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Original Article

Spatial distribution of malaria and primary healthcare in Cametá and Tucuruí, Pará state, Brazil

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Abstract

Introduction: Malaria cases in Brazil are concentrated in the Amazon region. In the state of Pará, malaria is considered an endemic disease, and the population has different levels of exposure, which contributes to different types of occurrence in the municipalities.

Methodology: A descriptive, cross-sectional, and ecological study was conducted using data from the Malaria Epidemiological Surveillance System of the municipalities of Cametá and Tucuruí, PA, Brazil, from 2014 to 2018; the Brazilian Institute of Geography and Statistics; and the National Registry of Health Institutions of the Ministry of Health. Statistical and spatial analyses of epidemiological, laboratory and public health service coverage variables were performed using the Bioestat 5.0 and ArcGis 10.5 software.

Results: 11,381 Malaria cases were reported in the two municipalities. The highest percentage of case notifications was reported in brown-skinned men aged from 19 and 59 years, and who had primary education levels. The predominant occupations were farming and livestock in Cametá and domestic activity in Tucuruí. The most common diagnostic examination used was a thick blood smear, and *Plasmodium vivax* was the species most often encountered. The percentage of primary care coverage increased during the study period. The spatial distribution of the disease was not homogeneous, and there were clusters of cases with different densities in Cametá and Tucuruí.

Conclusions: Malaria is a public health problem in the municipalities of Cametá and Tucuruí, because of its transmission dynamics and variable spatial distribution as well as the coexistence of factors that favor the exposure of resident populations to epidemiological situations, thus reflecting health inequities.

Key words: Malaria; epidemiology; primary healthcare; public health; spatial analysis.

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Introduction

Malaria is an acute infectious disease caused by unicellular protozoan species belonging to the genus *Plasmodium* and transmitted to humans through the bite of infected female *Anopheles* mosquitoes. It is considered the main endemic parasitic disease in the world and commonly occurs in tropical and subtropical countries [1,2].

According to the World Health Organization, Malaria occurs in 105 countries where over 40% of the world's population live. In 2018, 228 million cases of Malaria were reported worldwide, with 405,000 deaths from this disease; however, this disease is considered preventable and curable [3].

In Brazil, the number of cases has decreased since the 1960s, but Malaria endemicity in the northern region remains high. Malaria is considered a compulsorily notifiable disease in the Amazon region by the Brazilian Unified Health System, through the Computerized Malaria Surveillance System (SIVEP-Malaria) [1,4-6].

Approximately 99.7% of Malaria cases in Brazil occur in the Amazon region. Several factors contribute to the increase in disease rates in this region, including the precarious primary health care system, social fragilities, and environmental changes that enable an increase in the proliferation of *Anopheles* mosquitoes [6-8].

The state of Pará registered an increased number of cases from 2016 to 2018, with 14,495 cases in 2016, 36,826 in 2017 and 45,835 in 2018. Although the disease is considered endemic in this state, the

population has different levels of exposure to the factors responsible for its spread, contributing to the different types of occurrence in the municipalities. These factors include ecological imbalance and socioeconomic differences, such as poor housing conditions and continuous degradation of natural resources [10,11].

In this context, Cametá and Tucuruí reported a 200% increase in the number of cases from 2016 to 2018, since these territories experienced major socio-environmental changes due to the different anthropogenic activities that occurred, such as disorderly urbanization, deforestation along riverbanks for housing construction, and hydroelectric dam construction. The economy in the Cametá region is based on of plant extractivism, family farming and artisanal fishing. In Tucuruí, the main economic source of the municipality is the hydroelectric power plant, plant extractivism, rudimentary agriculture, extensive cattle ranching and fishing. These factors favor the proliferation of several species of the *Anopheles* genus and the exposure of the population to the disease [1,5,6,12].

The National Malaria Control Program helped reduce the incidence of Malaria nationwide due to the implementation of integrated control strategies and actions developed by the primary care system in different epidemiological and healthcare contexts. Thus, the Family Health Strategy is vital for providing differential clinical and laboratory diagnoses and appropriate treatment and as well as being the primary tool for preventing severe cases, eliminating infection sources and transmission, and controlling the disease and its complications [1,12].

In recent decades, a set of important techniques has been used for analyzing the spatial health data in order to understand the epidemiological scenarios of several infectious diseases. These allow the use of geographical space as an analysis category, identifying the spatial distribution patterns of collective risk factors for Malaria, characterizing epidemiological indicators, and are an effective tool for assisting in public policy planning [14-16].

In this context, this study aimed to analyze the spatial distribution of reported Malaria cases and their relationship with public health policies in two municipalities in the state of Pará, Brazil, from 2014 to 2018.

Methodology

This descriptive, cross-sectional, ecological study analyzed 11,381 cases of Malaria in the municipalities of Cametá and Tucuruí, Pará, Brazil, from 2014 to 2018.

The municipality of Cametá has an area of 3,081.36 km^2 and an estimated population of 139,364 inhabitants and is located in the northeast region of the state. The Municipal Human Development Index (MHDI) for Cametá in 2010 was 0.577 [6]. The municipality of Tucuruí has an area of 2,084.28 km^2 and an estimated population of 115,144 inhabitants, is located in the Southeast region, and its MHDI in 2010 was 0.666 [6]. Both municipalities are administratively divided into districts and census sectors.

Demographic and cartographic data of the municipalities were obtained from the 2010 Census of the Brazilian Institute of Geography and Statistics (IBGE). Epidemiological and laboratory data (sex, age, race/ethnicity, education, occupation, area of infection, *Plasmodium* species, diagnostic examination, and parasitemia) were obtained from SIVEP-Malaria, while the Family Health Strategy data from primary care units in the municipalities (coverage and location) were obtained from the National Registry of Health Institutions (CNES), both from the Ministry of Health (MS). Data on the cases that occurred in the municipal seat were considered as urban data, while those on the cases that occurred outside the municipal seat were considered as rural data.

The TabWin 36b software from the MS was used to debug the data by removing incomplete or inconsistent records. Subsequently, the researchers visited the study site three times for data collection and georeferencing using a Global Positioning System (GPS); the data were later stored in a geographic database (BDGEO).

Statistical analyses were performed using the Bioestat 5.0 software and included descriptive and quantitative analyses. A chi-square test of expected equal proportions was performed to assess any possible proportion differences among variables related to Malaria. A p-value of <0.05 was considered significant. In the geostatistical analysis, Kernel density interpolation was used to identify the spatial distribution pattern of cases in the study sites using the ArcGIS 10.5 software.

Ethical considerations were observed by preserving the identity of the patients and performing the study according to the Declaration of Helsinki, Nuremberg Code, and norms of Resolution 466/12 of the National Health Council. This study was approved by the Research Ethics Committee of the University of the State of Pará (CEP- UEPA opinion 3,786,719 of December 20, 2019).

Results

Data from 11,381 reported cases of Malaria in the municipalities of Cametá (9,989) and Tucuruí (1,392) from 2014 to 2018 were analyzed. Concerning the epidemiological profile of the disease in the municipality of Cametá, the highest percentages were observed in men (60.53%) aged 19–59 years (59.74%) with brown skin (90.0%). The predominant occupation of patients who contracted Malaria was farming and livestock production (51.72%) and they had primary education (71.53%) and were located in rural areas (81.03%).

In the municipality of Tucuruí, the prevalence of Malaria was the highest in men (65.30%) aged between 19 and 59 years (49.6%), with brown (88.8%), with the predominant occupation being domestic activity (41.88%), with primary education (72.99%), and living in rural areas (76.87%). Therefore, the two cities differed only in terms of patient occupations.

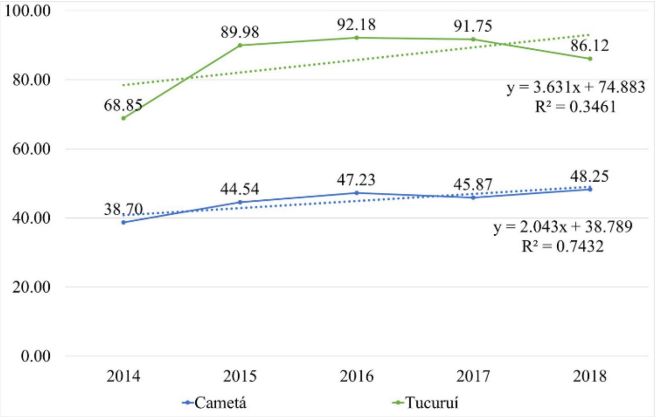
In terms of clinical variables, one of the most common diagnostic tests used in Cametá was the thick smear (94.39%) instead of the rapid test (5.61%). *Plasmodium vivax* infection was highly prevalent in the municipality of Cametá (95.90%), with a "++" parasitemia level as shown in the semiquantitative evaluation, indicating the presence of 501 to 10,000 parasites per mm3 in (42.69%).

In Tucuruí, the thick/thin smear was more commonly used to diagnose Malaria (99.93%) than the rapid test (0.07%). The thick/thin smear detected the presence of *Plasmodium vivax* in 99.78% of patients with infection and 74.28% of those with parasitemia, with a parasite level per mm^3 similar to the one identified in Cametá. All profile percentages showed statistical significance ($p < 0.05$; Table 1).

Concerning the percentage of primary health care coverage (PC) between 2014 and 2018, Cametá presented a median of 45.87% and a standard deviation (SD) of 3.75. In 2014, the aforementioned municipality had the lowest PC coverage (38.70%), with an increase in the following years (a discrete increase of 1.36% in 2017; Figure 1).

In the same period, Tucuruí presented a median of 89.98% for PC coverage (SD: 9.76). It showed a 68.85% increase in PC coverage after 2014, a 0.43% decrease in 2017, and an additional 5.63% decrease in

Figure 1. Percentage variation in primary care coverage in the municipalities of Cametá and Tucuruí, PA, Brazil, from 2014 to 2018.



Source: EPIGEO/CCBS/UEPA (2020).

Table 1. Sociodemographic and laboratorial profiles of malaria cases in the municipality of Cametá and Tucuruí, PA, Brazil, from 2014 to 2018.

Variables	Cametá n (%)	Tucuruí n (%)
Sex		
Male	6,046 (60.53)	909 (65.30)
Female	3,943 (39.47)	483 (34.70)
Age group		
Child (0–11 years)	2,254 (22.56)	366 (26.29)
Adolescent (12–18 years)	1,195 (11.96)	266 (19.11)
Adult (19–59 years)	5,967 (59.74)	691 (49.64)
Older adult (≥60 years)	573 (5.74)	69 (4.96)
Race/Ethnicity		
Indigenous	19 (0.19)	4 (0.29)
Yellow	23 (0.23)	4 (0.29)
White	523 (5.24)	85 (6.11)
Brown-skin	8,990 (90.00)	1,236 (88.79)
Black	434 (4.34)	63 (4.53)
Occupation		
Agriculture and livestock	5,166 (51.72)	181 (13.00)
Hunting/fishing	312 (3.12)	315 (22.63)
Gold digging	2 (0.02)	1 (0.07)
Road/dam construction	11 (0.11)	0 (0.00)
Tourism	83 (0.83)	15 (1.08)
Domestic	132 (1.32)	583 (41.88)
Other	4,283 (42.88)	297 (21.34)
Education		
Illiterate	434 (4.34)	52 (3.74)
Primary school	7,151 (71.59)	1,016 (72.99)
High school	1,440 (14.42)	134 (9.63)
Superior	173 (1.73)	13 (0.93)
Does not apply	791 (7.92)	179 (12.86)
Zone		
Urban	1,895 (18.97)	322 (23.13)
Rural	8,094 (81.03)	1,070 (76.87)
Diagnostic examination		
Thick/thin blood smear	9,429 (94.39)	1,391 (99.93)
Rapid Test	560 (5.61)	1 (0.07)
Species of *Plasmodium*		
P. vivax	9,579 (95.90)	1,389 (99.78)
P. falciparum	2 (0.02)	2 (0.14)
Mixed	0 (0.00)	1 (0.07)
Ignored	408 (4.08)	0 (0.00)
Parasitemia		
"+/2"	3,333 (33.37)	181 (13.00)
"+"	1,657 (16.59)	115 (8.26)
"++"	4,264 (42.69)	1,034 (74.28)
"+++"	194 (1.94)	61 (4.38)
"++++"	2 (0.02)	0 (0.00)
Ignored	539 (5.40)	1 (0.07)

The term Ignored refers to information that the person served does not know or cannot provide. Source: EPIGEO/CCBS/UEPA (2020).

2018, thus reaching an overall PC coverage rate of 86.12%.

The spatial distribution of cases in the municipality of Cametá was not homogeneous, with higher occurrence in all rural areas of the municipality. On the contrary, PC health establishments are distributed in both the rural and urban areas, with a mean health service coverage percentage of 44.92% in the municipality.

In Tucuruí, Malaria was highly prevalent in urban areas, where health services are more concentrated, with a mean PC coverage of 85.78%; this municipal seat is where 95.2% of the urban population lives. Figure 2 (A, B) presents the distribution of Malaria cases and health establishments during the study period in the municipalities of Cametá and Tucuruí.

Although there was is a spatial distribution of Malaria cases all over the territorial extension of the two municipalities, there was an absence of homogeneity in the case distribution as seen in Figure 2 (A, B). In Cametá, the density of Malaria cases was extremely high in the following areas: along the PA-156 highway, on the banks of Cupijó and Tocantins rivers, and close to the feeder road areas. In Tucuruí, few areas in the vicinity of BR-422 highway and the Cariné River had extremely high and medium densities of Malaria cases, while rural locations close to the Cocal and Cariné Rivers had a low density of cases (Figure 2B).

Discussion

The analysis of epidemiological data showed that Malaria has affected more men than women in both municipalities, a classic Malaria profile that may be related to the higher degree of exposure to risk factors, such as the development of occupational activities near sites favorable to the development of *Anopheles* spp [1,17].

The 19-59 age group, which was the most affected, was associated with greater exposure to Malaria in the economically active phase, which corroborated the findings of some studies that reported on the characteristics of workplaces [17-21]. Moreover, the non-use of individual protective measures probably increased the risk of disease transmission in certain environments [18,21].

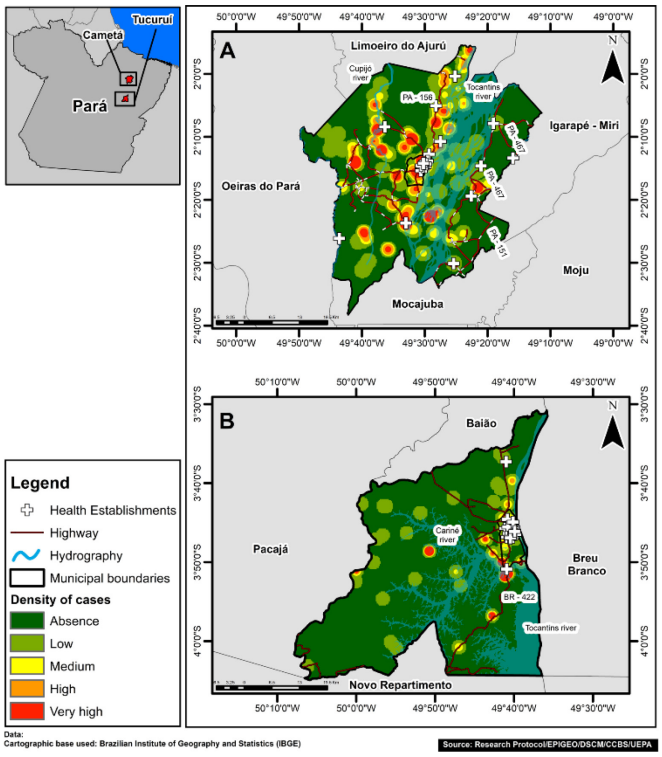
Most patients in this study were had brown skin, a predominant profile in the state of Pará, according to the 2010 Census conducted by IBGE, in which 70% of the inhabitants of this federative unit declared themselves as brown-skinned. No previous studies have demonstrated that genotypic and phenotypic characteristics can lead to greater vulnerability to infection; however, the social and health determinants associated with persons with this skin color increase the prevalence of the disease [15,22].

The predominant occupational activities of patients with Malaria were farming and livestock production in Cametá and domestic activity in Tucuruí, which may favor exposure and/or environmental changes that may increase the risk of disease transmission since they encourage the creation and maintenance of artificial larval habitats for *Anopheles* [18-20].

In Cametá, agriculture and livestock production, timber harvesting, road construction, mining, and placer gold mining activities expose the workers to mosquitoes that transmit Malaria [19]. Effects related to the occupation of individuals in the Amazon region and the proliferation of vector diseases have been identified since the implementation of development projects in the state of Pará and the northern region [15,17,19].

In Tucuruí, construction of the Tucuruí Hydroelectric Power Plant contributed to the proliferation of Malaria cases due to the disruption of ecological balance and the establishment of unfavorable socioeconomic conditions resulting from the migratory process, which leads to irregular housing conditions and

Figure 2. Density of Malaria cases and health establishments in the municipalities of Cametá and Tucuruí, PA, Brazil, from 2014 to 2018.



Source: EPIGEO/CCBS/UEPA (2020).

exposure to mosquito breeding sites in riverside areas. This favors the onset of Malaria in areas where domestic activity such as subsistence farming and extractivism is predominant [13,23-26].

More than 70% of Malaria patients in the two municipalities had completed only their primary education. Consequently these patients had less access to important information related to Malaria and had poor health conditions due to the lack of knowledge and non-use of individual and collective protective measures. These factors were associated with low socioeconomic levels and thus favored the occurrence of vector diseases such as Malaria [1,21].

The predominance of cases in the rural areas of the municipalities of Cametá and Tucuruí may be related to the natural history of the disease itself. Moreover, the migration and environmental imbalance in these locations imply greater exposure and susceptibility to Malaria due to certain situations that expose individuals to infected vectors, that allow precarious housing close to livestock farms, and that cause difficulty in accessing anti-vector measures [10,11,23,27].

The most widely used diagnostic method in both municipalities was the thick/thin smear test; this is considered the gold standard for Malaria diagnosis in endemic areas as it is simple, effective, and easy to perform, and is considered as a low-cost method. Therefore, the thick/thin smear was selected by the Ministry of Health as the primary method for diagnosing Malaria [1,5].

The high proportions of *P. vivax* infection identified in Cametá and Tucuruí are similar to those observed in other states and municipalities in the Northern Region. *P. vivax* Malaria, when diagnosed late and inadequately managed, can cause complications such as severe anemia, relapse, and even symptoms similar to those of *Plasmodium falciparum* infection, which has a high replication rate, frequently causes parasitemia and is a more severe disease [1,5,10].

Moderate parasitemia was observed in patients with Malaria. This condition should be evaluated because those who developed parasitemia in the first *P. vivax* infection have a higher risk of developing severe Malaria and relapses [12,28,29]. However, the increased health service coverage and the implementation of control measures have decreased the occurrence of more severe cases of Malaria [10,30].

The higher number of Malaria cases identified in Cametá may be attributed to the greater availability of healthcare resources in the most affected areas to diagnose and treat the disease as well as to the dispersion of services in the territory (the healthcare coverage rate in this area is already low). In Tucuruí, individuals living in urban areas have more access to healthcare services; however, even with a PC coverage of greater than 85%, patients living far from the urban area may experience difficulty in obtaining healthcare services [16,17].

Patients in the rural area had difficulty in accessing health units and were not usually diagnosed early because diagnostic laboratories were located far from the localities. They also failed to receive adequate treatment (i.e., received an inadequate prescribed scheme or took insufficient doses), and failed to adhere to the protocols. All of these situations imply inefficient disease control in both municipalities [5,10,31].

In this scenario, the distribution of healthcare services in the urban and rural areas of the municipalities reflects the unequal access to these services and thus implies healthcare inequalities in terms of identifying and controlling Malaria in this population. These situations suggest the need to strengthen PC and implement the measures recommended by the National Malaria Control Program guidelines [4,10,31].

The non-homogeneous distribution of cases shows that the populations living near the PA-156 and BR-422 highways, in Cametá and Tucuruí, respectively, are at a higher risk of acquiring the disease due to deforestation and disordered establishment of urban centers [17,24,25].

The occurrence of Malaria in individuals living on the banks of the Cupijó and Cariné rivers may be related to the vectorization of the disease due to the haphazard occupation process observed over the past decades. This is influenced by the construction of the Tucuruí dam, which is aimed at establishing a residential area far from the municipal center and is recognized as a barrier to obtaining health services [25,27].

In this context, the increased supply of PC services is important to reduce vulnerabilities in these municipalities, especially in rural areas. Although strengthening the PC is not a simple task, it should be prioritized considering the dynamics of spatial transformation, especially in places where Malaria is still present, with a view to reducing the number and severity of cases [10,15,22].

This study showed that Malaria is a public health problem in the municipalities of Cametá and Tucuruí, and is associated with its transmission dynamics, variable spatial distribution, the coexistence of environmental and socioeconomic factors, and a health service coverage that favors the exposure of resident

populations to epidemiological risk situations in these municipalities.

Thus, in addition to identifying the risk situations in order to develop effective policies for strengthening disease control measures, the use of spatial health data analysis techniques aided analysis of the epidemiological scenario of Malaria observed in this study. The use of technological tools to generate epidemiological maps is important in order to determine health inequities and establish effective public policies to strengthen the control measures and perform continuous surveillance of the disease in the areas studied.

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