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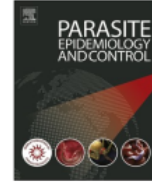
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Soil-transmitted helminth infections and anemia in children attending government run schools on Samosir Island, Indonesia

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ABSTRACT

Background: Worldwide, >654 million children live in regions where soil-transmitted helminth (STH) infections are endemic. These parasites cause a variety of symptoms, including anemia.

Methods: In May 2023, fecal and blood samples were collected from children aged 6 to 11 years attending government run (public) elementary schools in the Simanindo and Ronggur Nihuta sub-districts of Samosir Island, Indonesia where a twice a year mass drug administration (MDA) program is currently in place. A questionnaire was administered to students' parents or adult family members on possible risk factors for STH infections. Qualitative data were collected through in-depth interviews and focus group discussions.

Results: In total, 187 and 221 children in Simanindo and Ronggur Nihuta provided samples, respectively. The STH infection prevalence in Simanindo was 4.8% (9/187) and the infection prevalence in Ronggur Nihuta was 5.9% (13/221). In Simanindo, all infections were caused by *Trichuris trichiura* ($n = 9$), and in Ronggur Nihuta infections were caused by *Ascaris lumbricoides* ($n = 6$), *Trichuris trichiura* ($n = 5$), and *A. lumbricoides* + *T. trichiura* ($n = 2$). Three children had anemia but were negative for STH infections. While the results of the parent/adult questionnaires indicated access to a generally safe water supply and septic system, information from the in-depth interviews and focus groups revealed that the local water supply becomes greatly diminished during the dry season.

Conclusions: While MDA has been shown to effectively control roundworms and hookworms, additional measures to control trichuriasis are needed. There is also a need for the government to invest in improving the public water supply infrastructure.

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1. Introduction

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Species of soil-transmitted helminths (STHs) that commonly infect humans, include *Ascaris lumbricoides* (roundworm), *Trichuris trichiura* (whipworm), and *Ancylostoma duodenale* and *Necator americanus* (hookworms) (Badri et al., 2021; Sutisna et al., 2021; Kapti et al., 2021). Transmission of STHs is more common in areas with poor hand hygiene and poor environmental sanitation (Sutisna et al., 2021). Globally, an estimated 1.5 billion people are infected with STHs, representing about 25% of the world's population, and >654 million school-age children aged 6 to 11 years live in areas highly endemic for STH infections (WHO, 2023).

STH infections can result in clinical manifestations such as diarrhea and abdominal pain. Anemia is a serious sequelae of hookworm infection due to intestinal attachment of the adult worms (CDC, 2023a). This condition is especially problematic in young children. In STH endemic areas, anemia in children aged 6 to 11 years is strongly associated with moderate to heavy hookworm infections (Getnet and Worku, 2015; Molla and Mamo, 2018). Up to 740 million people worldwide are infected with hookworms (CDC, 2023b). Heavy infections with whipworms (*T. trichiura*) may also lead to anemia (Izurietta et al., 2018). A meta-analysis of STH infections in Asia found a pooled prevalence of 20.9% (95% CI: 14.7–27.9%) for *T. trichiura* infection in children aged 5 to 16 years (Badri et al., 2022).

The prevalence of STH infection in Indonesian provinces was reported to range from 2.5% to 62.0% (MHRI, 2017). On Samosir Island, the 2015 prevalence of STH infection in Simanindo and Ronggur Nihuta sub-districts was 46.8% and 66.7%, respectively (Wandra et al., 2020). The prevalence of hookworm and *T. trichiura* infection in Simanindo was 8.3% and 15.3%, respectively, whereas the prevalence of hookworm and *T. trichiura* infection in Ronggur Nihuta was 16.7% and 7.4%, respectively (Wandra et al., 2020). Current STH control programs in Indonesia include health promotion, parasite surveillance, patient management, and mass drug administration (MDA), with the goal of decreasing the prevalence of STHs to <10% in all districts and cities (MHRI, 2017). The aim of this study was to evaluate the prevalence of STH infection and anemia in children aged 6 to 11 years attending government run (public) schools in the Simanindo and Ronggur Nihuta sub-districts of Samosir Island as well as look at possible risk factors for infection.

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2. Materials and methods

2.1. Study area

Samosir Island is located in North Sumatra Province (BPS-SSR, 2022) and is one of 514 Indonesian districts. The rainy season is November through April, with an average temperature ranging from 27.6 to 29.5 °C and 74.3 to 81.7% humidity. In contrast, the dry season is May through October, with the average temperature ranging from 28.6 to 30.0 °C and 73.8 to 78.6% humidity (BPS-SSR, 2022).

The Simanindo and Ronggur Nihuta sub-districts of Samosir Island consist of predominantly rural farming communities, but Simanindo has a small tourist industry and more interaction with outside communities (Wandra et al., 2020). Simanindo had a 2021 population of 23,039, with 28 government elementary schools (2543 students), and two private elementary schools (316 students). Ronggur Nihuta had a 2021 population of 9755, and 12 government elementary schools (1513 students). There are no private elementary schools in Ronggur Nihuta sub-district (BPS-SSR, 2022) (Table 1, Fig. 1). Children in elementary schools are typically 6–11 years of age.

The study was conducted in seven government run elementary schools in Simanindo and five government run elementary schools in Ronggur Nihuta from May 11, 2023 to May 20, 2023 (Table 1, Fig. 1).

2.2. Participant selection

Participating schools were selected using simple random sampling, representing 12 villages and 30% of the government run schools in the two sub-districts. No a priori sample size calculation was performed. A total of 408 students (187 from Simanindo and 221 from Ronggur Nihuta) were invited to provide a fecal sample and a blood sample via a finger stick.

2.3. Questionnaire

After obtaining informed consent, each child's parent or adult family member 18 years of age or older was asked to complete a questionnaire focusing on possible risk factors for STH infection. The questionnaire was multiple choice and adapted from a survey

Table 1

Number of elementary school, school children, fecal samples and hemoglobin (Hb) examined by sub-district of Samosir Island, 2023

Sub-district	Government run elementary schools		No. of fecal sample and Hb examined			
	A*/B	No. of school children*	Fecal sample		Hb	
			n	Fecal sample positive (%)	n	Anemia [#]
Simanindo	28/7	2543	187	4.8 (9/187)	187	1.1 (2/187)
Ronggur Nihuta	12/5	1513	221	5.9 (13/221)	221	0.5 (1/221)
Total	40/12	4056	408	5.4 (22/408)	408	0.7 (3/408)

A: No. of government run elementary school, B: No. of government elementary school surveyed. *BPS-SSR, 2022. [#]Hb <11.5 mg/dL (WHO, 2001).

previously used by the Indonesian Ministry of Health as part of an STH control initiative (MHRI, 2017). Due to the rural nature of these communities and the lack of local public transportation, questions related to travel history were not included.

2.4. Evaluation of fecal and blood samples

During the 10-day study period, an average of 41 fecal samples were collected per day. All samples were evaluated the day of collection by one of 30 trained members of the research team. Fecal samples were examined microscopically using the Kato-Katz technique (Swastika et al., 2017; Wandura et al., 2020; Badri et al., 2022; MHRI, 2017), and blood samples were evaluated using a digital hemoglobin meter (EazyTouch®GCHb). The Kato-Katz technique was selected to align with government STH evaluation guidelines and due to its low cost and ease of use (MHRI, 2017). Each fecal sample was stirred 2 to 3 times and slides were evaluated 20–30 min after preparation.

All children with Hb levels lower than 11.5 g/dL were considered to be anemic (WHO, 2001). *A. lumbricoides* and hookworm infections were treated with a single dose of albendazole (400 mg), and *T. trichiura* infections were treated with albendazole (400 mg) for three consecutive days. Anemia cases were referred to a local healthcare facility for assessment and treatment (MHRI, 2018). At the time of sample collection, each child was also asked if they had ever heard of STHs (or worms in the environment that could make them sick) (Fig. 2a). Unstructured field observations were noted by the research team regarding students' hand hygiene (Fig. 3a), whether the children were wearing shoes outdoors (Fig. 3b), and local water sources in the study villages (Fig. 3c). Prior to sample collection, informed consent was obtained from all students' parents or guardians, and assent was obtained from participating children.

Prevalence of STH infection or anemia was defined as the number of participants with an STH infection or anemia divided by the total number of fecal or blood samples $\times 100$. The frequencies of STH infection and anemia were compared between populations and sub-groups using Pearson chi-square or Fisher's exact test as appropriate. Categorical questionnaire responses were described using proportions. P -value < 0.05 was considered statistically significant. Quantitative data analysis was conducted using SPSS v.21 (IBM).

2.5. Interviews and focus group discussions

Qualitative data on STH knowledge regarding risks, prevention, and treatment were collected through 10–15-min in-depth interviews and 45–60-min focus group discussions. Ten adults representing both sub-districts, including head of the Samosir district health office, the secretary of the Samosir district education office, elementary school principals ($n = 3$), individuals in charge of STH control programs at local health centers ($n = 3$), and student's parents ($n = 2$) participated individually in in-depth interviews. Twelve individuals, including a village leader, the village leader's secretary, a member of the village leader's staff, health cadres ($n = 4$), community leaders ($n = 2$), a religious leader, and midwives ($n = 2$) participated in focus group interviews. Focus group discussions were conducted at the Barita Local Health Center in Simanindo, with participants from both Simanindo ($n = 8$) and Ronggur Nihuta ($n = 4$). Focus group participants included four males and eight females, ranging in age from 32 to 55 years. The questionnaire, interviews, and focus group discussions were all conducted in the local language of Bahasa (Indonesian).

In-depth interview and focus group discussion data were evaluated using thematic analysis. All interviews and focus group sessions

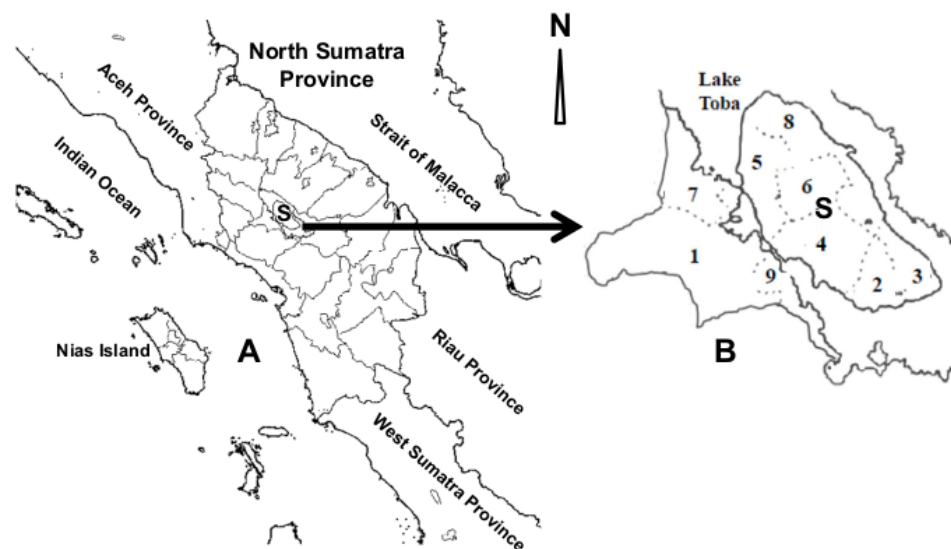


Fig. 1. Maps of North Sumatra Province (A) and Samosir Island (B) showing the Simanindo (8) and Ronggur Nihuta (6) subdistricts, the locations of the 2023 school-based survey. Samosir Island consists of Harian (1), Nainggolan (2), Onan Runggu (3), Palipi (4), Pangururan (5), Ronggur Nihuta (6), Sianjur Mula-mula (7), Simanindo (8), and Sitio-tio sub-districts (9).

were recorded. In order to ensure transcription accuracy, interviews recorded in Bahasa were translated to English and then translated back to Bahasa. For quality assurance, randomly selected portions of the transcript were compared to the audio recording. Key themes were identified by evaluating individual responses using a content analysis approach. At least two members of the research team separately coded each transcript using a matrix. Disagreements between the researchers about thematic interpretations were discussed until a consensus was established.

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2.6. Ethical considerations

This study was approved by the Research Ethics Committee of the Health Division, The National Research and Innovation Agency, Republic of Indonesia (Number 025/KE.03/SK/03/2023, dated March 30, 2023). Permission to take and use photographs was obtained from all participants at the time of enrollment.

3. Results

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The prevalence of STH infection in school-age children in the Simanindo sub-district of Samosir Island was 4.8% (9/187) (Tables 1 and 2). All infections were caused by *T. trichiura*. The prevalence of STH infection in school-age children in the Ronggur Nihuta sub-district was 5.9% (13/221), with no significant difference found in prevalence between the two sub-districts ($p = 0.3987$) (Table 2). Infections in Ronggur Nihuta were caused by *A. lumbricoides* (46.1%, 6/13), followed by *T. trichiura* (38.5%, 5/13), and *A. lumbricoides* + *T. trichiura* (15.4%, 2/13) (Table 2). No students with diarrhea were noted during sampling.

In Simanindo, 95 (50.8%) of the participants were male and 92 (49.2%) were female. There was no statistical difference in STH infection prevalence between males (4.2%, 4/95) and females (5.4%, 5/92) ($p = 0.4798$). In Ronggur Nihuta, 77 (34.8%) of the participants were male and 144 (65.2%) were female. Again, there was no statistical difference in STH infection prevalence between males (7.8%, 6/77) and females (4.9%, 7/144) ($p = 0.2802$) (Table 2). The prevalence of anemia in school-age children in Simanindo and Ronggur Nihuta was 1.1% (2/187) and 0.5% (1/221), respectively, with no significant difference between the two sub-districts ($p = 0.4375$) (Table 2). None of the children with anemia were positive for STH infection. Only about half of the students (50.2%; 205/408) demonstrated any previous knowledge of STHs.

Questionnaires were completed or partially completed by 408 parents or adult family members (187 from Simanindo and 221 from Ronggur Nihuta). Overall, the fathers of most of the surveyed students were farmers (78.5%; 285/363) as were the mothers (74.9%; 269/359). With regards to possible modes of STH transmission, the most common source of drinking water in the home was commercially supplied pipes (31.2%; 114/365). In addition, 82.4% (304/369) of respondents indicated that the family drank boiled



Fig. 2. Images showing a student being asked about worms in the environment that could make them sick (a), and collection of a blood sample from a student to look for anemia (b).



Fig. 3. Images showing nail hygiene of a student (a), students after playing a game in the schoolyard barefoot (b), and the use of natural pond water for bathing and collecting water for households in the Ronggur Nihuta sub-district (c).

Table 2

Prevalence of STH by infecting parasite and sex and anemia prevalence in school-age children in the Simanindo and Ronggur Nihuta sub-districts of Samosir Island, 2023.

Infecting parasite	Simanindo (n = 187)	p-value	Ronggur Nihuta (n = 221)	p-value
STH infection	4.8% (9/187)	–	5.9 (13/221)	0.3987*
Cause of infection				
<i>A. lumbricoides</i> (Al)	0.0% (0/9)	–	46.2 (6/13)	–
<i>T. trichiura</i> (Tt)	100.0% (9/9)	–	38.5 (5/13)	–
Al + Tt	0.0% (0/9)	–	15.4 (2/13)	–
Sex				
Male	4.2% (4/95)	0.4798*	7.8 (6/77)	0.2802*
Female	5.4% (5/92)		4.9 (7/144)	
Anemia	1.1% (2/187)	–	0.5 (1/221)	0.4375*

* p-value for comparison of STH infections and anemia between sub-district.

p-value for comparison of STH infections between males and female in each sub-district.

water, and 80.1% (289/361) indicated having a toilet in the home. There were significant differences in father's occupation (farmer versus non-farmer) ($p = 0.002$), mother's occupation (farmer versus non-farmer) ($p = 0.036$), source of drinking water ($p = 0.035$), use of boiled water ($p < 0.001$), and having toilet facilities in the home ($p < 0.0001$) between Simanindo and Ronggur Nihuta sub-districts (Table 3).

Hygiene and sanitation related to STH transmission, household water supply, and STH control program implementation were identified as community level themes from both the interviews and focus group discussions. While the results of the parent/adult

questionnaires indicated access to a generally safe water supply and septic system, information from the in-depth interviews and focus groups revealed that the local water supply becomes greatly diminished during the dry season. This lack of water often results in local toilets only functioning fully in the rainy season, with individuals commonly defecating in open fields during the dry season. In addition, hand washing is kept to a minimum to conserve water during the dry season.

4. Discussion

This study found an overall STH prevalence of 5.4% (22/408) in school-age children in Simanindo and Ronggur Nihuta. The target for district level STH control programs in Indonesia is to decrease the prevalence of STH infections to <10% (MHRI, 2017). The national MDA program includes administration of a single dose of albendazole two times a year if the local STH prevalence is >50%, once a year if the local prevalence is 20–50%, and selectively if the local prevalence is <20% (MHRI, 2017). This protocol has been in place for more than a decade (MHRI (Ministry of Health Republic of Indonesia), 2012; MHRI, 2017).

In Simanindo, all infections were caused by *T. trichiura*, likely due to the impact of an MDA program carried out in local schools two times a year. A single dose of albendazole (400 mg) effectively controls roundworm and hookworm infections. However, it is inadequate for trichuriasis (CDC, 2019; Sungkar et al., 2019; Namwanje et al., 2011; Tee et al., 2022). In a 2006 study conducted in students aged 9–15 years (elementary and junior high school) in Simanindo, 59.6% (28/47) were positive for *T. trichiura* eggs two weeks after being administered a single dose of albendazole (Wandra et al., 2020).

In contrast, in Ronggur Nihuta, infections were caused by *A. lumbricoides* and *T. trichiura*. Differences in student hygiene and access to sanitary facilities may partially account for the presence of *A. lumbricoides* in Ronggur Nihuta and not in Simanindo. The last MDA with a single dose of albendazole was given in Simanindo and Ronggur Nihuta during April 2023, which means that in Ronggur Nihuta, infection with *A. lumbricoides* likely occurred within one and a half months post-treatment. As a comparison, children in the Taman, Mambal, and Sibang Kaja villages of Badung district, Bali, had fecal samples collected for three consecutive months after treatment, with 1.3% of students infected with *A. lumbricoides* two months after treatment and 10.9% of students infected with *A. lumbricoides* three months after treatment (Kapti et al., 2005; Sutisna et al., 2021).

There were only three cases of anemia identified in the current study using a digital hemoglobin meter, none of which were diagnosed with a current STH infection. These cases were likely caused by other chronic conditions, with further diagnostic testing needed to confirm the underlying cause. A similar low prevalence of anemia was found in school children in Simanindo in 2005, where 2.5% (1/40) of children had anemia (Wandra et al., unpublished). In the current study, low hookworm infection prevalence and a relatively small sample size make it difficult to come to any general conclusions about the impact of STH-associated anemia on children in Indonesia. However, for the children included in this study, anemia does not appear to be a major problem. It should be noted that a study limitation was the inability to use the cyanmethemoglobin method to test for anemia due to the challenge of collecting venous blood samples from school children.

There were several limitations due to the design and scope of this study. Information bias is always a concern when collecting data through questionnaires. Also, since there was no a priori sample size calculation performed and this study only included children attending government run schools, findings may not be applicable to all children in Simanindo and Ronggur Nihuta. Future regional studies evaluating STH infections in children may want to consider including children attending both public and private schools. Since the current study was conducted over a 10-day period in May (the beginning of the dry season), future studies may also want to evaluate if there are seasonal differences in infection prevalence.

The local environment and poor hygiene-related behaviors likely contribute to ongoing transmission of STHs in children on Samosir Island (Sato et al., 2018; Steinbaum et al., 2016). Half of the students in this study indicated they had never heard of STHs. Even though most of the families (97.5%) in the current study reported having a toilet in their home, compared to only 82.4% of households in 2015 (82.4%) (Yulfi et al., 2017), access to water is still largely dependent on the rains. Inability to fully use indoor plumbing and clean water during the dry season likely contributes to ongoing STH infections in children. Additional hygiene-related practices, including not wearing shoes outdoors and poor hand/nail hygiene, also likely lead to infections in children.

5. Conclusions and perspectives

MDA programs have been shown to effectively control roundworms and hookworms (Herjanto et al., 1997; Kabatende et al., 2023). However, additional measures to control *T. trichiura* are needed. Health education related to personal hygiene and environmental sanitation should be included along with the MDA program aimed at children. One example is the use of popular board games, such as Snakes and Ladders that have been modified to teach children about infectious disease prevention and control (Wulanyani et al., 2019). Additionally, local governments should invest in improving the public water supply infrastructure.

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Declaration of competing interest

The authors report no conflict of interest. The authors are responsible for the content and writing of this paper.

Table 3

Responses to a questionnaire administered to parents or adult members of a student's household regarding possible risk factors for STH infection in the Simanindo ($n = 187$) and Ronggur Nihuta ($n = 221$) sub-districts of Samosir Island, 2023.

Parent of student's occupation and household sanitary facilities	Sub-district		p-value	Overall n (%)
	Simanindo	Ronggur Nihuta		
	n ^a (%)	n ^a (%)		
Father's occupation				
Farmer	118/165 (71.5)	167/198 (84.3)	0.002	285/363 (78.5)
Non-farmer	47/165 (28.5)	31/198 (15.7)		78/363 (21.5)
Mother's occupation				
Farmer	115/164 (70.1)	154/195 (79.0)	0.036	269/359 (74.9)
Non-farmer	49/164 (29.9)	41/195 (21.0)		90/359 (25.1)
Source of drinking water at home				
Sufficient (a)	60/165 (36.4)	54/200 (27.0)	0.035	114/365 (36.4)
Insufficient (b)	105/165 (63.6)	146/200 (73.0)		251/365 (63.6)
Drinking water at home				
Boiled water	151/167 (90.4)	153/202 (75.7)	< 0.001	304/369 (90.4)
Un-boiled water	16/167 (9.6)	49/202 (24.3)		65/369 (9.6)
Having toilet facilities				
Yes	143/159 (89.9)	146/202 (50.5)	< 0.0001	289/361 (80.1)
No	16/159 (10.1)	56/202 (77.8)		72/361 (19.9)

(a) Commercial water/water pipes.

(b) Simanindo: Borholes/open well ($n = 27$), natural pond ($n = 34$), rainwater ($n = 8$), lake ($n = 36$);

Ronggur Nihuta: Borholes/open well ($n = 14$), natural pond ($n = 28$), rainwater ($n = 73$), lake ($n = 31$).

^a Some questions have fewer responses due to participants being unwilling to answer.

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