RESEARCH ARTICLE

Burden of foodborne trematodiases and taeniasis in selected areas in southern Philippines

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ABSTRACT

Background: There are limited reports on foodborne trematodiases (FBT) and taeniasis prevalence and distribution in the Philippines.

Objective: This study aimed to describe their prevalence and distribution and determine the species causing these infections in selected areas in southern Philippines.

Methodology: The study was implemented in selected barangays in Caraga and Davao regions in southern Philippines. School-age children and adults with gastrointestinal manifestations within the last two weeks were examined using the modified Kato thick technique, while adults with cough for more than two weeks underwent sputum examination using NaOH concentration technique. The adult helminths from patients positive for FBT and/or taeniasis were processed, mounted, and stained for species identification.

Results: Variable FBT and taeniasis prevalence across geographic areas and population groups was seen with a highly focal distribution. Heterophyidiasis was the most common FBT with a 7.5% (168 out of 2,238) prevalence. Species not known to be endemic in the area were identified including *Haplorchis taichui*, *Opisthorchis felineus*, and *Echinostoma ilocanum*. Variable prevalence of soil-transmitted helminthiasis and schistosomiasis was also seen.

Conclusion: The study revealed the hidden burden of FBT and taeniasis and identified species not known to be endemic in selected areas in southern Philippines. Addressing this hidden burden will require enhancing service delivery. This may be done by utilizing more accurate diagnosis, updating treatment guidelines, implementing evidence-based control interventions, and improving surveillance. Integrating control programs, for instance, integrating FBT and taeniasis control with STH and schistosomiasis control, and integrating paragonimiasis control with the national TB program, may also help in optimizing resources.

Keywords: *foodborne trematodes, taeniasis, soil-transmitted helminths, schistosomiasis, Philippines*

Introduction

Foodborne trematodiases (FBT) and taeniasis are neglected tropical diseases which remain as public health concerns, especially in low- and middle-income countries such as the Philippines. FBTs such as clonorchiasis, opisthorchiasis, fascioliasis, and paragonimiasis as well as taeniasis are acquired through consumption of raw or undercooked food that harbor the parasite larva [1]. An estimated 83 million people worldwide have FBTs, resulting in 1.9 million disability-adjusted life years in 2017 [2,3]; while an estimated 2.5 million were infected with *Taenia solium* alone [4], causing approximately 2.8 million disability-adjusted life years [5]. These infections are known to exacerbate conditions of poverty as they result in pancreatitis, cirrhosis, and bronchiectasis, among others [6]. The Western Pacific Region experiences the highest mortality due to foodborne parasites globally [7].

There are limited reports on FBT and taeniasis prevalence and distribution in the Philippines. Challenges in surveillance include the low sensitivity of commonly used field diagnostics for parasitic infections as well as the limited capacity for diagnosis, treatment, and species identification [8,9].

This leads to underreporting and lack of surveillance data on these parasitic infections, causing continued neglect. Up-to-date epidemiologic data is needed in the Philippines to inform decision-making on FBT and taeniasis prevention and control [10]. Thus, this study aimed to describe the prevalence and distribution of FBT and taeniasis as well as to determine the species causing these infections in selected areas in southern Philippines.

Methodology

The study utilized a cross-sectional study design which involved parasitologic assessment in school-age children (SAC) and adults in selected sites in southern Philippines using stool examination, sputum examination, and adult helminth species identification using microscopy.

Setting

The study was implemented in Caraga and Davao regions in southern Philippines. Four provinces (two from each region), eight municipalities (two from each province), and 24 barangays or villages (three from each municipality) were selected as study sites (Figure 1). The provinces included were Agusan del Sur and Surigao del Norte in Caraga region, as well as Davao de Oro (previously known as Compostela Valley) and Davao Oriental in Davao region. Selection of sites was based on known FBT and taeniasis endemicity, willingness of local government units (LGUs) to participate in the study, and accessibility to the area.

Participants/Subjects

SAC (7 to 11 years old) and adults with gastrointestinal manifestations (18 years old and above) were recruited from selected barangays. Sampling was based on the World Health Organization (WHO) recommendations for FBT and taeniasis epidemiological surveys [1]. Those who received albendazole, mebendazole, or praziquantel within the last 30 days were excluded from the study.

Data Collection Procedures

Stool Microscopy for Intestinal Helminths

Stool collection kits with instructions were distributed. Stool samples collected were processed using modified Kato thick technique and examined by trained microscopists

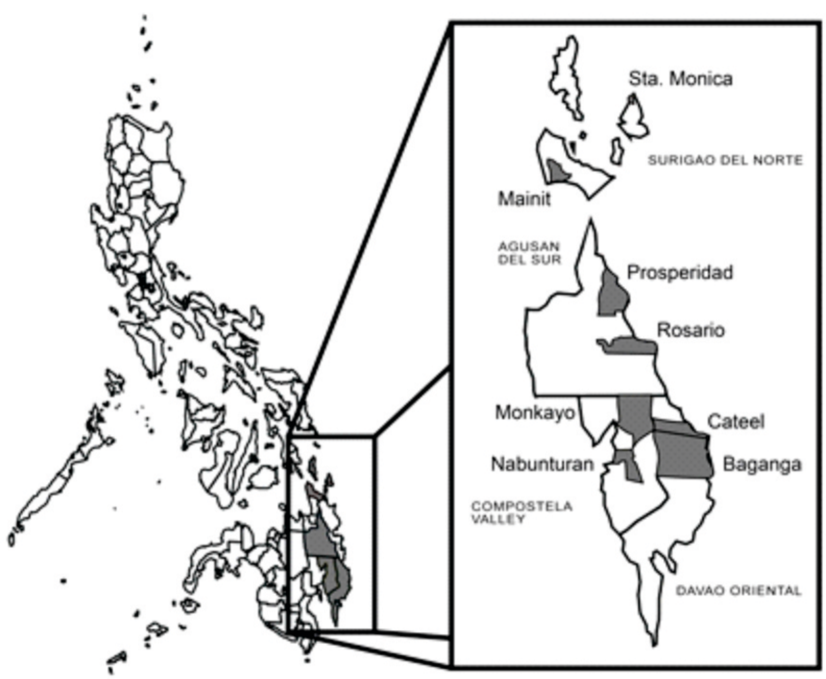

Figure 1. *Map of the Philippines (left) and provinces of Agusan del Sur, Surigao del Norte, Davao de Oro, and Davao Oriental highlighting the selected study sites (right)*

[11,12]. To ensure accuracy of stool microscopy, 10% of all smears were re-examined by a reference microscopist from the University of the Philippines Manila who was blinded to the initial results. The reference microscopist resolved discrepancies, if any, with the field microscopist or another University of the Philippines Manila microscopist. Diagnostic performance of field microscopists using the modified Kato thick technique was calculated using the reference microscopist as reference standard.

Sputum Microscopy for Paragonimus

Sputum microscopy was conducted in symptomatic adults living in low-lying *barangays* near bodies of fresh water where residents were known to consume raw crabs and cases of paragonimiasis had been reported. The inclusion criteria were: (1) productive cough lasting at least two weeks, (2) previously diagnosed pulmonary tuberculosis not responding to treatment, (3) previously diagnosed and treated pulmonary tuberculosis with recurrence of chronic productive cough, or (4) previously diagnosed paragonimiasis.

Early morning and spot sputum samples were collected and processed using 3% NaOH concentration technique which were used in previous studies [13-16]. After centrifugation of sputum specimens, all sediments were examined for *Paragonimus* ova by trained microscopists. Positive slides were validated by an on-site reference microscopist.

Helminth Collection and Identification in Adults

Participants found positive for *Taenia* spp., *Echinostoma* spp., and heterophyid ova by stool examination were included for adult helminth collection and identification. For bowel preparation, bisacodyl 10 mg (Dulcolax®) was given orally at bedtime, and bisacodyl (Dulcolax®) suppository was inserted into the anus on the morning of adult helminth collection following the methods in an earlier study [17]. Three doses of praziquantel 25 mg/kg (CesolTM) were administered by the project physician according to WHO guidelines [18]. An hour after the administration of the second dose, magnesium sulfate (30 g) dissolved in fruit juice was given. All stools passed out thereafter were collected and examined for adult helminths following the methods described in an earlier study [19]. Stools collected were washed with normal saline solution until the fecal matter was homogenous. The mixture was allowed to stand for 30 minutes for sedimentation, after which, the supernatant was decanted. The procedure was repeated until the supernatant became clear. Sediments were collected and examined for adult helminths. Specimens were processed, mounted, and stained for identification of species by an expert parasitologist using a taxonomic key.

Data Management and Statistical Analysis

The data collected were double encoded using Microsoft Excel 2010. Prevalence of FBT, taeniasis, and other intestinal helminth infections were determined. Chi-square test was used to determine the significant difference in prevalence between males and females, between SAC and adults, and across provinces. Data management and analysis were done using RStudio Desktop 1.3.959. A p-value of <0.05 was considered significant.

Ethical Considerations

The research protocol was approved by the University of the Philippines Manila Research Ethics Board (UPMREB-2012-0318). The scope, benefits, and risks of the study were explained to prospective participants, and a written informed consent and assent, as necessary, were obtained from each participant. A coding scheme was used from recording to reporting of results to ensure participants' anonymity. Treatment of patients found positive for FBT, taeniasis, and/or other parasitic infections was provided by concerned local health units according to WHO [18] and Department of Health guidelines [20-22].

Results

Prevalence of Foodborne Trematodiases and Taeniasis

A total of 2,238 participants, comprised of 1,150 SAC and 1,088 adults, were examined. Heterophyidiasis was the most common FBT across the four provinces, although the prevalence was generally low at 7.5%. Prevalence varied significantly across provinces (p-value<0.001) and was significantly higher in adults than in SAC (p-value<0.001). Prevalence was highest among adults in Agusan del Sur at 16.5% (Table 1). Heterophyidiasis prevalence varied significantly (p-value =0.006) between males (9.2%, 95% CI: 7.5-11.1%) and females (6.0%, 95% CI: 4.7-7.6%). Echinostomiasis was observed only in Caraga region (2.0%), with the highest prevalence in Sta. Monica, Surigao del Norte at 9.2% (24 out of 260). There was only one echinostomiasis case found outside Sta. Monica, which was in Prosperidad in Agusan del Sur. Echinostomiasis prevalence varied significantly (p-value =0.026) between males (1.7%, 95% CI: 1.0-2.7%) and females (0.6%, 95% CI: 0.3-1.3%). Taeniasis was only seen in three adults in Davao Oriental.

A total of 400 individuals from 16 *barangays* across six municipalities in all provinces except Davao de Oro were examined for paragonimiasis using sputum microscopy. Paragonimiasis was observed only in Barangay Aragon in Cateel, Davao Oriental with a prevalence of 16.2% (12 out of 74).

Species of Foodborne Trematodes and Taenia sp.

A total of 30 adult patients provided consent for adult helminth collection, but only 19 were observed to pass out adult helminths. In Agusan del Sur, a total of 152 adult helminths were recovered from six patients, with one patient expelling 142 of the collected specimens. Haplorchis taichui (Figure 2) was found in four patients, while Opisthorchis felineus (Figure 2) was found in the remaining two patients. In Surigao del Norte, three patients expelled a total of 30 adult helminths comprised of *E. ilocanum* (Figure 2) and *Ha. taichui*. A total of 11 *Ha. taichui* adults were collected from four patients in Davao de Oro. Ha. taichui and *T. saginata asiatica* (Figure 2) were recovered from six patients in Davao Oriental (Table 2).

Prevalence of Soil-transmitted Helminthiases and Schistosomiasis

The overall prevalence of soil-transmitted helminthiasis (STH) was 22.1%. The prevalence varied significantly across provinces (p-value<0.001) and was higher in adults than in SAC, although the difference was not significant (p-value=0.057). The STH prevalence was not significantly different (p-value =0.359) between males (23.0%, 95% CI: 20.5-25.6%) and females (21.3%, 95% CI: 19.0-23.8%). The STH prevalence was highest in Baganga, Davao Oriental at 62.3% (Table 3). Trichuriasis (12.2%) was the most common STH albeit its prevalence was generally low in all provinces, except Davao Oriental at 39.3%. Ascariasis was the next most common STH with an overall prevalence of 8.6%, with a similar prevalence across provinces. The overall hookworm prevalence (5.1%) was low in all provinces.

The overall schistosomiasis prevalence was 4.4%, with Rosario in Agusan del Sur having the highest prevalence at 13.0%. The prevalence was significantly higher (p-value<0.001) in the provinces of Caraga region than in Davao region, while the prevalence between SAC and adults was not significantly different (p-value=0.813). The schistosomiasis prevalence varied significantly (p-value =0.048) between males (5.3%, 95% CI: 4.1-6.9%) and females (3.5%, 95% CI: 2.6-4.8%).

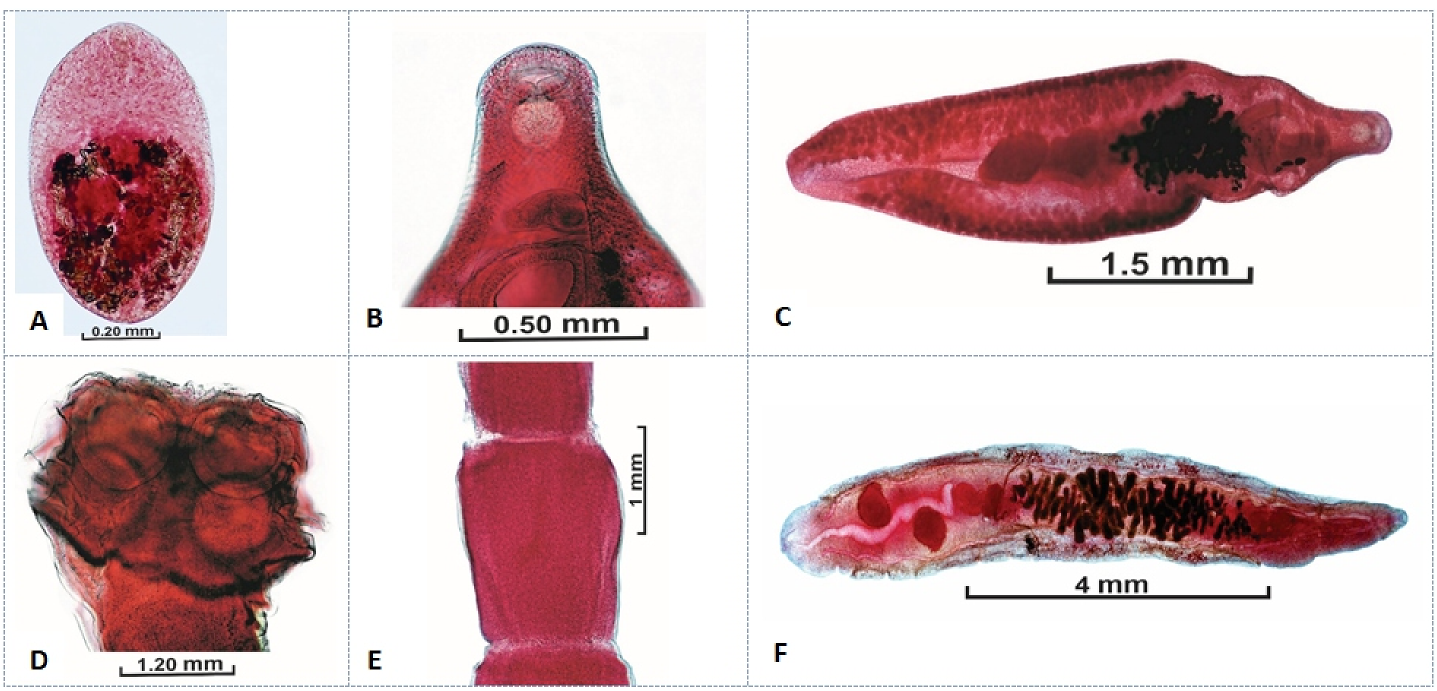

Figure 2. *(A) Adult Ha. taichui, (B) Adult E. ilocanum, anterior end showing oral and ventral suckers, (C) Adult E. ilocanum, (D) Adult T. saginata asiatica, scolex, immature, (E) Adult T. saginata asiatica, segment, immature, (F) Adult O. felineus*

Table 1. *Prevalence of Heterophyidiasis among SAC and Adults by Modified Kato Thick Method, in Selected Provinces and Municipalities in Caraga and Davao Regions, Philippines, 2014.*

Region/Province/Municipality	Number examined			Positive heterophyidiasis		
	SAC	Adults	Total	Among SAC	Among adults	Total
				n (%)	n (%)	n (%)
Caraga						
Agusan del Sur						
Prosperidad	186	182	368	14 (7.5)	43 (23.6)	57 (15.5)
Rosario	227	157	384	5 (2.2)	13 (8.3)	18 (4.7)
Subtotal	413	339	752	19 (4.6)	56 (16.5)	75 (10.0)
95% CI						(8.0-12.4)
Surigao del Norte						
Mainit	129	139	268	3 (2.3)	20 (14.4)	23 (8.6)
Sta. Monica	98	162	260	0	2 (1.2)	2 (0.8)
Subtotal	227	301	528	3 (1.3)	22 (7.3)	25 (4.7)
95% CI						(3.2-7.0)
Davao						
Davao de Oro						
Monkayo	163	156	319	18 (11.0)	30 (19.2)	48 (15.0)
Nabunturan	122	84	206	0	0	0
Subtotal	285	240	525	18 (6.3)	30 (12.5)	48 (9.1)
95% CI						(6.9-12.0)
Davao Oriental						
Baganga	124	123	247	2 (1.6)	4 (3.3)	6 (2.4)
Cateel	101	85	186	5 (5.0)	9 (10.6)	14 (7.5)
Subtotal	225	208	433	7 (3.1)	13 (6.3)	20 (4.6)
95% CI						(2.9-7.2)
Total	1150	1088	2238	47 (4.1)	121 (11.1)	168 (7.5)
95% CI				(3.1-5.4)	(9.3-13.2)	(6.5-8.7)

CI: confidence interval; n = number positive; SAC: school-age children

Heterophyid-STH as well as schistosomiasis-STH coinfections were observed in 1.8% and 1.5% of the study participants, respectively.

Discussion

Reporting of Foodborne Trematode Species Not Known Endemic in the Study Sites

Identification of foodborne trematode species is essential as morbidity and transmission vary across species. Examining egg morphology, however, is insufficient for identifying foodborne trematode and *Taenia* species. *Opisthorchis* eggs, for instance, resemble *He. heterophyes* eggs, which may lead to misdiagnosis [23]. Adult helminth identification through microscopy is useful in species identification in the absence of molecular techniques, particularly in resource-constrained settings.

Ha. taichui was the most common heterophyid species in the study sites, while *O. felineus* was found in only two individuals in Agusan del Sur. In the Philippines, a case of opisthorchiasis had been reported during a biliary tract surgery in a hospital in Davao [24]. The species of this case, however, was not identified. Thus, to our knowledge, the two reported cases in this study were the first documented cases of *O. felineus* in the Philippines. Species identification is particularly important for opisthorchiasis because *O. viverrini* has been associated with cholangiocarcinoma [25]. Studies suggest, however, that *O. felineus* infection and cholangiocarcinoma are potentially linked, but future epidemiological studies are

Table 2. *Helminth Species Identified from Selected Patients in Selected Municipalities and Barangays, Provinces of Agusan del Sur, Surigao del Norte, Davao de Oro, and Davao Oriental, Philippines, 2014.*

Municipality, Province/Barangay	Age/Sex	Stool microscopy results	Number adult helminths collected	Species identified
Prosperidad, Agusan del Sur				
Maug	43/M	Heterophyid	2	*Opisthorchis felineus*
Maug	37/F	Heterophyid, *Ascaris* sp	2	*Haplorchis taichui*
Azpetia	54/M	Heterophyid	3	*Haplorchis taichui*
Maug	35/M	Heterophyid	114	*Opisthorchis felineus*
Los Arcus	23/M	Heterophyid	2	*Haplorchis taichui*
Maug	50/F	Heterophyid	2	*Haplorchis taichui*
		Subtotal	152	
Sta. Monica, Surigao del Norte				
Libertad	65/M	*Echinostoma* sp	24	*Echinostoma ilocanum*
Libertad	42/F	Heterophyid	5	*Haplorchis taichui*
Libertad	40/M	*Echinostoma* sp	1	*Echinostoma ilocanum*
		Subtotal	30	
Monkayo, Davao de Oro				
San Isidro	58/M	Heterophyid, Hookworm	2	*Haplorchis taichui*
San Isidro	53/M	Heterophyid	3	*Haplorchis taichui*
San Isidro	47/M	Heterophyid, Hookworm	1	*Haplorchis taichui*
San Isidro	46/F	Heterophyid	5	*Haplorchis taichui*
		Subtotal	11	
Baganga, Davao Oriental				
Kinablangan	37/M	Heterophyid, *Trichuris* sp	38	*Haplorchis taichui*
Kinablangan	41/F	Heterophyid, *Trichuris* sp	3	*Haplorchis taichui*
Kinablangan	25/F	Heterophyid, *Trichuris* sp	1	*Haplorchis taichui*
Lambajon	36/M	*Taenia* sp	1	*Taenia saginata asiatica*
Kinablangan	57/M	*Taenia* sp, *Trichuris* sp	1	*Taenia saginata asiatica*
Alfonso	34/F	*Taenia* sp	1	*Taenia saginata asiatica*
		Subtotal	45	
		Total	238	

F: Female; M: Male

needed to determine association [26]. Two individuals in Surigao del Norte were found infected with *E. ilocanum*. This species, however, was known to be endemic only in northern Luzon [27]. The previously reported echinostome species in Surigao del Norte was *Artyfechinostomum malayanum* [28].

Variability in Foodborne Trematodiases and Taeniasis Prevalence Across Geographical Areas and Population Groups with Highly Focal Distribution

The FBT and taeniasis prevalence varied across the study sites. Heterophyidiasis was the most common FBT, albeit prevalence (7.5%) was lower compared to a previous study in Davao de Oro which had a prevalence as high as 36% [29]. In a nationwide survey in 1970–1980, less than 1% of approximately 30,000 stool specimens examined had heterophyid ova, with site-specific infection prevalence not exceeding 3% [27]. The prevalence was significantly higher (p-value<0.001) in adults than in SAC in all provinces, which supports the finding of another study [29]. Davao de Oro had the highest prevalence (6.3%) in SAC, but still lower than a previously reported prevalence in SAC in the same province at 32.4% [19].

The echinostomiasis prevalence was low and all cases, except for one, were in Sta. Monica, Surigao del Norte. The prevalence in Sta. Monica (9.2%) was similar to the previously reported prevalence of 11.4% in the same municipality in 2005 [28]. The only case found outside Sta. Monica was in Prosperidad, Agusan del Sur. Echinostomiasis was not observed in Davao region, although a survey in 1998 reported a prevalence of 1.4% in Monkayo, Davao de Oro [30].

Table 3. *Prevalence of STH and Schistosomiasis among SAC and Adults by Modified Kato Thick Method, in Selected Provinces and Municipalities, Caraga and Davao Regions, Philippines, March-June 2014.*

Region/Province/ Municipality	Number examined			Positive STH			Positive schistosomiasis		
	SAC	Adults	Total	SAC n (%)	Adults n (%)	Total n (%)	SAC n (%)	Adults n (%)	Total n (%)
Caraga									
Agusan del Sur									
Prosperidad	186	182	368	27 (14.5)	32 (17.6)	59 (16.0)	4 (2.2)30	3 (1.6)	7 (1.9)
Rosario	227	157	384	39 (17.2)	48 (30.6)	87 (22.7)	(13.2)	20 (12.7)	50 (13.0)
Subtotal	413	339	752	66 (16.0)	80 (23.6)	146 (19.4)	34 (8.2)	23 (6.8)	57 (7.6)
95% CI						(16.7-22.5)			(5.8-9.8)
Surigao del Norte									
Mainit	129	139	268	36 (27.9)	7 (5.0)	43 (16.0)	4 (3.1)	6 (4.3)	10 (3.7)
Sta. Monica	98	162	260	45 (45.9)	29 (17.9)	74 (28.5)	9 (9.2)	14 (8.6)	23 (8.8)
Subtotal	227	301	528	81 (35.7)	36 (12.0)	117 (22.2)	13 (5.7)	20 (6.6)	33 (6.3)
95% CI						(18.7-26.0)			(4.4-8.8)
Davao									
Davao de Oro									
Monkayo	163	156	319	12 (7.4)	19 (12.2)	31 (9.7)	1 (0.6)	3 (1.9)	4 (1.3)
Nabunturan	122	84	206	4 (3.3)	1 (1.2)	5 (2.4)	3 (2.5)	0	3 (1.5)
Subtotal	285	240	525	16 (5.6)	20 (8.3)	36 (6.9)	4 (1.4)	3 (1.3)	7 (1.3)
95% CI						(4.9-9.5)			(0.6-2.9)
Davao Oriental									
Baganga	124	123	247	93 (75.0)	61 (49.6)	154 (62.3)	0	0	0
Cateel	101	85	186	17 (16.8)	24 (28.2)	41 (22.0)	1 (1.0)	0	1 (0.5)
Subtotal	225	208	433	110 (48.9)	85 (40.9	195 (45.0)	1 (0.4)	0	1 (0.2)
95% CI						(40.3-49.9)			(0.0-1.5)
Total	1,150	1,088	2,238	273 (23.7)	221 (20.3)	494 (22.1)	52 (4.5)	46 (4.2)	98 (4.4)
95% CI				(21.3-26.3)	(18.0-22.9)	(20.4-23.9)	(3.4-5.9)	(3.1-5.6)	(3.6-5.3)

CI: confidence interval; SAC: school-age children; STH: soil-transmitted helminthiases

Taeniasis was observed in only three adults in Davao Oriental. A survey showed that *Taenia* sp. was diagnosed in less than 1% of the sampled population in Agusan del Norte [31]. Sporadic cases of the infection have been recorded in the Philippines. An average taeniasis prevalence of 0.5% was also reported in Visayas which predominantly affected males [32].

Paragonimiasis was observed only in Davao Oriental at 6.6% prevalence. All cases were from Barangay Aragon, Cateel where the prevalence was 16.2%, highlighting the highly focal infection distribution. The province was reported to be endemic for paragonimiasis [13], and a previous study found an 18.8% paragonimiasis prevalence in the barangay of San Alfonso in the municipality of Cateel [33].

FBT and taeniasis transmission only occurs if (1) an area has poor sanitation, (2) infected intermediate hosts are present, and (3) people consume raw or undercooked food with the parasite larva. These strict requirements may explain the focal distribution of these infections [34-36]. Consumption of a local delicacy known as *kinilaw* or *kilawen*, which is a preparation of raw fish with salt, vinegar, lime juice, and spices [37], is not uncommon in the study sites and may be a reason for the heterophyidiasis cases found. Additionally, local food preparation techniques such as *sabaw* (boiling for several minutes) and *sugba* (grilling over charcoal), may result in the incomplete cooking of the fish, thus not killing the infective metacercariae embedded in its tissues [17]. The relatively lower prevalence in SAC may reflect a lesser tendency to consume raw food preparations compared with adults as these delicacies are often consumed with alcohol. The practice of eating *kinilaw* may also be contributing to echinostomiasis cases in Caraga region as transmission occurs through consumption of raw or undercooked mollusks. In a study in

Surigao del Norte, all patients found positive for *Echinostoma* spp. had eaten snails, *kuhol*, and *kiambu-ay*, which were prepared raw with coconut milk and lime juice [28]. For taeniasis, the increasing fondness for partially roasted meat in men exposes them to infection [32] as transmission occurs through consumption of raw or undercooked beef containing *T. saginata* cysticerci. Paragonimiasis is linked to the consumption of raw or improperly cooked freshwater crabs and crayfish found in endemic areas [15] which are the intermediate hosts of *P. westermani*.

Challenges with Diagnosis and Surveillance

Effective control requires timely and accurate information to guide decision-making. Such information, however, is lacking due to (1) lack of more accurate field diagnostics, (2) limited capacity of health workers for accurate diagnosis, (3) absence of surveillance system, and (4) poor mapping of endemicity. While the modified Kato thick method is inexpensive and simple to perform in field conditions, it has a low sensitivity particularly in detecting low-intensity infections [1]. Collection of multiple specimens on different days, which is necessary to optimize sensitivity, was not done for this study [38].

More advanced diagnostics for FBT and taeniasis are needed. Formalin Ether Concentration and FLOTAC techniques, while more accurate, are more complex to perform and require specific equipment [1]. Serologic tests have high sensitivity and may be helpful in surveillance, however, these may have some degree of cross-reactivity which decreases its specificity [39]. Molecular methods offer the most accurate techniques for FBT and taeniasis diagnosis and may even be used for accurate species identification [1]. Imaging methods such as ultrasonography and X-rays can be used as complementary diagnostic tools. More accurate diagnostics should be complemented with the training of local medical technologists. Their lack of familiarity with trematode and other helminth eggs may lead to underreporting of infections.

Mapping FBT and taeniasis endemicity through baseline assessments in areas where conditions that promote transmission co-exist is also needed. This will contribute to evidence-informed decision-making for the control of these infections. Due to the highly focal distribution of paragonimiasis, an algorithm was developed to pre-select villages which are likely to be endemic, which helps maximize limited resources [40]. This may be adapted for surveillance of other FBT.

Opportunities for Enhancing Service Delivery

Enhancing service delivery in terms of diagnosis, treatment, surveillance, and control is needed to address the hidden FBT and taeniasis burden that this study revealed. Recent studies on FBTs in the Philippines provided insights on how service delivery could be improved, for instance, integrating diagnosis, surveillance, and control of paragonimiasis with Tb[15] [40]. These studies also provided epidemiological data on FBT as well as opportunities for capacity building. Effective FBT and taeniasis control, however, will rely on an effective control program and not on research alone. Consistent and strategic capacity-building activities should be provided to local health units. More accurate diagnostics, for instance, antigen and molecular-based techniques, should be used to minimize the possibility of missed cases which contribute to continuing morbidity and transmission. Diagnostic capacity of local health systems should be improved through utilization of more sensitive tools, provision of laboratory equipment, and capacity building. Treatment, likewise, should be improved. For instance, triclabendazole was shown to be more effective and easier to administer in treating paragonimiasis [41]. This, however, is yet to be used in the Philippines. Implementing a more comprehensive but cost-effective surveillance is also needed. For instance, questionnaires have been used to identify high-risk areas for paragonimiasis [42]. Intensified training, active surveillance, and control strategies could then be prioritized in these high-risk areas which will save the health system resources.

There is also a need to implement evidence-based interventions for FBT and taeniasis. Stages in the life cycle of these parasites may be targeted for different interventions. Improving sanitation through increasing sanitary toilet coverage and re-evaluating wastewater management may be done to prevent the release of eggs into the environment. Snail control activities and safe aquaculture may be conducted to prevent other intermediate hosts and/or humans from infection. This may be achieved through proper maintenance of pond sites to prevent fecal contamination and snail-breeding around the area [38]. Veterinary public health interventions may also be included as common domesticated animals (i.e. pigs, cats, dogs) may facilitate transmission. If consumption of these intermediate hosts is unavoidable, food safety measures such as thorough cooking of food are necessary. Behavioral change to alter eating practices may be difficult, hence, there is a need for a strong health education campaign among locals, highlighting risks and preventive measures, such as properly cooking their food.

Integrating control programs also allows an enhanced and cost-effective means of service delivery [43]. Control programs for FBT and taeniasis could be integrated with the schistosomiasis control program considering the use of similar tests (e.g. Kato-Katz technique), drug (i.e. praziquantel), and interventions (e.g. vector control, WASH, preventive chemotherapy, health promotion). This may even be integrated with the STH control program considering the use of the similar test and interventions (e.g. WASH, preventive chemotherapy, health promotion) and that albendazole could safely be co-administered with praziquantel [44]. One advantage of integrating these programs is the availability of data for these diseases. This study, for instance, produced data not only for FBT and taeniasis but also for schistosomiasis and STH. STH was the most common intestinal infection (22.1%) observed, with varying prevalence across provinces. On the other hand, a moderate prevalence of schistosomiasis was observed in the study sites with the highest prevalence in Rosario, Agusan del Sur at 13.8%.

On the other hand, paragonimiasis control could be integrated with TB control considering the similar manifestations (i.e., chronic cough and hemoptysis) and specimen used (i.e., sputum). Studies have shown that the Ziehl-Neelsen technique, the test used for TB diagnosis, could also detect paragonimiasis [45,46]. Surveillance for paragonimiasis may be integrated with case finding for pulmonary tuberculosis which can easily be incorporated into the existing National Tuberculosis Program of the Department of Health [15].

Limitations and Further Studies

The purposive sampling utilized in this study limits the generalizability of the results. The diagnostic tests used, namely the modified Kato thick technique and NaOH concentration technique, have low sensitivity and may thus have missed infection cases. This study, nonetheless, provides background data which may serve as a basis for further studies on transmission, epidemiology, risk factors, socio-cultural aspects, and intervention feasibility for FBT and taeniasis.

In conclusion, the study revealed the hidden burden of FBT and taeniasis, as well as identified species not known to be endemic in selected areas in southern Philippines. Addressing this hidden burden will require enhancing service delivery. This may be done by utilizing more accurate diagnosis, updating treatment guidelines, implementing evidence-based control interventions, and improving surveillance. Integrating control programs, for instance, integrating FBT and taeniasis control with STH and schistosomiasis control and integrating paragonimiasis control with the national TB program, may also help in optimizing the limited resources and maximizing health outcomes.

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Conflict of Interest Disclosure

The authors declare no conflicts of interest.

References

1. World Health Organization. (2011) Report of the WHO Expert Consultation on Foodborne Trematode Infections and Taeniasis/Cysticercosis, Vientiane, Lao People's Democratic Republic.
2. James SL, Abate D, Abate KH, Abay SM, Abbafati C, Abbasi N, *et al.* (2018) Global, regional, and national incidence, prevalence, and years lived with disability for 354 diseases and injuries for 195 countries and territories, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017. The Lancet 392(10159):1789-858.
3. Kyu HH, Abate D, Abate KH, Abay SM, Abbafati C, Abbasi N, *et al.* (2018) Global, regional, and national disability-adjusted life-years (DALYs) for 359 diseases and injuries and healthy life expectancy (HALE) for 195 countries and territories, 1990-2017: a systematic analysis for the Global Burden of Disease

Study 2017. The Lancet 392(10159):1859-922.
4. Aung AK, Spelman DW. (2016) Taenia solium Taeniasis and Cysticercosis in Southeast Asia. Am J Trop Med Hyg 94(5):947-54.
5. Torgerson PR, Devleesschauwer B, Praet N, Speybroeck N, Willingham AL, Kasuga F, *et al.* (2015) World Health Organization Estimates of the Global and Regional Disease Burden of 11 Foodborne Parasitic Diseases, 2010: A Data Synthesis. PLoS Med. 12(12):e1001920.
6. Fürst T, Sayasone S, Odermatt P, Keiser J, Utzinger J. (2012) Manifestation, diagnosis, and management of foodborne trematodiasis. Bmj. 344:e4093.
7. World Health Organization. (2015) WHO estimates of the global burden of foodborne diseases - Foodborne diseases burden epidemiology reference group 2007–2015. Geneva: Switzerland.
8. Belizario VJ, Diaz, AB, Esparar, DG, Bugayong, MG. (2005) Parasitologic Screening of Mall Employees Applying for Health Certificates at a Local Health Office in Cebu City: Implications for Policy and Practice. Phil J of Microbiol and Infectious Dis 34(2):65-70.
9. McCarthy JS, Lustigman S, Yang G-J, Barakat RM, García HH, Sripa B, *et al.* (2012) A Research Agenda for Helminth Diseases of Humans: Diagnostics for Control and Elimination Programmes. PLOS Neglected Tropical Diseases 6(4):e1601.
10. Belizario VJ, Anastacio M. (2007) Challenges in the Control of Food and Water-borne Parasitoses in the Philippines. Acta Medica Philippina 41(1):54-8.
11. Department of Health. (2010) The Philippine sustainable sanitation knowledge series: Guidebook for a disease prevention and control program for soil-transmitted helminth infections and diarrheal diseases.
12. World Health Organization. (2019) Bench aids for the diagnosis of intestinal parasites – Second edition. Geneva, Switzerland: WHO Press.
13. Cabrera BD. (1979) Current status of paragonimiasis in the Republic of the Philippines. Task Force on Parasitic Diseases, Paragonimiasis and Clonorchiasis; Manila: WHO Regional Office for the Western Pacific.
14. Cheesbrough M. (2005) Examination of Sputum for Paragonimus Eggs. In: Cheesbrough M, editor. District Laboratory Practice in Tropical Countries. 1. Cambridge: Cambridge University Press 295-7.
15. Belizario V, Jr., Totanes FI, Asuncion CA, De Leon W, Jorge M, Ang C, *et al.* (2014) Integrated surveillance of pulmonary tuberculosis and paragonimiasis in Zamboanga del Norte, the Philippines. Pathog Glob Health 108(2):95-102.
16. Belizario VY, Ortega AR, Guan M, Borja L, Leonardia W. (1997) Pulmonary paragonimiasis and tuberculosis in Sorsogon. Southeast Asian Journal of Tropical Medicine and Public Health (28):27-45.
17. Belizario VY, Jr., Leon WUd, Bersabe MJJ, Purnomo, Baird JK, Bangs MJ. (2004) A focus of human infection by Haplorchis taichui (Trematoda: Heterophyidae) in the Southern Philippines. Journal of Parasitology 90(5):1165-9.
18. World Health Organization. (1995) Control of Foodborne Trematode Infections. Geneva: Switzerland.
19. Belizario VJ, Bersabe M, delos Reyes A, de Leon W. (2004) School-based assessment of soil-transmitted helminthiases and food-borne parasitosis (Intestinal fluke infection) in Monkayo, Compostela Valley. Southeast Asian J Trop Med Public Health 35:123-39.
20. Department of Health. (2006) Administrative Order No. 2006-0028: Strategic and operational framework for establishing integrated helminth control program. Manila, Philippines.
21. Department of Health. (2007) Administrative Order No. 2007-0015: Revised Guidelines in the Management and Prevention of Schistosomiasis. Manila, Philippines.
22. Department of Health. (2010) Administrative Order No. 2010-0037: Issuance of Diagnosis and Treatment Guidelines for Paragonimiasis. Manila, Philippines.
23. Centers for Disease Prevention and Control. (2018) Heterophyiasis [Available from: https://www.cdc.gov/dpdx/heterophyiasis/index.html.
24. Leonardo LR TW. (2004) Liver flukes. In: Belizario VY Jr DLW, editor. Philippine textbook of medical parasitology. 2nd ed. Manila, Philippines: UP Manila-IPPAO.
25. World Health Organization. (2012) IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. Geneva: Switzerland
26. Pakharukova MY, Mordvinov VA. (2016) The liver fluke Opisthorchis felineus: biology, epidemiology and carcinogenic potential. Transactions of The Royal Society of Tropical Medicine and Hygiene. 110(1):28-36.
27. Cross J, Basaca-Sevilla V. (1984) Biomedical Surveys in the Philippines. Manila, Philippines: U. S. Naval Medical Research Unit No. 2.
28. Belizario VY, Geronilla GG, Anastacio MBM, de Leon WU, Suba-an AU, Sebastian AC, *et al.* (2007) Echinostoma malayanum infection, the Philippines. Emerg Infect Dis 13(7):1130-1.
29. Belizario VY, Jr., de Leon WU, Bersabe MJ, Purnomo, Baird JK, Bangs MJ. (2004) A focus of human infection

by Haplorchis taichui (Trematoda: Heterophyidae) in the southern Philippines. J Parasitol 90(5):1165-9.
30. Belizario VY, de Leon WU, Esparar DG, Galang JM, Fantone J, Verdadero C. Compostela Valley: a new endemic focus for Capillariasis philippinensis. Southeast Asian J Trop Med Public Health. 2000;31(3):478-81.
31. Carney W, Nocun R, Vergel AG, Pagaran I, Mercado A, Cross JH. (1987) Intestinal parasites of man in Agusan Del Norte, Philippines with Emphasis on Schistosomiasis and Capillariasis. Phil J Microbiol Infect Dis 16(1):5-9.
32. Leonardo L, Rivera P, Saniel O, Villacorte E, Lebanan MA, Crisostomo B, *et al.* (2012) A National Baseline Prevalence Survey of Schistosomiasis in the Philippines Using Stratified Two-Step Systematic Cluster Sampling Design. Journal of Tropical Medicine 2012:936128.
33. Zuazula JN, Roces MC, Fantone J, Belizario VY, Cho S-Y. (2000) Chronic cough in San Alfonso, Cateel, Davao del Norte. Internal Report. Philippines: Field Epidemiology Training Program, Department of Health.
34. Chai JY, Jung BW. (2017) Fishborne zoonotic heterophyid infections: An update. Food and Waterborne Parasitology 8(9):33-63.
35. World Health Organization. (2002) Joint WHO/FAO Workshop on Foodborne Trematode infections in Asia. Ha Noi: Vietnam
36. Yu SH, Mott KE. (1994) Epidemiology and morbidity of food-borne intestinal trematode infections. Trop Dis Bull (91):R125–R52.
37. Graczyk TK, Fried B. (1998) Echinostomiasis: a common but forgotten food-borne disease. Am J Trop Med Hyg 58(4):501-4.
38. World Health Organization. (2017) Expert Consultation to accelerate Control of Foodborne Trematode Infections, Taeniasis and Cysticercosis. Manila: Philippines.
39. World Health Organization. (2016) Taenia solium taeniasis/cysticercosis diagnostic tools- report of a stakeholder meeting. Geneva: Switzerland.
40. Belizario VJ, Jorge MC, Ng JV, Mistica MS, Lam HY, Rivera, LJ, Anino, MC, delos Trinos, JR. (2016) A Model for Integrating Paragonimiasis Surveillance and Control with Tuberculosis Control Program. Southeast Asian J Trop Med Public Health 47(4):625-37.
41. World Health Organisation. Foodborne trematodiases [Available from: https://www.who.int/news-room/fact-sheets/detail/foodborne-trematodiases.
42. Odermatt P, Veasna D, Zhang W, Vannavong N, Phrommala S, Habe S, *et al*. (2009) Rapid Identification of Paragonimiasis Foci by Lay Informants in Lao People's Democratic Republic. PLOS Neglected Tropical Diseases 3(9):e521.
43. World Health Organization. (2020) Ending the Neglect to Attain the Sustainable Development Goals - A road map for neglected tropical diseases 2021–2030. Geneva: Switzerland.
44. Belizario VY, Marfori JR, Chua PL, Naig JR, Erfe JM. (2015) School-based combined mass drug administration for soil-transmitted helminthiases and schistosomiasis among school-age children: lessons from two co-endemic areas in the Philippines. Asian Pacific Journal of Tropical Disease 5(5):358-62.
45. Delos Trinos JPC, Sison OT, Anino MRC, Lacuna JDM, Jorge MC, Belizario VY. (2020) Identification of suspected paragonimiasis-endemic foci using a questionnaire and detection of Paragonimus ova using the Ziehl-Neelsen technique in Zamboanga Region, the Philippines. Pathog Glob Health 114(3):127-35.
46. Slesak G, Inthalad S, Basy P, Keomanivong D, Phoutsavath O, Khampoui S, *et al.* (2011) Ziehl-Neelsen staining technique can diagnose paragonimiasis. PLoS neglected tropical diseases 5(5):e1048-e.