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Original Article

Serological survey for *Toxoplasma gondii* infection in two riverside communities in Northeastern Brazil

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Abstract

Introduction: Toxoplasmosis, a zoonosis caused by the parasite *Toxoplasma gondii*, is a significant global public health concern. Riverside communities often face unfavorable socioeconomic conditions that can lead to increased exposure to pathogens. This study aimed to investigate the frequency of antibodies against *Toxoplasma gondii* in two riverside communities in Northeastern Brazil.
Methodology: A cross-sectional, descriptive study was conducted between April/2022 and August/2024, involving the populations of the cities of Cabaceiras do Paraguaçu and Cachoeira in the Recôncavo Baiano region, Northeastern Brazil. Sociodemographic data were collected, and serological tests were performed to evaluate anti-*T. gondii* IgM and IgG.
Results: A total of 237 individuals were tested serologically for toxoplasmosis. The majority were female, self-identified as Black, with family incomes below the minimum Brazilian wage. In Cabaceiras do Paraguaçu, 40/74 (54.1%) individuals presented reactive anti-*T. gondii* IgG, while one (1.4%) was reactive for IgM. In Cachoeira, 80/163 (49.1%) were reactive for anti-*T. gondii* IgG, while 6 (3.7%) presented seropositivity for IgM. Individuals aged 31 years or older (Cabaceiras do Paraguaçu) and 15 years or older (Cachoeira) were associated with a higher chance of presenting anti-*T. gondii* IgG.
Conclusions: This study contributes to our understanding of the prevalence of toxoplasmosis and associated risk factors in riverside communities. The seroprevalence rates of toxoplasmosis identified in this study, including IgM-positive cases, reinforce the urgent need for interventions to prevent toxoplasmosis in riverside populations.

Key words: riverside populations; toxoplasmosis; antibodies; risk factors.

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Introduction

Toxoplasmosis is one of the most relevant zoonoses worldwide, accounting for the loss of 2 to 8 million disability-adjusted life years (DALYs) [1]. Around 2 billion people are chronically infected, with high seroprevalence rates reported in tropical regions of South America, Southeast Asia, and Africa [2]. In South America, severe forms of the disease are more common, possibly due to the genetic diversity of virulent strains [3–5]. In Brazil, toxoplasmosis is endemic, with some of the highest global infection rates and a significant burden of severe congenital forms [6].

Toxoplasmosis is caused by the protozoan *Toxoplasma gondii*, which has a worldwide distribution among mammals and birds. Both humans and domestic and wild animals have high rates of infection with *T. gondii*, although infection in humans is generally asymptomatic [7,8]. Toxoplasmosis is considered a major public health concern, since the parasite can infect several animal species and cause disease in humans, potentially leading to severe symptoms or death in immunocompromised individuals and in cases of congenital toxoplasmosis. Humans are primarily infected by ingesting water, fruits, or vegetables contaminated with oocysts excreted by felids, or by eating raw or undercooked meat containing tissue cysts [9].

The expression "riverside populations" or "riverside communities" refers to traditional groups that inhabit the banks of rivers, lakes, and streams in different regions across Brazil. These populations are characterized by an identity and lifestyle deeply shaped by the river, distinguishing them from urban and rural populations [10]. Riverside communities often face unfavorable socioeconomic conditions, including limited access to treated water, sanitation, and medical care [11], which can increase their vulnerability to parasitic diseases. These factors are especially relevant in the transmission dynamics of toxoplasmosis, given the parasite's ability to persist in the environment and infect multiple hosts [7,8].

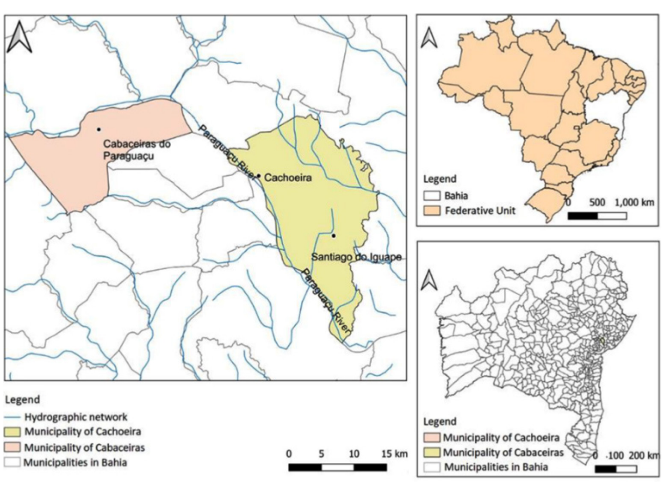
Frequent contact with rivers and forested areas, consumption of unfiltered water, and traditional dietary practices such as eating game meat and wild fruits can increase the risk of exposure to pathogens [12]. Furthermore, the lack of early diagnosis and limited health education exacerbates the situation, potentially allowing parasites to remain in the environment [13,14]. Therefore, this study aimed to evaluate the seroprevalence of toxoplasmosis and its associated risk factors in riverside communities of two municipalities of the Recôncavo da Bahia, Northeastern Brazil.

Methodology

Study design

This study was approved by the Research Ethics Committee of the Faculty of Pharmacy, Federal University of Bahia, Bahia, Brazil (protocol number 6,513,518). It is a cross-sectional and descriptive study carried out between April 2022 and August 2024, involving the riverside families of the cities of Cabaceiras do Paraguaçu and Cachoeira, located in the Recôncavo da Bahia, Bahia, in Northeastern Brazil [15,16]. The two municipalities are located approximately 150 km from the capital of the state of Bahia (Salvador), on the banks of the Paraguaçu River (Figure 1). The Paraguaçu River is the largest located entirely within the state of Bahia, with 500 kilometers, which crosses several cities and has great historical and economic importance for the Recôncavo region.

Figure 1. The geographic location of the two riverside communities included in the study.



The municipalities of Cabaceiras do Paraguaçu and Cachoeira are located on the banks of the Paraguaçu River, Recôncavo da Bahia region, state of Bahia, Northeastern Brazil.

After presenting the project to the communities and government representatives of the municipalities, families living on the river banks were invited to participate, with support of community representatives and municipal health sector. A total of 74 individuals from Cabaceiras do Paraguaçu and 163 from Cachoeira agreed to participate in the study. Families' members who voluntarily agreed to participate were invited to review and sign the Informed Consent Form, and for children aged 0 - 17 years, an Assent Form was also required. Upon consent, participants completed a questionnaire covering socioeconomic characteristics, household sanitary conditions and hygiene habits. Subsequently, blood collections were carried out on previously scheduled dates on the premises of a local school or at the families' homes.

Detection of IgM and IgG antibodies against T. gondii

Blood was collected from the cubital vein using a vacuum tube with separator gel and clot activator (BD Vacutainer ® SST ™ - Yellow Cap). After, blood samples were centrifuged at 1,200 x *g* for 10 minutes and serum samples were stored at -20 °C until testing.

Anti-*T. gondii* IgM and IgG antibodies were detected by chemiluminescence immunoassay (CLIA), using the ARCHITECT TOXO IgM and ARCHITECT TOXO IgG Reagent Kits (Abbott Laboratories, Chicago, IL, USA), according to the manufacturer's instructions, on the fully automated Architect® system i1000SR (Abbott Laboratories**).** Reactive results for IgM were confirmed using additional immunoassays: the MAGLUMI® Toxo IgM reagent (CLIA), on an automated MAGLUMI X3 system (Snibe Diagnostic®**,** Shenzhen, China), and the ELISA *Toxoplasma gondii* IgM (EUROIMMUN**,** Lübeck, Germany).

Statistical Analysis

Frequency, central tendency, and dispersion measures were analyzed. The choice between parametric and non-parametric tests was based on the Kolmogorov-Smirnov (KS) normality test. The binomial test for a single proportion was used to calculate the confidence interval (CI) of the proportions. Binary logistic regression analysis was used to identify risk factors associated with anti- *T. gondii* IgG. The odds ratios (ORs) were obtained from

Table 1. Anti-*T. gondii* IgG and IgM antibodies seropositivity in residents of two riverside communities of the Bahia state, Northeastern Brazil.

Municipality	Biomarker (anti- *T. gondii*)	Negative n (%)	Positive n (%)
Cabaceiras do Paraguaçu (n = 74)	IgG	34 (45.9)	40 (54.1)
	IgM	73 (98.6)	1 (1.4)
Cachoeira (n = 163)	IgG	83 (50.9)	80 (49.1)
	IgM	157 (96.3)	6 (3.7)

the Beta coefficient obtained from the multivariate model. Statistical significance was established as $p \leq 0.05$, with a 95% CI and two-tailed analysis. Statistical analyses were performed using SPSS® software, version 26.0 (IBM Corp., Armonk, NY, USA).

Results

Sociodemographic profile of the study population

In Cabaceiras do Paragaçu, the study population had a mean age of 33.84 years (± 20.92), ranging from 1 to 74 years. Most participants were between 31 and 60 years (45.95%) and were female (51.35%). In Cachoeira, the population had a mean age of 21.45 years (± 13.78), ranging from 11 to 65 years. Most participants were between 0 and 14 years old (51.53%) and were female (61.96%). Regarding household income, 74.32% individuals from Cabaceiras do Paraguaçu and 63.19% from Cachoeira reported earning less than the Brazilian minimum wage (around US$ 277.00) per month. More than 70% of participants from both communities self-identified themselves as Black or Brown (mixed race) and 25.68% individuals from Cabaceiras do Paraguaçu had no formal education (data not shown).

Considering that the population of Cachoeira was composed mostly of children and adolescents, while the population of Cabaceiras do Paraguaçu was composed mostly of adults, the subsequent analyses of seroprevalence of *T. gondii* infection and its associated risk factors were conducted separately for the two riverside populations. In particular, the analysis of toxoplasmosis in adolescents is also noteworthy, as there are few published studies involving this age group.

Frequencies of anti-T. gondii IgG and IgM antibodies in two riverside communities

In Cabaceiras do Paraguaçu, the overall

Table 2. Assessment of the association of risk factors with seropositivity for anti-*T. gondii* IgG in residents of the riverside community of Cabaceiras do Paraguaçu (n = 74), Northeastern Brazil.

Variable	Anti-*T. gondii* IgG negative n (%)	Anti-*T. gondii* IgG positive n (%)	OR (CI95%)	*p*
Age range				
30 years or younger	22 (64.7)	9 (22.5)	Ref.	< 0.001*
31 years or older	12 (35.3)	31 (77.5)	6.31 (2.27 – 17.56)	
Sex				
Male	20 (58.8)	15 (38.5)	Ref.	0.085
Female	14 (41.2)	24 (61.5)	2.28 (0.89 – 5.85)	
Income				
Greater than 1 minimum wage	0	6 (17.1)	**	**
Less than or equal to 1 minimum wage	26 (100)	29 (82.9)		
Occupation				
Other	24 (70.6)	22 (55.0)	Ref.	0.171
Farmer	10 (29.4)	18 (45.0)	0.51 (0.19 – 1.34)	
Racial self-identification				
White	2 (5.9)	2 (5.0)	Ref.	0.867
Black/Brown	32 (94.1)	38 (95.0)	1.18 (0.16 – 8.91)	
Education				
High school level or higher	4 (12.5)	9 (23.7)	Ref.	0.237
Incomplete high school level or lower	28 (87.5)	29 (76.3)	2.17 (0.60 – 7.87)	
Pets				
No	11 (32.4)	14 (35.0)	Ref.	0.810
Yes	23 (67.6)	26 (65.0)	1.13 (0.43 – 2.97)	
Walk barefoot on the ground				
No	13 (38.2)	17 (42.5)	Ref.	0.710
Yes	21 (61.8)	23 (57.5)	1.19 (0.47 – 3.04)	
Type of drinking water				
Bottled/filtered/boiled	20 (46.8)	30 (75.0)	Ref.	0.142
Untreated tap water	14 (53.2)	10 (25.0)	0.48 (0.18 – 1.28)	
How to sanitize fruits/vegetables				
Vegetable sanitizer (diluted bleach)	14 (41.2)	16 (40.0)	Ref.	0.918
Tap water/dish detergent	20 (58.8)	24 (60.0)	1.05 (0.41 – 2.66)	

* Statistically significant association; ** Unable to calculate; Statistical tests: Multivariate logistic regression; Ref. – Reference group.

seropositivity rate for chronic *T. gondii* infection was 54.1% (95% CI: 42.8% – 64.9%), while for anti-*T. gondii* IgM antibodies was 1.4% (95% CI: 0.24% - 7.3%). In Cachoeira, the frequency of anti-*T. gondii* IgG and IgM were 49.1% (95% CI: 41.5% - 56.7%) and 3.7% (95% CI: 1.7% – 7.8%), respectively (Table 1). The IgM-positive individuals were between 11 and 16 years old, five were female and two were male, and they did not present signs or symptoms of toxoplasmosis. The results were reactive in at least two different serological methodologies (CLIA and ELISA) (data not shown).

Association between socio-environmental determinants and the presence of anti-T. gondii IgG antibodies

The association of positivity for anti-*T. gondii* IgG with risk factors for the parasite infection was examined. In Cabaceiras do Paraguaçu, the prevalence of anti-*T. gondii* IgG was significantly higher among individuals aged 31 years or older (77.5%) compared to those aged 30 years or younger (22.5%) (OR = 6.31; 95% CI: 2.27–17.56; $p \leq 0.001$) (Table 2). Moreover, IgG seropositivity tended to be higher in women (61.5%) than in men (38.5%), although not significant (OR = 2.28; 95% CI: 0.89–5.85; $p = 0.085$). Other socioeconomic variables, such as family income, race, and educational level, were not statistically significant (Table 2).

In Cachoeira, the seropositivity for anti-*T. gondii* IgG was significantly higher among individuals aged 15 years or older (61.3%) compared to those under 15 years (38.8%) (OR = 2.94; 95% CI: 1.56–5.57; $p < 0.001$) (Table 3). No statistically significant associations were identified between infection and other sociodemographic variables analyzed, including sex, income, and education level (Table 3).

Discussion

The prevalence of toxoplasmosis can vary depending on regional and climatic differences. In general, riverside communities often face inequalities, and public policies struggle to reach them. This may be

Table 3. Assessment of the association of risk factors with seropositivity for anti-*T. gondii* IgG in residents of the riverside community of Cachoeira (n = 163), Northeastern Brazil.

Variable	IgG anti-*T. gondii* negative n (%)	IgG anti-*T. gondii* positive n (%)	OR (95% CI)	*p*
Age			Ref.	
0 to 14 years	54 (65.1)	31 (38.8)	2.94 (1.56 – 5.57)	0.001*
15 years or older	29 (34.9)	49 (61.3)		
Sex				
Male	32 (38.6)	30 (37.5)	Ref.	0.89
Female	51 (61.4)	50 (62.5)	1.05 (0.55 – 1.97)	
Income				
Greater than 1 minimum wage	18 (25.7)	21 (29.2)	Ref.	0.645
Less than or equal to 1 minimum wage	52 (74.3)	51 (70.8)	1.19 (0.57 – 2.49)	
Occupation				
Other	81 (100)	73 (97.3)	**	**
Farmer	0	2 (2.7)		
Racial self-identification				
White	2 (2.4)	0	**	**
Black/Brown	81 (97.6)	80 (100)		
Education				
High school level or higher	6 (7.2)	8 (10.1)	Ref.	0.514
Incomplete high school level or lower	77 (92.8)	71 (89.9)	1.45 (0.48 – 4.37)	
Pets				
No	20 (24.1)	26 (32.5)	Ref.	0.235
Yes	63 (75.9)	54 (67.5)	1.52 (0.76 – 3.01)	
Walk barefoot on the ground				
No	27 (32.5)	34 (42.5)	Ref.	0.19
Yes	56 (67.5)	46 (57.5)	1.53 (0.81 – 2.90)	
Type of drinking water				
Bottled/filtered/boiled	77 (96.3)	78 (97.5)	Ref.	0.652
Untreated tap water	3 (3.8)	2 (2.5)	0.66 (0.11 – 4.05)	
Wash fruits/vegetables before eating				
Yes	78 (94.0)	76 (95.0)	Ref.	0.775
No	5 (6.0)	4 (5.0)	0.82 (0.21 – 3.17)	
How to sanitize fruits/vegetables				
Vegetable sanitizer (diluted bleach)	32 (38.6)	25 (31.3)	Ref.	0.329
Tap water/dish detergent	51 (61.4)	55 (68.7)	1.38 (0.72 – 2.64)	
Eat raw or undercooked meat				
No	75 (90.4)	72 (90.0)	Ref.	0.938
Yes	8 (9.6)	8 (10.0)	0.96 (0.34 – 2.69)	

* Statistically significant association; ** Unable to calculate; Statistical tests: Multivariate logistic regression; Ref. – Reference group.

due to their location, which is often far from urban centers, and the lack of connection between these policies and the local population's way of life. Although riverside populations are present around the world, data about *T. gondii* infection and other communicable diseases are scarce. In Brazil, there are few studies carried out with these populations, restricted to Amazon region [17,18]. To our knowledge, there are no studies on prevalence of *T. gondii* infection in riverside populations in the state of Bahia.

The IgG seropositivity against *T. gondii* identified in our study (Cabaceiras do Paraguaçu - 54.1%, and Cachoeira - 49.1%) was comparable to other studies carried out in riverside communities. In riverside communities from the municipality of Lábrea, located in the State of Amazonas, Northern Brazil, the overall seroprevalence of anti-*T. gondii* antibodies was 56.7%, with 14 individuals reactive for IgM and 117 reactive for IgG [17]. A study carried out in the Marajó Archipelago, State of Pará, also in the Brazilian Amazon, the seroprevalence for IgG anti-*T. gondii* was 62.6% [18].

The prevalence of anti-*T. gondii* antibodies in the Brazilian population varies significantly across regions and is may be influenced by factors such as socioeconomic conditions, cultural habits, and environmental aspects. A serosurvey conducted in a non-riverside rural area of Ivaiporã city, Paraná State, Southern Brazil, has revealed 73.57% positive individuals for anti-*T. gondii* IgG [19]. Another study in the same state with four different Brazilian *quilombos* (Former Black Slave), located in non-riverside rural areas, revealed an anti-*T. gondii* IgG prevalence of 44.7% [12].

The detection of IgM antibodies against *T. gondii* in the studied population indicates recent contact with the parasite or acute-phase infection, representing an epidemiologically relevant finding. IgM antibodies typically appear within the first few weeks following infection and may persist for several months, which can hinder the distinction between recent infection and past infection with residual IgM [20].

Regarding the prevalence of anti- *T. gondii* IgM identified in our study (3.7% in Cachoeira and 1.4% in Cabaceiras do Paraguaçu), the only other study conducted in riverside communities that we are aware of was the one described previously [17]. The differences observed in IgM frequencies reported in the studies, may be associated with the socioeconomic conditions and dietary habits of the populations. In the present study, the cases of positive IgM occurred in individuals between 11 and 16 years old and were confirmed by at least two different serological methods. Despite the positive IgM results, these individuals did not report any signs or symptoms.

Studies involving children and adolescents in the same age range have shown a prevalence of IgM antibodies similar to that found in this study [21,22]. However, it is important to mention that a diagnosis based solely on the presence of IgM can lead to false positives; therefore, in suspected clinical cases, confirmatory tests such as IgG avidity testing or Polymerase Chain Reaction (PCR) are recommended [23], and these tests were not performed in our study.

The presence of IgM-positive individuals suggests that active transmission of toxoplasmosis may be occurring in the community. According to studies, toxoplasmosis transmission may be associated with environmental and behavioral factors, such as consumption of contaminated water or food, ingestion of undercooked meat, or contact with cats without proper hygiene measures [7,23,24]. Studies conducted in regions with similar socioeconomic conditions have also identified an association of low levels of education and social vulnerability with increased risk of acute *T. gondii* infection [2].

Unlike the population of Cabaceiras do Paraguaçu, slightly more than half (51.53%) of the individuals in the municipality of Cachoeira were between 0 and 14 years old. Considering the prevalence of IgG (36.47%) in this age group alone, it is comparable to the prevalence of 38.95% found in riverside communities in the Amazon [17]. Age was a variable significantly associated with anti-*T. gondii* IgG seropositivity in both riverside populations involved in our study. Individuals aged 31 years or older (Cabaceiras do Paraguaçu) and 15 years or older (Cachoeira) had a higher likelihood of presenting IgG anti-*T. gondii*.

Although the study carried out in riverside communities in the Amazon did not find an association with age [17], these results are in line with studies carried out in rural or urban populations [18–26]. Our findings are also in agreement with previous studies reporting that IgG seroprevalence increases with age, which is likely attributable to the cumulative risk of exposure to the parasite over time [27].

The seroprevalence observed in this study aligns with findings from other populations living under similar socioeconomic and environmental conditions, where rates above 50% are frequently reported, particularly in rural areas and communities facing high social vulnerability [18,25,26], including riverbank populations [17]. Although the results revealed that the riverside communities involved in our study were facing low socioeconomic conditions and were exposed to risk factors for toxoplasmosis, none of these variables showed a statistical association with the infection.

The limitations of this study include the differences in the age profile of the studied populations, since most of the participants in the riverside community of Cachoeira were adolescents and young individuals. Regarding the IgM results, although confirmed by at least two different serological methodologies, other confirmatory tests to determine whether these could be an active primary infection were not performed. Despite this, we consider that our results were similar and consistent between the two populations and when compared with other studies in the literature. It is important to emphasize that the presence of IgM antibodies to *T. gondii* in young women of childbearing age is a warning sign for the need for public health interventions, especially education on the prevention of congenital toxoplasmosis.

Conclusions

To date, there are few studies on communicable diseases in riverside communities. This study contributes to our understanding of the prevalence of toxoplasmosis and associated risk factors in these populations. These data are important for developing public policies that reach these populations and connect with their way of life. It reinforces the need for continuous epidemiological surveillance and the implementation of health education strategies aimed at preventing acute and chronic infections, especially in riverside areas, where risk factors are frequently present.

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Conflict of interest

No conflict of interest is declared.

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