High Prevalence and Risk Factors for Hookworm and Strongyloides Stercoralis Infections in Rural East Kalimantan, Indonesia

Jitbanjong Tangpong (rjitbanj@wu.ac.th)
Walailak University https://orcid.org/0000-0002-4768-7829
Blego Sedionoto
Walailak University, School of Allied Health Sciences
Sueptrakool Wasessombat
Walailak University
Chuchard Punsawad
Walailak University
Witthaya Anamnart
Walailak University
Manas Kotepui
Walailak University

Research

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Abstract

Background: Hookworm and *Strongyloides stercoralis* infections are neglected tropical diseases in developing countries, which have environmental risk factors with the potential for transmission of hookworm and *S. stercoralis* infections. This study aimed to explore the prevalence and risk factors for hookworm and *S. stercoralis* infections in East Kalimantan Province, Indonesia.

Methods: A cross-sectional study enrolled 213 participants from 28 villages, including 12 villages from Muara Kaman District and 16 villages from Marangkayu District in East Kalimantan Province. The data from 10-15 households of each village with 1-3 participants in each household were collected. In this study, Kato Katz and Koga agar plate cultures/KAP cultures were used for diagnosing hookworm and *S. stercoralis* infections among participants. The Pearson chi-square analysis was used to analyze the correlation between risk factors with hookworm and *S. stercoralis* infections.

Results: In this study, 72 (33.8%) and 17 (8.0%) participants were infected with hookworm and *S. stercoralis*, respectively. The prevalence of hookworm infection reported was higher than *S. stercoralis* infection in rural areas of East Kalimantan Province. Hookworm infection has been significantly associated with demographic factors, sanitation conditions and personal hygiene. In addition, high hookworm infection has been significantly associated with environmental factors such as locality of district, organic carbon content in the soil, temperature, humidity, number of days of rainfall, volume of rainfall, wet/dry soil around houses, and habitation. However, *S. stercoralis* infection has not been significantly correlated with demographic factors, sanitation conditions, and personal hygiene. The highest odds ratio of hookworm infection was in village areas surrounded by a river or coastal areas OR: 2.92 (95% CL: 1.38-6.24), while the highest odds ratio of *S. stercoralis* infection was in households with habitation with humans infected with *S. stercoralis* OR: 95% CL: 8.33 (2.27-30.61).

Conclusions: The high prevalence and risk factors of hookworm and *S. stercoralis* infections in rural communities in East Kalimantan Province. Characteristics of demographic factors, sanitation conditions, and personal hygiene that were correlated with hookworm and *S. stercoralis* infection should be used for control and prevention programs to reduce hookworm and *S. stercoralis* infections, especially in rural areas.

Background

Hookworm and *Strongyloides stercoralis* are two soil-transmitted helminths (STH) that are highly prevalent infections and serious public health concerns globally. Hookworm causes the highest public health burden among STH, while *S. stercoralis* causes long-lasting infections and significant morbidity. These two parasites are highly prevalent in poor rural communities in tropical and subtropical areas in many developing countries (1). They are transmitted through unprotected contact with soil that is endemic in tropical and temperate regions. In 2010, the prevalence of hookworm infection and *S. stercoralis* infection was estimated in 438.9 million people and 100 million people, respectively. Almost

70% of these infections occurred in Asia (2–4). Humans acquire hookworm and *S. stercoralis* infections through direct skin contact with infective third-stage larvae, where soil that was contaminated by human feces penetrate the intact human skin and eventually reach the small intestine (5). Generally, hookworm and *S. stercoralis* infections are found among poor people with poor environmental sanitation and where the climate is warm and humid (6, 7).

Factors affecting the difference in the prevalence of hookworm infection and *S. stercoralis* infection may include good hygiene practices among the population, availability of a sewage system, and length of the rainy season. Environmental factors have contributed to the transmission of diseases as well as to the growth and development of the worms (8, 9). Environmental factors, especially the long rainy season, may affect the decrease in the prevalence of *S. stercoralis* infection but not hookworm infection. A previous study demonstrated that the prevalence of *S. stercoralis* infection in Southern Thailand is lower than in other parts of the country. However, the prevalence of hookworm infection is still high in Southern Thailand because of the 10-months-long rainy season in Southern Thailand in contrast with the 4-months-long rainy season in other parts (10). Another study in Cambodia reported a lower prevalence of *S. stercoralis* infection in the areas with heavy rainfall than in low rainfall areas, where the high amount of the organic carbon content in the soil affects the lower prevalence of *S. stercoralis* infection (11). A previous study in Southern Laos demonstrated hookworm infection and *S. stercoralis* infection at about 56.1% and 41%, respectively (12).

Kutai Kertanegara Regency, East Kalimantan Province, Indonesia is located at 0.44019^0S and 116.98139^0E. The average temperature is 28^0C ($26\text{-}32^0$C). Muara Kaman District is located at the surrounding Mahakam River and is close in proximity with forest areas and palm plantations. In contrast, Marangkayu District is located in a coastal area and surrounded by rubber plantations, palm plantations, and rice fields. We collected data from 28 villages, consisting of 12 villages from Muara Kaman District and 16 villages from Marangkayu District. The prevalence of hookworm and *S. stercoralis* infections in rural East Kalimantan Province, Indonesia, remains unclear. Because the environment is suitable for hookworm and *S. stercoralis* infections in this area, it is important to determine the prevalence and risk factors for these two parasites. This study aimed to explore the prevalence and risk factors (including soil quality, surrounding vegetation, temperature, humidity, village areas, length of rainy season, type of pets (cats or dogs), personal hygiene, and sanitation conditions of households) for hookworm and *S. stercoralis* infections in East Kalimantan Province, Indonesia.

Methods

Study design

This cross-sectional study was conducted from July 2018 to September 2019 in rural areas of Muara Kaman District and Marangkayu District, Kutai Kertanegara Regency, East Kalimantan Province, Indonesia. Data was collected from 10–15 households in each village with 1–3 participants in each

household. The demographic data was collected from 213 participants and was analyzed with the environmental factors (13).

Study population, sample size, and sampling technique

Two districts in Kutai Kertanegara Regency, East Kalimantan Province, were selected for the purpose of this study: Muara Kaman District and Marangkayu District (Fig. 1), where these areas have differences in soil quality, number of days and yearly volume of rainfall, temperature, humidity, elevation above sea level, village areas, and surrounding vegetation. These areas were selected based on the potential risk of hookworm and *S. stercoralis* infections due to the following characteristics: rural areas, poor sanitation and hygiene practices, agricultural activity, and surrounding forests. The sample size was calculated using a prevalence rate (p) of 55.4% as detailed from a previous study (23), with a 95% confidence interval (z = 1.96) and a 10% margin of error (d = 0.1). Therefore, the calculated sample size was 95 participants per district. However, the final sample size would end up being reduced by around 15% due to subjects being unable to pass stool on the study date. Thus, the aim was for a sample size of 110 participants per district. A simple random sampling method was used to select the population from each district. Inclusion criteria for participants included the following: ≥2 years old, lived in both areas, and were able to complete questionnaires and provide stool samples. One hundred and ten participants per area were randomly selected and were given the instructions, and they were also provided the questionnaires and plastic containers for stool sample collection. In total, 220 participants were enrolled and completed the questionnaires. Seven participants were excluded from the study because they did not send in their stool samples. In total, 213 participants were included for this study.

Data collection and laboratory processing

The stool samples were collected and sent to The Biomedical Laboratory, School of Public Health, Mulawarman University. Two methods were performed to identify the parasites including agar plate culture and the Kato-Katz technique. A modified agar plate culture was performed as described by Koga et al., 1991. Briefly, approximately 2 grams of stool sample was placed at the center of nutrient agar and kept at room temperature for five days. Tracks from larva crawling and larvae or adult worms were observed under an inversed microscope. If any tract was spotted, 10 ml of 10% formalin was added to the agar surface for 5–10 minutes and transferred to a centrifuged tube. Centrifugation of suspension was performed at 2,500 rpm for 5 minutes, and then the supernatant was discarded. The sediment was further examined for hookworm and *S. stercoralis* larvae or adult worms. For the Kato-Katz thick smear, 50 mg of stool was placed on a slide and covered with a cellophane paper soaked in glycerin solution for 24 hours. The stool was spread out using a rubber stick and examined after 30 minutes, and the eggs of parasites were counted (14–16). The environmental conditions of houses surrounding the village were recorded on the same day or following the day after stool samples were collected.

Data analysis

Demographic data and personal hygiene of the participants were collected by questionnaires. The sanitation conditions of each household of the participants were collected by observation. Environmental data including surrounding vegetation, elevation of soil above sea level, type of soil around houses, type of pets, length of the rainy season, humidity, and temperature per year were collected. The quality of soil including the organic carbon content, clay content, and pH was determined at the soil laboratory at Mulawarman University. The vegetation and type of soil around houses were collected by a standardized-observation form. The types of pets were also recorded by researchers. The length of the rainy season, humidity, and temperature per year were collected from the Central Bureau of Statistics (https://www.bps.go.id) and the Central Bureau of Meteorology, Climatology, and Geophysical of Indonesia (https://www.bmkg.go.id). The prevalence of hookworm and *S. stercoralis* infections was stratified according to the demographic data, sanitation conditions and personal hygiene, and environmental data; and it was reported by descriptive statistic. Statistical analysis was performed by the Chi-square test using SPSS Version 22 (IBM SPSS Statistics for Windows, NY: IBM Corp). The association between the parasite infections and demographic data, sanitation conditions, personal hygiene, and environmental risk factors was analyzed using correlation analysis. The differences in demographic data, sanitation conditions, personal hygiene, and environmental risk factors were analyzed using the Chi-Square test with a confidence interval of 95%. The level of significance for all tests was considered at $p < 0.05$.

Results

Demographic characteristics

A total of 213 individuals from 28 villages participated in this study. Twelve villages were from Muara Kaman District and sixteen villages were from Marangkayu District, East Kalimantan Province, Indonesia (Fig. 1). Most of the participants (118/213, 55.4%) were from Marangkayu District, while 95 participants (44.6%) were from Muara Kaman District. The age of all participants ranged from 2 years to 70 years old. Males (130/213, 61%) were the dominant participants. The main occupations of the participants were farmers (70/213, 32.9%), at home (65/213, 25.8%), at school (81/213, 38.0%), and other (7/213, 3.3%). The sanitation conditions of the participants included the type of floor covering at the door, type of yard covering surrounding the house, waste water treatment, water sources for daily activity and drinking, and toilets. Personal hygiene of the participants included wearing shoes in outdoor activities, washing feet and hands after soil contact, washing fruits or vegetables before eating, eating uncooked vegetables, washing hands after pet contact, and using toilets in the home (Table 1).

Table 1
Characteristics of the 213 participants in the community-based study

Variable	Category	n (%)
Gender	Male	130 (61.0)
	Female	83 (39.0)
Age (years)	2–12	114(53.5)
	13 and above	99 (46.5)
Main occupation	Farmer	70 (32.9)
	At home	65(25.8)
	At school	81 (38.0)
	Other	7 (3.3)
Occupation	Non-Agricultural	75 (64.8)
	Agricultural	138 (35.2)
Type of indoor floor covering in the house	Sanitary floor (cement, wood, etc.)	212 (99.5)
	Soil floor	1 (0.5)
Type of yard covering	Not soil	35 (16.4)
	Soil	178 (83.6)
Waste water treatment	Healthy waste water treatment	108(50.7)
	Without waste water treatment	105 (49.3)
Water sources for daily activity	Sanitary water sources	92 (43.2)
	Unsanitary water sources	121 (56.8)
Drinking water	Sanitary drinking water	117(54.9)
	Unsanitary drinking water	96 (45.1)
Toilet	Sanitary toilet in the home	181 (85.0)
	Open defecation (in plantation, garden, or river)	32 (15.0)
Using shoes outdoors	Routine	74 (34.7)

Variable	Category	n (%)
	Not routine	139 (65.3)
Washing feet after soil contact	Yes	26 (12.2)
	No	187 (87.8)
Washing fruits/vegetables before eating	Routine	33(15.5)
	Not routine	180 (84.5)
Eating raw/uncooked fish/meat/vegetable	No	172 (80.8)
	Yes	41 (19.2)
Pet contact	No	161 (75.6)
	Yes	52 (24.4)
Washing hands after pet contact	Yes	4 (1.9)
	No	209 (98.1)
Washing hands after soil contact	Yes	25 (11.7)
	No	188(88.3)
Washing feet before entering the house	No	13 (6.1)
	Yes	200 (93.9)
Using the toilet at home	Yes	116 (54.5)
	No	97 (45.5)
Using sandals at the toilet	Routine	116 (54.5)
	Not routine	97 (45.5)
District	Muara Kaman	95 (44.6)
	Marangkayu	118 (55.4)
Organic carbon content in soil (%)	1.37–2.47	91 (42.7)
	> 2.47–4.04	122(57.3)

Variable	Category	n (%)
pH of soil	4.26–5.85	102 (47.9)
	> 5.85–6.92	111 (52.1)
Clay content in soil (%)	4-18.5	96 (45.1)
	> 18.5–42.50	117 (54.9)
Temperature (^{0}C)	28-28.6	118 (55.4)
	> 28.6–29.5	95 (44.6)
Humidity (%)	65	118 (55.4)
	66	95 (44.6)
Number of days of rainfall (day)	164	95 (44.6)
	174	118 (55.4)
Rainfall volume (mm^3)	3,549	95 (44.6)
	4,000	118 (55.4)
Elevation above sea level (m)	15-41.6	97 (45.5)
	> 41.6–50	116 (54.5)
Texture of soil	Sandy soil with organic material	139 (65.3)
	Non-sandy soil with organic material	74(37.3)
Vegetation	Surrounding palm plantations and/or rubber plantations	167 (78.4)
	Surrounding rice fields	46 (21.6)
Village areas	Buffer river/sea	166(77.9)
	Hill area	47(22.1)
Dry or wet soil surrounding the house	Dry soil	169(79.3)
	Wet soil	44 (20.7)
Having cats as pets	No	80 (37.6)

Variable	Category	n (%)
	Yes	133 (62.4)
Having dogs as pets	No	4(1.9)
	Yes	209 (98.1)
Hookworm in cats	Negative	80 (37.6)
	Positive	133 (62.4)
Hookworm in dogs	Negative	4 (1.9)
	Positive	209 (98.1)
S. stercoralis in cats	Negative	134 (62.9)
	Positive	79 (37.1)
S. stercoralis in dogs	Negative	52 (24.4)
	Positive	161 (75.6)
Habitation with humans infected with *S. stercoralis*	No	194 (91.1)
	Yes	19 (8.9)
Habitation with humans infected with hookworm	No	152 (71.4)
	Yes	61 (28.6)
Habitation with humans infected with hookworm and *S. stercoralis* co-infection	No	196 (92.0)
	Yes	17 (8.0)

The environmental data included the locality of the district, village areas, vegetation surrounding houses, elevation above sea level, carbon content in the soil, clay content in the soil, texture of the soil, dry or wet soil surrounding houses, humidity, temperature, length of the rainy season (number of days of rainfall yearly), volume of rainfall yearly, and type of pets (dogs or cats) (Table 1).

Prevalence of hookworm and *S. stercoralis* infections

Hookworm and *S. stercoralis* infections were examined using the Kato Katz technique and the APC method (Fig. 2). The results showed that 72 (33.8%) stool samples were positive with hookworm. The prevalence of hookworm infection in Muara Kaman District (53, 55.8%) was higher than in Marangkayu District (19, 16.1%), while the prevalence of *S. stercoralis* infection in Marangkayu District (14, 11.9%) was higher than in Muara Kaman District (3, 3.2%) (Fig. 3). The other details are listed in Table 2.

Table 2
Prevalence of hookworm and *S. stercoralis* infections in East Kalimantan Province

Infection	Muara Kaman District		Marangkayu District		Total	
	Positive	Negative	Positive	Negative	Positive	Negative
Hookworm	53 (55.8%)	42 (44.2%)	19 (16.1%)	99 (83.9%)	72 (33.8%)	141 (66.2%)
S. stercoralis	3 (3.2%)	92 (96.8%)	14 (11.9%)	104 (88.1%)	17 (8.0%)	196 (92%)
Co-infection	3 (3.2%)	92 (96.8%)	11 (9.3%)	107 (90.7%)	14 (6.6%)	199 (93.4%)

Risk factors of hookworm and *S. stercoralis* infections in East Kalimantan Province

Participant characteristics and household sanitation conditions in relation to the prevalence of hookworm/*S. stercoralis* infections were determined. The results showed that hookworm infections were significantly correlated with age ($p = 0.023$), occupation ($p = 0.044$), water sources for daily activity ($p = 0.000$), sources of drinking water ($p = 0.000$), and availability of toilets ($p = 0.012$) (Table 3).

Table 3
The association between participant characteristics and the prevalence of hookworm/*S. stercoralis* infections

Variable	Category	Positive n (%)		*P-value*	
		Hookworm	*S. stercoralis*	Hookworm	*S. stercoralis*
Gender	Male	47 (36.2)	3 (3.2)	0.364	0.218
	Female	25 (30.1)	14 (11.9)		
Age (years)	2–12	31 (27.2)	11 (9.6)	0.029	0.173
	13 and above	41 (41.4)	6 (6.1)		
Main occupation	Farmer	27 (38.6)	3 (4.3)	0.567	0.160
	At home	15 (27.3)	8 (14.5)		
	At school	27 (33.3)	6 (7.4)		
	Other	3 (42.9)	0 (0.0)		
Occupation	Non-Agricultural	39 (28.5)	14 (10.1)	0.044	0.114
	Agricultural	32 (42.7)	3 (4.0)		
Type of indoor floor covering in the house	Sanitary floor (cement, wood, etc.)	72 (34.0)	17 (8.0)	0.474	0.764
	Soil floor	0 (0.0)	0 (0.0)		
Type of yard covering	Not soil	72 (34)	3 (8.5)	0.648	0.888
	Soil	0 (0.0)	14 (7.9)		
Waste water treatment	Sanitary waste water treatment	33 (30.6)	8 (7.4)	0.310	0.754
	Without waste water treatment	39 (37.1)	9 (8.6)		
Water sources for daily activity	Sanitary water sources	19 (20.7)	8 (8.7)	0.000	0.737
	Unsanitary water sources	53 (43.8)	9 (7.4)		
Drinking water	Sanitary drinking water	18 (15.4)	13 (11.1)	0.000	0.63
	Unsanitary drinking water	54 (56.3)	4 (4.2)		
Toilet	Sanitary toilet in the home	55 (30.4)	14 (7.7)	0.012	0.752

	Open defecation (in plantation, garden, or river)	17 (53.1)	3 (9.4)

Personal hygiene and prevalence of hookworm and *S. stercoralis* infections

Hookworm infections were correlated with the use of shoes outdoors ($p = 0.034$), use of toilets at home ($p = 0.048$), and use of sandals at toilets ($p = 0.004$). *S. stercoralis* infections were not correlated significantly with personal hygiene. Data are shown in Table 4.

Table 4
The correlation between personal hygiene and the prevalence of hookworm and *S. stercoralis* infections

Variable	Category	Positive n (%)		P-value	
		Hookworm	*S. stercoralis*	Hookworm	*S. stercoralis*
Using shoes outdoors	Routine	32 (43.2)	4 (5.4)	0.034	0.311
	Not routine	40 (28.8)	13 (9.4)		
Washing feet after soil contact	Yes	6 (23.1)	4 (15.4)	0.217	0.137
	No	66 (35.3)	13 (7.0)		
Washing fruits/vegetables before eating	Routine	8 (24.2)	2 (6.1)	0.207	0.658
	Not routine	64 (35.6)	15 (8.3)		
Eating raw/uncooked fish/meat/vegetable	No	63 (36.6)	11 (6.4)	0.074	0.080
	Yes	9 (22)	6 (14.6)		
Pet contact	No	60 (37.3)	13 (8.1)	0.060	0.930
	Yes	12 (23.1)	4 (7.3)		
Washing hands after pet contact	Yes	0 (0.0)	0 (0.0)	0.149	0.551
	No	72 (34.4)	17 (8.1)		
Washing hands after soil contact	Yes	6 (24.0)	4 (16.0)	0.270	0.115
	No	66 (35.1)	13 (6.9)		
Washing feet before entering house	No	7 (53.8)	0 (0.0)	0.115	0.273
	Yes	65 (32.5)	17 (8.5)		
Using the toilet at home	Yes	46 (39.7)	10 (6.8)	0.048	0.706
	No	26 (26.8)	7 (7.2)		
Using sandals at the toilet	Routine	46 (39.7)	10 (8.6)	0.048	0.706
	Not routine	26 (26.8)	7 (7.2)		

Environmental risk factors of hookworm and *S. stercoralis* infections

The results of the chi-square analysis on the environmental risk factors in regard to the high prevalence of hookworm infection and low prevalence of *S. stercoralis* infection in East Kalimantan Province are

shown in Table 5 below.

Table 5
Environmental risk factors of hookworm and *S. stercoralis* infections in East Kalimantan Province

Variable	Category	Positive n (%)		*P-value*	
		Hookworm	*S. stercoralis*	Hookworm	*S. stercoralis*
District	Muara Kaman	53 (55.8)	3 (3.2)	0.000	0.020
	Marangkayu	19 (16.1)	14 (11.9)		
Organic carbon content in soil (%)	1.37–2.47	21 (23.1)	13 (14.3)	0.004	0.003
	> 2.47–4.04	51 (41.8)	4 (3.3)		
pH of soil	4.26–5.85	31 (30.4)	7 (6.9)	0.313	0.564
	> 5.85–6.92	41 (36.9)	10 (9.0)		
Clay content in soil (%)	4-18.5	35 (36.5)	7 (7.3)	0.458	0.737
	> 18.5–42.50	37 (31.6)	10 (8.5)		
Temperature (^{0}C)	28-28.6	19 (16.1)	3 (3.2)	0.000	0.020
	> 28.6–29.5	53 (55.8)	14 (11.9)		
Humidity (%)	65	19 (16.1)	14 (11.9)	0.000	0.020
	66	53 (55.8)	3 (3.2)		
Number of days of rainfall (day)	164	53 (55.8)	3 (3.2)	0.000	0.020
	174	19 (16.1)	14 (11.9)		
Rainfall volume (mm^3)	3,549	53 (55.8)	3 (3.2)	0.000	0.020
	4,000	19 (16.1)	14 (11.9)		
Elevation above sea level (m)	15-41.6	53 (55.8)	3 (3.1)	0.000	0.016
	> 41.6–50	19 (16.1)	14 (12.1)		
Texture of soil	Sandy soil with organic material	46 (33.1)	14 (10.1)	0.764	0.123
	Non-sandy soil with organic material	26 (35.1)	3 (4.1)		
Vegetation	Palm plantations and/or rubber plantations	65 (38.9)	12 (7.2)	0.003	0.414
	Rice fields	7 (15.2)	5 (10.9)		
Village areas	Buffer river/sea	65 (39.2)	12 (7.2)	0.002	0.446

	Hill area	7 (14.9)	5 (10.6)		
Dry or wet soil surrounding the house	Dry soil	51 (30.2)	15 (8.9)	0.028	0.345
	Wet soil	21 (47.7)	2 (4.5)		
Having cats as pets	No	30 (37.5)	5 (6.3)	0.376	0.470
	Yes	42 (31.6)	12 (9.0)		
Having dogs as pets	No	0 (0.0)	0 (0.0)	0.149	0.552
	Yes	72 (34.4)	17 (8.1)		
Hookworm/*S. stercoralis* in cats	Negative	0 (0.0)	10 (7.5)	0.474	0.716
	Positive	72 (34.4)	7 (8.9)		
Hookworm/*S. stercoralis* in dogs	Negative	0 (0.0)	1 (1.9)	0.000	0.064
	Positive	72 (34.4)	9 (9.9)		
Habitation with humans infected with hookworm and/or *S. stercoralis*	No	43 (26.3)	2 (1.0)	0.007	0.000
	Yes	29 (47.5)	15 (78.9)		

Hookworm infection was significantly correlated with the locality of the district ($p = 0.000$), organic carbon content in the soil ($p = 0.004$), temperature ($p = 0.000$), humidity ($p = 0.000$), number of days of rainfall ($p = 0.000$), rainfall volume ($p = 0.000$), elevation above sea level ($p = 0.000$), surrounding vegetation ($p = 0.003$), village areas ($p = 0.002$), dry or wet soil surrounding houses ($p = 0.028$), hookworm in dogs ($p = 0.000$), and habitation with humans infected with hookworm ($p = 0.001$). *S. stercoralis* infection was significantly correlated with the locality of the district ($p = 0.020$), organic carbon content in the soil ($p = 0.003$), temperature ($p = 0.020$), humidity ($p = 0.020$), number of days of rainfall ($p = 0.020$), rainfall volume ($p = 0.020$), and elevation above sea level ($p = 0.016$).

Discussion

The prevalence of hookworm infections showed higher than in *S. stercoralis* infections in rural East Kalimantan, Indonesia. In this study, we found that the prevalence of hookworm infection was higher in Muara Kaman District than in Marangkayu District, while the prevalence *S. stercoralis* infection was higher in Marangkayu District than in Muara Kaman District. The difference in environmental factors between Muara Kaman District and Marangkayu District was that Muara Kaman District is surrounded by palm plantations and river area, which might affect the increasing or decreasing prevalence of *S. stercoralis* infection in rural areas (2). A similar study was performed in Manufahi District, Timor Leste, with a prevalence of hookworm infection at 62.8% (17).

In regard to the organic carbon content in the soil, hookworm infection was higher in the category > 2.47–4.04% than in the category 1.37–2.47% with prevalence at 51 (41.8%) and 21 (23.1%), respectively. *S. stercoralis* infection was higher in the category 1.37–2.47 than in the category > 2.47–4.04% with prevalence at 13 (14.3%) and 4 (3.3%), respectively. The organic carbon content in the soil with the category > 2.47–4.04% was 1.70 times more likely for hookworm infection than in the category 1.37–2.47%, while the organic carbon content in the soil with the category 1.37–2.47% was 2.56 times more likely for *S. stercoralis* infection than in the category > 2.47–4.04%. A Cambodian study explained that high amounts of organic carbon content in the soil might not affect the prevalence of hookworm infection but might affect the prevalence of *S. stercoralis* infection (11). This may indicate that the organic carbon content in the soil in East Kalimantan Province might not reduce hookworm infection but might reduce *S. stercoralis* infection. From the study of Sebastian H, et al., the organic carbon content in the soil had an indirect effect on nematodes, but the effect of the organic carbon content via food organisms was usually on the abundance, cell size, and activity of bacteria (*Escherichia coli*) (18). Absorption of organic carbon by bacterial cells, serving as food for the nematodes, may be an important factor for the availability of organic carbon for hookworm.

The present study demonstrated that hookworm infection was associated with temperature, humidity, number of days of rainfall, rainfall volume, and elevation above sea level. These results were supported by a previous study that demonstrated that the rainy season may reduce the prevalence of hookworm and *S. stercoralis* infections (10). Another previous study also supported the results of this study by demonstrating that elevation contributed to the distribution of the prevalence hookworm and *S. stercoralis* infections (19). Environmental factors in East Kalimantan Province might be similar to Southern Thailand including long rainy seasons, temperature, and several geographical characteristics, which might have an impact on the higher prevalence of hookworm infection in East Kalimantan Province than in Southern Thailand (10). Another study in Southern Laos demonstrated a high prevalence of *S. stercoralis* infection during heavy rainfall with poor sanitation (12).

Hookworm infection was higher in households surrounded by vegetation and villages surrounded by palm plantations and/or rubber plantations than in villages surrounded by rice fields with the prevalence at 65 (38.9%) and 7 (15.2%), respectively; while *S. stercoralis* infection was higher in villages surrounded by rice fields than those surrounded by palm plantations and/or rubber plantations with the prevalence at 5 (10.9%) and 12 (7.2%), respectively. The reason is because the surrounding palm plantations have a higher temperature than the rice fields, which provide a suitable environment for hookworm but not for *S. stercoralis.* In addition, the soil covering at palm plantations might be a potential source for hookworm transmission rather than *S. stercoralis* infection, whereas rice fields might be a potential source for *S. stercoralis* infection during farming activity (20).

The prevalence of hookworm infection was higher in village areas with a river or coastal areas than in hill areas, while the prevalence of *S. stercoralis* infection was higher in hill areas. In addition, hookworm infection was more likely in houses surrounded by wet soil rather than dry soil, while *S. stercoralis* infection was more likely in houses surrounded by dry soil rather than wet soil. Hookworm and *S.*

stercoralis infections were more likely in participants who have dogs than those who do not have dogs. Dogs were a potential risk of transmitting hookworm and *S. stercoralis* among communities in rural villages with poor sanitation and a low quality of personal hygiene among members of the household. The results of this study were supported by a similar research conducted among Cambodian participants, where dogs were a serious risk factor for hookworm and *S. stercoralis* infections. Moreover, a previous study also demonstrated that dogs have a higher potential risk for hookworm and *S. stercoralis* infection than cats (21, 22). A study in Southern Thailand also demonstrated that dogs were correlated with hookworm and *S. stercoralis* infections (23). The factors related to the risk of hookworm and *S. stercoralis* infections consisted of poor hygiene, including infrequent hand washing and unclean feet after soil contact. These factors supported the penetration of *S. stercoralis* larvae to the human host (23, 24).

Conclusions

The prevalence of hookworm infection was higher than *S. stercoralis* infection in rural areas of East Kalimantan Province. The higher prevalence of hookworm infection than *S. stercoralis* infection might be due to environmental factors, sanitation conditions, and personal hygiene of the participants. Environmental factors such as the quality of the soil, length of rainy season, surrounding vegetation, and village areas were significant factors for increasing hookworm infection. In contrast, some of these factors became preventative factors for the prevalence of *S. stercoralis* infection. Demographic characteristics, sanitation conditions, and personal hygiene that were correlated with hookworm and *S. stercoralis* infections should be used for the control or reduction of hookworm and *S. stercoralis* infections in the rural areas of East Kalimantan Province.

List Of Abbreviations

S. stercoralis; Strongyloides stercoralis, OR; odds ratio, STH; soil-transmitted helminthes.

Declarations

Ethical approval and consent to participate

The study protocol was approved by the Ethical Clearance Committee on human rights related to research involving human subjects, Walailak University (HE: No. WUEc-18-034-01).

Consent for publication

Official permission and ethical clearance for collection of human fecal samples were obtained from the head of the village and the head of the household.

Availability of supporting data

All data related to the present study in this manuscript are available.

Competing interests

The authors declare that there is no conflict of interest regarding the publication of this article.

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Authors' contributions

All authors conceived of the idea and participated in the design of this study. BS, JT, and MK conducted the study. BS, SW, SP, WA, and JT were responsible for the interpretation of the results, drafting of the manuscript, and reading for intellectual content. All authors read and approved the final manuscript.

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Figures

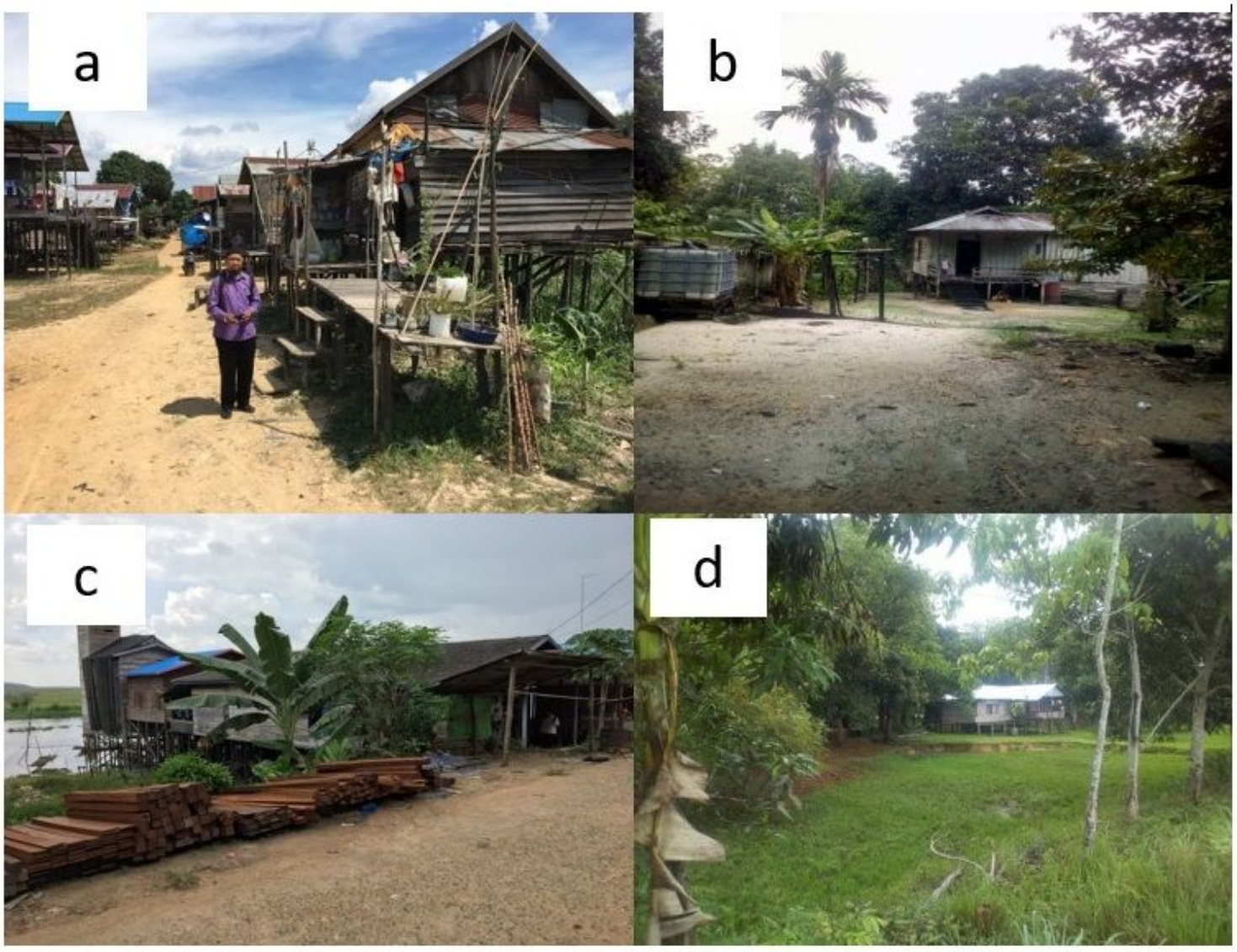

Figure 1

Data collection (a, b, c, d) in rural areas of Muara Kaman District and Marangkayu District, East Kalimantan Province

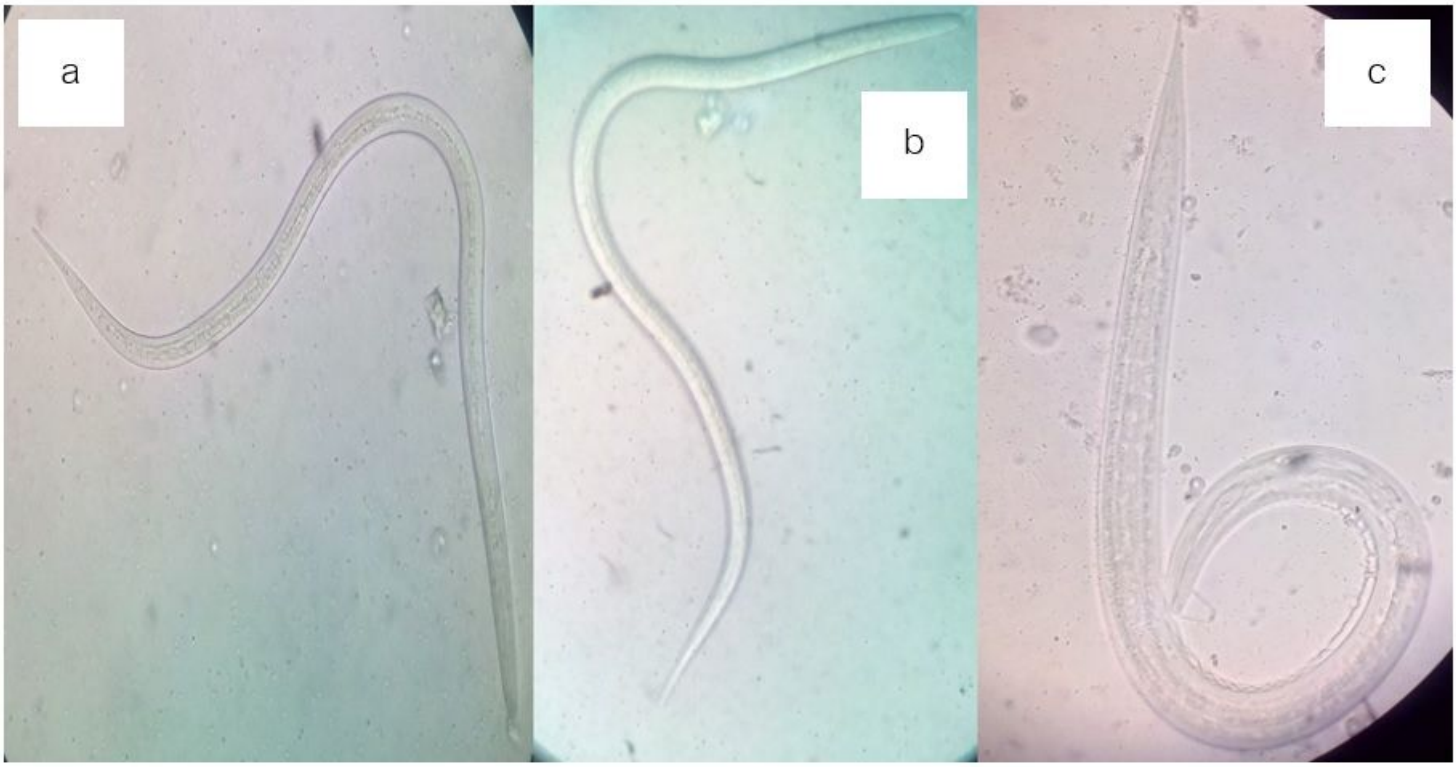

Figure 2

Modified agar plate techniques. (a, b, c) Hook worm filariform larva (L3). Microscopic observation under low power (x10)

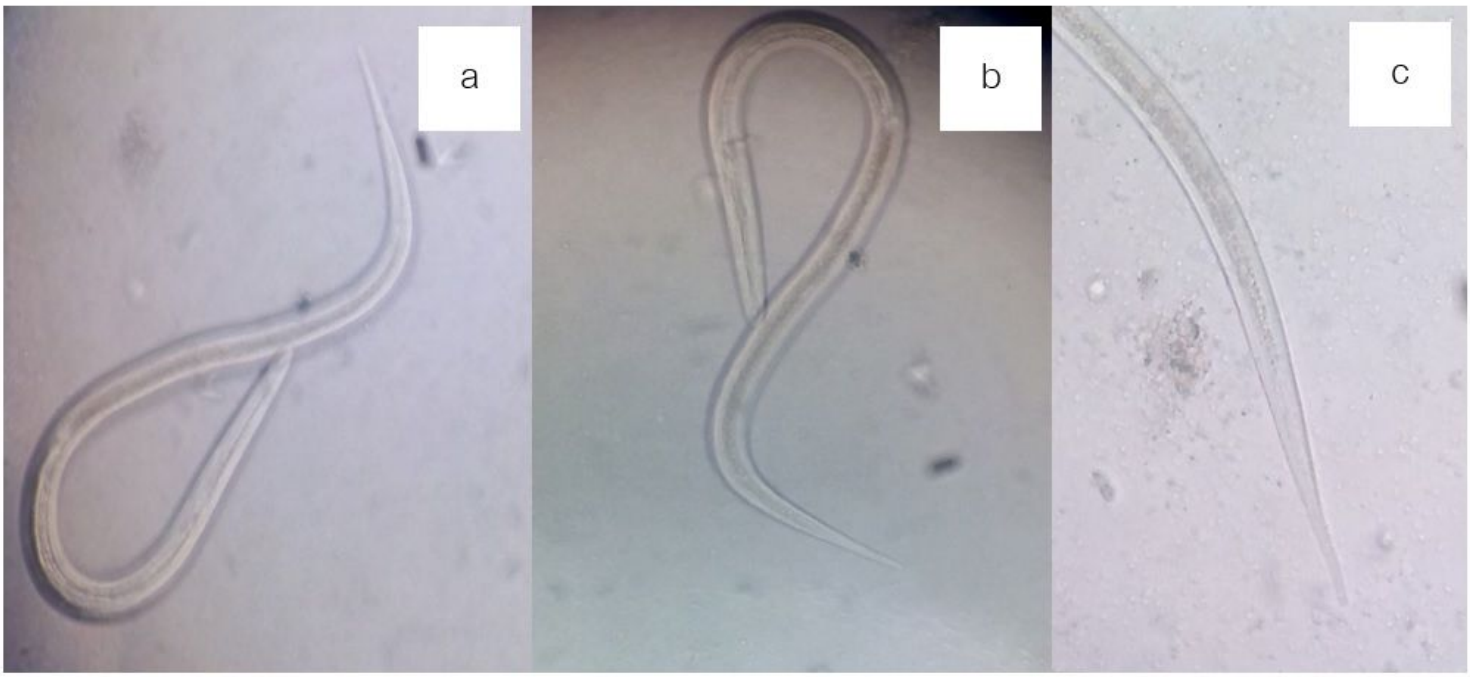

Figure 3

Modified agar plate techniques. (a, b ,c) Strongyloides stercoralis filariform larva (L3). Microscopic observation under low power (x10).