Original Article

Identification of intestinal parasite infections and associated risk factors in indigenous Tsáchilas communities of Ecuador

Manuel Calvopina, Richard Atherton[1], Daniel Romero-Álvarez[2], Byron Castaneda[1], Gabriela Valverde-Muñoz[1], William Cevallos[1], Ricardo Izurieta[3]

One Health Research Group, School of Medicine, College of Health Sciences, Universidad De Las Américas, Quito, [1]School of Medicine, College of Medical Science, Universidad Central del Ecuador, Quito, Ecuador, [2]Department of Ecology and Evolutionary Biology, Biodiversity Institute, University of Kansas, Lawrence, Kansas, [3]Department of Global Health, College of Public Health, University of South Florida, Tampa, Florida, USA

Abstract

Background/Aim: Tsáchilas are an indigenous group living in a rural tropical rain forest of Western Ecuador. Few studies have been conducted in Ecuador where intestinal parasite infections (IPIs) and associated risk factors have been examined. Hence, the aim of this study was to examine the prevalence of IPIs and identify the associated risk factors in Tsáchilas populations.

Subjects and Methods: A cross-sectional survey was conducted from August to October 2013 in seven Tsáchilas communities. The study consisted of 586 participants, and stool samples were examined microscopically using the formalin-ether concentration technique.

Results: *Protozoa* infections were more common than helminth infections (54.9% vs. 34.1%), and 68.1% of samples were found to contain one or more parasites. *Ascaris lumbricoides* was the most prevalent (29.4%), with *Giardia duodenalis*, *Blastocystis hominis,* and *Entamoeba histolytica*/dispar showing a prevalence of 3.9%, 19.6%, and 12.5%, respectively. Ova of *Amphimerus* and *Paragonimus*, two unexpected liver and lung flukes, respectively, were also found. A logistic model with forward selection showed the following variables to predict parasite infection: age (6–10 years) (odds ratio [OR] = 2.8, 95% confidence interval [CI] = 1.5–5.1, $P = 0.001$), unclean water supply (OR = 1.16, 95% CI = 1.14–2.4, $P = 0.01$), handwashing practice (OR = 2.5, 95% CI = 1.27–4.97, $P = 0.01$), and not washing food before eating (OR = 1.6, 95% CI = 1.09–2.21, $P = 0.01$).

Conclusions: The study shows that IPIs are highly prevalent among the Tsáchilas, which might be attributed to their low socioeconomic standards and poor hygienic habits. Educating the communities on risk factors which pose the highest risk of infection, in combination with a mandatory treatment program, would significantly lower the parasitic burden.

The following Graduate Medical Education core competencies were addressed: Medical knowledge, Practice-based learning, Communication skills.

Keywords: Ecuador, epidemiology, indigenous, intestinal parasite infections, prevalence, risk factors

Address for correspondence:
Dr. Manuel Calvopina, Universidad De Las Américas, Jose Queri s/n entre Av. Granados y Av. Eloy Alfaro. PO BOX. 17-17-9788, Quito, Ecuador.
E-mail: manuelcalvopina@gmail.com/manuel.calvopina@udla.edu.ec

Access this article online	
Quick Response Code:	Website: www.ijam-web.org
	DOI: 10.4103/IJAM.IJAM_15_19

How to cite this article: Calvopina M, Atherton R, Romero-Álvarez D, Castaneda B, Valverde-Muñoz G, Cevallos W, *et al*. Identification of intestinal parasite infections and associated risk factors in indigenous Tsáchilas communities of Ecuador. Int J Acad Med 2019;5:171-9.

Submission: 19-03-2019, **Revision:** 12-04-2019,
Acceptance: 04-06-2019, **Published:** 24-12-2019.

INTRODUCTION

Intestinal parasite infections (IPIs) are a major cause of health problems in tropical regions,[1] with an estimated 3.5 billion people infected. Four hundred fifty million of these people, mostly children, present with clinical symptoms.[2,3] A high prevalence of IPIs is found in people from low socioeconomic conditions with poor hygiene. According to the World Health Organization, "Hygiene refers to conditions and practices that help to maintain health and prevent the spread of diseases;" this definition encompasses living conditions and the access to food, clean drinking water, sanitation, education, and health care services. The risk of infection for IPIs is associated with poor environmental sanitation, unsafe water supply, and unhygienic personal habitat.[4,5]

Ecuador, a country located in the Western Pacific region of South America, lies on the Equator line and is crossed by the Andes mountain range. Previous studies in Ecuador have shown a high prevalence of IPIs in children,[6-9] including *Entamoeba histolytica*/dispar, *Giardia duodenalis*, *Ascaris lumbricoides,* and *Trichuris trichiura*. Of the protozoan parasites, *G. duodenalis* is a prevalent and widespread pathogen of humans and many other species of mammals,[10] and is estimated to infect 200 million people worldwide.[11] Infections by the soil-transmitted helminths, for example, *A. lumbricoides*, *T. trichiura,* and hookworm (*Necator americanus* and *Ancylostoma duodenale*), are estimated to infect approximately one-third of the world's population and are recognized as an important public health problem and the most prevalent of the IPIs.[12]

Few studies have been conducted in Ecuador where the IPIs and their associated risk of infection have been examined. One such study[7] looked at parasitic prevalence and associated risk factors in children and showed that 90% of children were infected with at least one pathogenic IPI. However, a similar study examining infection in people of all ages has not been previously conducted. Hence, our study had undertaken in-depth study aims to find several IPIs and their associated risk factors in low socioeconomic and indigenous population located in a tropical region of Ecuador.

SUBJECTS AND METHODS

Study community

The study was carried out in the province of Santo Domingo de los Tsáchilas located in the western slopes of the Andean mountains. The study area is characterized by a tropical climate with temperatures varying during the day from 18°C to 27°C. The rainy season lasts from October to April, with a maximum annual rainfall in 24 h of 128.7 mm and an annual relative humidity of 87%.[13] The participating Tsáchila population consisted of approximately 2237 inhabitants[14] and is comprised of the following seven communities [Figure 1]: Congoma Grande (578 population, 297 m above the sea level [masl]), Colorado del Bua (525 population, 316 masl), El Poste (328 population, 405 masl), Chigüilpe (299 population, 430 masl), Los Naranjos (208 population, 285 masl), Otongo Mapali (179 population, 412 masl), and Peripa (120 population, 500 masl). Despite being a prominent indigenous population with political representation, many communities lack basic services due to the fact of being located away from the main urban settlement of Santo Domingo de los Colorados. They speak their own language Tsáfiqui and also Spanish. The majority of houses in the community are made from breeze block or wood with a zinc roof and a cement or wooden floor. Access to clean water is varied, with some having a municipal supply, whereas others rely on wells, rivers, and rainwater. The majority of workers rely on farming as their main occupation. Both predoctoral and postdoctoral students participated in this field learning process.

Sample size

The sample size (n) for the study was calculated

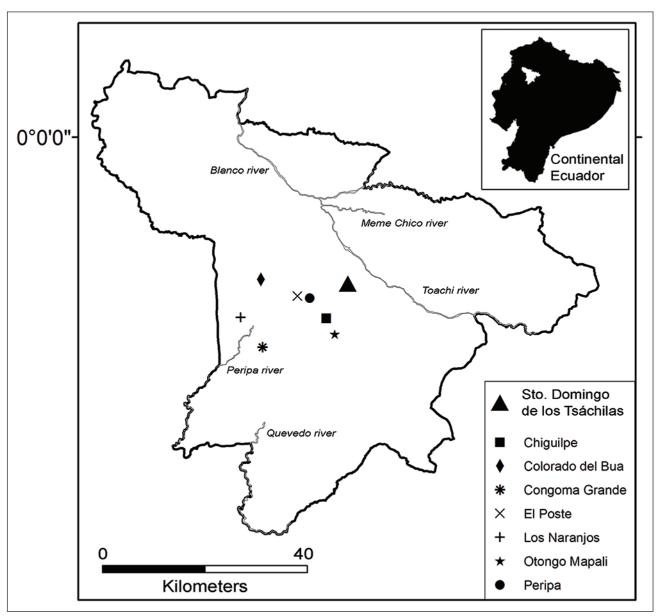

Figure 1: Map showing the location of Tsáchilas communities in Santo Domingo de los Tsáchilas – Ecuador

using the following single-population proportion formula: $n = p\ (1 - p)\ (Z/E)^2$, with P = prevalence of intestinal parasites in the population (estimated at 50%), E = margin of error (taken at 5%), and Z = the standard score which is 1.96 for the 95% level of confidence. This resulted in a minimum required sample size of 384 participants.

Questionnaire

A cross-sectional study was carried out in the seven communities between August and October 2013. The Tsáchila governor and each community leader were informed of the project, and volunteering participants were interviewed in a local community center via a structured questionnaire which gathered information on demographics, socioeconomic background, and the behavioral tendencies of the participating families. The questionnaire was modified according to one previously used questionnaire to assess sociodemographic risk factors of IPIs in children from a geographically similar area of Ecuador,[7] with an extra page added to collect additional data from the interviewed informant, including number of family members living in the household and their relationship.

Sample collection and fixing

The purpose, main objectives, and procedures of the study were first socialized and discussed with the Tsáchila governor and later with the local leaders of each Tsáchila community in a general assembly. Household head and all members of the family were requested to provide a consent and participate in the study by providing a fecal sample. On the same day, family leaders who agreed to participate signed a consent form. Each individual enrolled into the study was provided with a copro-parasitological flask (containing 10% formalin) for stool collection, and samples were collected within a few hours of stool passing. The flasks were labeled with date, community name, participant name, and age. During the next 2 days, all samples were collected at the community council building or at each house by house. Overall, the study gathered 586 samples from seven different communities and collected data from 169 households. The collected stool samples were transported back to Quito where microscopical analyses were conducted at laboratory facilities of the Centro de Biomedicina, Universidad Central del Ecuador.

Microscopy

Each formalin-fixed sample was prepared for examination using the concentration formalin-ether method.[15] The concentrated samples were then prepared as a wet mount, stained with Lugol's solution, and examined in duplicate under a cover slip using the ×10 (for helminth ova) and 40× objectives (for *protozoa* cysts).

Any participant found to have a pathogenic *protozoa* and/or helminth infection received medical treatment according to the guidelines of the Ecuadorian Ministry of Public Health. Treatment was free of charge and consisted on metronidazole and/or albendazole depending on the type of parasite found.

Data management and statistical analysis

Data were analyzed using SPSS software (IBM SPSS statistics version 20, Florida, USA) with the aim to determine which exposure variables predict the likelihood of parasite infection. Association between exposure and infection was initially examined using a Chi-squared test with the level of statistical significance set at $P \leq 0.05$. For each individual factor, an odds ratio (OR) (for the presence of any parasite) and 95% confidence interval (CI) were computed by univariate analysis, and further, statistical significance was identified with a multivariate logistic regression using forward selection.

Ethical considerations

Ethical approval of the study was provided by the Ethics Committee of Universidad Central del Ecuador (license number LEC IORG 0001932, FWA 2482, IRB 2483.COBI-AMPHI-0064-11). Each person completing the questionnaire was explained the aim and objectives of the study, and a signature was provided by one person representing each family to confirm his/her understanding and willingness to participation in the study.

RESULTS

Sociodemographics

This study collected 586 fecal samples, from 248 (42.3%) male and 338 (57.7%) female participants. The population was separated into the following age groups: ≤5 years old, 6–10 years old, 11–20 years old, 21–40 years old, 41–60 years old, and >60 years old, which comprised 71, 90, 115, 159, 112, and 39 study participants, respectively. The youngest participant was 6 months old and the oldest was 87 years old.

Intestinal parasite infections

From the 586 samples examined by microscopy, 16 different species of parasites were found, that is, 8 helminths and 8 *protozoa* species. Of the total samples collected and tested, 399 samples (68%) were found to contain one or more parasites [Table 1]. Of the study participants, 179 (30.5%) had 1 parasite, 132 (22.5%) had 2 parasites, 57 (9.7%) had 3 parasites, 24 (4.1%) had 4 parasites, and 7 (1.2%) had >4 parasites (data not shown).

Helminth infection was found in 200 (34.1%) samples; *protozoa* infection was observed in 322 (54.9%) samples and mixed helminth/*protozoa* infection was observed in 123 (21%) samples. *A. lumbricoides* was the most common parasite with a prevalence of 29.4%, and *G. duodenalis*, *Blastocystis hominis,* and *E. histolytica*/dispar occurred in 3.9%, 19.6%, and 12.5% of samples, respectively. Regarding helminths (besides *A. lumbricoides*), *T. trichiura*, *Hymenolepis nana,* and hookworm showed a prevalence of 11.4%, 0.2%, and 1.0%, respectively. Co-infection with *Ascaris* and *Trichuris* was observed in 52 (8.9%) samples, accounting for 77.6% of all positive *Trichuris* samples. *Entamoeba* spp. were present in 212 samples and infected 36.2% of the sample population. *E. coli* was the most commonly observed species with a prevalence of 27.5% followed by *E. histolytica*/dispar with a prevalence of 12.5% and *E. hartmanni* with a prevalence of 10.8%. Mixed infections of two or more *Entamoeba* species constituted 63 (10.8%) samples. Ova of trematode infections, which included the liver fluke *Amphimerus* and the lung fluke *Paragonimus,* were found in five samples (0.9%). No ova of *Taenia* spp. were present in any stool sample.

All age groups showed parasitic infection [Table 2], with the most infected age group being the 6–10 year olds, with an overall prevalence of 84.4%. The least parasitized group were the 41–60 years olds, with a relatively high infection rate (60.7%). Parasite prevalence increased again in the age group of above 60 years (64.1%). *G. duodenalis* was most commonly observed in the ≤5 and 6–10 age groups with a prevalence of 8.5% and 8.9% infected children, respectively. In other age groups, the prevalence of *Giardia* was markedly lower. *E. histolytica*/dispar was most common in the 21–40 years' age group, with a prevalence of 16.4%. *A. lumbricoides,* though highest in the 6–10 year olds and those greater than age 60, was equally high in all age groups with a prevalence ranging from 22.3% to 40%. A high prevalence of *B. hominis* (19.6%) in all ages was similarly observed. *T. trichiura* infection, similarly to *A. lumbricoides,* was observed to be highest in the 6–10 years' and over 60 years' age groups. High infection with *E. coli* was found in all age groups, though the highest infection rate as with *E. histolytica*/dispar was seen in the 21–40 years' age group. Infection by one or more *Entamoeba* species was also highest in this age group,

Table 1: Distribution and prevalence of intestinal parasite infections in Tsachilas communities

Species/location	Number of positive samples by community/parasite species								
	Colorado del Bua	Congoma Grande	El Poste	Chigüilpe	Otongo Mapali	Naranjos	Peripa	Prevalence %	Total
Protozoa									
Entamoeba histolytica/Dispar	18	7	4	13	10	9	12	12.5	73
Entamoeba coli	26	14	22	35	16	28	20	27.5	161
Entamoeba hartmanni	18	5	6	14	5	11	4	10.8	63
Entamoeba spp.	40	21	24	41	23	35	28	36.2	212
Giardia duodenalis	9	2	2	4	3	2	1	3.9	23
Blastocystis hominis	19	6	14	22	18	26	10	19.6	115
Chilomastix mesnili	3	0	0	2	1	1	1	1.4	8
Endolimax nana	13	2	2	4	1	6	1	4.9	29
Iodamoeba butschlii	4	3	1	7	1	3	2	3.6	21
Helminths									
Ascaris lumbricoides	16	24	15	30	30	29	28	29.4	172
Trichuris trichiura	9	11	5	11	9	5	17	11.4	67
Hymenolepis nana	1	0	0	0	0	0	0	0.2	1
Hookworm	4	0	0	2	0	0	0	1	6
Strongyloides stercoralis	3	0	0	0	0	0	0	0.5	3
Enterobius vermicularis	2	0	0	0	0	1	0	0.5	3
Paragonimus westermani	1	0	0	1	0	0	0	0.3	2
Amphimerus	0	0	0	0	0	0	3	0.5	3
Total number of positive samples	80	41	44	66	52	69	47	N/A	399
Total number of samples	141	74	66	79	70	101	55	N/A	586
Prevalence per community %	56.7	55.4	66.7	83.5	74.3	68.3	85.5	N/A	68.1

N/A=Not available

Table 2: Percent distribution of parasite prevalence, disaggregated by participants' age

Age groups	*n*	Parasite (*n* infected/percentage infected)								Percentage infected	*n* infected
		Giardia	*Entamoeba histolytica/Dispar*	*Ascaris*	*Trichuris*	*Escherichia coli*	*Entamoeba hartmanni*	*Blastocystis hominis*	*Entamoeba*		
≤5	71	6 (8.5)	4 (5.6)	18 (25.4)	5 (7.0)	17 (23.9)	4 (5.6)	15 (21.1)	18 (25.4)	62.0	44
6-10	90	8 (8.9)	10 (11.1)	36 (40)	19 (21.1)	28 (31.1)	7 (7.8)	23 (25.6)	37 (41.1)	84.4	76
11-20	115	3 (2.6)	15 (13.0)	35 (30.4)	19 (16.5)	27 (23.5)	16 (13.9)	23 (20.0)	38 (33.0)	67	77
21-40	159	4 (2.5)	26 (16.4)	45 (28.3)	13 (8.2)	53 (33.3)	23 (14.5)	23 (14.5)	66 (41.5)	68.6	109
41-60	112	2 (1.8)	15 (13.4)	25 (22.3)	4 (3.6)	26 (23.2)	9 (8)	25 (22.3)	40 (35.7)	60.7	68
>60	39	0 (0)	3 (7.7)	13 (33.3)	7 (17.9)	10 (25.6)	4 (10.3)	6 (15.4)	13 (33.3)	64.1	25
Total	586	23	73	172	67	161	63	115	212	68.1	399

with 41.5% of samples presenting an *Entamoeba* spp. infection and 16.4% of samples showing multiple *Entamoeba* spp. infections.

Risk factors that predict infection

A number of criteria were assigned to determine risk factors [Table 3], and crude associations with parasite infection were examined using univariate analyses. A total of seven of these risk factors were identified as significant (at an alpha level of 0.05) which included age (OR = 2.9; 95% CI = 1.6–5.3), family income (OR = 1.50; 95% CI = 1.01–2.2), working status (OR = 1.5; 95% CI = 1.01–2.06), school status (OR = 1.49; 95% CI = 1.02–2.18), water supply (OR = 1.7; 95% CI = 1.21–2.48), handwashing habits (OR = 1.2; 95% CI = 0.74–2.04), and food-washing habits (OR = 1.6; 95% CI = 1.1–1.5 [Table 4]. The multivariate analysis using a forward logistic regression model further confirmed that age, water supply, and hygienic habits significantly increased the risk of parasitic infection, where age between 6 and 10 years, drinking untreated water, and poor handwashing practice made it 2.8 (95% CI = 1.5–5.1), 1.2 (95% CI = 1.14–2.4), and 2.5 (95% CI = 1.27–4.97) times more likely to have an infection, respectively. Furthermore, not washing foods was found to significantly increase the risk for intestinal helminth infections (OR = 1.55; 95% CI = 1.09–2.21) [Table 4].

DISCUSSION AND CONCLUSIONS

In Ecuador, few studies have looked at the distribution, diversity, and associated risk factors of intestinal parasites within a complete population age range. Previous studies have mainly focused on the prevalence of IPIs in children.[7-9] The current study found high levels of parasitic infection within the study sample, identifying 16 different species, with 68.1% of the study population infected with one or more parasites. Although *A. lumbricoides* was the most common parasite (29.4%), *protozoa* infections were more commonly observed than helminths (54.9% vs. 34.1%).

Although all age groups were infected, the highest parasite prevalence was observed in schoolchildren from 6 to 10 year olds with 84.4% positivity, which is in agreement with Sackey *et al.*'s (2003) study, where 90% of the children were infected. In addition, as with studies from other countries,[16,17] statistical analysis confirms that children have a significantly greater risk of infection. In a community, children tend to be the primary sufferers of IPIs,[11,18] which can be attributed to social factors such as more exposure in play centers and schools and poor hygiene.[19] It is also plausible to think that helminth infection confers protective immunity after repeated exposures as proposed by the "peak shift" theory, Woolhouse, 1998.[20] *Giardia* infection was also found to be highly prevalent in young children, and the combined groups for ≤10 years were significantly more likely to be infected than older children and adults (univariate analysis: OR = 4.4; 95% CI = 1.9–10.4, $P < 0.001$). This increased infection in younger children has previously been reported.[21,22] Again, reasons for this are due to poor hygiene, but could also be due to a lack of protective immunity in children of this age range.[23]

The high prevalence of *Entamoeba* (36.2% in the total study population) and *Blastocystis* infections (19.6% in the total study population) and large diversity of protozoan parasites in our study population show that there is a high level of fecal-oral transmission occurring within all age groups. The most commonly infected age group by *Entamoeba* spp. infections comprised the 21–40 year olds, who showed the highest prevalence for *E. histolytica*/dispar*, E. coli, and E. hartmanni*. Previous studies[24,25] have also observed higher infection of *E. histolytica*/dispar in adults compared to children, and more information is required to ascertain how common this trend is within a general study population.

Table 3: Characteristics of the dataset

Categorical variables	*n* (%)
Total parasite infection	399 (68.1)
Protozoa infection	322 (54.9)
Helminth infection	200 (34.1)
Sex	
Male	248 (42.3)
Female	338 (57.7)
Ethnicity	
Indigenous	423 (72.2)
White or Mestizo	163 (27.8)
Household income ($)	
High >320	139 (23.7)
Low <320	447 (73.6)
Education	
None	117 (20.0)
Primary	372 (63.5)
Secondary	93 (15.9)
University	4 (0.7)
At school	194 (33.1)
Employed	225 (38.4)
Electricity in household	552 (94.2)
Improved floor material	538 (91.8)
Water supply	
Well/slopes	326 (55.6)
River/rain/piped river	260 (44.4)
Disinfect water	359 (61.3)
Distance from neighbors (m)	
≤10	199 (34.0)
>10	387 (66.0)
Home ownership	
Own	496 (84.6)
Rent	49 (8.4)
Borrow	41 (7.0)
Animals inside/outside house	571 (97.4)
Toilet location	
Outside toilet	386 (65.9)
Inside toilet	135 (23)
No toilet	65 (11.1)
Excrement removal*	
Unimproved	98 (16.7)
Improved	488 (83.3)
Garbage disposal	
Treated	472 (80.5)
Discarded	114 (19.5)
Drug Treatment	
Within 1 month	38 (6.5)
Within 2-3 months	33 (5.6)
Within last year	131 (22.4)
No treatment	384 (65.5)
Handwashing after using the toilet**	521 (88.9)
Washing food before eating	340 (58)
Handwashing before eating†	501 (85.5)
Total	586
Continuous variables (age), mean±SD	26.8±20.22

*Defined so that improved accounts for septic tank, latrine, and flush toilet and unimproved accounts for open air, discard outside, **Handwashing using soap, †Defined as always or frequently. SD=Standard deviation

Important drivers influencing high parasite transmission include a lack of clean water, adequate sanitation facilities, as well as poor hand hygiene and food preparation practices.[16,26,27] Within the study communities, a number of water supplies exist, including collected rain water, river water, wells, and water outlets from hillsides as well as municipal and pipe supply. However, in the majority of cases, the pipe supply is pumped directly from the river and is untreated; and knowing inhabitants defecate in the fields and in rivers, as a regular practice, it constitutes a high risk of parasitic infection. It was also observed that it was the use of river piped water and river water supply that provided a far greater risk for the community than the use of well water which is accessed from underground streams and is most likely uncontaminated.

Although not by itself an increased risk for an individual, the practice of outside defecation is present in the community. This can facilitate helminth transmission[28] due to contamination of fruit and vegetables where unwashed products will allow the ingestion of helminth eggs. Our study shows a significant increase in helminth infection for those who did not wash their food before eating. No increase in *protozoa* infection was observed with unwashed food, suggesting that infection from these parasites is more likely attributed to water supply and poor hygiene.

In the study population, poor hygienic practices seemed to be responsible for increased risk of infection in those that did not wash hands after defecation. These results provide further evidence of the relationship between poor hand hygiene and increased risk of parasite infection within the literature.[29-31] Therefore, educating these communities about the increased risk of transmission due to poor hygiene practices should be a critical component of programs seeking to prevent parasite transmission.

Hookworm and *Strongyloides*, though low in numbers, were also present in the study population. Findings show that only those walking barefoot outside were infected; however, 60.6% of those surveyed admitted to not wearing shoes (data not shown). Educating the populace on the transmission of these parasites is, therefore, required as wearing shoes has previously been reported to decrease the risk of hookworm infection.[32] *Amphimerus* ova were also identified in the study area. This is the first time this fish-borne parasite has been found in this region which has been previously recorded only in Esmeraldas province,[33] and it could either not have been previously identified in fecal samples by local laboratories or it could signify a geographical expansion of its distribution in Western Ecuador. Because of the fact that *Paragonimus* ova were also observed, there is a need for more research into fish- and crab-borne parasitic infections and

Table 4: Potential risk factors associated with intestinal parasite infections (univariate and multivariate analyses)

Risk factor	Values	Univariate		Multivariate	
		OR (95% CI)	*P*	OR (95% CI)	*P*
Gender	Male Female	0.80 (0.57-1.14)	0.22		
Age	6-10 Others	2.9 (1.6-5.3)	<0.001*	2.8 (1.5-5.1)	0.001*
Distance from neighbors (m)	≤10 >10	1.3 (0.90-1.92)	0.15		
House status	Own Borrowed	1.1 (0.67-1.74)	0.75		
Electricity in house	No Yes	1.6 (0.69-3.51)	0.28		
Family income ($)	<320 >320	1.5 (1.01-2.23)	0.045*		
Working status	No Yes	1.5 (1.01-2.06)	0.04*		
School status	At school Not at school	1.5 (1.02-2.18)	0.04*		
Education level	No education Any education	1.1 (0.69-1.66)	0.08		
Water treatment	Nontreated Treated	0.8 (0.51-1.14)	0.19		
Water supply	River pipe/river Well/slopes	1.7 (1.21-2.48)	0.003*	1.2 (1.14-2.4)	0.01*
Toilet status	No toilet Toilet	1.1 (0.61-1.85)	0.8		
Toilet elimination status	Unimproved Improved	1.2 (0.75-1.95)	0.44		
Contact with animals	Yes No	1.4 (0.50-4.10)	0.5		
Wash hands after toilet	No Yes	2.5 (1.28-4.91)	0.01*	2.5 (1.27-4.97)	0.01*
Wash hands before eating	No Yes	1.2 (0.74-2.2)	0.43		
Washing food	No Yes	1.1 (0.74-1.49)	0.79		
Wash food (intestinal helminths only)	No Yes	2.6 (1.1-1.5)	0.01*	2.6 (1.09-2.21)	0.01*
Wash food (protozoa only)	No Yes	0.9 (0.64-1.24)	0.48		
Disinfect drinking water	No Yes	1.1 (0.73-1.5)	0.79		
Garbage disposal	Dumped Treated	0.86 (0.55-1.33)	0.5		
Drug treatment	No <1 month ago	4.6 (2.29-9.18)	<0.0001		
	No 2-3 months ago	1.4 (0.67-2.90)	0.38		
	No >3 months ago	1.3 (0.82-1.94)	0.28		

*Significant association $P \leq 0.05$. CI=Confidence interval, OR=Odds ratio

their transmission in this area as well as educating the community on the presence and prevention of these food-borne parasites.

Although a drug treatment program is currently in place for all endemic communities of Ecuador, the treatment itself is not mandatory which focuses mainly on the supply of antiparasitic drugs to children. Our data show that current enrollment for drug treatment in the study population is low, with only 38 (6.5%) participants reporting having taken antiparasitic medication in the last month and 71 (12.1%) participants reporting having receiving treatment in the previous 3 months, whereas 384 (65.5%) participants have received no treatment in over a year. Considering that the program is noncompulsory, it is plausible that many cases go untreated, removing the possibility of a mass decrease in parasite burden, and arguably this provides little aid with regard to controlling transmission. Limited drug coverage creates a cycle of reinfection, where those having taken antiparasitic drugs within the last month show a decrease in prevalence which gradually rises again, until after 3 months, when there is no difference in prevalence rates between treated and untreated persons. When also considering the role that infected adults have in transmission, for example, within families and workers defecating in fields, there is further argument for the development and implementation of an integrated control system.

A few limitations were present during the study. Potential risk factors can be overlooked due to recent drug treatment. However, from our findings, we show that only treatment within the last month significantly lowered parasitic burden, which was only found in a small percentage of the study population (≤6.5%). Therefore, potential risk factors would only have been obscured for a few individuals. Furthermore, due to limitations with sample collection, infection with *Cryptosporidium* spp. was not tested in this study. However, in a recent Ecuadorian study from a neighboring province and in Quito,[34] *Cryptosporidium* was only identified in young children with a low prevalence. Therefore, addition of this parasite's prevalence to our population data would have only a minor effect on the results. Finally, although each sample was concentrated and examined in duplicate to improve sensitivity, only one sample was taken from each person. Estimation of prevalence could therefore have been improved if further samples had been taken. However, according to recent studies,[11] one or two stool samples are enough to detect up to 90% of *protozoa* present in feces.

CONCLUSIONS

There is currently a high prevalence of IPI among the study population of indigenous individuals living in the Tsáchilas communities in Santo Domingo de los Tsáchilas province, with all age groups affected. Our findings show that young age, low socioeconomic standards (lack of clean water supply), and poor hygienic habits (not washing hands after defecation and not washing food before eating) have increased association with IPIs. Introduction of measures is, therefore, required to reduce infection which would include improvement of water quality as well as better health education for children and parents to increase the awareness of parasite transmission and risks. Implementation of a mandatory control program such as mass deworming, especially in schools and high schools, would considerably reduce parasite burden within the communities, and the program in combination with an improved understanding of transmission would significantly lower parasite exposure and thus help prevent future infections.

Acknowledgments

The authors would like to thank the group of medical students from the 6th Semester of the Tropical Medicine course from Universidad Central del Quito. We would also like to thank Gumeresindo Aguavil, Governor of the Tsáchilas communities, for providing written permission to perform the study as well as all Tsáchilas participants who provided information and samples.

Financial support and sponsorship

This study was funded by the grants from the Universidad Central del Ecuador (CUP 91750000.0000.374072).

Conflicts of interest

There are no conflicts of interest.

Ethical conduct of research

The information collected in the questionnaires was entered in a database which can be accessed by the editor if requested. Required institutional approvals were obtained. The authors followed applicable EQUATOR Network (http://www.equator-network.org/) research reporting guidelines.

REFERENCES

1. Damen JG, Luka J, Biwan EI, Lugos M. Prevalence of intestinal parasites among pupils in rural North Eastern, Nigeria. Niger Med J 2011;52:4-6.
2. Arani AS, Alaghehbandan R, Akhlaghi L, Shahi M, Lari AR. Prevalence of intestinal parasites in a population in South of Tehran, Iran. Rev Inst Med Trop Sao Paulo 2008;50:145-9.
3. World Health Organization. Intestinal Parasite Control: Burden and Trends. Document No. WFP/UNESCO/WHO 98. Geneva: World Health Organization; 1998. p. 24.
4. Nkrumah B, Nguah SB. *Giardia lamblia*: A major parasitic cause of childhood diarrhoea in patients attending a district hospital in Ghana. Parasit Vectors 2011;4:163.
5. Karan A, Chapman GB, Galvani A. The influence of poverty and culture on the transmission of parasitic infections in rural Nicaraguan villages. J Parasitol Res 2012;2012:478292.
6. Gatti S, Swierczynski G, Robinson F, Anselmi M, Corrales J, Moreira J, *et al.* Amebic infections due to the *Entamoeba histolytica-Entamoeba dispar* complex: A study of the incidence in a remote rural area of Ecuador. Am J Trop Med Hyg 2002;67:123-7.
7. Sackey ME, Weigel MM, Armijos RX. Predictors and nutritional consequences of intestinal parasitic infections in rural Ecuadorian children. J Trop Pediatr 2003;49:17-23.
8. Rinne S, Rodas EJ, Galer-Unti R, Glickman N, Glickman LT. Prevalence and risk factors for protozoan and nematode infections among children in an Ecuadorian highland community. Trans R Soc Trop Med Hyg 2005;99:585-92.

9. Jacobsen KH, Ribeiro PS, Quist BK, Rydbeck BV. Prevalence of intestinal parasites in young Quichua children in the highlands of rural Ecuador. J Health Popul Nutr 2007;25:399-405.
10. Saki J, Khademvatan S, Masoumi K, Chafghani M. Prevalence of intestinal parasitic infections among food handlers in Khuzestan, Southwest of Iran: A 10-year retrospective study. Afr J Microbiol Res 2012;6:2475-80.
11. Mehraj V, Hatcher J, Akhtar S, Rafique G, Beg MA. Prevalence and factors associated with intestinal parasitic infection among children in an urban slum of Karachi. PLoS One 2008;3:e3680.
12. Bethony J, Brooker S, Albonico M, Geiger SM, Loukas A, Diemert D, *et al.* Soil-transmitted helminth infections: Ascariasis, trichuriasis, and hookworm. Lancet 2006;367:1521-32.
13. Meteorological Yearbook. Instituto Nacional de Meteorología e Hidrología. Anuario Meteorológico, Nro 51. Quito Ecuador: Instituto Nacional de Meteorología e Hidrología; 2011.
14. Ecuadorian National Census. Instituto Nacional de Estadísticas y Censos. VII Censo de Población y VI de Vivienda. Ecuador: Instituto Nacional de Estadísticas y Censos; 2010.
15. Wakid MH. Fecal occult blood test and gastrointestinal parasitic infection. J Parasitol Res 2010;2010. pii: 434801.
16. Ngui R, Ishak S, Chuen CS, Mahmud R, Lim YA. Prevalence and risk factors of intestinal parasitism in rural and remote West Malaysia. PLoS Negl Trop Dis 2011;5:e974.
17. Tahir Z. Comparison of prevalence of intestinal parasites in children and adult population. Biomedica 2002;18:74-5.
18. Harhay MO, Horton J, Olliaro PL. Epidemiology and control of human gastrointestinal parasites in children. Expert Rev Anti Infect Ther 2010;8:219-34.
19. Houmsou RS, Amuta E, Olusi T. Prevalence of intestinal parasites among primary school children in Makurdi, Benue state- Nigeria. Internet J Inf Dis 2010;8(1):1-5. [doi: 10.5580/205d].
20. Woolhouse ME. Patterns in parasite epidemiology: The peak shift. Parasitol Today 1998;14:428-34.
21. Abbas NF, El-Shaikh KA, Almohammady MS. Prevalence of *Giardia lamblia* in diarrheic children in Almadinah Almunawarh, KSA. J Taibah Univ Sci 2011;5:25-30.
22. Cook DM, Swanson RC, Eggett DL, Booth GM. A retrospective analysis of prevalence of gastrointestinal parasites among school children in the Palajunoj valley of Guatemala. J Health Popul Nutr 2009;27:31-40.
23. Suman MS, Alam MM, Pun SB, Khair A, Ahmed S, Uchida RY. Prevalence of *Giardia lamblia* infection in children and calves in Bangladesh. Bangl J Vet Med 2011;9:177-82.
24. Ngui R, Angal L, Fakhrurrazi SA, Lian YL, Ling LY, Ibrahim J, *et al.* Differentiating *Entamoeba histolytica*, *Entamoeba dispar* and *Entamoeba moshkovskii* using nested polymerase chain reaction (PCR) in rural communities in Malaysia. Parasit Vectors 2012;5:187.
25. Oyibo WA, Ike AA, Oladosu OO, Ojuromi OT, Sanyaolu AO, Olugbenga Olusanya AO, *et al*. Prevalence of *Entamoeba histolytica*/*Entamoeba dispar* among patients with gastro-intestinal complaints in Lagos, Nigeria. Arch Biomed Sci Health 2013;1:10-9.
26. Nobre LN, Silva RV, Macedo MS, Teixeira RA, Lamounier JA, Franceschini SC. Risk factors for intestinal parasitic infections in preschoolers in a low socio-economic area, Diamantina, Brazil. Pathog Glob Health 2013;107:103-6.
27. Wani SA, Ahmad F, Zargar SA, Ahmad Z, Ahmad P, Tak H. Prevalence of intestinal parasites and associated risk factors among schoolchildren in Srinagar city, Kashmir, India. J Parasitol 2007;93:1541-3.
28. Nunn CL, Thrall PH, Leendertz FH, Boesch C. The spread of fecally transmitted parasites in socially-structured populations. PLoS One 2011;6:e21677.
29. Tandukar S, Ansari S, Adhikari N, Shrestha A, Gautam J, Sharma B, *et al.* Intestinal parasitosis in school children of Lalitpur district of Nepal. BMC Res Notes 2013;6:449.
30. Gelaw A, Anagaw B, Nigussie B, Silesh B, Yirga A, Alem M, *et al.* Prevalence of intestinal parasitic infections and risk factors among schoolchildren at the University of Gondar Community School, Northwest Ethiopia: A cross-sectional study. BMC Public Health 2013;13:304.
31. Daryani A, Sharif M, Nasrolahei M, Khalilian A, Mohammadi A, Barzegar G. Epidemiological survey of the prevalence of intestinal parasites among schoolchildren in Sari, Northern Iran. Trans R Soc Trop Med Hyg 2012;106:455-9.
32. Strunz EC, Addiss DG, Stocks ME, Ogden S, Utzinger J, Freeman MC, *et al.* Water, sanitation, hygiene, and soil-transmitted helminth infection: A systematic review and meta-analysis. PLoS Med 2014;11:e1001620.
33. Calvopiña M, Cevallos W, Kumazawa H, Eisenberg J. High prevalence of human liver infection by *Amphimerus* spp. flukes, Ecuador. Emerg Infect Dis 2011;17:2331-4.
34. Vasco G, Trueba G, Atherton R, Calvopiña M, Cevallos W, Andrade T, *et al.* Identifying etiological agents causing diarrhea in low income Ecuadorian communities. Am J Trop Med Hyg 2014;91:563-9.