ARCHIVES OF Health Sciences

ORIGINAL ARTICLE
ISSN 2318-3691

DOI: 10.17696/2318-3691.31.01.2025.254

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Author's contributions: JLTL: collection, tabulation, study design, data analysis, writing, and discussion of the manuscript; LRSM: collection, tabulation, and discussion of the manuscript; MSM: writing and discussion of the manuscript; JRSSP: writing and discussion of the manuscript; MAOG: writing and discussion of the manuscript; MVSP writing and discussion of the manuscript; ADS: project guidance, study design, writing and discussion of the manuscript. All authors approved the manuscript´s final version.

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Conflict of interest: No

Funding: Coordination for the Improvement of Higher Education Personnel (CAPES of the Brazilian Ministry of Health) and National Council for Scientific and Technological Development (CNPq of the Ministry of Science, Technology and Innovation).

Acknowledgment: We would like to thank the State Department of Health of Sergipe, Brazil, for their support and provision of data to carry out this research.

Received: 21/08/2024
Aprovado: 25/02/2025

Epidemiological aspects and spatial distribution of cases o f *Toxoplasma gondii* infection i n pregnant women in the state of Sergipe, Brazil

Aspectos epidemiológicos e distribuição espacial dos casos de infecção pelo Toxoplasma gondii em gestantes no estado de Sergipe, Brasil

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ABSTRACT

Introduction: Toxoplasmosis is an infectious disease caused by the protozoan *Toxoplasma gondii*, which can infect humans and other warm-blooded animals. In humans, when contracted during pregnancy, it poses a significant public health concern due to the risk of vertical transmission. This transmission can lead to miscarriage or severe complications for the fetus and newborn. **Objective:** To analyze the epidemiological aspects and patterns of spatial distribution of the occurrence of *T. gondii* infection in pregnant women reported in the state of Sergipe, Brazil, between 2019 and 2021. **Methods:** Descriptive, retrospective study using spatial analysis techniques of reported cases of toxoplasmosis acquired during pregnancy in the state of Sergipe. Descriptive statistical analysis was performed, with absolute and relative frequencies of categorical variables, and for spatial analysis; the Kernel intensity estimator was used. **Results:** The cases primarily involved young, low-educated, single adult women of brown ethnicity residing in urban areas. Most were multiparous and consumed untreated water, raw or undercooked beef, and unprocessed veges. Spatial analysis revealed cases across all state regions, with clustering observed in certain municipalities. **Conclusion:** Low educational levels and socioeconomic conditions may increase women's vulnerability to risk; hinder preventive care and be directly associated with the incidence of gestational toxoplasmosis. This study provides an epidemiological and spatial characterization of cases, offering valuable insights to inform discussions and guide the development of new public health and educational policies.

Keywords: Spatial Analysis; Pregnancy Complications, Infectious; Disease Notification; Epidemiology; Toxoplasmosis.

RESUMO

Introdução: A toxoplasmose é considerada uma doença infecciosa causada pelo protozoário *Toxoplasma gondii*, provocando infecções em humanos e outros animais de sangue quente. Em humanos, quando ocorre durante a gestação, constitui um grave problema de saúde pública, devido ao risco de transmissão vertical, que pode ocasionar aborto e resultar em complicações para o feto e recém-nascido. **Objetivo:** Analisar os aspectos epidemiológicos e os padrões da distribuição espacial da ocorrência de infecção pelo *T. gondii* em gestantes notificadas no estado de Sergipe, Brasil, entre os anos de 2019 e 2021. **Métodos:** Estudo descritivo, de caráter retrospectivo e com técnicas de análise espacial dos casos notificados de toxoplasmose adquirida na gestação no estado de Sergipe. Realizou-se análise estatística descritiva, com frequências absolutas e relativas das variáveis categóricas e para a análise espacial utilizou-se o estimador de intensidade Kernel. **Resultados:** Observou-se que o perfil dos casos é de mulheres adultas jovens, pardas, com baixa escolaridade, solteiras, residentes na zona urbana, multigestas, multíparas, consomem água sem tratamento prévio, carne bovina crua e/ou malcozida e vegetais *in natura*. A análise espacial demonstrou a ocorrência de casos em todas as regiões do estado, com aglomeração em determinados municípios. **Conclusão:** A baixa escolaridade e as condições socioeconômicas podem tornar as mulheres vulneráveis ao risco e dificultar nos cuidados preventivos, podendo demonstrar relação direta com a incidência de toxoplasmose gestacional. Este estudo possibilitou a caracterização epidemiológica e espacial dos casos, trazendo subsídios que podem contribuir na discussão e implementação de novas estratégias de políticas públicas de saúde e educação.

Descritores: Análise Espacial; Complicação Infecciosa na Gravidez; Notificação d e Doenças; Epidemiologia; Toxoplasmose.

INTRODUCTION

Toxoplasmosis is a neglected systemic infectious disease caused by the parasitic protozoan Toxoplasma *gondii*. It infects humans and other warm-blooded animals and is classified as a zoonotic disease with global distribution. [1-5]. It prevails in hot and humid climates and varies in intensity according to geographic regions, sanitary conditions, dietary habits, and cultural and socioeconomic factors[6, 7].

In immune-competent individuals, infection by *T. gondii* is self-limiting, usually occurring asymptomatically or with mild symptoms such as fever, headache, and epigastric and muscle pain. However, when it occurs during pregnancy, it constitutes a serious public health problem, due to the risk of vertical transmission (VT), which can cause miscarriage or result in complications for the fetus and newborn, ranging from subclinical manifestations to ocular and neurological disorders[3, 8-9].

The global seroprevalence of toxoplasmosis in the general population ranges from 10 to 97.4% in the adult population and approximately one-third of women have reactive serology for latent toxoplasmosis[10-11]. In Brazil, seroprevalence in the adult population ranges from 40 to 80%, depending on the regions studied, 60 to 75% of women are infected at childbearing age, and during pregnancy, it is estimated to be around 14 cases per 1,000 pregnant women[12-14].

A study carried out in the city of Aracaju, state of Sergipe, revealed a high prevalence of seropositivity in pregnant women. Serum samples from 4,883 pregnant women were analyzed; 68.5% had *anti-T. gondii* antibodies and approximately 30% of these women were exposed to risk factors related to toxoplasmosis, such as low socioeconomic status and teenage pregnancy[15].

In Brazil, the rate of VT is six to 10% in the first quarter and 70 to 90% in the third quarter of pregnancy[3]. The estimated incidence of congenital toxoplasmosis (CT) ranges from 0.3 to 3.4 cases per 1,000 live births (LB) and mortality can range from 0.7 to 3.4 deaths per 100,000 LB[16]. The state of Sergipe is no different from the national scenario, with an estimated prevalence of CT at birth of four cases per 10,000 LB[17].

Timely reporting, investigation, and diagnosis of cases of toxoplasmosis acquired during pregnancy enable the identification of outbreaks, rapid blocking of the source of transmission, and the taking of timely prevention and control measures. In addition, providing appropriate therapeutic intervention and consequent reduction of VT, complications, sequelae, and deaths[2]. In this context, the epidemiological and spatial characterization of acute *T. gondii* infection in pregnant women contributes to a better understanding of the dynamics of toxoplasmosis, favoring the development of public policies that strengthen planning, prevention, perinatal health promotion, control, and epidemiological surveillance of toxoplasmosis.

Accordingly, this study aimed to analyze the epidemiological characteristics and spatial distribution patterns of *Toxoplasma gondii* infection in pregnant women reported in the state of Sergipe, Brazil, between 2019 and 2021.

METHODS

This is a descriptive, retrospective study using spatial analysis techniques on cases of toxoplasmosis acquired during pregnancy reported in the state of Sergipe from January 2019 to December 2021. Case data were obtained from the Notifiable Diseases Information System (Sinan), the Live Birth Information System (Sinasc), and the case investigation panel of the Health Surveillance Directorate (HSD) of the State Health Department (SHD) of Sergipe. The period chosen for the study was the first three years of the Toxoplasmosis Control and Epidemiological Surveillance Program in the state of Sergipe.

The state of Sergipe, one of the 27 states of the Federative Republic of Brazil, is located in the Northeast region, bordered by Bahia and Alagoas and the Atlantic Ocean to the east. Its territorial area is 21,938.188 km², with an estimated population of 2,338,474 inhabitants. The state has 75 municipalities, with the city of Aracaju as its capital, and is formed by eight geographic regions called: High Sertão, Lower São Francisco, Middle Sertão, Eastern, Central Agreste, South, Center and Greater Aracaju (Figure 1).[18-19].

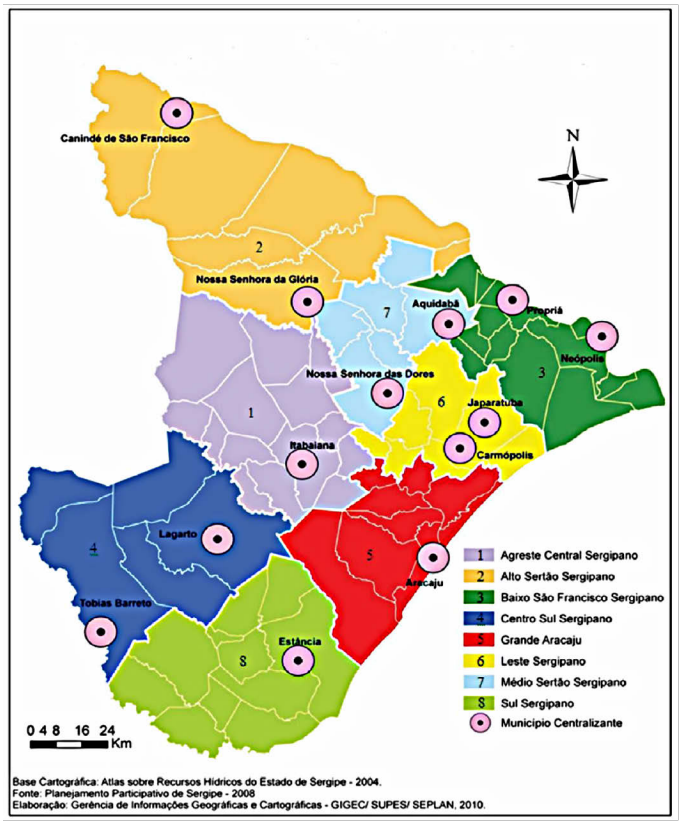

Figure 1. Map of the state of Sergipe, according to geographic regions
Source: Prepared by the State Planning Secretariat of Sergipe (2010).

After authorization and provision of data by the HSD/SHD; cases of toxoplasmosis acquired during pregnancy were tabulated and analyzed using the BioEstat 5.3 software. A descriptive statistical analysis was performed, with absolute and relative frequencies of categorical variables according to information from notification/conclusion forms available on Sinan, live birth certificates from Sinasc, and the monitoring panel for cases of toxoplasmosis acquired during pregnancy. The variables analyzed were:

- Sociodemographic variables: age group, race/color, education, occupation/profession, marital status, municipality of residence, area of residence;
- Prenatal and obstetric history variables: a quarter of pregnancy, number of prenatal consultations, number of pregnancies, number of births, pregnant woman living with HIV, contact with a cat during the current pregnancy, handling soil without gloves, exposure to garbage and/or waste and treatment for toxoplasmosis;
- Dietary habits variables: consumption of fresh cheese, consumption of cow's milk, consumption of raw/undercooked poultry, consumption of raw/undercooked beef, consumption of

raw/undercooked lamb, consumption of raw/undercooked pork, consumption of fresh fruit, consumption of fresh vegetables and legumes, and water consumption.

The detection rates were calculated by the number of reported cases of toxoplasmosis acquired during pregnancy (in a given year of diagnosis and place of residence) in the numerator and the number of live births (from mothers living in the same place and same year) in the denominator, multiplied by 1000.

For spatial location, the cases reported in Sergipe were georeferenced using geographic coordinates, according to the address of residence. The latitude and longitude of the geographic information were obtained from Google Earth Pro Version 9.189.0.0.

The maps were constructed and analyzed using TerraView 4.2.2 software. The cartographic projection corresponded to the Universal Transverse Mercator (UTM) system, using the SIRGAS 2000 Earth Datum model. The Kernel intensity estimator was used, a non-parametric technique that allows estimating the number of events per unit area in each cell of a regular grid covering the studied region. Through statistical smoothing or attenuation, this technique generates a density surface for the visual detection of "hot spots" or hotspots, understood as a concentration of events that somehow indicates agglomeration in spatial distribution and a continuous surface from point data[20-22].

The research project was approved by the Research Ethics Committee of the Federal University of Sergipe according to opinion number 4,910,598 and Certificate of Presentation for Ethical Assessment (CAAE) number 45061021.1.0000.5546 following the guidelines of Resolution 466 of December 12, 2012, of the National Health Council (NHC).

RESULTS

During the period from 2019 to 2021, 449 confirmed cases of toxoplasmosis acquired during pregnancy were reported in the state of Sergipe, with a mean of 149.87 cases/year and a detection rate of 4.7 cases per 1,000 LB. There was a decrease (6.38%) in notifications in 2020, and in 2021 there was an increase of 24.8% compared to 2020 (Figure 2).

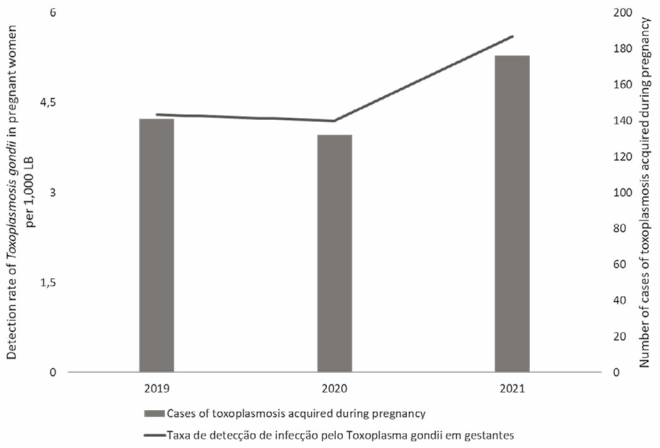

Figure 2. Reported cases of toxoplasmosis acquired during pregnancy and detection rate of Toxoplasma gondii infection in pregnant women (per 1,000 live births). Sergipe, Brazil, 2019-2021
Source: Prepared by the authors.

Analyzing the sociodemographic characteristics of the cases, it was observed that the predominant age group was young adults, between 20 and 29 years old, corresponding to 54.1% (243/449); a higher proportion of brown race/color with 68.6% (308/449); prevailing in women with low education, with a percentage of 59.7% (268/449) with incomplete high school education or lower levels of education; 67.3% (302/449) of the women were single; and 66.8% (300/449) lived in urban areas (Supplementary Table). Regarding the occupation or profession of these women; 39.9% (179/449) were housewives, followed by agricultural workers with 23.2% (104/449) and students with 12.9% (58/449).

Regarding the characterization of prenatal care, it was observed that 46.8% (210/449) of pregnant women were diagnosed during the second quarter; and 77.3% (347/449) had seven or more consultations during prenatal care. Regarding obstetric history, women who had had more than one pregnancy (multiparous) predominated, corresponding to 53.9% (242/449); 50.3% (226/449) were nulliparous, that is, they had never had children; 0.4% (2/449) of pregnant women were living with HIV; 33% (148/449) of women had contact with cats during pregnancy; 24.7% (111/449) handled soil without using gloves; 14% (63/449) were exposed to garbage and/or waste; and 84.7% (352/449) underwent drug therapy for *T. gondii* infection (Table 1).

Table 1. Distribution of reported cases of toxoplasmosis acquired during pregnancy, according to prenatal variables and obstetric history. Sergipe, Brazil, 2019 to 2021.

Variable	Year						Total	
	2019		2020		2021			
	n	%	n	%	n	%	n	%
Pregnancy quarter (diagnosis)								
1st quarter	26	18.4	25	18.9	25	14.2	76	16.9
2nd quarter	61	43.3	63	47.7	86	48.9	210	46.8
3rd quarter	32	22.7	30	22.7	45	25.6	107	23.8
No information	22	15.6	14	10.6	20	11.4	56	12.5
Number of prenatal consultations								
1-3	3	2.1	1	0.8	2	1.1	6	1.3
4-6	26	18.4	22	16.7	29	16.5	77	17.1
7 and more	107	75.9	105	79.5	135	76.7	347	77.3
No information	5	3.5	4	3.0	10	5.7	19	4.2
Number of pregnancies								
Primiparous	68	48.2	57	43.2	77	43.8	202	45
Multiparous	71	50.4	75	56.8	96	54.5	242	53.9
No information	2	1.4	0	0	3	1.7	5	1.1
Number of deliveries								
Nulliparous	75	53.2	63	47.7	88	50	226	50.3
Multiparous	64	45.4	69	52.3	85	48.3	218	48.6
No information	2	1.4	0	0	3	1.7	5	1.1
Pregnant woman living with HIV								
Yes	0	0.0	1	0.8	1	0.6	2	0.4
No	120	85.1	127	96.2	166	94.3	413	92.0
No information	21	14.9	4	3.0	9	5.1	34	7.6
Contact with cat during current pregnancy								
Yes	46	32.6	42	31.8	60	34.1	148	33.0
No	43	30.5	58	43.9	80	45.5	181	40.3
No information	52	36.9	32	24.2	36	20.5	120	26.7
Handling soil without gloves								
Yes	34	24.1	33	25.0	44	25.0	111	24.7
No	55	39.0	62	47.0	97	55.1	214	47.7
No information	52	36.9	37	28.0	35	19.9	124	27.6
Exposure to garbage and/or waste								
Yes	27	19.1	10	7.6	26	14.8	63	14.0
No	62	44.0	87	65.9	111	63.1	260	57.9
No information	52	36.9	35	26.5	39	22.2	126	28.1
Treatment for toxoplasmosis								
Yes	100	70.9	103	78.0	149	84.7	352	78.4
No	2	1.4	2	1.5	2	1.1	6	1.3
No information	39	27.7	27	20.5	25	14.2	91	20.3

Source: Prepared by the authors.

Regarding the characterization of the variables of eating habits; 58.3% (262/449) of the pregnant women consumed fresh cheese, 42.5% (191/449) consumed boiled cow's milk and 4.5% (20/449) consumed food in its natural form. Regarding the consumption of undercooked meat, 12% (54/449) of the pregnant women consumed poultry; 38.3% (172/449) consumed beef; 6% (27/449) consumed lamb; and 9.8% (44/449) consumed pork (Table 2).

Table 2. Distribution of reported cases of toxoplasmosis acquired during pregnancy, according to dietary habits variables. Sergipe, Brazil, 2019 to 2021.

Variable	Year						Total	
	2019		2020		2021			
	n	%	n	%	n	%	n	%
Consumption of fresh cheese								
Yes	68	48.2	79	59.9	115	65.4	262	58.3
No	15	10.6	19	14.4	22	12.5	56	12.5
No information	58	41.1	34	25.8	39	22.2	131	29.2
Cow's milk consumption								
Boiled	37	26.2	61	46.2	93	52.8	191	42.5
In natura	5	3.5	9	6.8	6	3.4	20	4.5
Pasteurized	36	25.5	13	9.8	28	15.9	77	17.1
Do not consume	8	5.7	16	12.1	12	6.8	36	8.0
No information	55	39.0	33	25.0	37	21.0	125	27.8
Consumption of raw/undercooked poultry meat								
Yes	23	16.3	15	11.4	16	9.1	54	12.0
No	63	44.7	82	62.1	122	69.3	267	59.5
No information	55	39.0	35	26.5	38	21.6	128	28.5
Consumption of raw/undercooked beef								
Yes	38	26.9	34	25.8	100	56.8	172	38.3
No	50	35.5	64	48.5	38	21.6	152	33.9
No information	53	37.6	34	25.8	38	21.6	125	27.8
Consumption of raw/undercooked sheep meat								
Yes	12	8.5	8	6.1	7	4.0	27	6.0
No	76	53.9	89	67.4	130	73.9	295	65.7
No information	53	37.6	35	26.5	39	22.2	127	28.3
Consumption of raw/undercooked pork								
Yes	17	12	16	12.1	11	6.3	44	9.8
Do not consume	71	50.4	82	62.1	127	72.2	280	62.4
No information	53	37.6	34	25.8	38	21.6	125	27.8
Consumption of fresh fruits								
Yes	85	60.3	92	69.7	136	77.3	313	69.7
Do not consume	3	2.1	7	5.3	3	1.7	13	2.9
No information	53	37.6	33	25.0	37	21.0	123	27.4
Consumption of fresh vegetables and legumes								
Yes	81	57.5	87	65.9	133	75.5	301	67.0
Do not consume	7	5.0	12	9.1	6	3.4	25	5.6
No information	53	37.6	33	25.0	37	21.0	123	27.4
Water consumption								
Cistern	2	1.4	1	0.8	1	0.6	4	0.9
Bottled	30	21.3	24	18.2	32	18.2	86	19.2
Boiled	3	2.1	3	2.3	1	0.6	7	1.6
Filtered	33	23.4	26	19.7	43	24.4	102	22.7
Well	16	11.3	24	18.2	27	15.3	67	14.9
Public network water	21	14.9	28	21.2	50	28.4	99	22.0
River or lake	1	0.7	1	0.8	3	1.7	5	1.1
Tank	1	0.7	0	0.0	0	0.0	1	0.2
No information	52	36.9	34	25.8	34	19.3	120	26.7

Source: Prepared by the authors.

Also in Table 2, regarding the consumption of natural vegetables; 69.7% (313/449) of the pregnant women consumed natural fruits; 67.0% (301/449) consumed fresh vegetables and legumes. Regarding water consumption; 22.7% (102/449) consumed filtered water, followed by 22% (99/449) who used the public network and 19.2% (86/449) bottled water. The cases that presented the variable without information stand out with 26.7% (120/449).

Spatial analysis techniques utilizing kernel density estimation identified patterns and clusters of toxoplasmosis cases acquired during pregnancy in the state of Sergipe, as depicted in four thematic maps.

A concentration of cases with a high detection rate in the regions of Eastern Sergipe and Greater Aracaju, with hotspots between the municipalities of Divina Pastora (49.2 per 1,000 LB) and Riachuelo (24 per 1,000 LB)in 2019 is shown in Figure 3A

The map in Figure 3B showed three hot spots in 2020 with high detection rates in the regions of Lower São Francisco Sergipe in the municipality of São Francisco (37 per 1,000 LB); in the Eastern Sergipe region in the municipalities of General Maynard (35.7 per 1,000 LB) and Divina Pastora (13.9 per 1,000 LB); and in the Greater Aracaju Region in the municipality of Santo Amaro das Brotas (12.8 per 1,000 LB).

In Figure 3C, during the period from 2019 to 2021; hotspots were identified, with high density in the detection of cases in four regions, in the South Center of Sergipe between the municipalities of Simão Dias (28.7 per 1,000 LB) and Lagarto (11.9 per 1,000 LB); in the Lower São Francisco region of Sergipe between the municipalities of Telha (20.4 per 1,000 LB), Japoatã (18.2 per 1,000 LB) and Cedro de São João (18.2 per 1,000 LB); between the regions of Eastern Sergipe and Middle Sertão Sergipe, in the municipalities of Santa Rosa de Lima (15.4 per 1,000 LB), Nossa Senhora das Dores (15.2 per 1,000 LB) and Divina Pastora (12.2 per 1,000 LB); and in the region of Agreste Central Sergipe between the municipalities of Frei Paulo (12.8 per 1,000 LB) and Macambira (12.7 per 1,000 LB).

A concentration in the detection of cases in the Eastern Sergipe Region, mainly in the municipalities of Divina Pastora (23.3 per 1,000 LB) and Santa Rosa de Lima (15.5 per 1,000 LB) (Figure 3D) was revealed by the Kernel estimator in the period between 2019 and 2021.

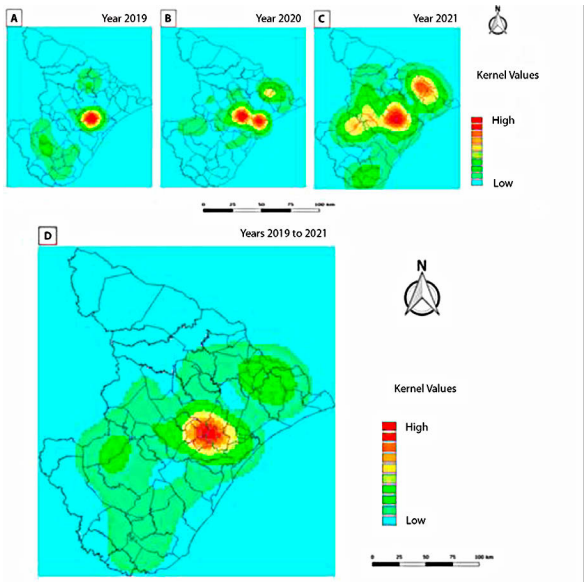

Figure 3. Annual distribution of detection rates of Toxoplasma *gondii* infection in pregnant women, through Kernel analysis. Sergipe, Brazil, 2019-2021. (A) Year 2019, (B) Year 2020, (C) Year 2021, and (D) Years 2019 to 2021.
Source: Prepared by the authors.

DISCUSSION

Toxoplasmosis studies mainly on the parasitic infection acquired during pregnancy as well as the risk of transplacental transmission of tachyzoites from pregnant women to the fetus, have been globally reported; especially, in Brazil, as it is an important indicator of infant morbidity and mortality, and relevant to the public health[2, 23-24]. This study is the first to highlight the epidemiological profile, case detection rate, and spatial distribution of *T. gondii* infection in pregnant women in the state of Sergipe.

The implementation of the State Program for Surveillance and Control of Toxoplasmosis by the State Department of Health of Sergipe State, with the organization of notification and investigation flows of cases, contributed significantly to the epidemiological characterization of *T. gondii* infection in pregnant women in the state of Sergipe. However, a small decrease in notifications was observed in 2020, which can be justified by the onset of the COVID-19 pandemic and the impact on surveillance and healthcare actions.

Notably, Sergipe exhibited a consistent pattern in the detection rates of toxoplasmosis acquired during pregnancy throughout the study period. However, comparisons with other studies in the state and the broader Northeast region of Brazil were not possible due to the limited number of studies reporting incidence in pregnant women. Most existing research focuses on estimating the prevalence of anti-*Toxoplasma gondii* antibodies and identifying risk factors associated with *T. gondii* infection.

In this study, young adult pregnant women presented a higher prevalence, similar to previous studies investigated. Seropositivity for toxoplasmosis increases in direct proportion to the age of pregnant women, conferring a protective factor, and eliminating the risk of VT[26]. Most cases occurred in the population that self-declared as black (brown and black); a characteristic that can be explained by the high presence of racial miscegenation in the Brazilian population and may be associated with the worse socioeconomic conditions experienced by the black population compared to the others[27].

Regarding the educational level of the pregnant women in this study, it is noteworthy that more than half had low levels of education. Limited education and the resulting lack of awareness about toxoplasmosis prevention increase their risk of infection and potential transmission to the fetus. In contrast, individuals with higher education levels are believed to practice better hygiene habits, thereby reducing the likelihood of Toxoplasma *gondii* infection [15, 28].

This study observed a higher prevalence in single women, a finding similar to a previous study that showed the aforementioned marital status as a risk factor for infection by *T. gondii* during pregnancy[29]. Regarding occupation, most of the pregnant women did not have a paid job; the majority was housewives. Corroborating this finding, Pugliese *et al.* (2020)[30] revealed in their study that in 73.7% of cases, the husband was responsible for the family income. Regarding the place of residence, most cases occurred in urban areas. In contrast to this information, a spatial analysis carried out in the state of Minas Gerais found a greater concentration of cases in rural and peri-urban areas.[31] The population in rural areas has less access to health services and, therefore, is difficult to identify in spatial distribution studies.[32].

The results of this study reveal that most pregnant women underwent serological tests for toxoplasmosis late in life. This is a worrying finding since ideally women of childbearing age should undergo serological tests for toxoplasmosis in the preconception period, and for patients who were not screened in the pre-gestational period, the antibody test should be performed at the first prenatal visit or in the first quarter[2, 33]. Because of this, it is necessary to raise awareness among professionals about early diagnosis and timely treatment to avoid the worst outcomes concerning gestational toxoplasmosis.

The Ministry of Health recommends at least six prenatal visits, preferably one in the first quarter, two in the second quarter, and three in the third quarter of pregnancy, as this is an important indicator for assessing the quality of care for pregnant women[34]. It was observed consistent findings in this study similar to those recommended by the Ministry of Health. It is expected that the greater the number of consultations performed, the more information pregnant women can receive about the risk factors and prophylactic measures for toxoplasmosis[2].

In this study, the fact that most pregnant women were multiparous and nulliparous represented a risk factor for infection by *T. gondii* during pregnancy. Câmara, Silva and Castro (2015)[35] showed in their study that pregnant women in multiparous have a greater chance of infection by the parasite compared to primiparous, demonstrating a 1.9 times greater chance of contracting the infection.

Contact with cats during pregnancy was not observed since a predominance of them did not report contact with felines, concluding that no relationship between cats and contamination by *T. gondii* was found in this study, corroborating findings in previous studies[26,30]. However, Silveira *et al.* (2020)[36] explain that direct contact with cats and/or other animals may be highly associated with infection by *T. gondii* in humans. Cats are definitive hosts of the parasite and can disseminate oocysts in the environment, while dogs can carry oocysts attached to their fur, aiding in the transmission of *T. gondii* oocysts[26, 28].

This study reveals a worrying scenario regarding eating habits, since a significant portion of pregnant women consumed untreated water, milk, and raw vegetables, showing that these practices represent a risk factor for infection by *T. gondii*. Taking into account that toxoplasmosis is transmitted mainly through the ingestion of contaminated water, vegetables, and food often causing outbreaks in several regions of the world[10], the findings of this study suggest the need for health education interventions to prevent toxoplasmosis.

Primary prevention guidelines should emphasize the importance of washing hands when handling raw meat; drinking treated and/or filtered water; and avoiding the consumption of undercooked meat and unpasteurized milk, as well as food exposed to flies, cockroaches, ants, and other insects. Other recommendations include mechanically washing vegetables that will be eaten raw to remove oocysts. It is also necessary to avoid contact with cats, wear gloves when handling these animals ´feces, and handle soil during gardening or when working in vegetable gardens and agriculture[15, 25, 37].

In southern Brazil, two of the largest and most important outbreaks of toxoplasmosis reported in the world have occurred. The first occurred in 2001, in the municipality of Santa Isabel do Ivaí, state of Paraná, and the second, also considered the largest outbreak of toxoplasmosis recorded in the world, occurred in 2018, in the municipality of Santa Maria, state of Rio Grande do Sul. Both have a common source of association with the consumption of contaminated water, as well as reports of cases of acute toxoplasma in pregnant women and CT, [10, 29].

Since it is known that the consumption of raw or undercooked meat is also a contributing factor to infection by *T. gondii*, a number of women reported inadequately consuming beef. Regarding the consumption of poultry, lamb and pork, a lower percentage of pregnant women who consumed raw or undercooked meat

was observed. The consumption of raw meat was associated with outbreaks of toxoplasmosis in Anápolis and Goiânia, state of Goiás, in 2006, where cysts were found in the muscles of cattle[35]. However, Pinto-Ferreira *et al*. (2019)[10] suggest that the popularization of freezers and improvements in animal handling and hygiene have substantially reduced the formation and viability of cysts in meat.

Spatial distribution has been used in the area of health research because it is an analysis that provides information on the spatial structure and dynamics of the disease, characterizing the health condition in a given region[15]. The findings of the present study have pointed out higher incidences of cases in some regions of the state of Sergipe, mainly in the regions: East, Greater Aracaju, Lower São Francisco, South Center, Central Agreste; with a concentration of cases in the total period studied in the East region, mainly clustered in the municipalities of Divina Pastora and Santa Rosa de Lima. These results are similar to the study carried out in Sergipe, between 2014 and 2015, with secondary data from anti-Toxoplasma tests, by Reis and Jeraldo (2022)[38], which demonstrate a concentration of toxoplasmosis seroprevalence in pregnant women in the South Center, South, Greater Aracaju, East and Lower São Francisco regions.

This study had some limitations, mainly in the results found in the variables of prenatal care, obstetric history and eating habits, for which high incompleteness was observed, that is, variables without information. The information obtained from the notifications allows for space-time monitoring and supporting actions for prevention and control. Poor completion of notification forms favors the generation of deficient and unreliable data, contributing to the lack of knowledge of the health disease process.

The detection rate of Toxoplasma *gondii* infection in pregnant women reflects the prevalence of the infection within a given region, providing insight into perinatal care and the effectiveness of toxoplasmosis surveillance and control programs. Several factors may have contributed to higher detection rates in certain municipalities in Sergipe, including increased exposure to risk factors and enhanced implementation of prevention, control, and epidemiological surveillance measures."

CONCLUSION

Low education levels and socioeconomic conditions can increase women's vulnerability to Toxoplasma *gondii* infection and hinder access to preventive care, potentially contributing to the incidence of gestational toxoplasmosis. Additionally, the findings indicate that these women were often diagnosed late, faced challenges in accessing diagnostic tests, and a significant proportion lacked access to drug treatment."

The findings of this study, along with previous research cited, provide insight into the potential direct relationship between socioeconomic factors and the incidence and prevalence of toxoplasmosis. However, the quality of the data limited the ability to draw definitive conclusions, due to incomplete variables in the notification forms, highlighting the need for alternative methodological approaches.

Through the investigation of geographic and temporal variations in the distribution of new cases of gestational toxoplasmosis, it was observed that cases are found in all regions of the state, with clusters in certain locations. Therefore, it is possible that the detection rate of gestational toxoplasmosis can be a proxy indicator of the incidence of toxoplasmosis in pregnant women and will be able to support planning, management, and evaluation processes of policies and actions to control toxoplasmosis in Sergipe and Brazil.

This study is noteworthy for addressing the gap in knowledge regarding the epidemiological profile of pregnant women infected with T. *gondii* in the state of Sergipe, particularly given the scarcity of epidemiological studies, especially ecological ones, on this topic at local, regional, and national levels. Nevertheless, it underscores the need for further research on toxoplasmosis, particularly concerning infection in pregnant women, risk factors, screening, prevention methods, and outcomes in congenital cases. Such studies are essential for informing the development of strategies for the prevention, control, and treatment of this infection, ultimately reducing the risk of unfavorable congenital outcomes of CT.

Finally, this study facilitated the epidemiological characterization and spatial distribution analysis of acute Toxoplasma *gondii* infections in pregnant women. The findings provide valuable insights that can inform discussions and support the development of new public health and education policies. These policies should consider socioeconomic, environmental, and cultural factors while promoting awareness, prevention, surveillance, and control of gestational toxoplasmosis to reduce the risk of vertical transmission and severe complications in fetuses and newborns."

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