



RESEARCH ARTICLE

Low prevalence of soil-transmitted helminth infections and hookworm predominance among adults across ecological settings in southern and Central Highlands Vietnam

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ABSTRACT

Soil-transmitted helminth (STH) infections remain a significant public health concern in endemic regions. This study aimed to determine the prevalence, infection intensity and distribution of STH infections across age groups and ecological settings in southern and Central Highlands Vietnam. A cross-sectional survey was conducted among 1241 individuals in four provinces. Faecal samples were examined using the Kato-Katz technique, and infection intensity was classified according to WHO criteria. Differences in prevalence among provinces and age groups were analyzed using Chi-square and Fisher's exact tests. The overall prevalence of STH infections was 7.2% (89/1241). Hookworms were the predominant species (6.9%), followed by *Trichuris trichiura* (0.3%), while *Ascaris lumbricoides* was not detected. Lam Dong Province showed a significantly higher prevalence (12.7%) compared to Tay Ninh (7.9%), Binh Duong (5.4%), and Ba Ria-Vung Tau (0.8%) ($P < 0.001$). Single infections accounted for 7.1% of cases, whereas co-infections were rare (0.08%). The highest prevalence was observed among adults aged 19-65 years (9.5%) (Fisher's exact test, $P < 0.001$). Working-age adults may serve as an important reservoir of infection, particularly for hookworm, highlighting the need to consider adult populations in future surveillance and control strategies.

Keywords: Soil-transmitted helminths; prevalence; infection intensity; southern Vietnam; Central Highlands Vietnam.

INTRODUCTION

Soil-transmitted helminths (STHs) are among the most common parasitic infections worldwide and primarily affect populations living in poor and underdeveloped communities with inadequate sanitation (Jourdan *et al.*, 2018; WHO, 2023). Infection occurs when parasite eggs excreted in human faeces contaminate the soil and subsequently infect humans through ingestion or skin penetration. According to the World Health Organization, over 1.5 billion individuals are infected worldwide. The main species infecting humans include the roundworm (*Ascaris lumbricoides*), the whipworm (*Trichuris trichiura*), and hookworms (*Necator americanus* and *Ancylostoma duodenale*) (WHO, 2023). These parasites are widely distributed across tropical and subtropical regions, including Vietnam.

STH infections can have substantial affect human health, particularly in vulnerable populations. Chronic infections may contribute to malnutrition, anemia, impaired physical growth, and reduced cognitive development, especially among children, while severe or ectopic infections may occasionally result in life-threatening complications (Pullan *et al.*, 2014; Pabalan *et al.*, 2018).

Environmental and ecological conditions in tropical countries, including temperature, humidity, soil characteristics, and agricultural practices, provide favorable conditions for the survival and development of helminth eggs and larvae. In addition, inadequate sanitation, poor hygiene practices, and frequent occupational contact with contaminated soil may contribute to the persistence and transmission of STH infections in endemic communities (Hotez *et al.*, 2007; Pullan *et al.*, 2014; WHO, 2023).

In Vietnam, although the burden of STH infections has declined following national deworming and sanitation programs, transmission remains heterogeneous across different ecological regions. Previous studies have shown geographical variation in the distribution of STH species throughout the country. Van der Hoek *et al.* (2003) reported that the prevalence of *A. lumbricoides* and *T. trichiura* decreased from northern to southern Vietnam, whereas hookworm infections remained more evenly distributed, particularly in peri-urban and rural areas (Van der Hoek *et al.*, 2003). Other studies conducted in highland provinces such as Lam Dong and Dak Lak have demonstrated the continued presence of STH infections in areas with favorable environmental conditions for parasite development (Nguyen & Nguyen, 2012; Bui *et al.*, 2016). In southern Vietnam,

hookworm infection has also been reported among adults in Tay Ninh province, indicating that occupational and environmental exposure may contribute to infection risk in working-age populations (Tran *et al.*, 2015). Together, these findings highlight the potential influence of ecological variation on STH transmission patterns in Vietnam.

Recent national deworming programs and community-based chemotherapy interventions have contributed to a substantial reduction in the prevalence and intensity of STH infections in many endemic regions. However, the distribution of these infections remains heterogeneous and may vary across different ecological settings due to differences in environmental conditions, sanitation, and population exposure patterns. Therefore, updated epidemiological data from distinct ecological regions remain important for monitoring residual transmission and supporting targeted control strategies (Bowie *et al.*, 2004).

Epidemiological comparisons across different ecological settings remain limited in Vietnam. Therefore, this study was conducted to assess the prevalence and infection intensity of STHs in selected provinces representing different ecological settings, including highland areas in Central Vietnam; lowland, and island areas in southern Vietnam. In addition, the study aimed to provide exploratory epidemiological insights into potential ecological differences in STH transmission patterns across these settings.

MATERIALS AND METHODS

Study area

The study was conducted from January to December 2024 in four purposively selected provinces representing distinct ecological settings in southern and Central Vietnam, including Lam Dong, Tay Ninh, Binh Duong, and Ba Ria-Vung Tau Province (with Con Dao Island) (Figure 1). Lam Dong Province, located in the Central Highlands region, is characterized by mountainous terrain, cooler temperatures, high humidity, and intensive agricultural activities, particularly coffee and vegetable cultivation. Tay Ninh and Binh

Duong provinces represent lowland areas in southeastern Vietnam, with tropical climate, flat lowland areas, and mixed agricultural and industrial activities. In contrast, Ba Ria-Vung Tau Province, including the island area of Con Dao, is characterized by coastal and island ecosystems with marine tropical climate. These diverse ecological and environmental conditions may influence the survival and transmission of STHs, particularly hookworm species.

Sampling method

A community-based cross-sectional study was conducted using a multistage sampling approach. Four provinces were purposively selected to represent different ecological settings (Figure 2). Within each province, communes were randomly selected, followed by systematic random sampling of households. All individuals aged over 2 years in the selected households were invited to participate. The working-age adults engaged in a wide range of occupations. Faecal samples were collected from consenting participants for parasitological examination.

The study received ethical approval from the Ethics Council and the Science and Technology Council of the Institute of Malaria, Parasitology and Entomology in Ho Chi Minh City, under Decision No. 441/QD-VSR dated November 23, 2023. Written informed consent was obtained from participants or guardians.

Parasitological examination

Faecal samples were examined using the Kato-Katz thick smear technique, the WHO-recommended standard method for epidemiological surveys of STH infections, to detect and quantify helminth eggs. Approximately 10 g of fresh faeces was collected from each participant into clean screw-capped containers and transported to the laboratory for examination. Samples were processed immediately upon arrival whenever possible. Samples that could not be examined immediately were stored under refrigerated conditions prior to processing to preserve specimen quality and minimize egg degradation. A measured amount of sieved faeces was placed on a glass slide using a standard template with a known aperture size.

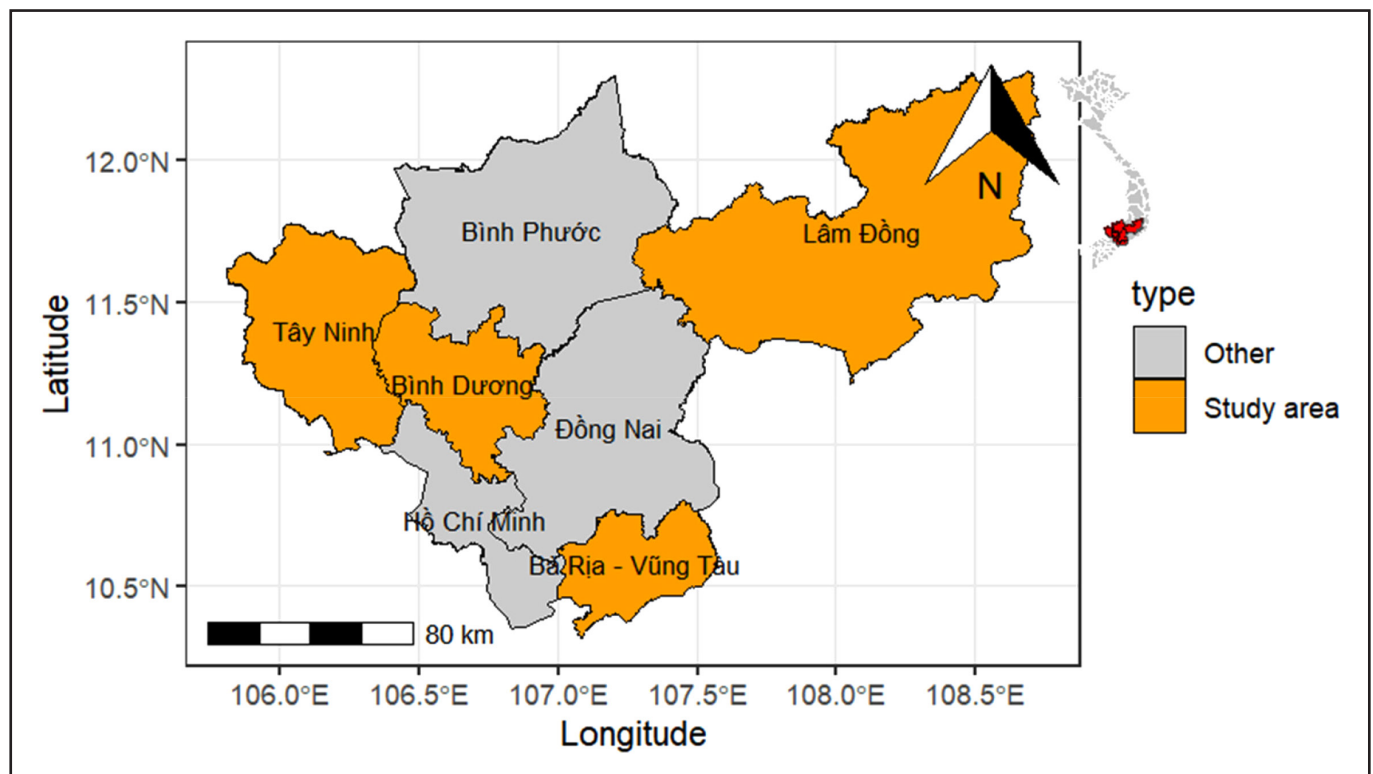


Figure 1. Location of study area in Southeast Vietnam.

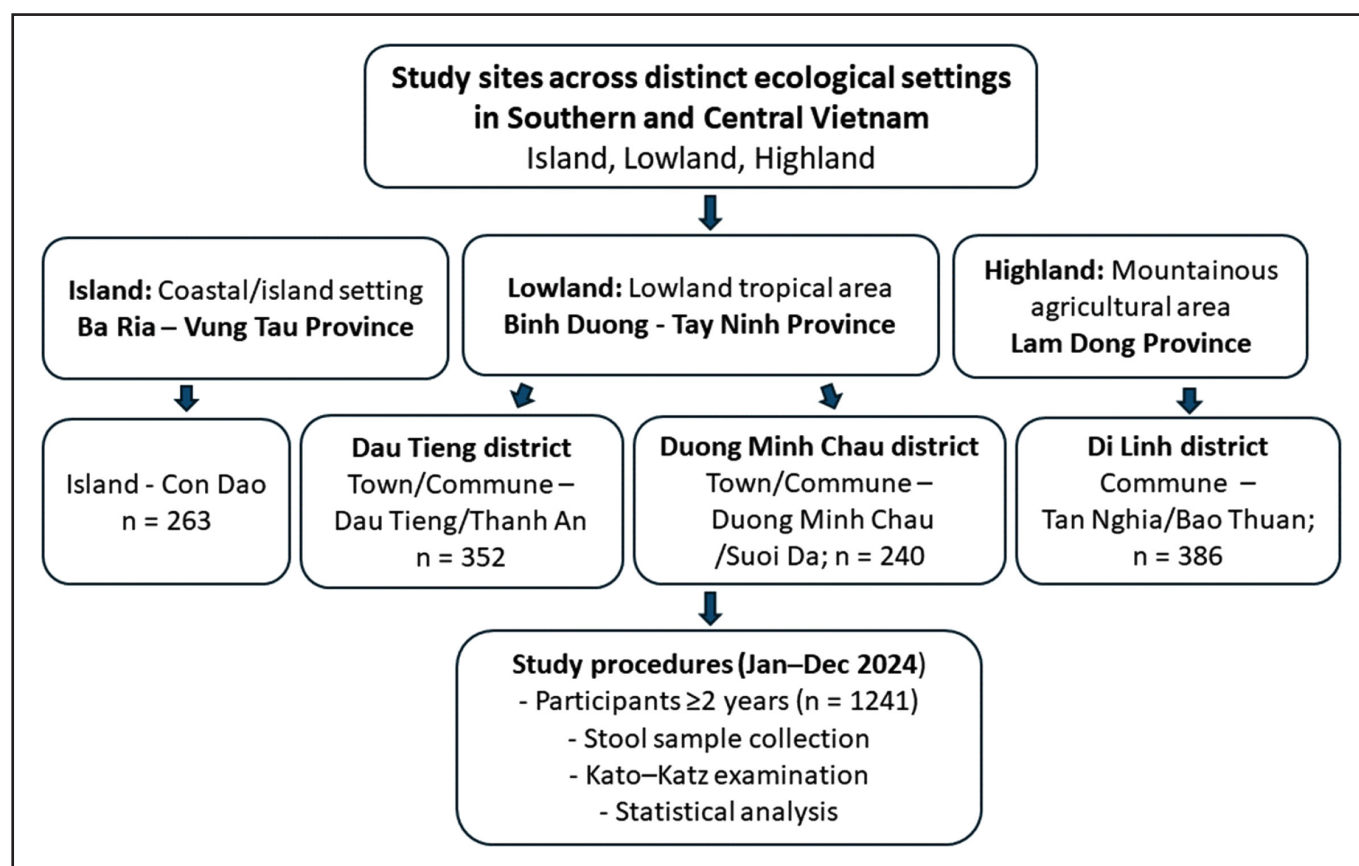


Figure 2. Specimen collection and workflow summary.

Different sieve sizes were used for faecal examination: 6 mm (1.5 mm thick, 41.7 mg of faeces; multiplication factor 24), 9 mm (1 mm thick, 50 mg of faeces; multiplication factor 20), and 6.5 mm (0.5 mm thick, 20 mg of faeces; multiplication factor 50). The smear was then covered with a cellophane strip pre-soaked in glycerol-malachite green solution and gently pressed to evenly spread the specimen.

Slides were allowed to clear for 15–60 minutes before microscopic examination. Each slide was systematically examined under light microscopy at 100 $\times$ magnification, with confirmation at 400 $\times$ when necessary. The number of eggs for each helminth species was counted and expressed as eggs per gram of faeces (EPG), calculated by multiplying the counted egg number by the appropriate conversion factor based on the template used. For quality assurance, three slides were prepared from each faecal sample.

Assessment of infection intensity

The intensity of STH infections was determined by quantifying the number of eggs per gram of faeces (EPG). Infection intensity was classified according to the World Health Organization criteria (WHO, 2024). For *A. lumbricoides*, light, moderate, and heavy infections were defined as 1 – 4999 EPG, 5000 – 49 999 EPG, and $\geq 50\,000$ EPG, respectively. For *T. trichiura*, the corresponding thresholds were 1 – 999 EPG (light), 1000 – 9999 EPG (moderate), and $\geq 10\,000$ EPG (heavy). For hookworms, light infection was defined as 1 – 1999 EPG, moderate infection as 2000 – 3999 EPG, and heavy infection as ≥ 4000 EPG.

Statistical analysis

Statistical analyses were performed using RStudio (R software, version 4.4.0). Descriptive statistics were used to summarize the data and are presented as numbers and percentages (%). The association between age groups and STH infection was assessed using Fisher's exact test. Significant differences between types of provinces were evaluated using the Chi-square test and Fisher's exact test. Statistical significance was set at $P < 0.05$.

RESULTS

Prevalence of STH infections across ecological settings

A total of 1241 faecal samples collected from seven communes/towns/ islands across four provinces representing different ecological settings in southern and Central Highlands Vietnam, were examined for *A. lumbricoides*, *T. trichiura*, and hookworms (*A. duodenale* and *N. americanus*). The results are presented in Table 1.

The overall prevalence of STH infections among participants was 7.2%. The highest prevalence was observed in the highland area of Lam Dong Province (12.7%), followed by the lowland setting represented by Tay Ninh (7.9%) and Binh Duong province (5.4%), whereas the lowest prevalence was observed in the island setting of Ba Ria–Vung Tau (0.8%) (Table 1). Among the 89 STH-positive cases, hookworm infection accounted for the majority of infections (85/89; 95.5%), followed by *T. trichiura* infection (4/89; 4.5%), while no *Ascaris* infection was detected. Most infections are single infections.

Table 1. Distribution of STH infections by province (n = 1241)

Characters	Overall (n=1241)	Tay Ninh (n=240)	Binh Duong (n=352)	Ba Ria-Vung Tau (n=263)	Lam Dong (n=386)	P-value
STH infection status^a	n (%)	n (%)	n (%)	n (%)	n (%)	
Positive	89 (7.2)	19 (7.9)	19 (5.4)	2 (0.8)	49 (12.7)	<0.001 ^b
Negative	1152 (92.8)	221 (92.1)	333 (94.6)	261 (99.2)	337 (87.3)	
Species						
<i>T. trichiura</i>	4 (0.3)	1 (0.4)	1 (0.3)	0 (0)	2 (0.5)	>0.05 ^c
<i>A. duodenale</i> / <i>N. americanus</i>	85 (6.9)	18 (7.5)	18 (5.1)	2 (0.8)	47 (12.2)	<0.001 ^b
Type of parasitism						
Single infection	88 (7.1)	19 (7.9)	19 (5.4)	2 (0.8)	48 (12.4)	<0.001 ^b
Dual infection	1 (0.08)	0 (0)	0 (0)	0 (0)	1 (0.08)	

^aParticipants infected with any STHs (*A. lumbricoides*, *T. trichiura*, or *A. duodenale*/*N. americanus*). Significant difference between type of province based on

^bChi-square and 'Fisher's exact test.

Prevalence of STH by age group

Table 2 shows variation in infection prevalence across age groups. Hookworm was the predominant STH species in all age groups, and the highest overall prevalence was observed among adults aged 19-65 years (9.5%), followed by individuals older than 65 years (7.0%) and those aged 18 years or younger (2.2%). A significant association was observed between age group and STH infection (Fisher's exact test, $P < 0.001$).

According to WHO classification criteria, all detected STH infections were of light intensity. Specifically, all hookworm (85 cases) and *T. trichiura* (4 cases) infections were classified as light infections, and no moderate or heavy infections were identified in the study population.

Variation in hookworm prevalence across ecological settings

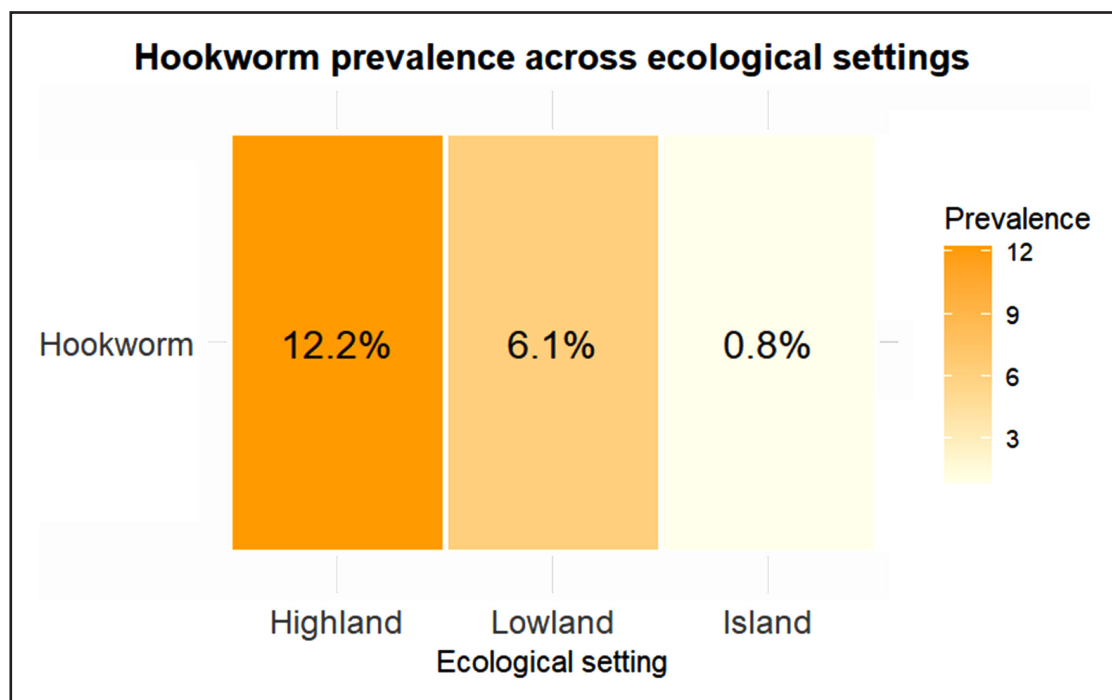
Hookworm prevalence differed significantly across ecological settings (Fisher's exact test, $P < 0.001$). As illustrated in the heatmap (Figure 3), prevalence was highest in the highland setting (12.2%), intermediate in the lowland setting (6.1%), and lowest in the island

setting (0.8%). The heatmap uses a sequential color gradient from light cream to dark orange, with darker shades indicating higher prevalence. Accordingly, the highland setting is represented by the darkest orange, the lowland setting by a lighter orange, and the island setting by a pale cream color, reflecting the observed prevalence gradient.

Table 2. Prevalence of STH infections by age group

Age group n = 1241	No. of tests	<i>T. trichiura</i> Pos. (%)	<i>N. americanus</i> / <i>A. duodenale</i> Pos. (%)	Total Pos. (%)
2 – 18	358	0 (0.0)	8 (2.2)	8 (2.2)
19 – 65	783	4 (0.5)	70 (8.9)	74 (9.5)
> 65	100	0 (0.0)	7 (7.0)	7 (7.0)
Total	1241	4 (0.3)	85 (6.9)	89 (7.2)

No. = number of samples; Pos. = number of positive cases; % = percentage.

**Figure 3.** Heatmap of hookworm prevalence across ecological settings.

DISCUSSION

This study investigated the prevalence of STH infections among residents from seven communities, including four communes, two towns, and one island, representing highland, lowland, and island ecological settings in southern and Central Highlands Vietnam. The overall prevalence of STH infection was 7.2%. Hookworm was the most frequently detected species (6.9%), followed by *T. trichiura* (0.3%), while no *A. lumbricoides* infections were detected. Statistical analysis revealed significant variation in infection prevalence across age groups and ecological settings. These findings suggest that demographic and ecological factors may contribute to the observed distribution of hookworm and other STH infections in the study areas.

In general, the prevalence observed in the present study was substantially lower than that reported in several previous studies conducted in Vietnam, including surveys among school-aged children in Dak Lak and Ha Giang Province (Bui *et al.*, 2016; Dang *et al.*, 2025). This decline may reflect the impact of long-term deworming programs and improvements in sanitation and living conditions. Nevertheless, hookworm remained the predominant species, consistent with reports from other regions of Vietnam (Bui *et al.*, 2016; Tran *et al.*, 2019), suggesting that hookworm transmission may persist despite the overall reduction in STH prevalence.

Lam Dong showed the highest STH prevalence, which may be associated with its humid highland climate and extensive agricultural activities that increase human contact with contaminated soil. Nguyen & Nguyen (2012) reported that environmental and occupational conditions in Lam Dong Province, including intensive agricultural activities, frequent soil contact, and limited sanitation in rural areas, could facilitate the transmission of STHs. Particularly for hookworm transmission, these conditions may favor the survival and development of infective larvae in the soil, thereby increasing opportunities for transmission. However, due to the lack of detailed demographic and behavioral data, the relative contributions of ecological and population-related factors could not be assessed in this study. The prevalence observed in the current study was substantially lower than that previously reported in Lam Dong Province (Nguyen & Nguyen, 2012). In addition, all detected infections were of light intensity which may indicate the effectiveness of ongoing deworming programs and improvements in sanitation that have reduced parasite burden and transmission intensity over time. Likewise, the differences in infection prevalence among provinces may be related to environmental and socioeconomic conditions. Tay Ninh also has favorable conditions for transmission due to widespread agricultural practices and tropical environmental conditions. The prevalence observed in our study was also lower than that reported by Vuong *et al.* (2022) in Tay Ninh Province (Vuong *et al.*, 2022). In contrast, Binh Duong, with a higher level of urbanization and improved sanitation infrastructure, may present a lower risk of infection. The lowest prevalence observed in Con Dao (Ba Ria-Vung Tau Province) could be explained by its limited agricultural activities and smaller population, which may reduce opportunities for soil contamination and STH transmission.

Single infections predominated in the current study, whereas multiple infections were rare. These findings are in line with previous reports from Vietnam and may indicate the relatively low prevalence and transmission intensity of STH infections in the study sites (Nguyen & Nguyen, 2012; Phan *et al.*, 2017). Notably, no cases of *A. lumbricoides* were detected in the present study which may be associated with the continued impact of national deworming programs and improvements in sanitation and hygiene practices that have reduced transmission in many areas of Vietnam. In addition, the Kato-Katz technique may have limited sensitivity for detecting low-intensity infections in low-transmission settings,

potentially leading to underestimation of residual infections. The absence of *A. lumbricoides* and the predominance of hookworm may indicate changing transmission dynamics of STHs in the surveyed communities.

To provide an overview of STH infections across age groups, participants were categorized into three age groups (2-18 years, 19-65 years, and >65 years) to improve statistical stability and reflect major epidemiological population groups. The results showed that infections were mainly concentrated in the working-age group (9.5%) and the elderly group (7.0%). The lowest prevalence was observed among participants aged 2-18 years (2.2%). Similar findings have been reported in Vietnam, with studies demonstrating higher hookworm prevalence among adults and older age groups. (Tran *et al.*, 2015; Dinh, 2017). The higher prevalence observed among working-age adults is an important epidemiological finding. Unlike school-aged children, who are routinely targeted by school-based deworming programs, adults may receive less frequent treatment and continue to experience occupational exposure through agricultural and outdoor activities. Consequently, adults may contribute to the persistence of hookworm transmission within communities, even in settings where the overall prevalence of STHs has declined. These findings suggest that continued surveillance of adult populations may be important for achieving sustainable control of hookworm infection.

This study has several limitations. Participant demographic data by province, including sex and occupation were not available in the retained surveillance dataset, limiting further stratified analyses. In addition, no questionnaire survey was conducted, therefore, potential behavioral and environmental factors related to helminth transmission could not be assessed. The Kato-Katz technique may also underestimate low-intensity infections in low-transmission settings. Finally, the ecological comparison on this study was exploratory, and future studies incorporating questionnaire-based surveys and environmental data are needed to better understand variations in hookworm distribution across different ecological settings.

CONCLUSION

In conclusion, hookworm was the predominant STH species across the surveyed ecological settings, with the highest prevalence observed among working-age adults. The observed variation in prevalence across highland, lowland, and island settings suggests that ecological factors may influence hookworm transmission. These findings highlight the importance of continued surveillance and the inclusion of adult populations in control strategies, particularly in areas where hookworm remains the dominant STH.

Declaration of Competing Interests

The authors declare no conflict of interest.

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