A Survey of Intestinal Parasites Including Associated Risk Factors in Humans in Panama

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Abstract

Background

Intestinal parasitic infections are among the most common infections worldwide, leading to illness with serious and long lasting implications in children and immunocompromised people. Transmission of intestinal parasites is more frequent in tropical and sub–tropical areas where sanitation is poor and socioeconomic conditions are deficient. Panama is a country where climate and social conditions could be reflected in a high number of people infected with intestinal parasites. The presence, prevalence, and distribution of intestinal parasites in this country have been approached to date only in very restricted areas and population groups, but the impact of intestinal parasite infections at the national level is unknown.

Methodology/Principal Findings

We conducted a cross–sectional survey between 2008 and 2010 to determine the prevalence of intestinal parasites across Panama. Overall, 14 municipalities in seven provinces of Panama were surveyed. The presence of eggs, cysts, and larvae was assessed by microscopy in 1,123 human fecal samples using a concentration technique. A questionnaire to identify risk factors associated with the frequency of intestinal parasites in the study population was also prepared and performed. Overall, 47.4% of human samples presented parasites. Variables including community type, age group, occupation, co–presence of commensals and socioeconomic factors (use of shoes and type of sanitation) were significantly associated with intestinal parasites ($p<0.05$).

Conclusions/Significance

The preliminary data obtained in the current study, showing a high prevalence of fecal–oral transmitted parasites in Panama, place intestinal parasitism as a major health problem in this country. Specific interventions should be planned for the indigenous population, the group most afflicted by intestinal parasites.

1. Introduction

Intestinal parasitic infections are endemic and widespread in socio–economically deprived communities in the tropics and subtropics (Norhayati et al., 2003). These are among the major public health problems due to their negative effect on nutritional status, development, cognitive functions and learning ability of infants (www.who.int/neglected_diseases; Garbossa et al., 2013). Prevalence of intestinal parasites in a specific country depends on environmental, socioeconomic and demographic factors, including health–related behavior of the population and access to hygienic latrines and to treated water (Garbossa et al., 2013; Cook et al., 2009; Rayan et al., 2010). Policies for the control of intestinal parasites should be based on epidemiological data such as infection prevalence and associated risk factors, but up–to–date data are not available for many countries.

In Panama, according to the 2008 living standard report from the Panamanian authorities, 96% of the indigenous population, 51% of the rural population and 18% of the urban population lived in poverty (Pan American Health Organization, 2012). Health facilities have notably improved in the last decades, although the national averages conceal major inequalities in access to health services, to the detriment of rural and indigenous populations. The increase of physical infrastructures related to sanitation and water systems are also of paramount importance to improve the health of the population. In this respect, the Panamanian national statistics for 2010 show that 55% of houses in indigenous areas lack potable water supply and 60.5% lack hygienic sanitation, either connected with the sewage or with a septic tank. In non–indigenous rural areas, 15% lack potable water and 7.2% lack hygienic sanitation, while in urban areas percentages drop to 0.7% and 1.1% (http://www.unicef.org/panama/ spanish/Sitan2011–web.pdf).

This combination of climatic, socioeconomic and sanitary factors found in Panama could be the key to support the active transmission of intestinal parasites at high rates. Nevertheless, surveys of intestinal parasites have been only done in specific population groups and very limited areas of the country, and no national survey in the different provinces or for different community types are available.

We therefore conducted a comprehensive review of previous studies on intestinal parasites in Panama and planned a preliminary epidemiological survey of intestinal parasites to evaluate the evolution and update the situation in the country regarding prevalence of intestinal parasites. A cross-sectional descriptive study following STROBE (Elm et al., 2007) to assess the prevalence of intestinal parasites in 14 municipalities of seven provinces, representing the different groups of population and climatic and socio-economic conditions present in Panama, was designed. We also investigated the influence of specific potential risk factors on the prevalence of these parasites.

2. Methods

2.1 Literature Review

An exhaustive review of the literature on the prevalence and epidemiology of intestinal parasitism in Panama was performed. Literature was searched in PubMed, Google Scholar, the PAHO repository, the Revista Médica de Panamá, the Revista Médico Científica de la Universidad de Panamá and the Gorgas Institute repository. Search terms were: Panama or Panamanian plus intestinal, helminths, parasites, Chiriqui, Cocle, Herrera, Los Santos, Veraguas, Colon, Darien or Bocas del Toro. Available data from each of the retrieved documents were extracted in an excel table, including year and place of sampling, number of samples, sample processing (concentration method), parasite species/genus found in the samples, number of positive samples for each parasite, prevalence, studied population group, associated risk factors and potential biases of the approach.

2.2 Ethics Statement

Official permission and ethical clearance for the collection of human fecal samples was obtained from the Regional Directorate of Health in each sampled province. For each sampled municipality, a meeting at the corresponding health center to inform about the study was announced in advance to the population. The meeting also included representatives of the health centers and primary schools. During the meeting, people were informed that sampling will take place in the health center two weeks after the meeting. Informed written consent was obtained from individuals who participated in the study. Individuals found to be positive for intestinal parasites were informed and referred to the nearby health center for appropriate treatment. For children and dependents, their parents and guardians or the relevant adult signed the consent.

2.3 Study Design, Sample Size and Distribution

A cross–sectional study was carried out from 2008 to 2010 in urban, semi–rural, rural and indigenous population of Panama, including male and female individuals of any age. Due to the lack of data on prevalence rates, the minimum number of human samples was calculated as the sample size for an infinite population with an unknown probability of parasitism (p, q), using a confidence level of 95% (Z) and an allowed error of 3% (d), following the formula described in (Martín–Andrés and Luna del Castillo, 1993):

$$n = Z^2 * p * q / d^2$$

With the above–mentioned parameters, the minimum sample size resulted in 1,067, statistically representing the total population of Panama in this study. Human sample collection was planned in 14 representative municipalities of Panama belonging to seven different provinces (Figure 1), selected on the basis of their differences in total population, living standards, and climatic and orographic conditions (Figure 1; Table 1). 2010 data on population, land elevation, percentage of population with agricultural activity, access to potable water, access to sanitation facilities, and climatic and land data, were gathered for each sampled municipality from the National Institute of Statistics in Panama (http://www.contraloria.gob.pa/inec/; Table 1).

Regarding the two main population groups that could be screened in Panama (indigenous and non–indigenous), a confidence level of 95% (Z) and an allowed error of 6% was calculated as appropriate to evaluate intestinal parasite prevalence levels. With those statistical parameters, the minimum sample size for indigenous individuals are 163, and for non–indigenous population are 267.

2.4 Sample Collection and Questionnaires

Health centers close to each sampled neighbourhood in the different municipalities were localized and contacted for sample collection (one per municipality). Participants of each municipality were instructed to deposit their fecal samples in their closest eligible health center. The list of neighbourhoods sampled in each municipality in the different provinces is shown in Table 2, including community type, number of samples and number of samples with parasites, and single latitude and longitude coordinates registered for each neighbourhood at points of sampling, extracted from the Geo-Postal Codes Database Mapanet, available at http://www.mapanet.es/en/Postal_Codes.

Pre-labelled wide mouth screw capped containers with scoop were distributed in the health centres to each participant, instructed to scoop a thumb size fecal sample into the container. Participants were asked to return the samples to the corresponding health center within a maximum of 24 hours after collection. Samples were fixed in 7% formalin and delivered to the Environmental Parasitology Laboratory of the University of Panama for analysis.

The participants were asked by a trained field assistant to answer each of the questions in the questionnaire, and an interpreter from the community was used when needed for indigenous groups, to assess the potential risk factors for intestinal parasitic infections (Table 3). For children and dependents, the questionnaire was completed by interviewing their parents and guardians. Parents/guardians provided consent on behalf of all child participants and all adults provided consent for themselves. Questionnaires were identified with the same code number than the corresponding fecal sample, and data were stored in a computer associated with the respective codes to ensure confidentiality.

2.5 Sample Processing and Analysis

Fixed human fecal samples were examined under a microscope after concentration of parasites by flotation, mixed with one drop of lugol. Flotation was performed as follows: 3 g of fixed feces were placed in a 100 ml plastic tube. 50 ml of saturated zinc sulfate solution was added to the feces and mixed thoroughly. The resulting suspension was strained through a double-layer of lint in a 50 ml tube standing in a rack, leaving a convex meniscus at the top of the tube. A coverslip was placed on top of the tube a left for 20 min. The coverslip was carefully lifted carrying a drop of fluid and immediately placed in a drop of lugol on a microscope slide. All samples were examined under a microscope at 4x, 10x, 40x and 100x to detect the parasites and commensals present in the feces. When detected, parasites (*Giardia intestinalis*, *Cystoisospora belli*, *Ascaris lumbricoides*, *Trichuris trichiura*, hookworms, *Strongyloides stercolaris*, *Hymenolepis* sp., *Balantidium coli*, *Blastocystis hominis*) and commensals (*Chilomastix mesnili*, amoebas) were identified by using pictorial and dichotomised keys available in different specialized documents.

The evolution of the total prevalence rate over time for indigenous, semi-rural and rural groups has been represented extrapolating the percentage of the most prevalent parasite from the previous studies as the global prevalence. This representation has not been approached for urban settings, since only two previous reports refer to this group.

2.6 Statistical Analysis

Statistical analysis was carried out using the SPSS software version 13 (SPSS, Chicago, IL, USA). Initial data entry was cross-checked by two independent individuals. Before each analysis, data were again checked for consistency. For descriptive data, number and rate (percentage) was used to describe the characteristics of the studied population, including the variables registered in the official data, the questionnaires and the prevalence rates of parasites and commensals. The **Pearson's** X^2 was used to test the associations between each variable. The chi-square test for independence, also called the chi-square test of association, is used to discover if there is a relationship between two categorical variables. It measures the likelihood that the observed association between the independent variable and the dependent variable is caused by chance. The dependent variables were prevalence of parasites and commensals, while the independent variables were those from the official data or registered in the questionnaires. The level of statistical significance was set as $p<0.05$.

3. Results

3.1. Literature review.

The literature review on intestinal parasitism in Panama resulted in a total of 26 retrieved references (Supplementary Table 1). From these, six were discarded [Carrera et al., 1984; Holland et al., 1988; Taren et al., 1987; Robertson et al., 1992 a,b; Hotez et al., 2014) because the corresponding documents showed either epidemiological data included in previous publications or non-epidemiological data. Four full texts could not be retrieved (Cort et al., 1929; Ramos, 1975; Carrera, 1983; Taren et al., 1992), although partial data from those studies were extracted from the rest of the retrieved full texts, in which they were detailed in their discussion sections.

Sampling year ranged from 1926 to 2011 and sample number from 42 to 3,000, with a single study of a 40 years case series from the Gorgas Hospital in Panama City including all hospital patients (558,556) for that time period (Tucker, 1946). Studies included very restricted areas in the provinces of Cocle, Panama, Colon, Darien, Veraguas, Chiriqui and Bocas del Toro. Only one document included the geographical coordinates (single latitude and longitude) of the studied area (Pineda et al., 2011). From the retrieved documents, only 13 detailed the sample concentration method. Five of them used the zinc sulphate flotation method (Reverte and Perez, 1955; Perez and Pedreschi, 1953; Jung et al., 1955; Cosgrove, 1960; Sanchez et al., 1990), four the ether or ethyl acetate concentration method (Cutting, 1975; Holland, 1987; Pineda et al., 2011; Jiménez Gutiérrez et al., 2014), and four the Kato-Katz method in combination with the FLOTAC method in two cases (Robertson et al., 1989; Payne et al., 2007; Halpenny et al., 2012, 2013). Only few documents referred the examination of more than one sample per participant collected at different time points (Sanchez et al., 1990; Payne et al., 2007; Halpenny et al., 2012, 2013). In general, studies were biased due to the election of a specific population group: 13 out of 20 studies were done exclusively or mainly in children (Reverte et al., 1955; Perez and Pedreschi, 1953; Jung et al., 1955; Cutting, 1975; Carrera, 1983; Holland et al., 1987; Robertson et al., 1989; Taren et al., 1992; Payne et al., 2007; Halpenny et al., 2012, 2013; Pineda et al., 2011; Jiménez Gutiérrez et al., 2014) , and two in American citizens living close to the dam in Panama City (Tucker, 1946; Cosgrove, 1960). Risk factors are described in seven of the documents (Faust, 1931; Tucker, 1946; Kourany et al., 1983; Holland et al., 1987; Sanchez et al., 1990; Halpenny et al., 2012, 2013), being rural and indigenous populations the most afflicted by intestinal parasites, compared with semi-rural and urban populations, and children compared with adults for *Giardia intestinalis* infections. Only three documents analyse the different risk factors in a multivariate analysis (Sanchez et al., 1990; Halpenny et al., 2012, 2013).

Detected parasites included, in addition to those found in our study (see Figure 2), *Taenia saginata*, *T. solium*, *Diphyllobothrium latum*, *Enterobius vermicularis*, *Cryptosporidium parvum* and *Cyclospora calletanensis*. *Cystoisospora belli* and

Blastocystis hominis, found in our samples (Figure 2), were not reported in the previous studies.

3.2. Sampling.

In our study, a total of 1,123 human fecal samples were collected, including 333 indigenous samples and 790 non–indigenous samples (Figure 1, Table 2). The number of collected samples was higher than the minimum number of samples calculated for an unknown probability of parasitism needed for the preliminary assessment of the epidemiological situation of intestinal parasitism in Panama (for the whole population n=1,067; for indigenous population n=163; for non–indigenous population n=267, calculated on the population officially registered in Panama for 2010 – http://panama.unfpa.org/poblacion–panama–). Samples were collected from different population groups (urban –including only children younger than 6 years–, semi–rural, rural and indigenous) (Table 1). Total population in each municipality varied from 1,682 (Santa María, Herrera) to 15,873 (San Miguelito, Panama). Elevation of sampled areas ranged from 9 meters (Chepigana, Darién) to 2,030 meters above the sea level (Cerro Punta, Chiriquí). The three main types of land (crops, forest and potentially flooded areas) and the areas between the highest and the lowest average of annual rainfall occurring in Panama were included in our study. Percentage of houses with non–potable water supply ranged from 21.8% (Escobal, Colon) to 0.1% (San Miguelito, Panama and Santa María, Herrera). Houses lacking hygienic toilet ranged from 87% (San Jose del General, Colon) to 3.6% (San Miguelito, Panama), and without any sanitary facility from 23.1% (Chepigana, Darien) to 0.5% (San Miguelito, Panama and Santa María, Herrera).

The frequency of the different variables registered in the questionnaires associated to each human sample was calculated (Table 3). Regarding the community type, majority of samples were of semi–rural origin (42.0%), followed by indigenous (29.6%), rural (21.0%) and urban (7.1%) samples. All the urban samples were collected from school children at Panama City. Notably, *G. intestinalis* and *B. hominis* were the only parasites found in this group.

In our study there were more females (60.5% of the total) than males. Regarding age groups, the first three (0–5, 6–15 and 16–60 years) were similar (from 21.2% to 31.4%), and participants older than 60 years account for 6.2%. The percentage of the 6 to 15 and >60 years old groups are similar to the percentage of those age groups over the total population in Panama (2010 data, http://www.contraloria.gob.pa/inec/). Concerning occupation, more than the half of samples fit in the category "student" (54.7%), followed by homemaker (24.8%), office worker (8.8%) and agriculture (8.4%), this last percentage close to the 10.3% (mean) calculated from the official data of the sampled municipalities (Table 1). The 68.8% of participants usually wear shoes, and have sanitation at home (86%), and the type of sanitation was in a minority hygienic (connected to the sewage or to a septic tank; 30%), and mostly non hygienic (latrine, hollow or none; 63.7%), a percentage higher than the mean calculated from the official data for the sampled municipalities (48.1%, Table 1).

3.3. Prevalence of intestinal parasites and associated risk factors in Panamá.

In the studied population, the overall prevalence of fecal parasites was 47.4%. The prevalence was also calculated for each of the studied municipalities (Figure 1; Table 2). The highest prevalence rate (87.6%) was found at Chepigana in the province of Darien, close to the border with Colombia, where majority of inhabitants are indigenous and afro-descendants. People sampled in this municipality were all indigenous. The remaining parasite prevalence ranged from 76% registered at Cativa (Colon) to 7.1% at Cañazas (Veraguas). Commensals prevalence was above 40% in all of the studied communities, with the exception of Cañazas in Veraguas (27.9%, data not shown).

The prevalence of each parasite was calculated in the whole sample and for each socio-economic group (Figure 2 and Table 4). Morphological classification was done to the species level when feasible and to broader taxonomic groups when morphology prevented the species-specific classification (http://www.parasitologiaambiental.com/). The most prevalent parasite was *Blastocystis hominis* (38.6%), followed with much lower percentages by *Giardia intestinalis* (18.9%), *Ascaris lumbricoides* (15.6%), hookworm (8%), *Trichuris trichiura* (5.2%), *Hymenolepis* sp. (2.7%), *Strongyloides stercoralis* (1.4%), *Cystoisospora belli* (1.4%) and *Balantidium coli* (0.7%). Suprisingly, *B. hominis* was not detected before by other authors in Panamanian surveys. In contrast, *G. intestinalis*, *A. lumbricoides*, hookworm and *T. trichiura* were found in the same order of prevalence than here in the last two surveys of intestinal parasites done at Panama in 2009 and 2010 (Halpenny et al., 2013; Jiménez Gutiérrez et al., 2014). This order of prevalence was different for the studies done before the 80´s (see Supplementary Table 1), when the most frequent ranking found in the screenings was first hookworm, second *T. trichiura*, third *A. lumbricoides* and fourth *G. intestinalis*.

A mathematical method for estimating the prevalence of any soil transmitted helminthic (STH) infection from the prevalence of single STH infections has been described [34]. When applied to our data, the highest prevalence of STH infections (71%) is registered at Chepigana, and a global STH prevalence of 33% is calculated for the whole country.

The identified commensals were amoebas (51.3%) including *Entamoeba* sp., *Endolimax nana* and *Iodamoeba butschlii*, and *Chilomastix mesnili* (21.8%). Although trophozoytes were found, the differentiation of the parasitic species *Entamoeba histolytica* from the commensal *Entamoeba dispar* could not be achieved in any case. The global number of parasites was also evaluated (Figure 2). In 52.5% of samples no parasite was detected. 25.4% of samples showed one parasite and 22.1%of samples showed more than one parasite.

In table 4 we also present detailed information regarding the specific risk factors for each parasite in the different population and socio-economic groups. Taking into account the global prevalence of parasites, the risk factors increasing the likelihood of having intestinal parasites, from those registered in the questionnaires (p<0.05), are: (i) belonging to indigenous communities, (ii) not wearing shoes, (iii) not having a hygienic toilet and (iv) having high prevalence rates of commensals. When comparing specific parasite prevalences, performing agricultural activities –for hookworm–, having age below 15 years –for *Blastocystis hominis*– and having age below 5 years for *Giardia lamblia* are significant risk factors. ,. Two of the analysed variables were not risk factors: having private or shared sanitation and being male or female.

Regarding official data shown in Table 1, elevation, water supply and climate did not show to increase the risk of intestinal parasitic infections. Conversely, the total absence of sanitation (e.g., defecating in the field) and the type of land (seasonally flooded areas) showed to be risk factors for the acquisition of intestinal parasites (P<0.05).

The evolution of the total prevalence rate over time for indigenous, semi–rural and rural groups can be represented extrapolating the percentage of the most prevalent parasite from the previous studies as the global prevalence, adding a trend line for each group. This representation has not been approached for urban settings, since only two previous reports refer to this group. Regarding the total prevalence rate over time, previous published data about prevalence have been represented in the Supplementary Figure 2 together with our data, without discriminating groups representing all age groups or only children.

4. Discussion

A survey of intestinal parasites at national level has never been done in Panama, where prevalence of fecal parasites is still largely unknown in many areas and population groups. We here detect a high prevalence of fecal-oral transmitted parasites in Panama, mainly in the indigenous population, identifying key risk factors for acquiring intestinal parasite infections in these settings.

A total prevalence of 47.4% was found in our study. From the previous literature, none of the documents reported the total number of parasitized samples for the four population groups studied here. Only three of them detail global rates, but for single population groups (Cosgrove, 1960; Cutting, 1975; Pineda et al., 2011). The rest of the documents inform about the prevalence for specific groups and separately for each parasite. We therefore decided to perform a comparison of the prevalence found in our survey with those from the already published reports, extrapolating from the previous cross-sectional studies done from 1926 to 2011, the percentage of the most prevalent parasite as the global prevalence for a specific population group –regardless age group– in a defined time period. For the rural group, a downwards tendency is detected, with changes in prevalence from 83.1% in 1926 to 22.6% in 2010 (mean of (Jiménez Gutiérrez et al., 2014) and our data). Rates in semi-rural people did not substantially vary from 1930 to 2010, although studies performed in 1984 and 1987 showed lower prevalence (Holland et al., 1987; Robertson et al., 1989), resulting in a slightly downwards tendency line of the prevalence of intestinal parasites in this population group. In our study, prevalence in rural and semi-rural groups was very similar. Prevalence of intestinal parasites have remained very high over time –from 71.5 in 1955 (Jung et al., 1955) to 76.5 in 2011 (Pineda et al., 2011)– for indigenous people. It should be mentioned that sampling in this specific group could be biased due to their lack of trust in the formal health sector. Data on indigenous population screenings also show that the frequency of intestinal parasites is very similar for all age groups, in contrast with data in other population groups, where people between 0 and 15 years old are the most affected by intestinal parasites (Supplementary Table 1, our data). This analysis of historical trends in prevalence has some limitations, due to the lack of studies directly comparable among them or to our results, thus it should be regarded as preliminary.

This comparison could not be performed with the available data for urban population, due to the low number of previous studies in this group (two; Faust, 1931; Cosgrove, 1960) and to their biases (e.g., screening only of symptomatic patients; Cosgrove, 1960). The urban group was also biased in our study, because only children younger than 6 years were sampled. Notably, our results in urban children showed the presence of *B. hominis* and *G. intestinalis* in their feces, and the absence of the other parasites detected in the rest of the sampled individuals. This could indicate that the rate of intestinal parasitism with specific parasites (e.g., soil transmitted helminths –STH–) in urban settings in Panama is generally low, and that urban settings in Panama are comparably developed than urban settings in the strongest economies of the world, although sampling of different age groups should be performed to confirm this observation.

The relative frequency found here for each parasite species was compared with those described in previous studies in Panama. The most frequent finding in our samples was *B. hominis*. This parasite has a widespread geographic distribution and is found at a rate of >50% in less developed areas (Boorom et al., 2008), a percentage very similar to that found here. Strikingly, *B. hominis* has not been reported by other authors before in Panama in similar studies, most probably due to its recent classification as parasite and not to its absence. The second most abundant parasite, *G. intestinalis*, was found at similar rates in Panama before (Supplementary Table 1).

The worldwide ranking situating the STH *A. lumbricoides*, hookworm and *T. trichiura* as the first, second and third most frequent human roundworm infections (http://www.who.int/intestinal_worms/en/) matches with our results and with those found in Panama in 2009 and 2010 by other authors (Halpenny et al., 2012, 2013; Jiménez Gutiérrez et al., 2014). In older studies on Panamanian population (from the **50's to the 80's),** hookworm ranged first more frequently than *A. lumbricoides* and *T. trichura*. The downwards trend of hookworm infection rates runs parallel to the downwards trend in the percentage of labor force in agriculture in Panama, which has dropped from 46% in 1965 to 26% in 1986, and maintained until 2010 (http://www.contraloria.gob.pa/inec/). This observation matches with our finding showing that performing agricultural activities is a risk factor for hookworm infection.

The World Health Organization (WHO) recommends deworming all school–aged children at least once every year when the prevalence of STH ranges between >20% and ≤50%, and twice per year when the prevalence is >50% (http://whqlibdoc.who.int /publications/2011/ 9789241548267_eng.pdf). The estimation of STH prevalence in our cohort (>30% for the whole sample and >70% for indigenous population) could indicate the need of one deworming cycle per year for children in rural and semi–rural settings, and two cycles for children and adults from indigenous groups.

The fifth major STH is *S. stercoralis* (http://www.who.int/intestinal_worms/en/). We found this species with a much lower overall prevalence (1.4%) than the rest of STH. Detection of *S. stercoralis* in feces is more sensitive when culture methods are used (e.g., Khieu et al., 2014), but they are rarely standard procedures in clinical parasitology laboratories. The use of the Baermann or the Harada–Mori methods in our cohort could have resulted in the detection of *S. stercoralis* in a higher percentage of people. It should be mentioned, however, that the only epidemiological study of intestinal parasites in Panama performing fecal culture of samples, detected a similarly low percentage of *S. stercoralis* infected samples than here (1%; Sanchez et al., 1990).

Hymenolepis nana is the most common cestode in humans and its transmission is mostly from human to human contact and auto–infection, thus related with poor hygiene habits. Here, prevalence of this parasite was 2.5%, while one of the few reports on the presence of this parasite in Panama in 1975 found a prevalence of 0.5% (Cutting, 1975). Dissimilarities in geographical origin and characteristics of sampled individuals between the previous study and ours could account for those differences in prevalence, since the study of Cutting (1975) was done in a specific area of Darien and in an heterogeneous population group, and our results show that hymenolepids are mainly found in indigenous children, although this could only be confirmed analyzing a higher number of samples.

C. belli has been the only coccidian identified here. The identification of other parasites of this subclass like *Cryptosporidium* sp. was not achieved perhaps due to the need of specific staining procedures that were not performed in this case. Last, *B. coli* affects less than 1% of the human population worldwide (Roberts and Janovy, 2008) a percentage matching with that found here. Comparison of the prevalence figures among municipalities showed that Chepigana at Darien displays the highest prevalence. This municipality contributed with the majority of indigenous samples and it is the only one of the areas sampled here situated in a seasonally flooded area. Both factors showed to constitute risk factors for intestinal parasitism in our cohort. Neither elevation nor rainfall average showed to be risk factors in our study. Rainfall has shown to influence the survival and transmission rate of intestinal parasites. Overall, the occurrence of rainfall is >75% for the entire country including high grounds, and differences are not very high among different areas. Our results suggest that in Panamanian settings, overall rainfall could influence intestinal parasite transmission mainly in areas where high levels of rainfall onto saturated soil could facilitate the transfer of contaminating parasite eggs into surface water. This could be also applicable to the second municipality in our prevalence ranking –Cativa– which was affected by floods in 2010 (http://mensual.prensa.com/mensual/contenido/2010/11/08/hoy/nacionales/2393633.as).

The influence of improved access to safe drinking water and sanitation on *A. lumbricoides* and *T. trichiura* infection rates, among other factors, has shown to be positive in a recent systematic review (Strunz et al., 2014). Accordingly, sanitation showed to be a risk factor in our population, where prevalence of intestinal parasites was higher when sanitation was not hygienic or was not available. Conversely, water supply did not emerge as a risk factor in our study, as judged using official data classifying water supply in treated and non–treated water. This discrepancy could be due to sub–optimal water treatment or to contamination sources downstream treatment. The review of Strunz *et al.* (2014) also associate reduced odds of STH infection with the variable "wearing shoes", and this is confirmed by our analysis.

A number of limitations were detected in our study. First, it is primarily a descriptive study that followed a simple cross–sectional design. Nevertheless, due to the lack of previous comparisons of intestinal parasitic prevalence among different population groups and among the several orographic and climatic conditions found in Panama, we believe that this initial survey could aid focalizing subsequent surveys in this country. A second limitation is the methodology used for the analysis of samples. Zinc sulfate flotation is not adequate for the detection of some parasites requiring specific approaches (e.g., *S. stercoralis*; Khieu et al., 2014). Nevertheless, it is considered a good approach to use in initial surveys to establish which groups of parasites are present, and as such it has been frequently used by other authors for the same kind of studies (e.g., in Panama; Reverte and Perez, 1955; Perez and Pedreschi, 1953; Cosgrove, 1960; Sanchez et al., 1990). Additionally, sensitivity of our approach can be affected when only one sample is collected from each participant. In this sense, Sanchez *et al.* (1990) showed in a survey in Panama that when more than one sample per participant is examined at different time points, incidence rates increased 3 to 4 fold compared with those calculated with single samples.

Panama has experienced a huge socio–economic development in the last two decades. This could be related with the lower prevalence of intestinal parasites found in our study compared with those registered before for rural population, and the similarities on the rates and type of intestinal parasites found in the urban population sampled here with that of countries with the highest per capita income. The disproportionate percentage of intestinal parasites in indigenous people maintained from **the 50's until today show that this population, either to their ethnic condition or to their** greater degree of poverty, has been left behind prosperity.

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Figure Legends

Figure 1. Sampled areas. The map shows the ten provinces of Panama. Numbers from 1 to 14 show the sampled municipalities in seven provinces. The name of each municipality and the percentage of parasitized samples found in each municipality are shown.

Figure 2. Prevalence of each parasite found in the survey. (A) Prevalence in percentage (%) and number of samples over the total of specific parasites found in human feces are shown. (B) Total samples without, with one, and with more than one parasite are also shown in percentage and number.

Figure 1
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Figure 1

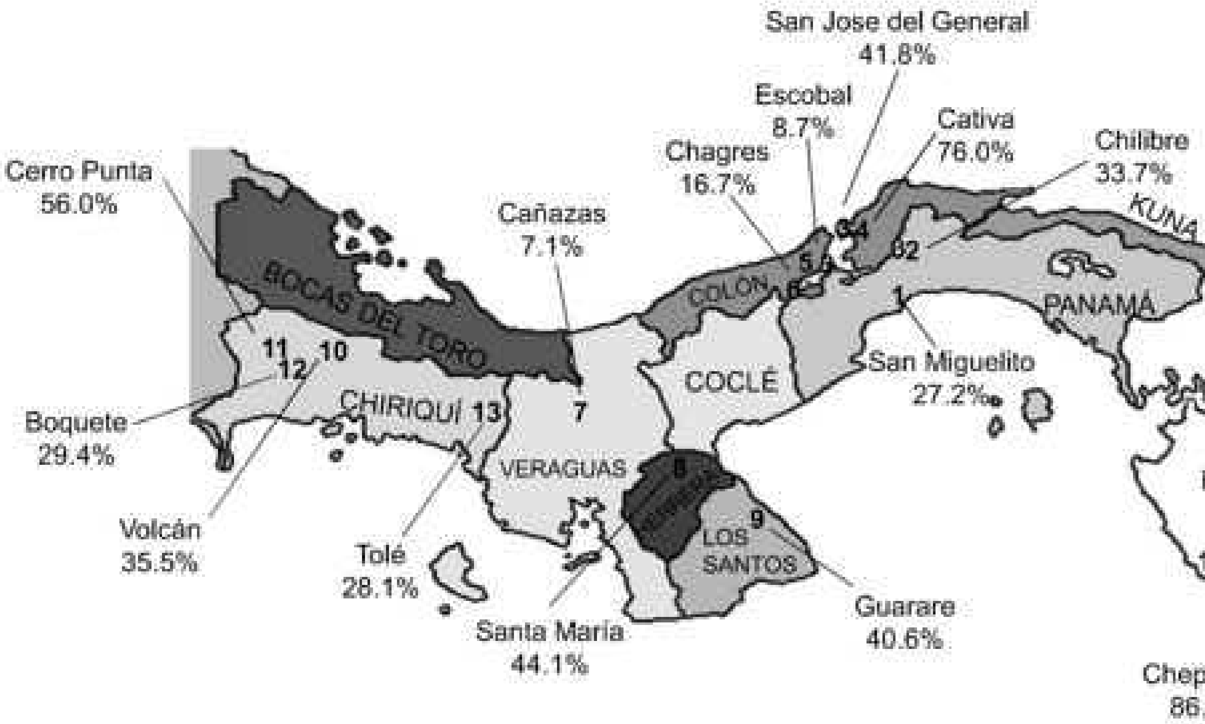

Figure 2
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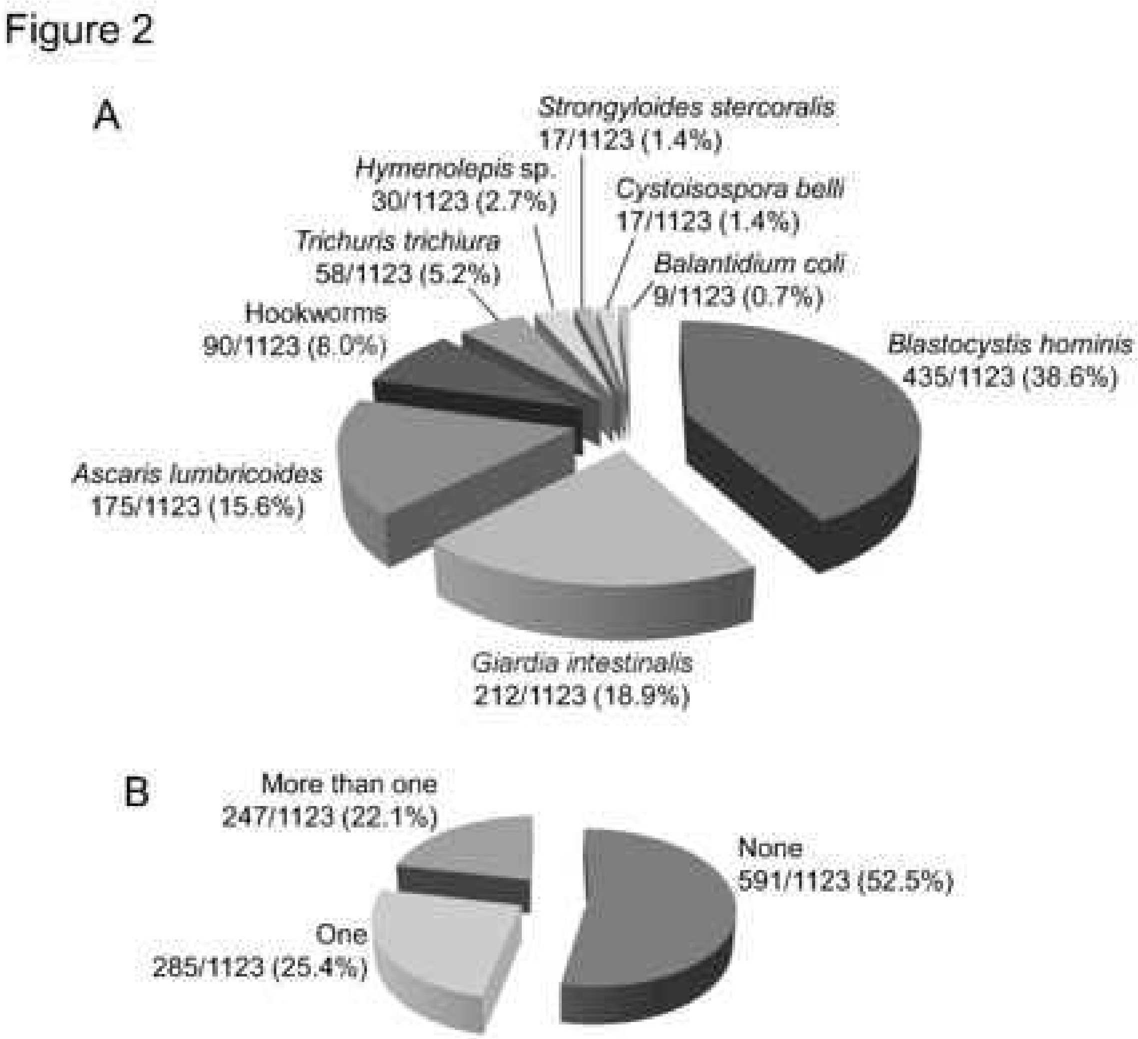


Tables

Table 1. Geographic, demographic and socio-economic data of the sampled Panamanian municipalities.

Province	Municipality	Population (thousands)	Height (m)	Agricultural activity	Water supply	Sanitation (latrine)	Sanitation (lack)	Days of rain (%)	Type of land
Panamá	San Miguelito	15,873	14	0.6%	0.1%	3.6%	0.5%	98.9%	Scrub, savannah and crops
	Chilibre	3,262	54	2.5%	7.4%	46.5%	3.1%	62.9%	Mixed evergreen and deciduous forest
Colón	San José del General	2,248	121	10.1%	18.8%	87.0%	6.7%	75.7%	Evergreen forest
	Cativa	8,328	52	1.0%	0.2%	33.2%	1.7%	82.1%	Scrub, savannah and crops
	Escobal	2,388	42	8.1%	21.8%	67.0%	3.9%	92.9%	Scrub, savannah and crops
	Chagres	9,563	27	9.2%	0.8%	41.9%	2.1%	91.9%	Evergreen forest
Veraguas	Cañazas	4,836	203	17.5%	17.3%	72.0%	6.7%	93.2%	Scrub, savannah and crops
Herrera	Santa María	1,682	49	8.9%	0.1%	45.6%	0.5%	99.4%	Scrub, savannah and crops
Los Santos	Guararé	4,524	29	4.2%	0.3%	33.6%	0.6%	97.9%	Scrub, savannah and crops
Chiriquí	Volcán	12,717	1433	14.2%	4.0%	22.4%	2.3%	92.1%	Highland evergreen forest
	Cerro Punta	7,754	2030	34.6%	9.9%	46.7%	3.1%	92.5%	Highland evergreen forest
	Boquete	4,493	1124	10.8%	1.5%	16.3%	1.7%	94.3%	Highland evergreen forest
	Tolé	3,241	326	6.5%	5.4%	51.7%	3.3%	87.1%	Scrub, savannah and crops
Darién	Chepigana	2,386	9	15.9%	11.0%	48.1%	23.1%	94.5%	Evergreen forest and swamp and seasonally flooded areas

Agricultural activity: percentage of population with agricultural activity; Water supply: percentage of houses without potable (treated) water; Sanitation (latrine): percentage of houses with latrine or hollow without connection to sewage or to a septic tank; Sanitation (lack): percentage of houses without any sanitation facility; Days of rain: % days of rain in rainy season.

Table 2. Sampled neighborhoods in each municipality: type and number of samples, number of positive samp

Province	Municipality	Neighborhood	Community type	Nº samples/ Nº of positive samples	Prevalence o parasitism (
Panama	San Miguelito	Belisario Porras	Urban	81/24	29.6
	Chilibre	Victoriano Lorenzo	Rural	21/10	47
		La Laguna	Rural	106/5	4.7
		Embera Para-Puru and Tusipono	Indigenous	60/55	91.6
Colon	San Jose del General	Coclesito	Rural	53/29	54.7
	Cativa	Villa del Carmen	Rural	25/19	76
	Escobal	Escobal	Semirural	23/2	8.7
	Chagres	El Guabo	Semirural	3/1	33.3
		Santa Fe	Semirural	1/0	0
		El Platano	Semirural	2/0	0
Veraguas	Cañazas	Cañazas	Semirural	42/3	7.1
Herrera	Santa Maria	Santa Maria	Semirural	64/24	0.3
		El Rincon	Semirural	29/17	58.6
Los Santos	Guarare	Guarare	Semirural	30/10	33.3
		El Nanzal	Rural	23/12	52.2
		El Jobo	Semirural	3/1	33.3
		Cienaga Larga	Semirural	13/4	30.7

Chiriqui	Volcan	Volcan	Semirural	31/14	45.1
		Vista Hermosa	Semirural	5/1	20
		Nueva California	Semirural	7/1	14.3
		Fila de Caisan	Semirural	7/0	0
		Bijao	Semirural	7/0	0
	Cerro Punta	Cerro Punta	Semirural	48/30	62.5
		Barrio Guadalupe	Semirural	3/0	0
	Boquete	Bajo Boquete	Semirural	5/0	0
		Alto Lino	Semirural	5/2	40
		Altos del Boquete	Semirural	20/7	35
			Indigenous	3/1	33.3
		El Frances Arriba	Semirural	2/0	0
		Palmira Abajo	Semirural	2/1	50
		Jaramillo Arriba	Semirural	2/0	0
			Indigenous	2/0	0
		Los Naranjos	Indigenous	3/1	33.3
	Tole	Tole	Semirural	41/7	17
		Barniz	Semirural	1/1	100
		Bajo Solis	Semirural	1/0	0
		Veladero	Semirural	11/2	18.2
		El Retiro	Semirural	3/1	33.3
		Alto Caballero	Semirural	1/0	0
		Buenos Aires	Semirural	1/0	0

Darien	Chepigana	Jaque	Indigenous	266/233	87.6	7.51826	−78.16343

Table 3. Frequency of the different variables registered in the questionnaires.

Question	Variable	Number	Percentage
Community type	Semirural	472	42.0
	Indigenous	333	29.6
	Rural	237	21.0
	Urban	81	7.1
Sex	Female	681	60.5
	Male	442	39.5
Age (years)	0–5	238	21.2
	6–15	249	22.2
	16–60	354	31.4
	>60	71	6.2
	NR	217	19.2
Occupation	Student	614	54.7
	Homemaker	280	24.8
	Agriculture	96	8.4

	Office worker		112	8.8
	NR		27	2.3
Socioeconomic level	Use of shoes			
		Always	774	68.8
		Occasionally	304	27.1
		Seldom	34	3.0
		NR	17	1.4
	Private sanitation			
		Yes	967	86.0
		No	110	9.8
		NR	52	4.5
	Sanitation type			
		Hygienic*	337	30.0
		Non hygienic$	717	63.7
		NR	61	5.3

N, Not reported. *Connected to the sewage or to a septic tank; $Latrine, hole, none

Table 4. Detailed prevalence for each parasite and commensal and global prevalence of intestinal infections stratified regarding demographic and socio-economical variables.

	PARASITES												
	Giardia	*Isospora*	*Ascaris*	*Trichuris*	*Hookworm*	*Strongyloides stercoralis*	*Hymenolepis*	*Balantidium*	*Blastocystis*	*PP*	*Chilomastix mesnili*	*Amoebas*	*PC*
COMMUNITY TYPE													
Rural	6	0.4	0.4	0	2.6	0	0	0.7	27.6	30.5	26	45	60
Semirural	0.12	1.8	1	0.5	1	0.5	0	0.5	18.1	33.2	24	45	59
Urban	9.5	2.4	0	0	0	0	0	0	34.5	36.9	29	24	47
Indigenous	37*	0	51.2*	16.8*	23.8*	4.5*	9*	1.2	71.6*	84.5*	11	77*	80
AGE (years)													
0–5	16.4*	2.1	4.2	0	1.3	0	0	1.3	20.8*	37	29	35	54
6–15	10.8	1.6	3.2	0.4	2.4	0.4	0.4	1.6	27.7*	40	30	45	64
16–60	7.3	0.8	2	0.3	2.8	0.6	0	0.6	25.4	35	28	49	63
>61	5.6	1.4	0	0	4.2	0	0	0	8.5	17	13	41	50
SEX													
Female	17	1	16	5	9*	2	2	1	36	45	20	53	64
Male	20	0.5	13	4.5	5.5	1	4	0.5	38	50	25	49	42
OCUPATION													
Student	20.2	1.7	16.6	6.7	5.2	1.5	4.1	1.3	36.2	49	25	50	64
Homemaker	15.7	0.9	15	4	12.5	1.4	0.4	0	40.4	47	17	57	65
Agricultural	18.9	1.4	15.8	2.1	14.7*	2.1	1.1	0	47.4	60	29	65	75
Other	17	33	14.3	2.7	5.4	1.8	2.7	0	41.1	44	13	48	58
USE OF SHOES													
Always	14	1.6	7.2	2.1	4	0.9	1.2	0.3	32.7	41	25	45	60
Occasionally	27.5	43	34.2	13.2*	14.5*	2.6	6.9*	1.6*	49.7*	62*	16	66	74

Seldom	35*	59	41*	6	35*	6*	0	3*	59*	74*	12	79	82
SANITATION TYPE													
Hygienic	11	1.5	1	0.3	1	0	0	0.3	29.5	38	32	31	54
Non hygienic	21*	29	23*	7.5*	11*	2*	4*	0.6	43*	52*	17	65*	69
WATER SOURCE													
Treated	37*	2.2	70*	44*	17*	20*	4	9	68	75	6	65	70
Non treated	11.5	1.3	4.6	0.5	3.4	0.5	0.5	1.1	26.5	39	28*	48	63

PP: prevalence of parasites; PC: prevalence of commensals.

$p<0.05$

Supplementary tables

Supplementary Table 1. Literature review of the epidemiological studies on intestinal parasitism in Panama.

REFERENCE NUMBER	SUBNUMBER	FIRST AUTHOR	REFERENCE	TITLE	SAMPLING YEAR	SAMPLING PLACE (ending in Province)	NUMBER OF SAMPLES	CONCENTRATION METHOD	PARASITES	NUMBER OF POSITIVE SAMPLES	PREVALENCE	POPULATION GROUPS	RISK FACTORS	BIAS	COMMENTS
8	1	Cort, WW	American Journal of Hygiene (Monographic series), 1929, 9:1–215.	Studies on hookworm, Trichuris and Ascaris in Panama	1926	Cocle	3000	NA	*Ascaris lumbricoides*	1470	49	NA (Rural)	NA	NO	The original document could not be retrieved. Data extracted from Robertson et al., 1987.
	2								*Hookworms*	2493	83.1				
	3								*Trichuris trichiura*	1497	49.9				
9	1	Faust, EC	Science, 1931, Jan 9;73(1880):43–45.	Investigations in Panama during the summer of 1930	1930	Santo Tomas Hospital, Panama city, Panama	1246	NA	*Entamoeba histolytica/dispar*	223	18	Urban	Rural population compared with urban and semi–rural population, children compared with adults for giardiasis	NO	
	2					Canal Area, Panama city, Panama	143			4	2.7	Urban, Office worker			
	3					Gorgas Hospital, Panama city, Panama	153			13	8.5	Urban, Settler			
	4					Chagres, Colon	542			183	34	Semi–Rural			
	5					Tiura, Darien	105			NA	38	Rural, Children <16			

	6									NA	18	Rural, Adults >16			
	7					All studied areas	2089		*Giardia intestinalis*	140	6.7	All			
	8								*Trichuris trichiura*	1776	85				
	9								*Balantidium coli*	4	0.2				
10	1	Tucker, HA	PR J Public Health Trop Med, 1946, Jun;21:364.	Intestinal cestode infections in natives of Panama	1904 to 1944	Gorgas Hospital, Canal Zone, Panama city, Panama	558556	NA	*Taenia saginata*	99	0.02	Urban, rural	Mestizos population compared with white American citizens	YES (MAJORITY OF SAMPLES FROM AMERICAN CITIZENS)	
	2								*Hymenolepis nana*	16	<0.01				
	3								*Taenia solium*	8	<0.01				
	4								*Diphyllobothrium latum*	1	<0.01				
11	1	Reverte, JM	Bol Oficina Sanit Panam, 1955, Nov;(Suppl 2):27–32.	[Clinical nutritional studies in communities of Panama. I. La Mesa, Provincia de Veraguas]	1950	La Mesa, Veraguas	42	Flotation zinc sulfate	*Hookworms*	33	79	Semi–rural, children (7–10 years old)	NA	YES (CHILDREN, POOREST)	
	2								*Ascaris lumbricoides*	29	69				
	3								*Trichuris trichiura*	18	43				
	4								*Entamoeba sp.*	7	17				
	5								*Giardia intestinalis*	4	10				
	6								*Strongyloides stercoralis*	4	10				
	7								*Enterobius vermicularis*	1	2				

12	1	Perez, C	http://hist.library.paho.org/Spanish/BOL/v39s2p33.pdf, 1953	Estudios clínicos nutricionales en poblaciones de Panama. 2. Barrio el Chorrillo, ciudad de Panama	1950	Barrio el Chorrillo, Panama city, Panama	121	Flotation zinc sulfate	*Entamoeba sp.*	NA	>10	Urban, children (0–10 years old)	NA	YES (CHILDREN, POOREST)	
	2								*Trichuris trichiura*	NA	>10				
	3								*Ascaris lumbricoides*	NA	>10				
	4								*Giardia intestinalis*	NA	>10				
	5								*Chilomastix mesnilii*	NA	<10				
	6								*Hookworms*	NA	<10				
	7								*Enterobius vermicularis*	NA	<10				
	8								*Balantidium coli*	NA	<10				
	9								*Strongyloides stercoralis*	NA	<10				
13	1	Jung, RC	Am J Trop Med Hyg, 1955, Nov;4(6):989–997.	Fumagillin and erythromycin in the treatment of amebiasis	1955	El Real, Yaviza and Pinogana, Darien	752	Flotation zinc sulfate	*Trichuris trichiura*	538	71.5	Indigenous, Afro–descendants, mainly school children	NA	YES (MAINLY SCHOOL CHILDREN)	
	2								*Ascaris lumbricoides*	524	69.6				
	3								*Hookworms*	352	46.8				
	4								*Strongyloides stercoralis*	71	9.4				
	5								*Enterobius vermicularis*	16	2.1				
	6								*Entamoeba coli*	444	59				

	7								*Entamoeba nana*	374	49.7				
	8								*Iodameba butschlii*	249	33				
	9								*Entamoeba histolytica/dispar*	158	21				
	10								*Giardia intestinalis*	148	19.7				
	11								*Chilomastix mesnilii*	29	3.9				
	12								*Balantidium coli*	6	0.8				
	13								*Dientamoeba fragilis*	1	0.1				
14	1	Cosgrove, GE	Am J Trop Med Hyg, 1960, Mar;9:173–174.	Intestinal parasites in the Panama Canal Zone	1955 to 1957	Gorgas Hospital, Canal Zone, Panama city, Panama	2500	Flotation zinc sulfate	*All*	733	29.3	Urban	NA	YES (AMERICAN CITIZENS, PATIENTS WITH SYMPTOMS)	
	2								*Giardia intestinalis*	163	6.5				
	3								*Trichuris trichiura*	305	12.2				
	4								*Hookworms*	251	10				
	5								*Strongyloides stercoralis*	146	5.8				
	6								*Ascaris lumbricoides*	121	4.8				
	7								*Enterobius vermicularis*	10	0.4				
	8								*Taenia saginata*	4	0.16				
	9								*Entamoeba sp.*	222	8.9				

	10								*Endolimax nana*	82	3.3				
	11								*Chilomastix mesnilii*	15	0.6				
	12								*Iodameba buschli*	14	0.6				
15	1	Cutting, JW	Bull Pan Am Health Organ, 1975, 9(1):13–18.	A survey of intestinal parasitism in a community on the Pan American Highway route in eastern Panama	1972	Yaviza, Darien	202	Ether concentration	*All*	181	90	Indigenous, Afro–descendants, mainly school children	NA	YES (POPULATION <14 YEARS OLD IS 66.8%)	
	2								*Trichuris trichiura*	162	80				
	3								*Ascaris lumbricoides*	125	62				
	4								*Hookworms*	83	41				
	5								*Entamoeba sp.*	32	16				
	6								*Strongyloides stercoralis*	15	7				
	7								*Giardia intestinalis*	10	5				
	8								*Hymenolepis diminuta*	1	<1				
16	1	Kourany, M.	Rev Med Panama, 1983, Jan;8(1):32–44.	[Incidence of pathogenic enterobacteria and intestinal parasitosis in the population of the Río Bayano region upstream from the	1974	Villages around Bayano river, districts of Chepo & Madugandi, Panama	124	NA	*Hookworms*	70	56.5	Rural	Rural population compared with semi–rural population	NO	
	2								*Trichuris trichiura*	22	17.7				
	3								*Ascaris lumbricoides*	31	25				
	4								*Strongyloides stercoralis*	4	3.2				
	5								*Giardia intestinalis*	7	5.6				
	6								*Entamoeba sp.*	2	1.6				

	7			dam]			171		*Hookworms*	68	39.8	Semi-Rural			
	8								*Trichuris trichiura*	30	17.5				
	9								*Ascaris lumbricoides*	20	11.7				
	10								*Strongyloides stercoralis*	18	10.5				
	11								*Giardia intestinalis*	11	6.4				
	12								*Entamoeba sp.*	1	0.6				
	13					El Higo, Panama	320		*Hookworms*	123	38.4	Semi-rural			
	14								*Trichuris trichiura*	63	19.7				
	15								*Ascaris lumbricoides*	27	8.4				
	16								*Strongyloides stercoralis*	10	3.1				
	17								*Giardia intestinalis*	17	5.3				
	18								*Entamoeba sp.*	4	1.3				
17	1	Ramos, CM	Boletin informativo, Facultad de ciencias Naturales y Farmacia, Universidad de Panama, 1975	Estudio de la incidencia de parasitos gastrointestinales en algunas comunidades de la region montaños	1974	Cocle	NA	NA	*Ascaris lumbricoides*	NA	22.9	NA (Rural)	NA	NA	The original document could not be retrieved. Data extracted from Robertson et al., 1989.
	2								*Hookworms*	NA	21.3				
	3								*Trichuris trichiura*	NA	27.8				

				a de la provincia de Cocle, relizado en 1974											
18		Carrera, E	PhD Thesis, Cornell University, 1983	Ascaris lumbricoides infection and lactose malabsorption	1981	Barrio San Jose, David, Chiriqui	NA	NA	*Ascaris lumbricoides*	NA	43	Children (semi–rural)	NA	YES (CHILDREN, WITH SYMPTOMS)	The original document could not be retrieved. Data extracted from Holland et al., 1987.
19		Carrera, E	Am J Clin Nutr, 1984, 39(2):255–264.	Lactose maldigestion in Ascaris–infected preschool children	1981	Barrio San Jose & Obaldia Hospital, David, Chiriqui									Data refer to selected groups (infected and controls). Discarded.
20	1	Holland, CV	Parasitology, 1987, 95 (Pt 3):615–622.	Ascaris lumbricoides infection in pre-school children from Chiriqui Province, Panama	1983 to 1984	Barrio San Jose, Chiriqui	140	Ether concentration	*Ascaris lumbricoides*	36	25.5	Semi–rural, children (3–5 years old)	Rural population compared with semi–rural population; poor socio–economic status	YES (CHILDREN)	
	2								*Trichuris trichiura*	31	22.4				
	3								*Hookworms*	2	1				
	4								*Giardia intestinalis*	23	16.3				
	5					Barrio San Jose & Chiriqui, Chiriqui			*Entamoeba sp.*	7	5	Semi–rural, rural, children (3–5 years old)			
	6								*Strongyloides stercoralis*	6	4				

	7					Chiriqui, Chiriqui			*Ascaris lumbricoides*	43	31	Rural, children (3–5 years old)			
	8								*Trichuris trichiura*	83	59.5				
	9								*Hookworms*	60	43				
	10								*Giardia intestinalis*	17	12				
21		Holland, CV	Soc Sci Med, 1988, 26(2):209–213.	Intestinal helminthiases in relation to the socioeconomic environment of Panamanian children											Same data as in Holland et al., 1987. Discarded.
22	1	Sanchez, JL	Mil Med, 1990, 155(6):250–255.	Parasitological evaluation of a foodhandler population cohort in Panama: risk factors for intestinal parasitism	1985	Canal Area, Panama city, Panama	196	Flotation zinc sulfate; culture; multiple samples	*Giardia intestinalis*	49	25	Indigenous, Urban	Indigenous population compared with urban population	NO	Multivariate analysis of risk factors. When examination of faeces was done several times in one year, incidence rates increased 3 to 4 fold.
	2								*Entamoeba sp.*	19	10				
	3								*Ascaris lumbricoides*	17	9				
	4								*Trichuris trichiura*	9	5				
	5								*Endolimax nana*	8	4				
	6								*Iodameba buschli*	5	3				
	7								*Hookworms*	4	2				
	8								*Strongyloides stercoralis*	1	1				

	9								*Chilomastix mesnilii*	1	1				
23		Taren, DL	Parasitology, 1987, 95(Pt 3):603-613.	Contributions of ascariasis to poor nutritional status in children from Chiriqui Province, Republic of Panama	1987										No epidemiological data. Discarded.
24	1	Robertson, LJ	Parasitology, 1989, 99(Pt 2):287-292.	Soil-transmitted helminth infections in school children from Cocle Province, Republic of Panama	1987	Penonome, Rio Hato, Anton and Nata, Cocle	661	Kato-katz	*Ascaris lumbricoides*	120	18.2	Semirural, children	NA	YES (CHILDREN)	Sex group is not a risk factor
	2								*Hookworms*	79	12				
	3								*Trichuris trichiura*	182	27.5				
25		Robertson, LJ	Trans R Soc Trop Med Hyg, 1992, 86(6):654-656.	Haemoglobin concentrations and concomitant infections of hookworm and Trichuris trichiura in Panamanian primary	1987										Same data as in Robertson et al., 1989. Discarded.

				schoolchildren											
26	1	Taren, DL	Arch Latinoam Nutr, 1992, 42(2):118–126.	The nutritional status of Guaymi Indians living in Chiriqui province, Republic of Panamá	1992	San Felix, Chiriqui	NA	NA	*Ascaris lumbricoides*	NA	40.7	Indigenous, children (1 to 3 years old)	NA	YES (CHILDREN)	The original document could not be retrieved. Data extracted from Holland et al., 1987.
	2					Alto Caballero, Chiriqui				NA	80				
27		Robertson, LJ	Transactions of the Royal Society of Tropical Medicine and Hygiene, 1992, 86:656–657.	Trichuris trichiura and the growth of primary schoolchildren in Panama	1992										Same data as in Robertson et al., 1989. Discarded.
28	1	Payne, L	J Nutr, 2007, 137:1455–1459.	Benefit of vitamin A supplementation on Ascaris re–infection is less evident in stunted children	2007	Bocas del Toro	328	Kato-katz, duplicate	*Ascaris lumbricoides*	261	79.5	Indigenous, children (1 to 5 years old)	NA	YES (CHILDREN)	Ngawbe–Bugle group
	2								*Trichuris trichiura*	62	19				
	3								*Hookworms*	NA	<1				

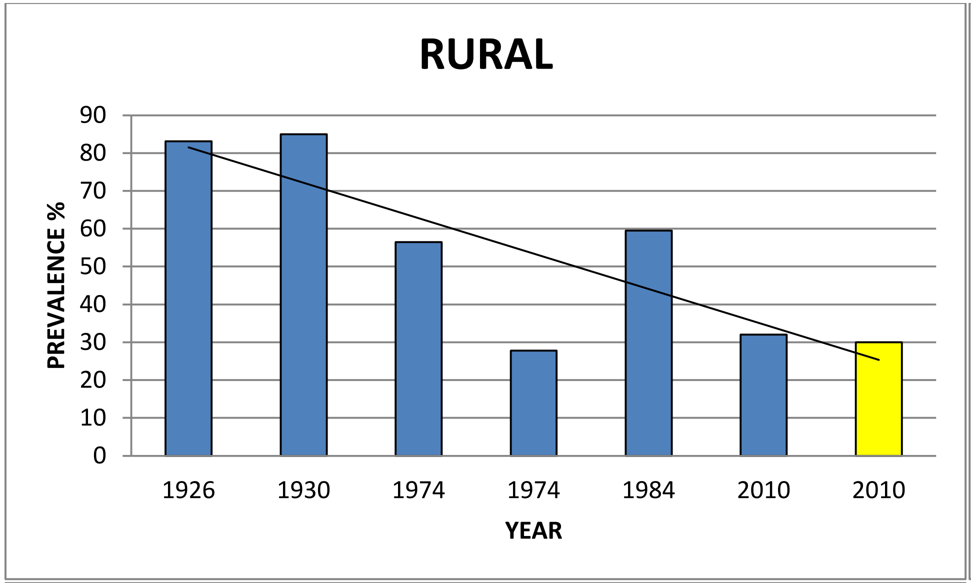
29	1	Halpenny, CM	Am J Trop Med Hyg, 2012, 86(2):280–291.	Prediction of child health by household density and asset–based indices in impoverished indigenous villages in rural Panamá	2008 to 2009	Soloy and Emplanada de Chorcha, district of Besiko, Bocas del Toro	373	Kato-katz and FLOTAC, multiple	*Giardia intestinalis*	97	26	Indigenous, children (<4 years old)	NA	YES (CHILDREN, EXTREME POVERTY)	
	2								*Entamoeba histolytica/dispar*	13	3.5				
30	1	Halpenny, CM	PLoS Negl Trop Dis, 2013, 7(2):e2070.	Regional, household and individual factors that influence soil transmitted helminth reinfection dynamics in preschool children from rural indigenous Panamá	2008 to 2009	Soloy and Emplanada de Chorcha, district of Besiko, Bocas del Toro	373	Kato-katz and FLOTAC, multiple	*Ascaris lumbricoides*	75	20	Indigenous, children (<4 years old)	NA	YES (CHILDREN, EXTREME POVERTY)	Same population as in Halpenny et al., 2012.
	2								*Hookworms*	19	5				
	3								*Trichuris trichiura*	4	1				
31		Hotez, PJ	Int J Parasitol, 2014, doi: 10.1016/j.ijpara.2014.04.001.	Neglected tropical diseases in Central America and Panama: Review of their prevalence,	2009 to 2013										General review, no data to extract. Discarded.

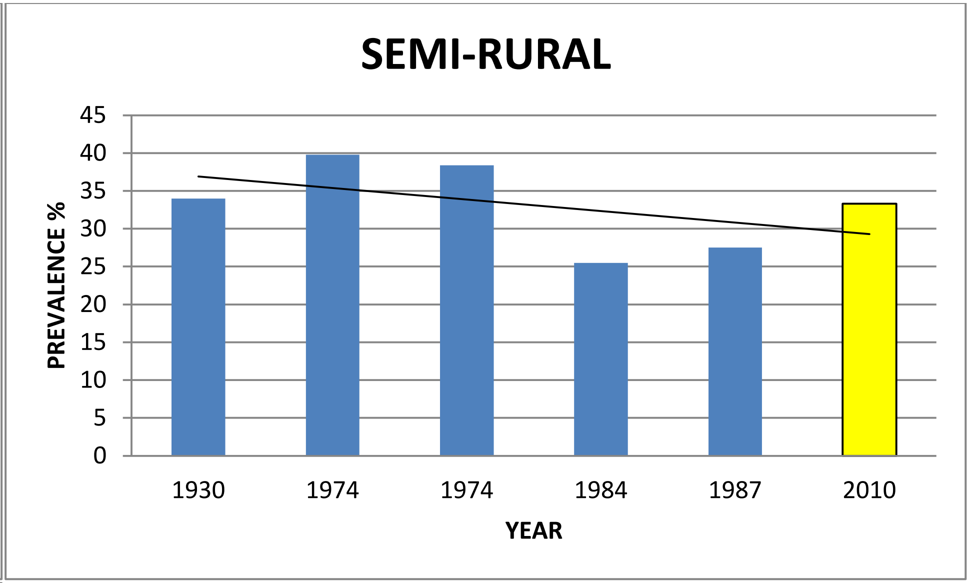
				populations at risk and impact on regional development											
32	1	Pineda, V	X Congreso de la Asociación Centroamericana y del Caribe de Parasitología y Medicina Tropical & IV Congreso Nacional de la Asociación Panameña de Microbiología y Parasitología, 2011	Parásitos Intestinales en la Población Infantil y Perros de la Comunidad Indígena de Ipetí–Choco, Distrito de Chepo, 2011	2011	Ipetí – Choco (N 08°58'07.7''; W 078°30'56.7''), distric of Chepo, Panama	81	Ether concentration	*All*	62	76.5	Indigenous, children (<10 years old)	NA	YES (CHILDREN)	Genotyping of Giardia lamblia demonstrated antroponotic but not zoonotic transmission.
	2								*Giardia intestinalis*	33	40.7				
33	1	Jiménez Gutiérrez, E	Am J Trop Med Hyg, 2014, Jun 30. pii: 13-0438.	Enteric Parasites and Enteroaggregative Escherichia coli in Children from Cañazas County, Veraguas Province, Panama	2010	Cañazas, Veraguas	100	Ethyl acetate concentration	*Giardia intestinalis*	32	32	Rural, children (<5 years old)	NA	YES (CHILDREN <5 YEARS OLD)	
	2								*Ascaris lumbricoides*	14	14				
	3								*Entamoeba coli*	12	12				
	4								*Iodameba butschlii*	8	8				
	5								*Entamoeba histolytica/dispar*	4	4				
	6								*Hookworms*	1	1				
	7								*Cryptosporidium sp.*	1	1				
	8								*Cyclospora*	1	1				

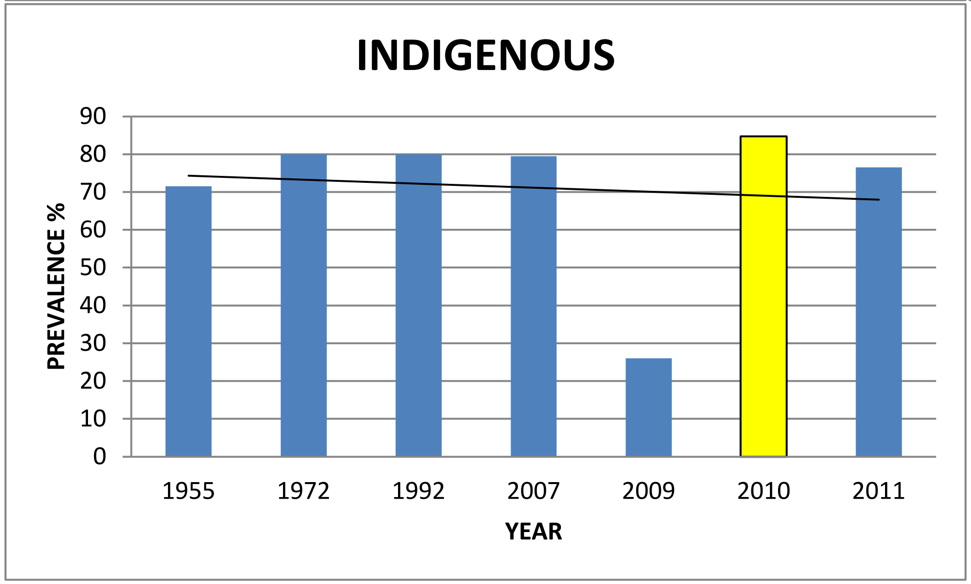
									cayetanensis						
	9								*Endolimax nana*	1	1				
	10								*Hymenolepis nana*	1	1				

Supplementary Table 2. Trends of prevalence rates of intestinal parasites in Panama for rural, semi-rural and indigenous groups. In yellow, data obtained in our study. The trend line is shown in each graphic.

REFERENCE (from Supplementary Table 1)	YEAR	PREVALENCE (%)	PROVINCE	POPULATION GROUP	AGE GROUP
8	1926	83,1	COCLE	RURAL	ALL
9	1930	85	DARIEN	RURAL	ALL
16	1974	56,5	PANAMA	RURAL	ALL
17	1974	27,8	COCLE	RURAL	ALL
20	1984	59,5	CHIRIQUI	RURAL	CHILDREN
33	2010	32	VERAGUAS	RURAL	CHILDREN
	2010	30	ALL	RURAL	ALL
9	1930	34	COLON	SEMI-RURAL	ALL
16	1974	39,8	PANAMA	SEMI-RURAL	ALL
17	1974	38,4	PANAMA	SEMI-RURAL	ALL
20	1984	25,5	CHIRIQUI	SEMI-RURAL	CHILDREN
24	1987	27,5	COCLE	SEMI-RURAL	CHILDREN
	2010	33,3	ALL	SEMI-RURAL	ALL
13	1955	71,5	DARIEN	INDIGENOUS	ALL
15	1972	80	DARIEN	INDIGENOUS	ALL
26	1992	80	CHIRIQUI	INDIGENOUS	CHILDREN
28	2007	79,5	BOCAS DEL TORO	INDIGENOUS	CHILDREN
29	2009	26	BOCAS DEL TORO	INDIGENOUS	CHILDREN
	2010	84,7	ALL	INDIGENOUS	ALL
32	2011	76,5	PANAMA	INDIGENOUS	CHILDREN


RURAL
PREVALENCE %
90
80
70
60
50
40
30
20
10
0
1926
1930
1974
1974
1984
2010
2010
YEAR


SEMI-RURAL
PREVALENCE %
45
40
35
30
25
20
15
10
5
0
1930
1974
1974
1984
1987
2010
YEAR


INDIGENOUS
PREVALENCE %
90
80
70
60
50
40
30
20
10
0
1955
1972
1992
2007
2009
2010
2011
YEAR