lumbricoides* and *T. trichiura* were found as 11.14% and 3.43%, respectively) than that observed in the present investigation (92% *A. lumbricoides* and 6% *T. trichiura*). The substantially higher prevalence observed in the present study may reflect differences in study populations, environmental conditions, detection techniques, or sampling strategies. A study conducted in Wolaita Sodo University in Ethiopia among food handlers of students reported a prevalence of 23.6%. Strong associations were found between infection and poor hygiene practices, such as untrimmed fingernails and lack of soap use before food handling (Kumma *et al.*, 2019). This finding indicates that high infection rates are expected in settings with compromised sanitation. *D. latum* is classically associated with temperate and cold regions due to its fish-borne life cycle (Scholz & Kuchta, 2016); however, human infections have also been reported from tropical settings, including Bangladesh. Previous investigations in Dhaka City have consistently documented the presence of *D. latum* ova in urban populations, including school-going children in local slums and street vendors (Hossain *et al.,* 2019; Barua *et al.,* 2024). Furthermore, Akter *et al.* (2015) reported a notable prevalence of 36.90% for *D. latum* in agricultural night soil samples. Historical data confirm that *D. latum* has long been present in the river system of Bangladesh (Uddin *et al.,* 1982). In the present study, the relatively high prevalence (29%) may be associated with occupational exposure to freshwater fish among residential hall staff involved in food preparation (Mustafa *et al.,* 2024). Additionally, zoonotic spillover cannot be ruled out. Domestic stray dogs and cats are well-documented reservoirs of *D. latum* in Bangladesh (Samad, 2013).

Aunamika *et al.* (2021) reported the presence of plerocercoid of *Diphyllobothrium* spp. in fish samples from Bhola district, indicating that local aquatic food chains may serve as a potential source of human exposure. These findings suggest that local freshwater fish may represent a potential source of exposure while the role of zoonotic reservoirs remains unclear and warrants further investigation.

Although some parasites appeared to differ in prevalence between males and females, no statistically significant association between sex and parasite burden was observed in the regression analyses. Yet, several studies have reported sex-specific differences in the prevalence of intestinal parasitic infections. For instance, Duedu *et al.* (2015) found that intestinal parasitic infections were significantly higher in males (18.8%) compared to females (4.8%), indicating a clear sex-specific difference in infection prevalence. Similarly, a large retrospective study reported that protozoan parasites were more prevalent among males than females which indicated sex-based variation in parasite distribution (Yosef *et al.*, 2025). Additionally, Nacher *et al.* (2003) demonstrated gender differences in helminth infections and suggested that behavioral and environmental factors may contribute to differential exposure between males and females. Soil-transmitted helminths such as *Ascaris lumbricoides* and *Trichuris trichiura* are transmitted via fecal-oral routes and are strongly linked to environmental contamination with human faeces. A systematic review and meta-analysis has shown that improved sanitation is consistently associated with reduced odds of infection (Strunz *et al.*, 2014). Likewise, sanitation-related exposure contributes to helminth transmission risk. However, these effects may be modified by behavioral and environmental factors (Freeman *et al.*, 2017). In contrast, *Blastocystis spp.* is widely distributed across populations and demonstrates limited dependence on sanitation status, consistent with multiple transmission routes including waterborne, foodborne and possible zoonotic pathways (Scanlan *et al.*, 2014). The exclusive detection of *Enterobius vermicularis* among shared sanitation users aligns with its well-established transmission via direct contact and fomite contamination (Cook, 1994). However, no significant association between toilet type and parasite burden was detected in the present study, possibly because most participants shared similar sanitation conditions.

Our findings reveal an extraordinary state of polyparasitism, with 96% of participants harboring multiple parasite species concurrently. It is consistent with previous evidence indicating that polyparasitism is a common feature of parasite-endemic communities rather than an exception (Donohue *et al.,* 2019). A cohort of slum-dwelling malnourished adults in Bangladesh showed a 78.6% prevalence of *Blastocystis* with co-infection

Table 5. The Five Most Common Observed Parasite Coinfection Combinations Among Study Participants

		Univariate Logistic Regression			Reduced Multivariable Logistic Regression			Fully Adjusted Multivariable Logistic Regression		
Characteristic	**N**	**OR**	**95% CI**	**p-value**	**OR**	**95% CI**	**p-value**	**OR**	**95% CI**	**p-value**
Age	100	1.03	0.99, 1.09	0.18				1.04	0.99, 1.10	0.15
Sex	100			0.10			0.41			0.48
Male		—	—		—	—		—	—	
Female		0.44	0.15, 1.18		0.61	0.18, 1.99		0.63	0.16, 2.32	
Education	100			0.58						0.77
Illiterate		—	—					—	—	
Primary		0.53	0.12, 2.19					0.58	0.11, 2.79	
Secondary+		0.50	0.12, 1.84					0.58	0.11, 2.73	
Hall Type	100			0.071			0.36			0.22
Male		—	—		—	—		—	—	
Female		0.48	0.21, 1.06		0.62	0.22, 1.71		0.51	0.17, 1.49	
Toilet	100			0.19			0.53			0.55
Personal		—	—		—	—		—	—	
Share		0.44	0.11, 1.49		0.64	0.15, 2.48		0.65	0.15, 2.59	
Smoker	100			0.43						0.87
No		—	—					—	—	
Yes		1.37	0.62, 3.04					0.92	0.34, 2.51	
Income	100			0.53						0.38
6,000-10,000		—	—					—	—	
11,000+		0.71	0.23, 2.07					0.53	0.12, 2.19	
House Type	100			0.55			0.43			0.39
Building		—	—		—	—		—	—	
Tin-shed		1.35	0.51, 3.69		1.52	0.54, 4.37		1.58	0.55, 4.71	
Nail Bite Habit	100			0.90			0.86			0.74
No		—	—		—	—		—	—	
Yes		1.06	0.44, 2.55		1.09	0.43, 2.77		0.84	0.31, 2.30	

Abbreviations: CI = Confidence Interval, OR = Odds Ratio

rates of *T. trichiura* being 28% and suggested that crowding and poor hygiene play a crucial role in promoting polyparasitism (Fahim *et al.*, 2021). A study in the rural Philippines found that 65.3% of participants had two or more simultaneous infections. One of the most common co-infections was of *Blastocystis* (26.7%). Although *Cystoisospora* and *Ascaris* were not assessed, the high rate of polyparasitism highlights that mixed infection is common in tropical, under-resourced environments (Weerakoon *et al.*, 2018).

To explore factors associated with the number of parasite types detected, the outcome was categorized into two groups: participants with three or fewer parasite types detected and those with four or more. This classification was based on the total number of parasite types identified among the seven parasite types investigated. Binary logistic regression was used to assess factors associated with detection of four or more parasite types.

The results from the univariate, reduced multivariable, and fully adjusted multivariable logistic regression models are presented in Table 6. The reduced multivariable model was fitted considering the modest sample size and the possibility of sparse observations in some covariate categories. This model included selected variables considered epidemiologically relevant to parasite transmission, including sex, hall type, toilet type, house type, and nail-biting habit. The fully adjusted model included all candidate covariates considered in the study to examine whether the findings remained consistent after broader adjustment. Table 6. Univariate, reduced multivariable, and fully adjusted logistic regression analyses of factors associated with having four or more parasite types detected among the seven parasite types investigated.

In the reduced multivariable model, none of the selected predictors showed a statistically significant association with having four or more parasite types detected. The fully adjusted model produced similar findings after adjustment for all candidate covariates. Overall, no demographic, socioeconomic, behavioral, or environmental factor was significantly associated with the odds of having four or more parasite types detected among the seven parasite types investigated.

These findings should be interpreted with caution. The absence of statistically significant associations does not necessarily indicate that the investigated factors have no role in parasite occurrence. Rather, the modest sample size and sparse observations in some covariate categories may have limited the statistical power and produced imprecise estimates. However, the consistency between the reduced and fully adjusted models suggests that the overall conclusion was not highly sensitive to the choice of model specification. Future studies with larger sample sizes, parasite-specific analyses, and additional hygiene- and environment-related variables may provide clearer evidence regarding factors associated with parasite detection among staff.

This, however, aligns with several previous studies, including research conducted in Ghana and Thailand. A community-level survey in Ghana found no significant associations between parasitic infection and toilet type, water source, age, or sex (Forson *et al.*, 2017). Similarly, among village health volunteers in southern Thailand, infection rates showed no variation by occupation or education. It could be due to participants sharing a similar environment and hygiene habits (Punsawad *et al.*, 2017). These patterns mirror our observations, where the homogeneity of exposure (88% sharing toilet facilities) and similar housing may have obscured any detectable associations at the individual level. Similarly, Abate *et al.* (2013) reported in a study of 410 participants that overall parasitic prevalence reached 62.2%, yet no statistically significant association was found between infection and either sex or educational status ($p = 0.97$ and 0.28, respectively). This suggests that when environmental exposure is widespread, individual-level variables may not explain variation in infection risk.

Nonetheless, it is important to note that many studies report associations between infection rates and factors such as hygiene behavior, education, income, or toilet type. In Ethiopia, the absence of toilets and failure to wash hands after defecation were significantly linked to higher infection risk ($P < 0.05$) (Abate *et al.*, 2013). Similarly, in Côte d'Ivoire, latrine access, defecation habits, and hand hygiene showed strong effects against helminth and protozoan infections (Schmidlin *et al.*, 2013). Together, these contrasting findings suggest that while behavioral and demographic factors can influence infection risk, their impact may be diminished in settings with uniformly poor sanitation and environmental exposure. The high prevalence of intestinal parasites observed among residential hall staff highlights the importance of regular screening and preventive measures within university residential settings. Given the role of some staff members in food preparation and service, maintaining appropriate hygiene and intervention remains essential.

A limitation of this study is the dependency on microscopy and formal-ether concentration technique for parasite detection instead of molecular assays. Therefore, the prevalence estimates should be interpreted cautiously until validated by molecular diagnostic approaches. Future studies could use molecular techniques such as Polymerase Chain Reaction (PCR) and Enzyme-Linked Immunosorbent Assay (ELISA) for detection. Furthermore, a broader sample size covering multiple universities will enhance the application of the findings.

CONCLUSION

Based on microscopic screening, this study indicates a notably high parasitic burden, uniform co-infection patterns, and an absence of demographic or behavioral associations within the investigated institutional setting. Even though this study is restricted by a modest sample size and localized cohort, these preliminary findings suggest that ubiquitous environmental contamination and collective exposure pathways may overshadow individual risk factors. Consequently, these outcomes underscore the need for public health interventions at the institutional level, alongside regular screening using highly sensitive molecular assays for future investigations.

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