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Potential impact of macroclimatic variability on the epidemiology of giardiasis in three provinces of Cuba, 2010—2012

Angel A. Escobedo[a,b,c], **Pedro Almirall**[d], **Raisa Rumbaut**[e], **Alfonso J. Rodríguez-Morales**[b,f,g,*]

[a] *Department of Parasitology, Hospital Pediátrico Universitario ''Pedro Borrás'', La Habana, Cuba*
[b] *Working Group on Zoonoses, International Society for Chemotherapy, Aberdeen, United Kingdom*
[c] *Committee on Clinical Parasitology, Panamerican Association for Infectious Diseases (Asociación Panamericana de Infectología), La Habana, Cuba*
[d] *Analisys and Health Trends Unit, Unidad Municipal de Higiene, Epidemiología y Microbiología, Plaza, La Habana, Cuba*
[e] *Ministerio de Salud Pública, La Habana, Cuba*
[f] *Research Group Public Health and Infection, Faculty of Health Sciences, Universidad Tecnológica de Pereira (UTP), Pereira, Risaralda, Colombia*
[g] *Committee on Zoonoses and Hemorrhagic Fevers of the Colombian Association of Infectious Diseases (Asociación Colombiana de Infectología, ACIN), Bogotá, Colombia*

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Summary Climate change and variability are common phenomena affecting various infectious diseases. Many studies have been performed on vector-borne diseases; however, few studies have addressed such influences on intestinal parasitic diseases (e.g., giardiasis). In this study, using nonlinear Poisson regression models, we assessed the potential associations between macroclimatic variation and giardiasis cases in children and school workers from three provinces of Cuba in the context of large sampling and parasitological assessment. Between 2010 and 2012, 293,019

* Corresponding author at: Research Group Public Health and Infection, Faculty of Health Sciences, Universidad Tecnológica de Pereira (UTP), Pereira, Risaralda, Colombia. Tel.: +57 3008847448.
E-mail addresses: arodriguezm@utp.edu.co, ajrodriguezmmd@gmail.com, ajrodriguezm_md@hotmail.com (A.J. Rodríguez-Morales).

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subjects were assessed, resulting in 6357 positive for *Giardia* (216.95 cases/10,000 pop.; 95%CI 211.7—222.2). The variation in time for those giardiasis rates ranged from 35.8 to 525.8 cases/10,000 pop. Nonlinear Poisson regression models between the ONI index and the giardiasis incidence indicated a significant association ($p < 0.01$). With lower values of ONI, lower incidence of giardiasis was observed at Havana (pseudo $r^2 = 0.0576$; $p < 0.001$) and Guantánamo (pseudo $r^2 = 0.0376$; $p < 0.001$). Although these results are preliminary and the magnitude of association is not higher, the results were of statistical significance. This result indicates the need to assess in detail in further studies the impact of additional macroclimatic and microclimatic variables on the epidemiology of this still important intestinal parasitic disease, not only in Cuba but also in other countries of the Caribbean and Latin American region.

Introduction

Giardia lamblia (synonymous with *G. intestinalis* and *G. duodenalis*) is probably the most frequent pathogenic intestinal protozoan found in children and adults throughout the world. This flagellated organism, when present in the gut of human beings, is associated with diarrhea, abdominal cramps, weight loss, nausea and vomiting [1].

Both the duration and severity of *Giardia* infection are extremely variable, requiring in some cases hospitalization [2—4]. Fortunately, for the majority of infected persons, the symptoms generally subside within 2—3 weeks in otherwise healthy individuals. However, in some cases, this infectious disease has long-term consequences, including chronic diarrhea with or without intestinal malabsorption, recurrent abdominal pain and weight loss [1,5].

Data from surveys, excluding documented outbreaks, indicate that in industrialized countries, the prevalence rate of *Giardia* infection ranges between 2% and 5%; in contrast, it varies from 20% to 30% in developing countries [1]. Data on the prevalence of giardiasis in many countries is limited, as is the case for Cuba. However, in Cuba, the last national survey performed in 2009 found an overall prevalence of *Giardia* infection estimated at a level of 6.02% [6], similar to the 7.2% found in the previous national survey performed in 1984 (unpublished report). Despite this decrease, higher rates of prevalence were found among young children attending day-care centers and primary schools [7—10], which is presumably related to the poor hygiene of such children and the way this facilitates the fecal—oral transmission of *Giardia* cysts.

Similar to vector-borne infectious diseases [11,12], food-borne (parasitic and non-parasitic) infections could be associated with multiple factors, including changes in environmental and social elements that may influence their epidemiology [12,13]. In particular, the effects of climate change and variability have been studied in many vector-borne diseases, such as malaria [14], dengue [11,12] and leishmaniasis [15], but not for intestinal protozoan diseases, such as giardiasis.

If climate is influencing the epidemiology of such diseases, environmental control efforts are necessary, which requires an integrated and systematic approach at both the national and community level to reduce and mitigate the impact on disease epidemiology; such efforts are obviously linked to educational programs and other interventional measures [16].

The climate may also influence the complex interacting factors, including where *Giardia* cysts can be found and favored; in this way, the possibility to produce disease could be increased significantly. This influence of climate on the spread of *Giardia* infection could be an interesting subject of investigation.

A Mexican study, using data from the period of 1976 to 1988, analyzed the seasonality of giardiasis at the national and state levels and found that for that period, this disease had a stable pattern of highest incidence in the months of July and August for the country and in 11 states of the country [17].

Based on the above-mentioned background, in this first study, we assessed the potential associations between macroclimatic variation and giardiasis cases in the context of a provincial parasitological survey in three different geographical settings of Cuba.

Figure 1 Study locations in Cuba during the period of January 2010—December 2012: the provinces of Havana (3), Ciego de Ávila (9) and Guantánamo (15).

Methods

Setting

Cuba is an island country in the Caribbean Sea (Fig. 1), including the main island of Cuba, the Isla de la Juventud and several minor islands. Havana, the capital of Cuba, has a population of 2,106,146 (according to the 2012 census); Ciego de Ávila, 422,576 pop., and Guantánamo, 510,863 pop., are two other major population centers in Cuba. According to the United Nations Development Program (UNDP), Cuba ranks 59th in the Human Development Index for 2012 (0.780), with a life expectancy of 79.3 years (http://hdrstats.undp.org/en/countries/profiles/CUB.html).

With the increasing participation of women (including mothers) in the paid labor force, a resulting demand for child care options has arisen. In Cuba, one of the formal options (i.e., regulated care settings) in child care arrangements are daycare centers (DCC), each of which are similar in terms of the facilities, organization and the level of training of their staff. Children aged from 1 to 5 years spend nearly 8 h a day in DCCs. In a DCC, in addition to regular care and educational activities, children are surveyed for intestinal parasites every 6 months. A fecal specimen, collected by parents or relatives, is obtained from each child and examined for the presence of parasitic and commensal intestinal infections by direct wet mount (a technique primarily to detect motile protozoan trophozoites, e.g., *Giardia*) and brine flotation techniques (used to confirm the presence of the parasite, the lower weight of the parasite can be identified by this technique, the parasite will float to the test tube mouth or the bottle mouth, where samples can be obtained of specimens such as the stool or other type). Families receive the results of the laboratory diagnosis, and all of those who harbored pathogenic intestinal parasites are referred to the appropriate healthcare units (mainly to their family doctors), where they may receive specific treatment and follow-up treatments.

Study design

For this record-based, ecological study, the epidemiological data were constituted of all of the half-year records of the confirmed giardiasis cases in children and adults (workers of children schools) diagnosed during the period January 1, 2010, to December 31, 2012, according to the methodology previously described. Sampling was performed at three different provinces of Cuba that covers a sample per province: Havana (capital), Ciego de Ávila (central area of the island) and Guantánamo (southeastern region) (Fig. 1). The giardiasis incidence rate was calculated as the number of cases per 10,000 population (pop.) per period (6 months). Accurate data on giardiasis was not available before 2010. Because the investigation was retrospective and based entirely on the results of the routine investigation of children and the staff of the DCCs, informed consent was not obtained specifically for the purposes of the present study.

Climatic data

The climatic data were based on one global macroclimatic index, the Oceanic Niño Index (ONI), classifying the climatic periods according to the National Oceanographic and Atmospheric Administration (NOAA, USA) classification, and the months were categorized as El Niño, Neutral and La Niña to establish differences in the giardiasis incidence according those climatic periods.

Satellite images

Monthly satellite images for Total Rainfall were obtained from the Tropical Rainfall Measuring Mission (1 month — TRMM) imagery database NASA Earth Observations (NEO, NASA, USA) (http://neo.sci.gsfc.nasa.gov/) and analyzed for Cuba using the Google Earth® software.

Data management and statistical analysis

Qualitative and quantitative comparisons were performed for the different climatic periods. Nonlinear Poisson regression models were used for determining potential associations between the climatic and the epidemiological variables analyzed at the semester level. Statistical significance was defined as $p < 0.05$. Statistical analyses were performed using Stata 11.0®.

Results

Giardiasis incidence

During the study period, 293,019 subjects were assessed, with 80.6% children and 19.4% workers. Of these subjects, 6357 were found to be positive for *Giardia*, representing a global rate of 216.95 cases/10,000 pop. (95%CI 211.7—222.2). The cumulated rates for children were significantly higher, 244.73 cases/10,000 pop. (95%CI 238.5—251.0), compared to the workers, 101.82 cases/10,000 pop. (95%CI 93.5—110.2) (Table 1). Globally, there were significant differences in the cumulated rates among the three provinces assessed, with the highest rate at Guantánamo (413.6 cases/10,000 pop.; 95%CI 413.6—455.4) (Table 1). This difference was also found for children and workers (Table 1).

Time variation in giardiasis during these 3 years exhibited different patterns according to children and workers and the three assessed provinces in Cuba (Fig. 2), varying from 35.8 to 521.9 cases/10,000 pop. (in workers) and from 88.1 to 525.8 cases/10,000 pop. (in children) (Fig. 2).

Climatic impact on giardiasis incidence

During the considered climatic periods there was a significant change from an ONI of −1.33 (La Niña) to +0.70 (El Niño). These patterns for the macroclimatic indicators were consistent with the observation of the changes in the rain patterns in Cuba, particularly at the assessed provinces, which begin in 2010 with a dry season and little rain (<100 mm) up to a rainy season (>100 mm) in 2011 (Fig. 3).

At Havana and Guantánamo, the incidence rates of giardiasis were higher at higher values of ONI (Table 2), but at Ciego de Ávila, those rates were lower at higher values of ONI (Table 2).

Nonlinear Poisson regression analysis for Havana, Ciego de Ávila and Guantánamo between the ONI index and the giardiasis incidence showed a significant association ($p < 0.01$). With lower values of ONI (below 0, La Niña periods) lower incidence of giardiasis was observed at Havana (pseudo $r^2 = 0.0576$; LR $\chi^2 = 34.05$; $p < 0.001$) (Fig. 4A) and Guantánamo (pseudo $r^2 = 0.0376$; LR $\chi^2 = 23.05$; $p < 0.001$) (Fig. 4C). At Ciego de Ávila, with lower values of ONI (below 0, La Niña periods), higher incidence of giardiasis was observed (pseudo $r^2 = 0.0080$; LR $\chi^2 = 12.88$; $p < 0.001$) (Fig. 4B).

Discussion

Giardiasis continues to be one of the most important intestinal parasitic diseases all over the world, occurring at higher incidences at developing countries, such those in Latin America. Clinical giardiasis in some countries, such as Cuba, has been reported as a common reason for hospitalization in pediatric hospitals in Havana, the capital city, where [18—21], according to a study of risk factors for *Giardia* infection among hospitalized children, it appears that, at least at the individual level, giardiasis-prevention activities in Havana should be focused on health education to improve personal hygiene and food related practices [20].

Where *Giardia* cysts transmission occurs, multiple factors can affect its dynamics, including environmental phenomena, such as the climate and its variability, and extreme anomaly phenomena, such as the El Niño Southern Oscillation (ENSO). Such effects on the transmission dynamics are profoundly incident in Latin America, particularly in countries with Ocean Pacific coasts, such as Peru and Ecuador, and in countries with Caribbean coastal regions, such as Honduras [12], Colombia [22] and Venezuela [23], where this has been demonstrated.

The ENSO phenomena is considered as a periodic change in the atmosphere and ocean of the tropical Pacific region, manifested in the atmosphere by changes in pressure and in the ocean by warming or cooling of sea surface at the tropical Eastern Pacific Ocean. In South America, the effects of ENSO on tropical diseases, including dengue and leishmaniasis have been well documented [11,15]; however, regarding giardiasis, there are no reports, either in Latin America or any other region of the World,

Table 1 Global epidemiology of giardiasis in the provinces assessed in Cuba, 2010–2012.

	Sampled subjects					Positive for giardiasis			
	Havana	Ciego de Avila	Guantánamo	Total		Havana	Ciego de Avila	Guantánamo	Total
Children									
2010–1	22,547	21,452	4967	48,966		478	189	257	924
2010–2	25,618	21,147	5292	52,057		389	203	245	837
2011–1	27,557	4850	5300	37,707		554	255	218	1027
2011–2	21,543	5517	4936	31,996		495	230	254	979
2012–1	21,789	7397	4736	33,922		378	367	226	971
2012–2	20,218	6318	4872	31,408		527	298	214	1039
Total	139,272	66,681	30,103	236,056		2821	1542	1414	5777
%	59.0	28.2	12.8	100.0	**Rates**[a]	202.55	231.25	469.72	244.73
					95CI%	195.1–210.0	219.8–242.7	445.7–493.8	238.5–251.0
Workers									
2010–1	5341	5151	989	11,481		45	31	31	107
2010–2	5862	5268	1259	12,389		21	28	22	71
2011–1	6591	1254	1267	9112		43	32	26	101
2011–2	5505	1345	1299	8149		33	27	31	91
2012–1	5217	1992	1073	8282		31	23	56	110
2012–2	4627	1834	1089	7550		45	24	31	100
Total	33,143	16,844	6976	56,963		218	165	197	580
%	58.2	29.6	12.2	100.0	**Rates**[a]	65.78	97.96	282.40	101.82
					95CI%	56.9–74.6	82.8–113.1	242.8–322.0	93.5–110.2
Total	172,415	83,525	37,079	293,019		3039	1707	1611	6357
%	58.8	28.5	12.7	100.0	**Rates**[a]	176.26	204.37	434.48	216.95
					95CI%	170.0–182.5	194.7–214.0	413.6–455.4	211.7–222.2

[a] Cases per 10,000 pop., 95CI = 95% confidence interval.

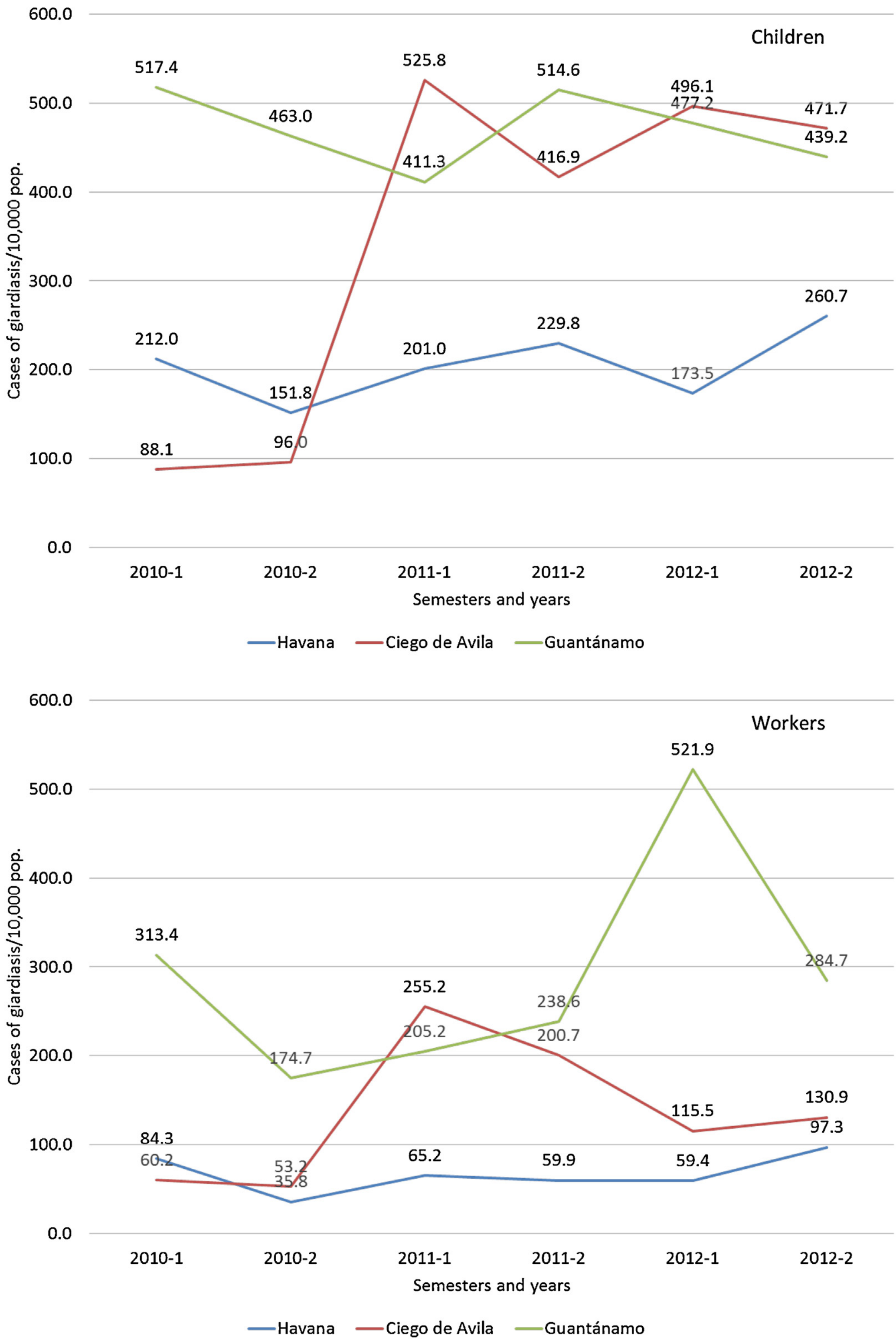

Figure 2 Time variation in rates of giardiasis (cases/10,000 pop.) in children (upper graph) and workers (lower graph), according the assessed provinces, Cuba, 2010—2012.

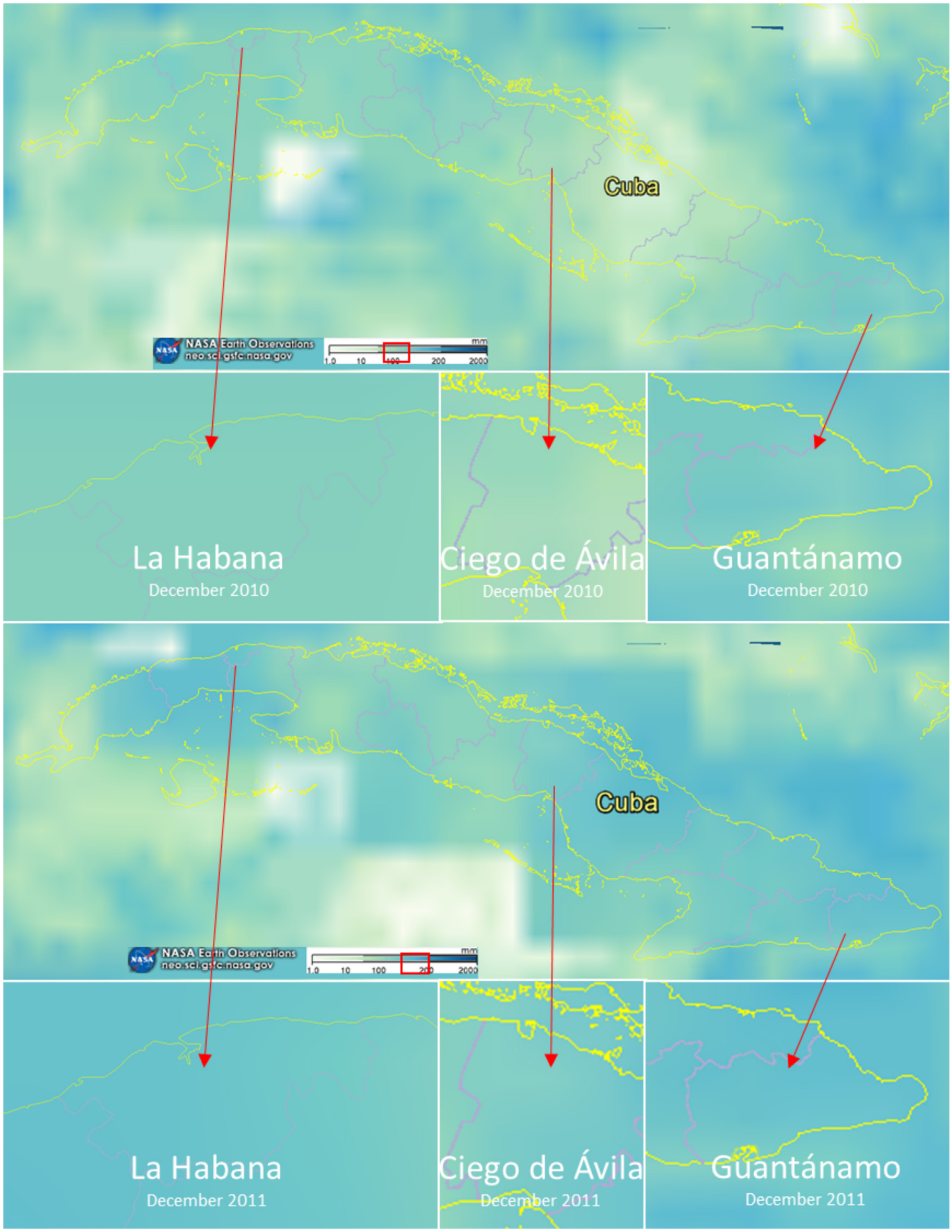

Figure 3 Rain pattern maps from the TRMM satellite for the study locations in Cuba during December 2010 and December 2011 (NEO/NASA).

specifically describing the effects of climate change on this intestinal parasitic disease.

As previously mentioned, in a study performed in Mexico, a circannual stable pattern of highest incidence was described in the months of July and August, but they did not assess the influence of climatic factors [17]. However, they suggested that their results could be associated or influenced by the environmental temperature, which, according to our criteria, seems to be a variable that should be included in further studies [17]. Similar to the work of these authors, in further studies, seasonal

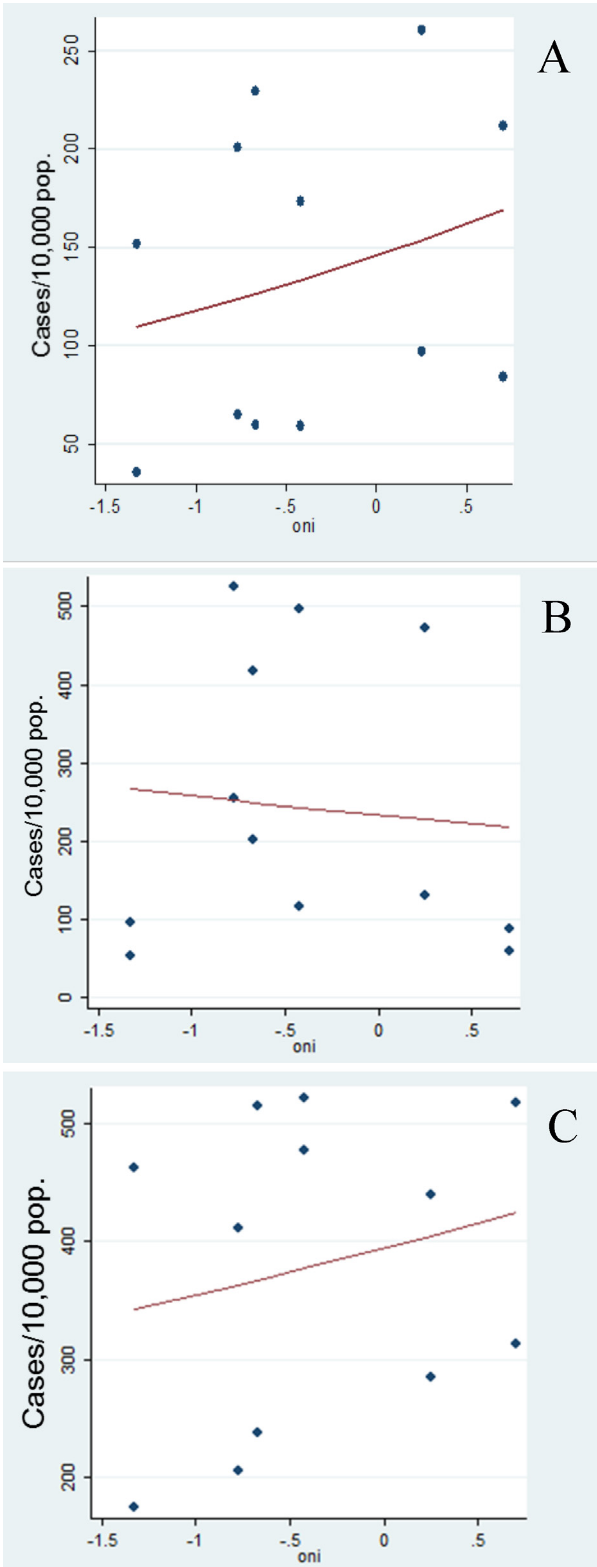

Figure 4 Regression models for Havana (A), Ciego de Ávila (B) and Guantánamo (C).

Table 2 Estimated incidence of giardiasis in the provinces assessed in Cuba, 2010—2012, according the range of ONI values.

ONI range	Estimated rate[a]	95%CI	
Havana and Guantánamo			
−1.5 to −1.0	206.3	82.6	495.3
−0.9 to −0.4	263.1	152.0	374.3
−0.39 to 0.49	270.5	47.7	493.2
0.50 to −1.00	281.8	9.3	572.9
Ciego de Ávila			
−1.5 to −1.0	74.6	53.15	95.99
−0.9 to −0.4	335.0	115.46	525.77
−0.39 to 0.49	301.3	130.86	471.67
0.50 to −1.00	74.1	60.18	88.10

[a] Cases per 10,000 pop., 95CI = 95% confidence interval.

variability data should be considered and included in the analyses.

Measurement of the ENSO phenomena has proven to be useful in vector-borne diseases epidemiology through the use of the Oceanic Niño Index (ONI) in modeling one of the independent factors affecting the dynamics of case incidence [11,23], but further studies for intestinal protozoan diseases should be extended and validated in more complete assessments. ENSO has two main phases, El Niño, the period when water in the Pacific region is warmer than the mean values (of the temperature during the previous period) while La Niña is the period when the water is colder than the mean values (of the temperature during the previous period). These periods could be measured by the ONI: positives values indicate the El Niño phase, and negative values indicate the La Niña phase. In this study, the El Niño phase was significantly associated with an increase of giardiasis incidence in Havana and Guantánamo. However, in this study at Ciego de Ávila, the trend was the opposite, with higher ONI values (El Niño) corresponding to a significant decrease, according to the regression model.

These results can be explained by the existence of environmental conditions that are influenced by that macroclimatic change and that are favorable for cyst viability in relation to the increase of rain, as is reflected in the satellite maps.

El Niño in Cuba has probably influenced microclimatic conditions, such as an increase in the rainfall and humidity and a lowering of temperatures. However, further studies using those variables in a longer time series of giardiasis incidence are required. In this study, despite its limitations, we found significant association between the climate variability and the incidence of giardiasis at Guantánamo and Havana, which is highly relevant.

However, at Ciego de Avila, we were not able to demonstrate such associations. This discrepancy could be related to the nature of the study, i.e., retrospective and lacking the ability to detect low or mild associations in some environments, such as those in that area of the country. More studies are required to demonstrate if there are significant impacts of climate variability on giardiasis incidence in that region.

Despite the limitations of our study (e.g., lack of vegetation data, such as NDVI or EVI, short-time data series, the data used here comes from only a single El Nino to La Nina transition period and cannot reflect trends for multiple events, and the use of microclimatic data), these preliminary results indicated that in this 3-year study, a significant increase of disease is observed during an El Niño event, and with La Niña, a significant decrease is observed. These inputs could be modeled and validated in additional studies using longer time series of more reliable data to develop predictive models. Furthermore, more detailed studies in Cuba and other countries in the Caribbean region are required because these models, with longer data and other variables, can be applied to surveillance via predicting trends in giardiasis and other intestinal protozoan diseases incidence in this and other countries. To improve these analyses on the effect of a variable that changes on a multi-year scale, other drivers of giardiasis should also be considered, as has been proposed for dengue [24].

The results of the potential impacts of climate variability on giardiasis epidemiology should be considered in public health policies, particularly those focused on surveillance, forecast and prediction of disease.

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Competing interests

None declared.

Ethical approval

Not required.

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