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Prevalence and intensity of helminths among inhabitants of the Chi River and Lahanna water reservoir areas of Northeastern Thailand

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Abstracts. Helminth infections (HIs) are an important public health problem in tropical countries, and the associated problems have been neglected in rural areas of Thailand. Therefore, this study reports the prevalence and intensity of HIs among inhabitants of the Khon Sawan district, Chaiyaphum province, and Kaeng Samnam Nang district, Nakhon Ratchasima province, which are located near the Chi River and Lahanna water reservoir, northeastern Thailand. A cross-sectional descriptive study was conducted between July 31, 2018, and June 30, 2019, among rural villagers from 40 rural villages in 4 subdistricts. The participants were selected from the village enrolment list after proportional allocation of the total sample size. Faecal samples from 691 inhabitants were prepared using solvent-free faecal parasite concentrator, and helminths were then detected using a light microscope. Statistical analysis included the Chi-square test with Yates correction, and multivariable logistic regression was performed. A P-value of <0.05 was considered statistically significant. The prevalence of HIs was 2.03%. The most prevalent helminths were *Opisthorchis viverrini* (1.31%), followed by *Strongyloides stercoralis* (0.44%), *Ascaris lumbricoides* (0.29%), hookworm (0.15%), *Teania* spp. (0.15%) and one minute intestinal fluke (0.15%). Coinfections were identified in 2 cases for *S. stercoralis* and hookworm and 1 case for *O. viverrini* and *S. stercoralis* infection. All infected participants had a light intensity of HI. There was no significant difference between general characteristics for all HIs. The prevalence of HIs was not significantly associated with general characteristics. This study indicates that the infections result mainly from foodborne helminths and skin-penetrating nematodes. Therefore, interventions should concentrate on the personal hygiene of the population and improving sanitation to reduce HIs in this area.

INTRODUCTION

Helminth infections (HIs) are widely distributed in tropical and subtropical areas, with the greatest numbers occurring in sub-Saharan Africa, the Americas, China and East Asia (World Health Organization, 2018). Statistics indicate that more than 1.5 billion people, or 24% of the world's population, are infected with soil-transmitted helminths (STHs). In ASEAN countries, it is estimated that 300 million people are infected with HIs caused by STHs; specifically, 126.7 million people are infected with *Ascaris lumbricoides*, 115.3 million are infected with *Trichuris trichiura*, and 77.0 million are infected with hookworm (Hotez *et al.*, 2015). More than 10 million people in ASEAN countries (particularly Thailand, Lao's People Democratic Republic, Cambodia, and

Vietnam) suffer from either liver or intestinal fluke infections caused by foodborne helminths (FBHs) (Hotez *et al*., 2015). The HIs caused by liver flukes, including *Opisthorchis viverrini* and *Clonorchis sinensis*, are classified as group 1 carcinogens by the World Health Organization's International Agency for Research on Cancer (International Agency for Research on Cancer, 2011). In 2014, the national prevalence rate of HIs was 18.1% among 15,555 Thais, with a high prevalence rate of liver fluke and hookworm infections in certain areas of the country (Wongsaroj *et al*., 2014). Previous studies have assessed the prevalence and intensity of HIs among rural villagers in Waeng Noi district, Khon Kaen Province, northeastern Thailand, which is located near the Lahanna fresh water reservoir, and this area is adjacent to Nakhon Ratchasima and Chaiyaphum provinces. Of the 400 faecal specimens examined, 23 were positive for at least one intestinal helminth, resulting in a prevalence of 5.75%. The most prevalent helminths were *Taenia* spp., 10 (2.50%); followed by hookworm, 5 (1.25%); *T. trichiura*, 4 (1.0%); *A. lumbricoides*, 3 (0.50%); and *O. viverrini*, 1 (0.25%). This study reveals that HIs, particularly those from food-borne and soil-transmitted species of helminths, are prevalent in adults in rural subdistricts (Kaewpitoon *et al*., 2019). In addition, Kaewpitoon *et al*. (2016) reported the prevalence of *O. viverrini* infection among villagers in the border areas of three provinces in northeastern Thailand. In the 978 participants screened, *O. viverrini* infection was found in 1.74%, and the majority of positive cases were found in participants who lived in the Khon Sawan district (8.43%) and Kaeng Sanam Nang district (1.84%). From this updated report, no information was available regarding the prevalence and intensity of HIs among the residents at the subdistrict level in Khon Sawan district, Chaiyaphum province, and Kaeng Sanam Nang district, Nakhon Ratchasima province, especially in the villages located near the Chi River and Lahanna fresh water reservoir. Consequently, this study was undertaken to determine the prevalence and intensity of HIs among people living in four districts from two provinces in the northeastern region of Thailand. These data are useful for further intervention and research approaches in the study area.

MATERIALS AND METHODS

Ethics statements

This study was approved by the Ethics Committee for Research Involving Human Subjects of Suranaree University of Technology, Thailand (EC- 59-38).

Study design and area

A cross-sectional survey was carried out from July 31, 2018, to June 30, 2019, and included people living in 40 rural villages located in the Yang Wai (7 villages) and Kok Mang Ngoy (11 villages) subdistricts, Khon Sawan district, Chaiyaphum province, and in Bueng Phalai (11 villages) and Bueng Samrong (9 villages) subdistricts, Kaeng Sanam Nang district, Nakhon Ratchasima province, northeastern Thailand. The study areas are located 376.4 km (Khon Sawan) and 341.3 km (Kaeng Sanam Nang) northeast of Bangkok and cover an area of 776.1 km^2 (Figure 1). Four subdistricts are located near the Chi River (which is 765 km long and the longest river flowing wholly within Thailand), and the Lahanna fresh water reservoir (which covers 11.2 km^2 of the catchment area for water from the Chi River). Participants were selected from each village using a voluntary sampling method. A total of 691 volunteers were recruited from Yang Wai (n=210), Kok Mang Ngoy (n=213), Bueng Phalai (n=176) and Bueng Samrong (n=92). Data on sociodemographic characteristics were collected using a questionnaire. All participants provided their own written consent before submitting stool specimens.

Faecal collection and examination

Clean plastic containers were distributed to the participants at enrolment with detailed instructions about the procedure for faecal specimen collection. All faecal samples were collected early in the morning and stored in coolers before transportation to the

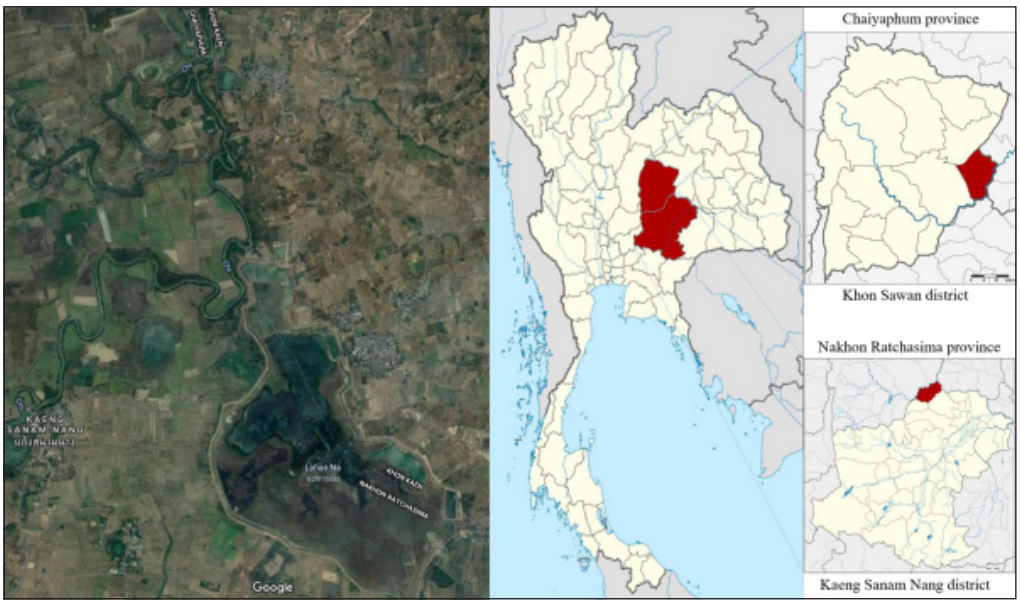

Figure 1. Map of Thailand showing the study area in Chaiyaphum and Nakhon Ratchasima provinces, Thailand.

laboratory at the Parasitic Disease Research Center (PDRC), Institute of Medicine, Suranaree University of Technology. Each specimen was prepared and examined for the presence of intestinal helminth organisms with solvent-free faecal parasite concentrator (Mini Parasep® SF) (Kaewpitoon *et al.*, 2016; Kaewpitoon *et al.*, 2018). Each specimen was examined under a microscope and initially screened with a 10× objective; the magnification of the low, medium, and high power objectives was 4×, 10×, and 40×, respectively. Suspected intestinal helminth objects were subsequently examined under a high-power objective. All samples were examined by two laboratory technologists from the PDRC. Patients who were infected with helminths and other known parasites were treated with anti-intestinal helminthic drugs and asked to attend health education sessions.

Statistical analysis

Statistical analyses were performed using the computer program STATA for Windows, version 13 (StataCorp LLC, Lakeway Drive, College Station, Texas, USA). The socio-demographic characteristics of the participants are presented as frequencies and percentages for categorical variables. The number of eggs per gram of faeces (epg) was calculated as follows: (number of eggs/drop × total number of drops of faecal solution)/(gram of faeces). The intensity of infection was expressed as epg of faeces for each participant. According to the WHO guidelines, the intensity of infection was classified as "light", "moderate" or "heavy" on the basis of the faecal egg count (Elkins *et al.*, 1991; Montresor *et al.*, 1998). The differences in infection between the categorical variables were assessed using the Chi square test. Multivariable logistic regression analysis was performed to estimate the odds ratios (OR) and 95% confidence intervals (95% CI) to assess the associations between potential risk factors and the prevalence of HIs. A P-value of <0.05 was considered statistically significant.

RESULTS

Of the 691 faecal specimens examined, 14 were positive for at least one intestinal helminth, resulting in an overall prevalence of 2.03%. The overall prevalence rate was 2.76% (11/398) in females and 1.02% (3/293) in males. Participants aged 41–50 years had a higher prevalence rate, 3.53% (7/198), than

participants in the other age groups. Participants who had attended secondary school had a higher prevalence rate, 2.52% (6/238), than participants in the other education groups. A high prevalence of helminths was found in participants who are housewives (5.55%, 1/18). When the participants were classified by occupation, HIs were most frequent among those with income levels of ≤5,000 Baht/month, at 3.70% (9/216). By location, participants from the Kok Mang Ngoy subdistricts had a higher prevalence rate, 2.81% (6/213), than participants in the Bueng Phalai 2.27% (4/176), Bueng Samrong 2.17% (2/92) and Yang Wai 0.95% (2/210) subdistricts. However, there was no significant difference between the prevalence of infection for each district. The socio-demographic characteristics of the participants and HIs were analysed for each variable using the Chi-square test; there were no significant differences between the prevalence of helminths for each characteristic. The influence of sociodemographic characteristics on the prevalence of helminths is shown in Table 1. Six species of helminths were identified; 3 species were identified as FBHs, and 3 species were the other STHs (Figure 2). FBHs were among the most common helminths, including *O. viverrini*, at 1.30% (9/689); minute intestinal fluke, at

Table 1. Positive rate of intestinal helminthic eggs categorized by general characteristics (n=691)

Variables	No. Samples n (%)	No. positive n (%)	Infection rate (%)	Chi-square test	P-value
Gender					
Male	293(42.40)	3(1.02)	0.43	0.110	2.555
Female	398(57.59)	11(2.76)	1.59		
Age (yr)					
≤ 20	4(0.58)	0		0.787	3.934
21 – 30	13(1.88)	0			
31 – 40	60(8.68)	1(1.66)	0.14		
41 – 50	198(28.65)	7(3.53)	1.01		
51 – 60	249(36.03)	3(1.20)	0.43		
> 60	167(24.17)	3(1.79)	0.43		
Education					
Illiterate	8(1.16)	0	0	0.907	1.018
Primary	417(60.34)	8(1.92)	1.16		
Secondary	238(34.44)	6(2.52)	0.87		
Diploma	8(1.16)	0	0		
Academic	20(2.89)	0	0		
Job Status					
Famer	562(81.33)	11(1.96)	1.59	0.803	2.319
Employed	68(9.84)	2(2.94)	0.29		
Trade	17(2.46)	0	0		
Housewife	18(2.60)	1(5.55)	0.14		
Government officer	16(2.31)	0	0		
Other	10(1.44)	0	0		
Family Income ($, per month)					
≤ 5,000	216(31.25)	9(3.70)	0.14	0.998	20.331
5,001 – 10,000	83(12.01)	3(3.61)	0.43		
10,001 – 15,000	13(1.88)	0	0		
15,001 – 20,000	14(2.02)	1(7.14)			
>20,000	16(2.31)	0			
Unknown	349(50.50)	1(0.29)			
Location (sub district)					
Yang Wai	210(30.39)	2(0.95)		0.582	1.955
Kok Mang Ngoy	213(30.82)	6(2.81)			
Bueng Phalai	176(25.47)	4(2.27)			
Bueng Samrong	92(13.31)	2(2.17)			

Data are presented as frequencies (%). *Chi-square.

Figure 2. Morphology of intestinal helminth eggs and larvae identified by light microscopy in faecal samples.
(A) Hookworm egg (×400). (B) *Ascaris lumbricoides* egg (×400). (C) *Strongyloides stercoralis* larvae (×100). (D) Minute intestinal fluke egg (×400). (E) *Opisthorchis viverrini* egg (×400). (F) *Taenia* spp. egg (×400).

Table 2. Intestinal helminth infection among 691 rural villagers in Chaiyaphum and Nakhon Ratchasima provinces, northeastern Thailand

Type of Intestinal Helminth	No. positive	Prevalence (%)
Opisthorchis viverrini	9	1.31
Strongyloides stercoralis	3	0.44
Ascaris lumbricoides	2	0.29
Hookworm	1	0.15
Teania spp.	1	0.15
Minute intestinal fluke	1	0.15
Total	**17**	**2.46**

*Co-infection 3 cases.

Table 3. Egg counts (eggs per gram of faeces) used to describe the intensity of infection (n=691)

Type of Intestinal Helminth	Intensity of infection (egg count per gram)	Level of intensity
Strongyloides stercoralis	460.33	light
Hookworm	381.75	light
Opisthorchis viverrini	100.50	light
Teania spp.	28.00	light
Minute intestinal fluke	25.00	light
Ascaris lumbricoides	24.00	light

0.15% (1/689); and *Taenia* spp. at 0.15% (1/689). STHs were identified as *S. stercoralis*, at 0.44% (3/689); *A. lumbricoides*, at 0.29% (2/689); and hookworm, at 0.15% (1/689). Three cases were found to have coinfections, including 2 cases of *S. stercoralis* and hookworm and 1 case of *O. viverrini* and *S. stercoralis* infection. The types of HIs are shown in Table 2. Of the 14 infected participants, all had light infection with *S. stercoralis*, *O. viverrini*, hookworm, minute intestinal fluke, *Taenia* spp. and *A. lumbricoides*. The summary of HI intensity in Table 3 shows that there were no heavy or moderate infections. Sociodemographic characteristics associated with HIs were analysed using multivariable logistic regression analysis, as shown in Table 4.

Table 4. Factors associated with intestinal helminth infection in the multivariable logistic regression analysis

Variables	No. Samples n (%)	No. positive n (%)	Infection rate (%)	*OR	95% CI	P-value	**ORadj	95% CI	P-value
Gender									
Male	293(42.40)	3(1.02)	0.43	2.738	(0.757-9.904)	0.125	2.698	(0.736-9.893)	0.134
Female	398(57.59)	11(2.76)	1.59						
Age (yr)									
≤ 20	4(0.58)	0		0.856	(0.527-1.390)	0.529	0.909	(0.530-1.560)	0.730
21 – 30	13(1.88)	0							
31 – 40	60(8.68)	1(1.66)	0.14						
41 – 50	198(28.65)	7(3.53)	1.01						
51 – 60	249(36.03)	3(1.20)	0.43						
> 60	167(24.17)	3(1.79)	0.43						
Education									
Illiterate	8(1.16)	0	0	0.969	(0.439-2.139)	0.937	0.989	(0.395-2.464)	0.976
Primary	417(60.34)	8(1.92)	1.16						
Secondary	238(34.44)	6(2.52)	0.87						
Diploma	8(1.16)	0	0						
Academic	20(2.89)	0	0						
Job Status									
Famer	562(81.33)	11(1.96)	1.59	0.818	(0.367-1.822)	0.623	0.804	(0.373-1.733)	0.579
Employed	68(9.84)	2(2.94)	0.29						
Trade	17(2.46)	0	0						
Housewife	18(2.60)	1(5.55)	0.14						
Government officer	16(2.31)	0	0						
Other	10(1.44)	0	0						
Family Income ($, per month)									
≤ 5,000	216(31.25)	9(3.70)	0.14	1.000	(1.000-1.000)	0.765	1.000	(1.000-1.000)	0.648
5,001 – 10,000	83(12.01)	3(3.61)	0.43						
10,001 – 15,000	13(1.88)	0	0						
15,001 – 20,000	14(2.02)	1(7.14)	0.14						
>20,000	16(2.31)	0	0						
Unknown	349(50.50)	1(0.29)	1.30						
Location									
Yang Wai	210(30.39)	2(0.95)	0.29	1.190	(0.758-1.867)	0.450	1.179	(0.742-1.873)	0.486
Kok Mang Ngoy	213(30.82)	6(2.81)	0.87						
Lahan Na	176(25.47)	4(2.27)	0.59						
Kan Lueang	92(13.31)	2(2.17)	0.29						

*Crude odds ratio from univariate analysis. **Adjusted odds ratio for all other variables.

No significant association was found between HIs and the participants' general characteristics (P >0.05).

DISCUSSION

HIs are an important public health problem in many countries, including Thailand. People with infections of heavier intensity can exhibit a range of symptoms, including intestinal manifestations, abdominal pain and diarrhoea, general malaise and weakness, malnutrition, and impaired growth and physical development. Infections of very high intensity can cause intestinal obstruction that should be treated surgically. Patients with a light infection intensity usually do not suffer from the infection (World Health Organization, 2018). Therefore, active screening is required for rural communities where there remains a lack of hygiene and an inadequate supply of sanitary water (Boonjaraspinyo *et al.*, 2013) and to ensure that mass drug administration is provided to populations at risk for HIs. Studies conducted with participants living throughout Thailand during a national survey of HIs have reported that the overall prevalence of HIs was 18.1% (Wongsaroj *et al.*, 2014). Here, the overall prevalence of HIs among the entire tested participant group living in rural communities in the Khon Sawan district, Chaiyaphum province and Kaeng Sanam Nang district, Nakhon Ratchasima province, was 2.03%. This result was slightly lower or comparable to the findings of a current national survey of HIs in Thailand. These results were compared to those of other studies, and the recent infection rates reported in these studies were lower than those previously reported among gardeners who were studied in Nakhon Ratchasima (Kaewpitoon *et al.*, 2015; Kaewpitoon *et al.*, 2016), Khon Kaen (Kaewpitoon *et al.*, 2015; Kaewpitoon *et al.*, 2019), and Chachoengsao provinces (Suntaravitun and Dokmaikaw, 2018). Prevention and control campaigns by health personnel, health volunteers, community leaders, and local university staff for HIs, especially *O. viverrini*, in these areas were launched five years ago. The infection rate of HIs has decreased, which might be due to the continuous campaign that possibly affected the population. Our study demonstrated that FBHs and STHs were found frequently in both sexes and were not significantly associated with the prevalence of helminths. The infection rate was slightly higher in females than in males. A high prevalence of intestinal helminths was found in participants that are housewives. This result was similar to previous findings (Graczyk and Fried, 1998). Although the patterns of other food-borne trematodiases have changed in Asia following changes in habits, cultural practices, health education, industrialization, and environmental alteration, human echinostomiasis remains a health problem. The disease is most prevalent in remote rural places among low-wage earners and in women of childbearing age. In a recent study, the sex difference may be due to female-specific cultural roles and tasks, such as taking risks with their work on the farm, catching shrimp, fish, and snails and gathering water and fresh vegetables along the river or water reservoir, or eating raw meat during cooking. Rural female cultural roles include collecting food materials in the areas around their villages and cooking for their family. In our study, the prevalence of HIs in older people was higher than that in young people (age <40 years). This result is similar to that of previous studies showing that older people need to be screened for HIs. Kaewpitoon *et al.* (2019) reported that the prevalence of HIs in older people was higher than that in young people (age <51 years). In addition, Suntaravitun and Dokmaikaw (2018) and Boonjaraspinyo *et al.* (2013) reported that the prevalence of HIs was higher in male participants >40 years of age than in young people. Moreover, Rangsin *et al.* (2009) reported that the prevalence of *O. viverrini* infection was correlated with an age of >60 years. This correlation may arise because older people have poorer education, live in conditions of poor sanitation, and partake in the culturally embedded habit of eating uncooked food (Songserm *et al.*, 2012). Health education programmes should target this group and teach individuals about the benefits of

wearing shoes and discontinuing risky eating habits. In the stratification by educational level, the highest prevalence rate was found for those who attended secondary school, followed by those who attended primary school. There was no significant difference among all education categories. However, health literacy is a concern in the secondary school group. Padchasuwan *et al.* (2018) indicated that health literacy can be used as a desirable strategy among secondary school students in Northeastern Thailand for informing those with a lower practice level of liver fluke prevention and control. The behavioural intervention is focused on cognitive skills, communication skills, and media literacy skills for this group. Ross *et al.* (2012) reported that low socioeconomic status, poor sanitation, and proximity to water sources were all reliable indicators of infection status in Northern Samar, Philippines. In addition, Muslim *et al.* (2019) reported that low socioeconomic status was highly associated with STH infections in some parts of Malaysia, while socioeconomic development has shown a significant reduction in intestinal parasitism in the general population. Our study is similar to those studies in which HIs were most frequent among individuals with incomes of ≤5,000 Baht/month. This result will aid in the targeting of limited income groups for treatment and health education efforts. Our data indicated that HIs were found in all subdistricts located around the Chi River and Lahanna fresh water reservoir. There was no significant difference between the prevalence of infection for each district. A previous study reported that HI infection was associated with the lower land near the Lahanna fresh water reservoir, Waeng Noi district, Khon Kaen province, Northeastern Thailand. This study indicated that lower elevation was associated with a higher infection rate than higher elevations. Loam and clay loam soils are associated with lower odds of *A. lumbricoides* infection, while sandy loam soils are associated with increased odds of *Necator americanus* infection (Wardell *et al.*, 2017). The porosity of sand provides a favourable environment for hookworm survival, offering drainage during wet conditions to prevent hookworm larvae from being waterlogged while also enabling hookworm larvae to migrate downward to prevent desiccation during hot and dry conditions (Wardell *et al.*, 2017; Brooker and Michael, 2000). Ribas *et al.* (2017) reported intestinal parasitic infections and environmental water contamination in a rural village of northern Lao's PDR. The level of microbial pathogen contamination was associated with human activity, with greater levels of contamination found at the downstream site than at the village and upstream sites, and the microbial population included several pathogenic microbes that were detected in the local river, a natural water source for consumption in the village. Basically, adequate warmth and moisture are key features for each of the STHs and FBHs. Wetter areas area associated with increased transmission, and in some endemic areas, both STH infections exhibit marked seasonality (Brooker and Michael 2000). However, a recent study showed that location was not significantly associated with the prevalence of intestinal helminths. However, there were infections with STHs and FBHs in all districts. Therefore, more efforts from local administrations, particularly health education campaigns for villagers, are required for prevention strategies to minimize HIs and improve sanitation conditions and, consequently, the general health of the villagers.

Six species of intestinal helminths were identified from the faecal specimens of this study; 3 species were identified as FBHs, and 3 species were STHs. FBHs were among the most common intestinal helminths, including *O. viverrini*, at 1.30%, which was the highest prevalence in this study, but the prevalence of this was lower than that reported in a previous study. The national prevalence rate of *O. viverrini* was reported at 5.1% among 15,555 Thais, which was the highest prevalence in certain areas of the country (Wongsaroj *et al.*, 2014). Kaewpitoon *et al.* (2018) reported that the prevalence of *O. viverrini* infection among a rural Thai population of 560 individuals from Nakhon Ratchasima, Khonkaen, and Chaiyaphum provinces was 2.86%. In addition, Kaewpitoon

et al. (2016) reported the prevalence of *O. viverrini* infection among 978 villagers in the border areas of three provinces in northeastern Thailand. *O. viverrini* infection was found in 1.74% of those tested, and the majority of positive cases were found in participants who lived in the Khon Sawan district (8.43%), Chaiyaphum province and Kaeng Sanam Nang district (1.84%), or Nakhon Ratchasima province. These results indicate that *O. viverrini* still exists in rural parts of Thailand, which raises concerns regarding public health. Other FBHs included minute intestinal fluke (0.15%) and *Taenia* spp. (0.15%), which showed the lowest prevalence in this study. Wongsaroj *et al*. (2014) reported that the national prevalence rate of minute intestinal fluke was 1.6%. *O. viverrini* infection was the most prevalent infection in certain areas of the country. A previous study reported the pattern of trematode infection with *O. viverrini* and other minute intestinal flukes that coexist in endemic areas. Sato *et al*. (2015) analysed the patterns of infections of *O. viverrini* and *H. taichui*, a minute intestinal fluke, in Lahanam and Thakhamlien villages (Savannakhet province, Lao PDR) in two cross-sectional investigations. Out of a total of 207 human participants, post-anthelmintic treatment positivity rates for expelled worms were 170 (82.1%) for *H. taichui* and 65 (31.4%) for *O. viverrini*. Both of these species coexist in the study villages. In addition, minute intestinal fluke infection, especially haplorchiasis (74%), is more common in northern Thailand. The high prevalence of haplorchiasis in Nan and Lampang provinces, Thailand, was proven by adult worm recovery from suspected opisthorchiasis cases. It was found that 39 of 50 cases (78.0%) from Nan Province had *H. taichui*, with intensities ranging from 5 to 1,250 with an average of 62 worms/case (Wijit *et al*., 2013). Moreover, Wongsawad *et al*. (2012) demonstrated the mixed infection of *O. viverrini* and *H. taichui* and confirmed the extended distribution of *O. viverrini* and minute intestinal fluke in Northern Thailand. However, the eggs of *Opisthorchis* and minute intestinal infections are easily confused under a microscope unless specific techniques are used (Kaewkes *et al*., 1991; Tesana *et al*., 1991; Sukontason *et al*., 1999; Wijit *et al*., 3013). Therefore, worm recovery after anthelminthic treatment or molecular techniques should be used for confirmation in endemic areas. *Taenia* spp. infection had the lowest prevalence in this study. The prevalence of this was similar to that reported in a previous study. Wongsaroj *et al*. (2014) reported the national prevalence rate of *Taenia* spp. was 0.7%. The prevalence of *Taenia* spp. infection was 0.5% among 199 faecal samples submitted for routine examination in the clinical pathology laboratory of Suranaree University of Technology Hospital, Nakhon Ratchasima province, Thailand (Kaewpitoon *et al*., 2016). In addition, in 209 faecal samples were analysed in rural areas of Nakhon Ratchasima province, Thailand, and the prevalence of *Taenia* spp. infection was 0.48% (Kaewpitoon *et al*., 2015). However, Kaewpitoon *et al*. (2018) reported the prevalence rate of *Taenia* spp. was 2.5% among 400 rural areas in Khon Kaen province, northeastern Thailand. These results indicate that people still have the culturally embedded habit of eating uncooked meat and have poor education. Health education programmes should target this group and teach individuals about risky eating habits. The findings from our study showed that STHs were identified as *S. stercoralis* (0.44%), *A. lumbricoides* (0.29%) and hookworm (0.15%). The prevalence of *S. stercoralis* infections has been surveyed in rural communities in Thailand. Laoraksawong *et al*. (2019) reported that the prevalence rate of *S. stercoralis* was 23.0% among 526 rural villagers. Suntaravitun and Dokmaikaw (2018) reported that the prevalence rate of *S. stercoralis* was 5.0% among 224 inhabitants from rural communities. The national prevalence of *S. stercoralis* was 1.7%, and a national cross-sectional survey was conducted in 75 provinces (Wongsaroj *et al*., 2014). Although the prevalence rate of *S. stercoralis* was low in this study, strongyloidiasis can lead to gastrointestinal symptoms, dermatological

symptoms, hyperinfection, or fatal outcomes (Grove, 1996; Forrer *et al.*, 2017). Additionally, chronic strongyloidiasis can lead to malnutrition in children and adolescents, causing growth retardation (Forrer *et al.*, 2017). Therefore, awareness campaigns and appropriate control programmes should be developed to reduce strongyloidiasis, especially in farmers and housewives in rural communities. Other STHs, including *A. lumbricoides* (0.29%) and hookworm (0.15%), had a slight prevalence in this study. The prevalence of infection with these prevalent STHs was lower than that reported in other studies in Thailand, mainly that of Suntaravitun and Dokmaikaw (2018), who reported that the prevalence of *A. lumbricoides* was 1.3%. Kaewpitoon *et al.* (2018) showed that *A. lumbricoides* prevalence was 0.75% among villagers living in rural areas. Comparison of our current data and the national survey of Thailand data from 2014 (Wongsaroj *et al.*, 2014) showed that our study found a slightly lower prevalence of *A. lumbricoides* (0.5%) than the national survey. Previous studies reported a high prevalence of hookworms by specialists. In addition, hookworm infection was lower in our study than in other studies. Kaewpitoon *et al.* (2019) indicated that hookworm infection was commonly found among villagers from Khon Kean province, Thailand. Punsawad *et al.* (2017) reported the high prevalence of intestinal parasitic infection and associated risk factors among village health volunteers in rural communities of southern Thailand. These studies showed that hookworm infection is more prevalent than other types of STH infection. Hookworms are an STH with a direct life cycle, and the main route of exposure is contact with larvae-contaminated soil due to a lack of footwear (Ribas *et al.*, 2017). Therefore, preventive measures should be taken to improve the health of the people against such helminths. Our study found that three cases were coinfections for *S. stercoralis* and hookworm. The two parasites have the same infection route, i.e., skin penetration. Both parasites are mostly prevalent in rural areas with poor sanitation conditions and a warm and humid climate that favours larvae survival in the environment (Brooker *et al.*, 2004; Hotez *et al.*, 2008; Schär *et al.*, 2013). Forrer *et al.* (2018) reported that 43.8% of the cases were coinfections between *S. stercoralis* and hookworm among 2,576 participants in 60 villages of Preah Vihear Province, Cambodia. Both parasites were ubiquitous in the province, with coinfections accounting for almost half of all cases. Coinfection risk was positively associated with longer walking distances to a health centre and exhibited a small clustering tendency. *S. stercoralis* and hookworm infections are important health problems and are major contributors to morbidity and mortality in the developing world (Becker *et al.*, 2011). Wesolowska *et al.* (2018) presented unusual dual *S. stercoralis* and hookworm infections in a traveller from Poland – a low-prevalence country – during low-budget travel in Southeast Asia. *Strongyloides* and hookworm infestations are rare in moderate climate zones and primarily occur in tropical and subtropical areas. Therefore, current information underscores that *S. stercoralis* and hookworm must not be neglected. Our study showed that 1 case presented coinfection with *O. viverrini* and *S. stercoralis*. This is found frequently in rural areas of Thailand. Laoraksawong *et al.* (2019) evaluated the prevalence of *S. stercoralis* and *O. viverrini* infections in rural communities in northeast Thailand. The overall prevalence of *S. stercoralis* infection was 23.0%. The prevalence of *O. viverrini* infection was 19.4%. This study demonstrated that the updated prevalence of intestinal parasite infections is still high in rural communities in northeast Thailand, especially strongyloidiasis and opisthorchiasis. Moreover, Boonjaraspinyo *et al.* (2013) demonstrated coinfection of *S. stercoralis* and *O. viverrini* among rural communities in northeastern Thailand at 3.3% (8/253). The study demonstrated that the prevalence of *S. stercoralis* and *O. viverrini* has not declined. These results indicated that the majority of the participants had a light infection of STHs and FBHs. None of the participants had a heavy HI intensity. The

light intensity of HIs in the present study may be due to differences in the study population, general living conditions, and the accessibility of health services. In general, the majority of people infected with HIs have a light infection intensity and no symptoms. The participants who were infected with these HIs were informed and treated following the Centers for Disease Control and Prevention, Ministry of Public Health recommendations regarding the type of HI. In Thailand, the cost of anti-parasitic drugs is generally low (Suntaravitun and Dokmaikaw *et al*., 2018; Boonjaraspinyo *et al*., 2013; Punsawad *et al*., 2017).

CONCLUSIONS

In conclusion, our results show a prevalence rate of HIs among inhabitants living around the Chi River and Lahanna fresh water reservoir. These infections result mainly from foodborne helminths and skin-penetrating nematodes. Therefore, interventions should concentrate on the personal hygiene of the population and improving sanitation to reduce HIs in this area.

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CONFLICT OF INTERESTS

The authors declare that there are no conflicts of interest.

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