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Geographic differences in the distribution of parasitic infections in children of Bolivia

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ABSTRACT

Background: A high percentage of the population in Latin America lives with intestinal parasitic infections, a neglected tropical disease frequently not treated. Intestinal parasitism is associated with other disorders, but information about the epidemiological situation in countries like Bolivia is scarce. Environmental conditions play a role in the prevalence of certain parasites. The main objective was to know the current situation of parasitic infections among children under 12 years old from different geographical areas of Cochabamba – Bolivia.
Methods: We analysed the laboratory reports of four second-line hospitals in different areas and the Tertiary Care Hospital. Results of stool examinations performed between 2011 and 2015 in children under 12 years of age were collected.
Results: We gathered the results of 23,221 examinations. The 89% of children were less than five years old. Pathogenic parasites were found in 31%. *Entamoeba histolytica* and *Giardia lamblia* were the two most prevalent parasites in all areas. Helminths were 19% of positive samples and *Ascaris lumbricoides* was the most prevalent. Parasitic infections are more frequent in tropical areas where helminths are highly concentrated. Pre-school age children (OR: 5.296; 95% CI: 4.81–5.83) and semi-tropical area (OR: 3.26; 95% CI: 2.90–3.66) were strongly associated to the presence of pathogenic parasites.
Conclusions: Parasitic infections in children are still very prevalent in Bolivia. Protozoan infections are a major problem, while the prevalence of helminths seems to be decreasing. The most vulnerable population is still concentrated in semi-tropical and tropical areas, where the risk of parasitic infection is probably increased due to poor environmental conditions. Our results could allow reconsideration of more effective parasitic disease control policies, taking into account regional characteristics.

1. Introduction

Parasitic infections are distributed all around the world, and the establishment of some species is defined by favourable conditions

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Abbreviations

ELISA	Enzyme-linked immuno sorbent assay
CI	Confidence interval
m	meters
OR	odds ratio
PAHO	Pan American Health Organization
PCR	Polymerase chain reaction
PHC	primary health care
SEDES	Spanish abbreviation of “Servicio Departametal de Salud” corresponds to the local health direction of the department of Cochabamba.
STH	Soil-transmitted helminths
SUMI	Spanish abreviation of “Seguro Universal Materno – Infantil” corresponds to universal maternal and infant insurance.

Parasites names
A. duodenale *Ancylostoma duodenale*
A. lumbricoides *Ascaris lumbricoides*
E. histolytica/dispar Complex *Entamoeba histolytica*/dispar
E. vermicularis *Enterobious vermicularis*
G. lamblia *Giardia lamblia*
H. nana *Hymenolepis nana*
N. americanus *Necator americanus*
S. stercoralis *Strongyloides stercoralis*
T. solium *Taenia solium*
T. trichiura *Trichuris trichiura*

such as temperature, humidity, season, host, etc. For example, tropical areas present many conditions for infections produced by soil-transmitted helminths (STH)·(Gyorkos et al., 2013) Data available in Latin America show that 20% of the population lives with an intestinal parasitic infection of one, two or more species. For this reason, these infections are defined as “the most common infections among poor people in the Americas”.(PAHO, 2011)

Intestinal parasites are primarily associated more with morbidity and disability than with mortality. According to the World Health Organization, intestinal parasitism is still important because it is related to nutritional disorders and development injuries in very young and school-aged children·(Chan, 1997) Some illnesses related to parasitic infections are malnutrition, iron deficiency, anaemia, malabsorption syndrome, intestinal obstruction, chronic dysentery, rectal prolapse, respiratory complications, and poor weight gain. Species commonly associated with these disorders are directly or indirectly STH, although certain protozoa have also been implicated (PAHO, 2011)·(Ojha et al., 2014)

Epidemiological information on STH or protozoan infections is poor in Latin America. A brief review of studies on parasitic infections conducted by PAHO reported a prevalence of STH of 50% and higher in schoolchildren and indigenous groups·(Saboyá et al., 2011) In Bolivia, a country with many ecological areas such as the Andean mountains, valleys and the Amazon basin, the national policy of control for helminth infections is limited to children under five years and the epidemiological surveillance system follows infections caused by protozoa·(MSD, n.d.) In both cases, either for protozoa or helminths, there are no studies that assess the impact of these programs in child population.

The Department of Cochabamba, with an area of 55,631 km^2 and 1,758,143 inhabitants, is located in the middle of Bolivia and has different ecological areas: low and high valleys, semi-tropical and tropical areas. The climate (temperature, atmospheric pressure and humidity) varies greatly depending on the altitude(INE, n.d.)·(SENAMHI - BOLIVIA, n.d.) The variation of these conditions is important to see interactions between the environment and the frequency of parasitic infections, as well as other variables such as social determinants in the population·(Torgerson et al., 2015) Unfortunately non-official data or publications were found of mortality association with intestinal parasites in Bolivia. Some estimates in a document from 2006 tell that 36% of deaths under five years old were related to enteric diseases in general·(Mollinedo and Prieto, 2006)

The objective of our study was to describe, by geographical area, the distribution of intestinal parasites that affect children under 12 years old in the Department of Cochabamba. This knowledge will allow us to identify vulnerable populations and set out a combined intervention for children susceptible to parasitic infections. More than a contribution to new knowledge, it is an update of the situation of intestinal parasites in Bolivia, since little recent documentation has been found in order to propose an evaluation of programs or policies and the possibility of improving the current measures for these.

2. Material and methods

We performed a retrospective study of laboratory reports from 2011 to 2015 from hospitals of 3rd and 2nd lines situated in different geographical areas of Cochabamba. The Bolivian health system, based on primary health care (PHC), has a basic level of care close to the most remote populations as a first line, the second-line offers more complex services (e.g. laboratory) and the third line is a hospital of more complexity and capacity usually located in big cities·(Carmen and René, 2011) The areas considered were: high valley with an altitude of 2761 m, an average humidity of 40% and variation from 6 to 23 °C of temperature according to the season; low valley, between 2200 and 2700 m with an average humidity of 55% and variation from 10 to 26 °C of temperature; semi-tropical area, from 1800 to 900 m, with an average humidity of 60% and a variation from 25 to 30 °C of temperature; and finally, the tropical area under 900 m with an average humidity of 70% and temperature variations from 21 to 35 °C.(SENAMHI - BOLIVIA, n.d.)

One of the greatest difficulties of the Bolivian health system is the dispersion of its population. The difficulty of access and road communication makes people look for the nearest primary health centre. In most of the cases, a laboratory is offered from the second line forward.(Carmen and René, 2011) Thus, the cases collected from second-line hospitals can be considered the closest and most representative of their areas. We choose reference centres in each area, taking into account the availability of reports of the study period:

- The third-line hospital of the main city (Cochabamba) is the only public centre of this level in Cochabamba City and in the department. Therefore, it is the reference hospital for all the population with no social insurance (80% of the population); more or less 1,500,000 inhabitants depend on it. People living in the city represent 60% of the patients and the remaining 40% come from different areas of the department. Only two years of reports were available (2014 and 2015).
- Four second-line hospitals from each geographical region of the department.
- High valley area: Hospital of Punata, which corresponds to eight first-line centres and 40,288 inhabitants.
- Lower valley area: Hospital of Vinto, which corresponds to seven first-line centres, seven points of health care and 46,924 inhabitants.
- Semi-tropical area: Hospital of Mizque, with seven first-line centres and 40,173 inhabitants.
- Tropical area: Hospital of Ivirgarzama, which assembles seven first-line centres and 25,094 inhabitants.

From the laboratory reports, we obtained data from stool samples that were requested in medical consultation for detection of parasites, results were registered in handwritten books at the time of receiving sample collection. No link to the medical records of each patient was possible because of the absence of digital systematisation of laboratory or medical records in the public health system. We included samples from children aged 0–12 years old. We included one stool sample per child per year and the first sample of the year, regardless of the result. This means that a child could have repeated samples within a period of five years, but not a repeated sample in one year. This was ensured by the government insurance identification system for children with the birthdate, initials of their first and last names, which allows in a certain way to measure the number of visits of a child to a centre; however, it is not systematised and a child can be taken as new if he visits another establishment. A child can visit the first-line as a new case and if he does not find a solution, he is referred to the second-line and he will also be counted as a new case; hence, the importance of only taking the data corresponding to second-line hospitals and/or third level.

It was excluded illegible, incomplete or confusing data. We also excluded samples from patients whose age data were missing. Only the available data from hospitals were digitised for this study.

The techniques for stool sample analysis were direct simple examination and direct serial examination (one stool sample per day for three days). Incomplete serial procedures (only 2-stool examination) were classified as a direct simple examination and we considered a positive result even if only one of the two samples was positive or negative in case the two samples were negative. Other kinds of processes, like the modified Ritchie method, ELISA (enzyme-linked immunosorbent assay*)* just for *Entamoeba histolytica/dispar* or a method similar to a culture for *Strongyloides stercoralis* (Dancescu method) in stool were also included in the collected data.

For this study, enteroparasites considered as pathogenic are Complex *Entamoeba histolytica/dispar*, *Giardia lamblia, Ascaris lumbricoides,* Ancylostomidae *(Ancylostoma duodenal/Necator americanus), Trichuris trichiura, Strongyloides stercoralis, Taenia solium, Enterobious vermicularis* and *Hymenolepis nana.* All the other intestinal parasites reported were considered commensals and are not detailed in our description: *Blastocystis hominis, Entamoeba coli, Chilomastix mesnilli, Iodamoeba bütschlii* and *Endolimax nana.* These parasites are not considered pathogenic for this study because they are not considered for treatment either in the epidemiological surveillance of the Bolivian PHC·*(*Bolivia, Ministerio de Salud y Deportes*, 2012)*

It is worth mentioning that most of the secondary care centres use simple examination as the main diagnostic technique; techniques with higher sensitivity, such as the modified Ritchie technique or molecular tests are rarely used. For this reason is not possible to distinguish between *E. histolytica* and *E. dispar.*

Most hospitals of public health services in Bolivia do not have a digital system, but handwriting notebooks of monthly reports. The third-line hospital (city hospital) was able to keep the reports for only two years (2014 and 2015). Transcribing and cleaning process was developed by the main researcher. This study has the approval by the ethical committee of the University of San Simon and the local health direction of the Department of Cochabamba.

Descriptive data such as mean and standard deviation for age variable and frequencies for the others: area (high valley, low valley, semi-tropical, tropical and city), group of parasites (helminths, protozoan), diagnosis (pathogenic, non-pathogenic, no parasites observed), season (spring, summer, autumn, winter) and age groups used for analysis took into account the paediatric classification used in Bolivia to follow child development. For so we have:

- Minor infant: From day zero to 12 months (0–1 year old).
- Older infant: From 12 months 1 d to 24 months (1.1–2 years old).
- Pre-school age child: From 24 months 1 d to 48 months (2.1–4 years old).

- School age child: From 48 months 1 d to 12 years old (4.1–12 years old).

The association of available variables (sex, age group, area, and season) with the presence of pathogenic parasites was analysed using a binary logistic regression model and the degree of association was expressed as odds ratio (OR). The defined value of $p < 0.05$ were considered as statistically significant.

3. Results

3.1. General data

We gathered 23,535 reports, among which we excluded 314 samples for missing age data. Data available from each hospital are presented in Table 1. Of the 23,221 reports, 75% were from the second-line (5 years of reports) and 25% from the third-line hospital of Cochabamba (two years of reports).

The median age was 1 year old. Nearly 90% of the samples were from children under 4 years old. The age distribution was similar across all the regions. The major group was the older infant group, the minor infant group were the second highest percentage of samples and less than 20% in each of the other two groups (pre-school age and school age). The sex ratio (male/female) was 1.16.

A simple examination was done in 22,514 patients (96.9%) and serial examinations in 675 (3.1%). Other methods, such as modified Ritchie, ELISA, or culture, were used just in 32 samples (0.1%).

3.2. Distribution of positive samples

At least one pathogen parasite was found in 30.8% ($n = 7161$). We also found a non-pathogenic parasite in 1277 samples (5.5%). The distribution of parasites is displayed in Fig. 1. The protozoa *E. histolytica/dispar* and *Giardia lamblia* were identified in more than 90% of the positive samples as unique or combined diagnoses. Helminths were observed in one quarter of the positive samples ($n = 1817$), with *A. lumbricoides* being the most important.

Regarding multiparasitism, 83% of the positive samples ($n = 5956$) had only one parasite, 14% samples two parasites ($n = 1028$) and 2,5% samples ($n = 177$) three to four parasites. We found 41 combinations of multiparasitism, *Giardia lamblia* with *E. histolytica/ dispar* was the most common combined diagnosis, and two helminth combinations were the second one (*A. lumbricoides* and *A. duodenale/ N. americanus*).

3.3. Positive samples according to geographic area and season

The proportion of positive stool samples differed by area (p-value <0,05 Chi^2); a higher percentage was observed in the semi-tropical area, where half of the stool samples showed a pathogen (see Fig. 2). In all areas, protozoa were found dominant in the positive stools, except in the tropical area where helminths represent nearly half of the pathogens. *E. histolytica/dispar* and *G. lamblia* were present in all the areas as the main diagnoses. Only in *the* tropical area, we found a higher prevalence of *G. lamblia* (33%) than *E. histolytica/dispar* (24%). Fig. 3 shows the distribution of helminths in the tropical area, in which *A. lumbricoides* was the most prevalent, followed by *A. duodenale/ N. americanus* and *S. stercoralis*.

The distribution of the positive samples according to the seasons and their annual trends did not show a clear pattern, with the presence of protozoa or helminths being predominant in any one season (Fig. 4). There were large variations each year that did not establish a significant association with the presence of pathogenic parasites (p-value = 0,28 Chi^2).

3.4. Positive samples according to age and gender

No differences were found in the sex group; 3683 of 12,003 samples (30,7%) were positive in males, while 3341 of 10,349 samples (32,3%) were positive in females. The repartition of parasites differed according to age group (p–value <0,05 Chi^2). Protozoan infections are more common in younger groups, while helminths have an increasing proportion with respect to age groups: from 12% in minor infants to 18%, 24% and 21% in older infants, preschool age and school age, respectively. In the tropical area, an increase in

Table 1
Number of laboratory reports by area/year in the target population of Cochabamba, Bolivia 2011–2015.

Area	Year					Total	(%)
	2011	2012	2013	2014	2015		
High Valley	938	1009	982	1140	979	5048	22
Lower Valley	521	520	569	628	573	2811	12
Semi Tropical	369	367	383	407	390	1916	8
Tropical	1332	1455	1347	1718	1866	7718	33
City[a]	0	0	0	2188	3540	5728	25
Total	3160	3351	3281	6081	7348	23,221	100

[a] City: Refers to the only 3rd line hospital from Cochabamba.

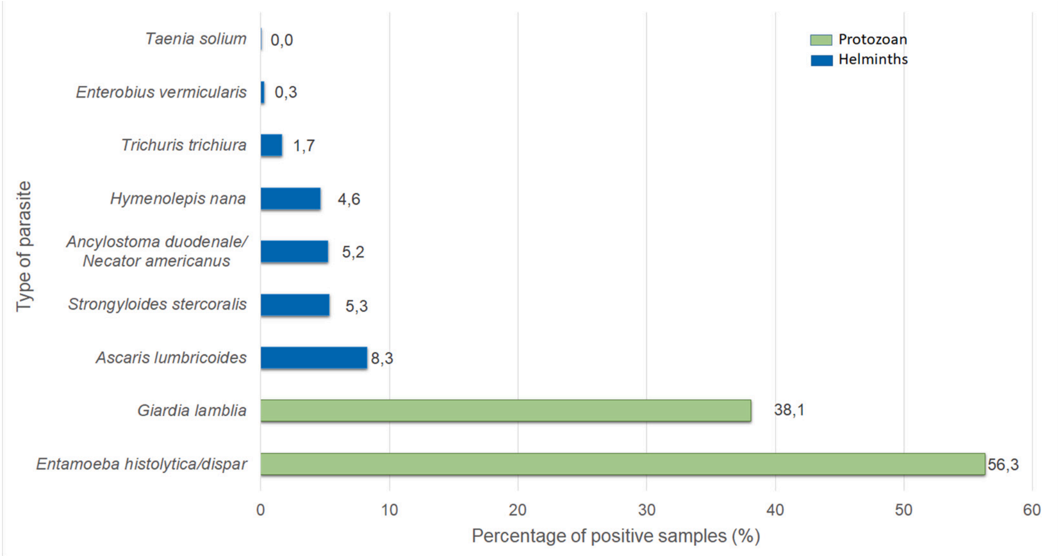

Fig. 1. Distribution of parasite species in positive stool samples (%).
Some species are the main diagnoses or can be combined with others.

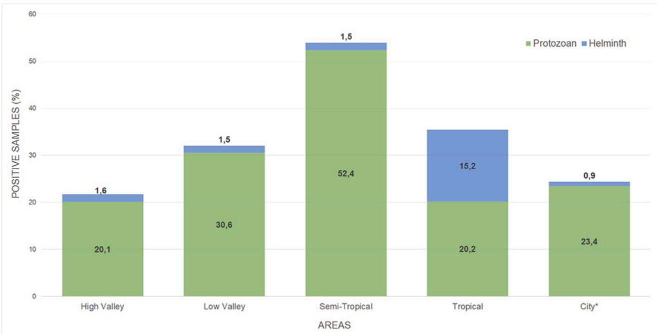

Fig. 2. Distribution of positive stool samples by area with differentiation of groups of parasites (%).
*City - Refers the only 3rd line Hospital from Cochabamba. Difference between areas is significant (p-value <0,05 Chi^2)

helminths according to age was also found, but with a higher prevalence than in other areas, see Fig. 5.

3.5. Analysis of the available variables

A binary logistic regression model showed that the group of pre-school children had a significantly higher risk (OR: 5.296; 95% CI: 4.81–5.83) to the presence of pathogenic parasites, compared to the other groups. In the same model, semi-tropical areas were strongly associated with parasitic infections (OR: 3.26; 95% CI: 2.90–3.66). Sex and season of the year have not been shown to have a significant association to explain the presence of pathogenic parasites in children, see Table 2.

4. Discussion

This study focused on the current situation of parasitic infections in children under 12 years of age in one region of Bolivia (Cochabamba), which includes four ecological areas. Our study confirms that parasitic infections remain still a public health problem in Bolivia, as pathogenic parasites were found in nearly one-third of stool samples, with the highest percentage in semi-tropical and tropical areas. Protozoan infection remains a major problem, except in tropical areas where both helminthic and protozoal infections are frequent.

Only two publications on parasitic infections that included all Bolivian regions have been published. The first one was a cross-sectional study performed in 1987 that included 22,828 laboratory reports of patients from all age groups, from children to adults of social security hospitals in urban and peri-urban areas from different regions of the country·(Navone et al., 2017) It showed different prevalence of parasitic infections by areas, 47% in andean areas, 75% in valleys and 65% in tropical areas. The protozoan prevalence

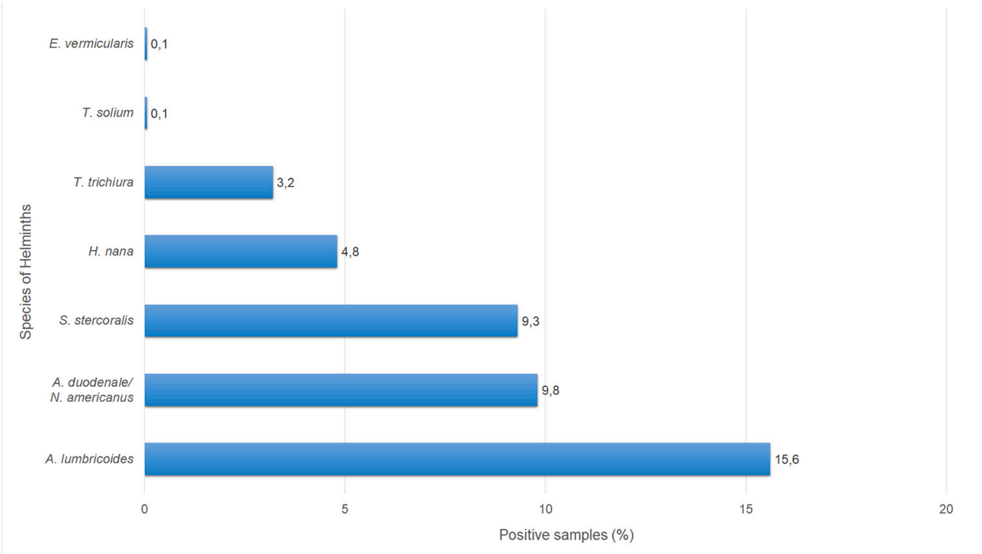

Fig. 3. Distribution of the most prevalent helminth species in positive samples from tropical areas (%).

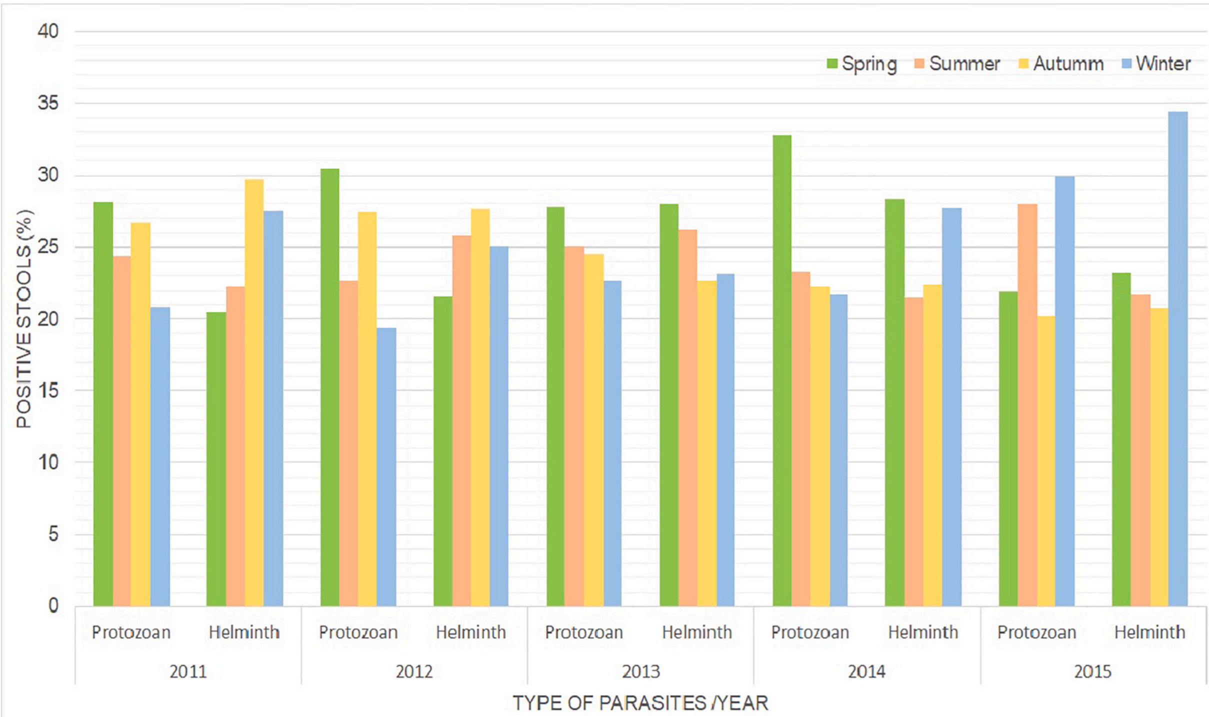

Fig. 4. Distribution of positive samples by season with the differentiation of group of parasites (%).

was 29% in general. The most important protozoan was *G. lamblia,* with a similar distribution in all areas (15 to 18%), while *E. histolytica* was important only in valley areas (24%). Helmithic infections were identified more in tropical areas with a prevalence of 69%, with the most important being *A. lumbricoides* (42%) and *A. duodenale/N. americanus* (10%) and *S. stercoralis* (4%).

The second one was a compilation of different research reports on intestinal parasites in different populations and areas of Bolivia from 1975 to 2004. It showed a great prevalence variability depending on geographical area: Andean areas (66%), valleys (73%) and tropical areas (81%). The conclusion of these different studies shows that the prevalence of parasitic infections increases from Andean to tropical areas. For both groups, protozoan and helminths, the increase was clear, but it was more evident for helminths. In the three regions, the protozoan prevalence rose from 20 to 40% and from 10 to 90% for heltminths. This confirms a higher rate of parasitic

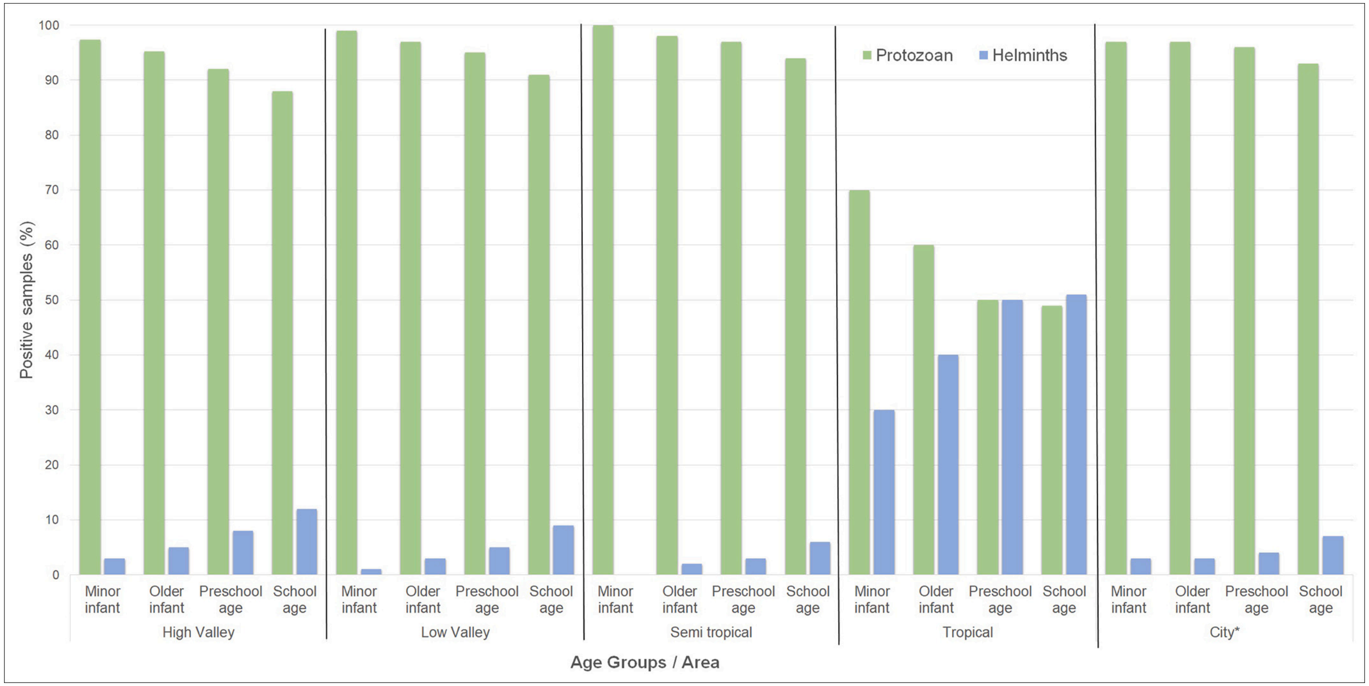

Fig. 5. Repartition of parasites (%) according to age group per geographical area where data were collected.
*City: Refers to the only 3rd line hospital from Cochabamba.

Table 2
Binary logistic regression analyses of available variables associated with parasitic infections.

Variables	N	Positive Stool		Univariate analysis	Multivariate analysis
		n	%	OR (95% CI)	OR (95% CI)
Gender					
Male	12,003	3683	31	1	1
Female	10,349	3341	32	1.07 (1.01–1.14)*	1.02 (0.96–1.08)
Age group					
Minor infant	7137	1049	15	1	1
Older infant	9634	3137	33	2.80 (2.59–3.03)*	2.72 (2.50–2.95)*
Pre-school age	3612	1730	48	5.34 (4.86–5.85)*	5.30 (4.81–5.83)*
School age	2838	1245	44	4.54 (4.11–5.01)*	4.66 (4.20–5.16)
Area					
High Valley	5048	1159	23	1	1.
Low Valley	2811	868	31	1.50 (1.35–1.66)*	1.49 (1.34–1.67)*
Semi-Tropical	1916	930	49	3.17 (2.83–3.54)*	3.26 (2.90–3.66)*
Tropical	7718	2573	33	1.68 (1.55–1.82)*	1.80 (1.66–1.96)*
City	5728	1631	28	1.34 (1.22–1.46)*	1.37 (1.25–1.50)*
Season					
Spring	6508	1938	30	1.04 (0.96–1.12)	1.08 (0.99–1.17)
Summer	5149	1770	34	1.28 (1.18–1.39)*	1.23 (1.13–1.34)*
Autumn	5457	1681	31	1.09 (1.01–1.18)*	1.07 (0.98–1.17)
Winter	6107	1772	29	1	1

Not: * = $p < 0.05$

infections in tropical areas and a high percentage of them are produced by helminths.(Verhagen et al., 2013) Our results go in the same way even if it is difficult to compare because the methodology design or age groups of the population included are quite different.

Making a comparison between other Latin American countries is quite difficult. Many studies of regional literature have concentrated just on one ecological area. A study in Argentina was the most comparable because it gathered information on different ecological areas. This study showed that the prevalence of pathogenic parasites is different. *G. lamblia* is an important pathogen in many ecological areas in Argentina, whereas our study has *E. histolytica* as the main pathogen. Among helminths, we also have different distributions; in Argentina, *E. vermicularis* has an important prevalence (from 14% to 51%), while we found more aggressive helminths in our study·(Mollinedo and Prieto, 2006)

There have been many years of diligence in South America to decrease the prevalence rate; nevertheless, according to some authors, there was not a big change in many areas compared to 50 years ago(Taylor-Robinson et al., 2015)·(Oberhelman et al., 1998) According to a national health care plan in 2002, all children under five years old should receive systematic helminthic treatment with mebendazole 500 mg every six months, especially in endemic areas. This was part of the recommendations by childhood insurance coverage called SUMI (from Spanish abreviation of universal maternal and infant insurance)(MSD, n.d.)·(Bolivia, Ministerio de Salud y Deportes, 2012) The decreasing prevalence of helminths found in our study could be related to this governmental policy. Unfortunately, we did not find a report on the evaluation of this policy, about its effectiveness or verification of compliance. Even so, it is remarkable that the prevalence of intestinal parasites remains high in younger groups and tropical areas.

Therefore, the tropical area has concentrated our attention for its high prevalence in helminths. Compared with other tropical areas in the region, the distribution was similar. *A. lumbricoides* is the most important helminth in tropical areas of Ecuador, Peru and Brazil (Pezzani et al., 2009)·(Solano et al., 2008) with an average prevalence of 25%. Hookworms with 72% is the most important in Venezuela·(Wang et al., 2012) However, it is different in Argentina; *E. vermicularis* is the helminth with a higher prevalence (20 to 51%), while aggressive helminths are less than 10%·(Navone et al., 2017) The prevalence of helminths in Bolivia, besides environmental conditions, could also be related to social factors like unsatisfied basic needs, poor sewage systems and lack of safe water in almost 70% of the population living in this area, according to statistical reports from past years(INE, n.d.)·(Gunawardena et al., 2011)

Similarly, on updated data on intestinal parasite situation in Bolivia, no studies have been found that could demonstrate the negative impact on the Bolivian health system or social security, since as a neglected tropical disease, policies have improved little or not at all in recent years.(Ministerio de Salud Bolivia, 2012) An additional factor also important for spreading parasitic infections could be the low level of education, especially in rural areas. Risky behaviours are more frequent in children without health education in very simple matters like the correct form of washing hands·(Gyorkos et al., 2013)

Our study has several limitations. Even if we included a large number of samples from different areas of Cochabamba, the main source of the data was hospital laboratory reports. This means that the samples came from children who reached hospitals for a reason. Second, the reason for stool examination was not available in laboratory reports; it could have been a routine analysis or a clinical problem. Third, there is a high representation of children younger than 5 years-old explained by the coverage in the Bolivian public health system for this group. Fourth, not having the complete third-level data no longer in the hospital anymore, does not allow the comparison of results according to urbanisation and the effect of this factor on the prevalence of intestinal parasites, since it is assumed that the children who go to the third-level hospital are mainly those living in urban or peri-urban areas of the city. Finally, detection of the pathogen was based mainly on direct examination; techniques with higher sensitivity, such as Ritchie or ELISA, were not used and it was not possible to distinguish between *E. histolytica* and *E. dispar*, the main protozoan in our study. Due to the limitations of the Bolivian health system, more complex examinations are not performed in second-line hospitals; for that reason, other types of parasites were not detected.

In conclusion, parasitic infections are still a major public health problem. It is clearly a neglected tropical disease due to the lack of specific health policies for early detection or treatment, especially in vulnerable populations. The trends of these infections have somewhat changed over the last ten years but not enough to stop the struggle against parasitic infections in children under 12 years old in countries like Bolivia.

The most important contribution of the findings is to make visible the differences in prevalent species by geographical areas, since in Bolivia, public health policies still have weaknesses in considering this factor when implementing control measures such as mass deworming with anthelmintics and not with more specific treatments according to what is present in each region.

Knowledge of intestinal parasite distribution by area could help to reconsider the current measures. New control policies related to parasitic infections could be more local and specific for each area, particularly in tropical areas where maybe some other factors may interact, such as lack of education and/or sanitation policies. Further studies are needed on the individual factors associated with the presence of parasitic infections that could help to improve acces to diagnosis and treatment.

Ethics approval and consent to participate

This study was approved by the local health authorities of Cochabamba to have access to laboratory reports from different hospitals. Consent for participation was not applicable in this study.

Consent for publication

Not applicable.

Availability of data and material

The dataset supporting the conclusions of this article is included within the article and its additional file [DATASET CBBA_PAR].

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Authors' contributions

Camacho-Alvarez Ivana digitised, analysed and interpreted the hospital data regarding stool examination results. Jacobs Frédérique and Goyens Philippe contributed to writing the manuscript. Luizaga-López Marcela contributed to the supervision and review process as well. All authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

Acknowledgments

Not applicable.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.parepi.2021.e00217.

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