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Incidence of malaria among indigenous people associated with the presence of artisanal mining

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Incidência de malária entre indígenas associada à presença de garimpos

Incidencia de malaria entre pueblos indígenas asociada a la presencia de minería

Rosinelle Janayna Coêlho Caldas[a]
Laura Maria Vidal Nogueira[a]
Ivaneide Leal Ataíde Rodrigues[a]
Erlon Gabriel Rego de Andrade[a]
Carla Monique Lavareda Costa[a]
Lidiane de Nazaré Mota Trindade[b]

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ABSTRACT

Objective: To analyze the incidence of malaria among indigenous people associated with the presence of artisanal miningin the state of Pará.

Method: Analytical, cross-sectional study conducted with 20,774 cases of malaria in indigenous people in the state of Pará (2011 to 2020). The data came from the Malaria Epidemiological Surveillance Information System, obtained from the Pará State Department of Public Health. In the analysis, Spearman's correlation coefficient was used, with a significance of 5% ($p < 0.05$).

Results: Incidence rates were high, especially in the Tapajós River Indigenous Special Health District (372.2/1,000 inhabitants). There was association between the incidence of malaria and the presence of indigenous people in artisanalmining activities on the Tapajós River ($p=0.0008$).

Conclusion: The occurrence of malaria is unequal among the Special Indigenous Health Districts, being more frequent in those with greater mining activity, configuring exposure to the disease. It is necessary to adopt intersectoral measures, especially in areas of vulnerability to illness.

Keywords: Malaria. Incidence. Indigenous peoples. Mining.

RESUMO

Objetivo: Analisar a incidência da malária entre indígenas associada à presença de garimpos no estado do Pará.

Método: Estudo analítico, transversal, realizado com 20.774 casos de malária em indígenas do estado do Pará (2011 a 2020). Os dados foram oriundos do Sistema de Informação de Vigilância Epidemiológica da Malária, obtidos na Secretaria de Estado de Saúde Pública do Pará. Na análise, utilizou-se o coeficiente de correlação de Spearman, com significância de 5% ($p < 0,05$).

Resultados: As taxas de incidência se mostraram elevadas, com destaque ao Distrito Sanitário Especial Indígena Rio Tapajós (372,2/1.000 habitantes). Houve associação entre incidência da malária e a presença dos indígenas nos garimpos no Rio Tapajós ($p=0,0008$).

Conclusão: A ocorrência da malária é desigual entre Distritos Sanitários Especiais Indígenas, sendo mais incidente naqueles de maior atividade garimpeira, configurando exposição à doença. Faz-se necessária a adoção de medidas intersetoriais, sobretudo em áreas de vulnerabilidade ao adoecimento.

Palavras-chave: Malária. Incidência. Povos indígenas. Mineração.

RESUMEN

Objetivo: Analizar la incidencia de malaria entre indígenas asociada a la presencia de la minería en el estado de Pará.

Método: Estudio transversal analítico realizado con 20.774 casos de malaria entre indígenas del estado de Pará (2011 a 2020). Los datos provienen del Sistema de Información de Vigilancia Epidemiológica de la Malaria, obtenidos de la Secretaría de Salud Pública del Estado de Pará. En el análisis se utilizó el coeficiente de correlación de Spearman, con una significación del 5% ($p < 0,05$).

Resultados: Las tasas de incidencia fueron altas, especialmente en el Distrito Sanitario Especial Indígena Río Tapajós (372,2/1.000 habitantes). Hubo asociación entre incidencia de malaria y la presencia de indígenas en las minas del Río Tapajós ($p=0,0008$).

Conclusión: La ocurrencia de malaria es desigual entre los Distritos Especiales de Salud Indígena, siendo más frecuente en aquellos con mayor actividad minera, configurando la exposición a la enfermedad. Es necesario adoptar medidas intersectoriales, especialmente en áreas de vulnerabilidad a la enfermedad.

Palabras clave: Malaria. Incidencia. Pueblos indígenas. Minería.

[a] Universidade do Estado do Pará (UEPA), Escola de Enfermagem Magalhães Barata, Programa de Pós-Graduação em Enfermagem. Belém, Pará, Brasil.

[b] Universidade Federal do Rio de Janeiro (UFRJ), Escola de Enfermagem Anna Nery, Programa de Pós-Graduação em Enfermagem. Rio de Janeiro, Rio de Janeiro, Brasil.

INTRODUCTION

Malaria, an infectious disease, represents an important contemporary public health problem in many countries, and its occurrence is related due to environmental, climatic, ecological and socioeconomic factors. Such factors, when associated with the difficulty of access and low quality of health services, as well as the fragility of epidemiological surveillance actions, result in an increase in the dynamics of the disease[1]. Worldwide, in the year 2020, around 241 million cases of the disease were recorded, with an incidence of 59 cases per 1,000 inhabitants and an estimated number of 627,000 deaths, with the African region standing out globally, with 95% of cases and 96% of deaths from malaria[2].

The eradication of malaria is a global challenge, with a goal of reducing incidence and mortality rates by at least 90% by the year 2030. To do so, funding strategies and special attention to biological, environmental, sociodemographic, political, economic determinants and strength of health systems must be ensured[3].

In Brazil, the number of cases of malaria reported in 2020 was 145,188. Despite the 7.8% reduction when compared to 2019, mortality increased by 18.9%, suggesting notification of more severe cases of infection. The distribution of the disease in the country is uneven, with 99% of cases in the Amazon, which classifies the region as an endemic area[4].

Such cases are arranged in diverse ways in the territory, with higher rates in certain areas, such as indigenous territories, settlements and mining. Although there was a general reduction in disease transmission, in the first semester of 2021, compared to the same period in 2020, there was a significant increase of 94% in mining areas[4].

The state of Pará registered, in 2020,24,556 cases, and comparing the periods from January to June 2020 and 2021, there was a reduction of 17.5%. However, malaria control in indigenous areas and artisanal mining areas is one of the main challenges for the State, since the municipalities that are home to indigenous populations and mineral exploration, through artisanal mining, are more than 50% of cases, with growth trend[4].

Due to its importance, mineral extraction is a legal practice in Brazil, as it boosts the country's economic development. However, it becomes illegal when it occurs without proper permission from regulatory bodies, becoming even more harmful to the environment, in addition to increasing human exposure to the malarial vector. This is due to the destruction of the forest, changing the habitat of the vector, causing the displacement of insects to urbanized territories, as well as exposure due to work activity in mining areas, which is very common in the indigenous context[5–7].

On the border between Brazil and French Guiana, in the Amazon region, a study that analyzed the incidence of malaria among indigenous and non-indigenous people, in a municipality in the state of Amapá, from 2007 to 2016, showed a higher Annual Parasitic Incidence (API) among indigenous people, with 261 cases/1,000 inhabitants, attributable to the great cross-border mobility of indigenous people and the persistent incursion of artisanal prospectors into these areas[8].

Another epidemiological analysis, in the state of Roraima, from 2016 to 2018, pointed out that most of the cases notified in the State (90.6%) were imported, due to the high mobility of artisanal miners from endemic areas of Venezuela and Guyana, which moved to Roraima. According to records, as mining activities increased, in 2018, cases of imported malaria increased exponentially, indicating a direct relationship between mineral exploration in artisanal mines and the disease. Moreover, there are currently 1,097 illegal mining sites located in Venezuela, Guyana and Brazil, especially in Yanomami indigenous lands, generating high population mobility in search for employment in mining sites, suggesting exposure of native peoples[5].

In the state of Pará, a study that analyzed the spatial pattern of malaria in indigenous and non-indigenous people, from 2010 to 2015, identified higher rates of illness in indigenous populations, in the Southwest mesoregion of the State, with API=163.05/1,000 inhabitants and 165.27/1,000 inhabitants, in 2010 and 2011, respectively. The study suggests that the increased incidence may be associated with the presence of artisanal mining close to indigenous villages, favoring exposure to the malaria vector[9].

In view of the evidence, the present study is justified by considering knowledge gaps about the occurrence of malaria among indigenous people associated with the presence of artisanal mining in the state of Pará. Knowledge of the local reality, focused on economic aspects and cultural and social diversity, is important for monitoring and controlling the disease in populations that live in remote and hard-to-reach areas, and represents an important challenge for public health authorities[6].

Thus, the question was: is there a relationship between the incidence of malaria among indigenous peoples and the presence of artisanal mining in the state of Pará? Based on the hypothesis that the incidence of malaria among indigenous people is associated with the presence of these mines, this study aimed to analyze the incidence of malaria among indigenous people associated with the presence of artisanal mining in the state of Pará.

METHODS

This is an analytical, cross-sectional study, with a quantitative approach, conducted with 20,774 cases of malaria, notified among indigenous people living in the state of Pará from 2011 to 2020. It was defined to study a decade to obtain a more comprehensive analysis, minimizing possible direct influences on the data, due to the oscillation of prospecting activity in the territory.

The data were made available by the Pará State Department of Public Health (*Secretaria de Estado de Saúde Pública do Pará* – SESPA) and come from the Malaria Epidemiological Surveillance Information System (*Sistema de Informação de Vigilância Epidemiológica da Malária* – SIVEP Malária). Population data from the 2010 Demographic Census were also used, extracted from the website of the Brazilian Institute of Geography and Statistics (*Instituto Brasileiro de Geografia e Estatística* – IBGE), which is publicly accessible.

Information on the number of artisanal mines in Pará was made available by the National Mining Agency (*Agência Nacional de Mineração* – ANM), upon online request via the Ombudsman and Access to Information Platform of the Federal Government of Brazil (*Plataforma Integrada de Ouvidoria e Acesso à Informação*). It is a government agency that strictly controls legalized mining, which is why this study did not include information on illegal mining. Data collection took place in March and April 2021.

The state of Pará is in Northern Brazil, is divided into 144 municipalities, with an area of 1,245,870.707 km^2, being the second largest State in the country in territory. It has an estimated population, in 2021, of 8,777,124 inhabitants, of which 39,081 are indigenous, according to the 2010 Census[10].

The indigenous people of Pará are grouped, for health management purposes, into four Special Indigenous Health Districts (DSEI) based in the State, namely: Altamira, Kaiapó do Pará, Guamá-Tocantins and Rio Tapajós. The DSEI comprise a model for structuring services directed according to ethnocultural, population and geographic criteria, in line with the specificities of indigenous health[11].

The Altamira DSEI, with a territorial extension of 78,064.08 km^2, accounts for 4,704 indigenous people of 10 ethnic groups, distributed in 103 villages. The Kaiapó do Pará DSEI covers an area of 78,808.34 km^2, with 5,998 indigenous people from six ethnic groups, inhabiting 58 villages. The Guamá-Tocantins DSEI comprises the largest territory,325,754.25 km^2, with 17,782 indigenous people of 54 ethnic groups, in 197 villages. The Rio Tapajós DSEI, with 231,906.74 km^2, has 13,487 indigenous people of 10 ethnic groups, in 158 villages[11].

The inclusion criterion considered was being case of malaria registered in indigenous villages. And, as exclusion criteria, duplicate cases and/or with incomplete data were considered. Thus, the population consisted of 25,717 cases, of which 4,943 were excluded, totaling a sample of 20,774. The variables used were sociodemographic information (age, gender, schooling, occupation), clinical information (test results, number of malaria cases, municipality of infection, DSEI of infection, year of notification, API) and the number of artisanal mines.

The analysis was conducted in three stages: in the first, the selection of epidemiological data and mining data was carried out, using spreadsheets in Microsoft Office Excel® 2019 software, to filter the set of variables of interest for the study, grouping them by DSEI. The sociodemographic and clinical characteristics of the indigenous people were analyzed using descriptive statistics, whose results are expressed in relative and absolute numbers.

In the second stage, API were calculated, stratified by DSEI and by number of artisanal mining sites in the state of Pará, according to the year of notification, by the expression: Number of positive tests for malaria/total resident population in the year of analysis x 1,000. The population data resulted from the number of inhabitants, using the 2010 IBGE Census. The API indicator is classified into four categories: very low risk area (<1.0), low risk (1.0 to 9.9), medium risk (10.0 to 49.9) and high risk (≥ to 50.0)[4].

In the third stage, statistical analyzes were performed using the Bioestat 5.3 software, to measure the association between the incidence of malaria, the number of artisanal mines and the number of indigenous people engaged in mining activities. Spearman's correlation coefficient was used, considering a significance level of 5% ($p < 0.05$).

The project was approved by the Research Ethics Committee (REC) of the Undergraduate Nursing Course of the *Universidade do Estado do Pará* (UEPA), under opinion No.4,567,136/CAAE: 43229221,0,0000,5170.

RESULTS

According to Table 1, there was a prevalence of cases in males (54.5%; n=11,317), with a higher number in the age group of 21 to 30 years (41.7%; n=8,657) for both genders. Regarding schooling, 52.3% (n=10,856) had incomplete primary education, highlighting that in 25.7% (n=5,340) the field "schooling" was not completed. As for occupation, 12.0% (n=2,491) reported carrying out activities related to agriculture/vegetal extraction; 11.4% (n=2,374), hunting/

fishing activities; and 60.3% (n=12,529), other activities. As for the clinical form of the disease, 88.7% (n=18,419) was due to infection by *Plasmodium vivax*.

In Figure 1, it was observed a variation in the malaria parasite index over the years studied, showing important differences between the DSEI. The Rio Tapajós and Altamira DSEI showed higher rates in the years 2011 and 2012. In 2014, the incidence was similar in the two DSEI, registering an increase in the DSEI Guamá-Tocantins in the year 2017. The Rio Tapajós and Altamira DSEI showed a trend of growth in the API from 2019. The Kaiapó do Pará DSEI had the lowest incidences over the period.

In Table 2, it was possible to show that the API values and the number of artisanal mining in Pará showed variations according to the district, with the highest records in the Rio Tapajós DSEI, with values in the high risk and medium risk classifications, oscillating between 372, 2/1,000 inhabitants, in 2012, and 19.3/1,000 inhabitants, in 2015. There is a concentration of artisanal mining in this DSEI and with increasing variation over the years. It was also observed that the lowest rates occurred in the Altamira DSEI, in 2016 and 2017, respectively with 0.5/1,000 inhabitants and 0.2/1,000 inhabitants, classified as very low risk, being a DSEI with a small number of artisanal mining sites.

The Altamira DSEI showed the highest variations, with high-risk API in 2011, 2012 and 2020, medium risk in 2013, 2014 and 2019, low risk in 2015 and 2018, and very low risk in 2016 and 2017. In the Guamá-Tocantins DSEI, the API was classified as high risk in 2011, medium risk in 2012 and 2017 to 2020, and low risk in 2013 to 2016. Stands out the absence of mining sites in the geographical area of the Guamá-Tocantins DSEI and the API varying from medium risk in 2012 to low risk in 2013 (Table 2).

Labor activity in artisanal mining showed a statistically significant association with API in the Rio Tapajós DSEI (p=0.0008) (Table 3).

Table 1 – Distribution of malaria cases among the indigenous population, according to sociodemographic and clinical variables. Pará, Brazil, 2011 a 2020

DSEI	Altamira	Guamá-Tocantins	Kaiapó do Pará	Rio Tapajós	Total
Variables	**N (%)**	**N (%)**	**N (%)**	**N (%)**	**N (%)**
Gender					
Female	570 (48.0)	938 (42.0)	257 (42.4)	7,692 (45.9)	9,457 (45.5)
Male	617 (52.0)	1,297 (58.0)	349 (57.6)	9,054 (54.1)	11,317 (54.5)
Age (years)					
< 1 year	29 (2.4)	54 (2.4)	14 (2.3)	226 (1.3)	323 (1.6)
1 to 10	30 (2.5)	71 (3.2)	8 (1.3)	308 (1.8)	417 (2.0)
11 to 20	34 (2.9)	72 (3.2)	15 (2.5)	411 (2.5)	532 (2.6)
21 to 30	517 (43.9)	867 (38.8)	202 (33.3)	7,071 (42.2)	8,657 (41.7)
31 to 40	329 (27.7)	601 (26.9)	192 (31.7)	5,225 (31.2)	6,347 (30.6)
41 to 50	145 (12.2)	283 (12.7)	91 (15.0)	2,122 (12.7)	2,641 (12.7)
51 to 60	71 (6.0)	195 (8.7)	59 (9.7)	923 (5.5)	1,248 (6.0)
> 60	32 (2.7)	92 (4.1)	25 (4.1)	460 (2.7)	609 (2.9)

Table 1 – Cont.

DSEI	Altamira	Guamá-Tocantins	Kaiapó do Pará	Rio Tapajós	Total
Variables	**N (%)**	**N (%)**	**N (%)**	**N (%)**	**N (%)**
Schooling					
No schooling	121 (10.2)	596 (26.7)	91 (15.0)	1,402 (8.4)	2,210 (10.6)
Incomplete primary school	571 (56.5)	965 (43.2)	313 (51.7)	8,907 (53.2)	10,856 (52.3)
Complete primary school	15 (1.3)	92 (4.1)	19 (3.1)	696 (4.2)	822 (4.0)
Incomplete high school	10 (0.8)	34 (1.5)	5 (0.8)	739 (4.4)	788 (3.8)
Complete high school	7 (0.6)	19 (0.9)	3 (0.5)	390 (2.3)	419 (2.0)
Incomplete higher education	1 (0.1)	7 (0.3)	0 (0.0)	57 (0.3)	65 (0.3)
Complete higher education	0 (0.0)	6 (0.3)	0 (0.0)	27 (0.2)	33 (0.2)
Not applicable	45 (3.8)	30 (1.3)	56 (9.2)	110 (0.7)	241 (1.2)
Field not filled	317 (26.7)	486 (21.7)	119 (19.6)	4,418 (24.4)	5,340 (25.7)
Occupation					
Agriculture/Vegetal extraction	139 (11.7)	212 (9.5)	47 (7.8)	2,093 (12.5)	2,491 (12.0)
Hunting/fishing	417 (35.1)	815 (36.5)	78 (12.9)	1,064 (6.4)	2,374 (11.4)
Construction of roads/dams	1 (0.1)	0 (0.0)	0 (0.0)	4 (0.0)	5 (0.0)
Domestic	157 (13.2)	88 (3.9)	59 (9.7)	1,620 (9.7)	1,924 (9.3)
Prospecting/Mining	22 (1.9)	3 (0.1)	74 (12.2)	582 (3.5)	681 (3.3)
Farming	3 (0.3)	0 (0.0)	0 (0.0)	11 (0.1)	14 (0.1)
Traveler	0 (0.0)	0 (0.0)	1 (0.2)	16 (0.1)	17 (0.1)
Tourism	5 (0.4)	9 (0.4)	3 (0.5)	62 (0.4)	79 (0.4)
Others	317 (26.7)	1,074 (48.1)	258 (42.6)	10,880 (65.0)	12,529 (60.3)
Field not filled	126 (10.6)	34 (1.5)	86 (14.2)	414 (2.5)	660 (3.2)
Test Result					
Plasmodium falciparum	43 (3.6)	307 (13.7)	7 (1.2)	1,596 (9.5)	1,953 (9.4)
Plasmodium vivax	11,132 (95.4)	1,922 (86.0)	596 (98.3)	14,769 (88.2)	18,419 (88.7)
Mixed	12 (1.0)	6 (0.3)	3 (0.5)	381 (2.3)	402 (1.9)

Source: Secondary data from SIVEP Malaria, 2021.

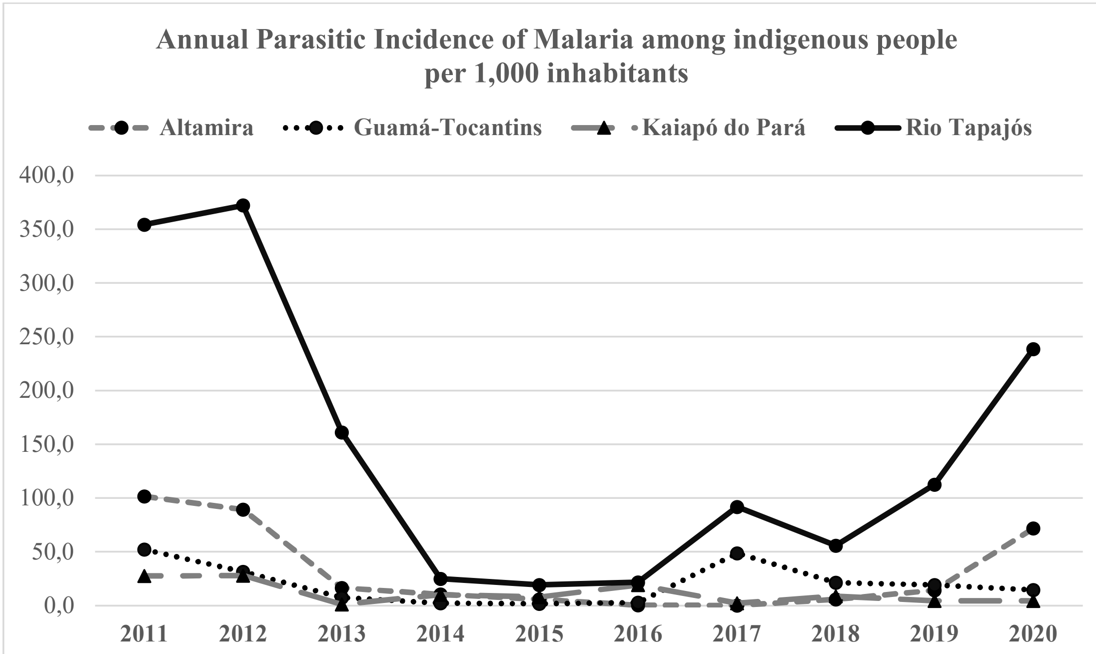

Figure 1 – Annual Parasitic Incidence of Malaria among indigenous people, per 1,000 inhabitants, by DSEI in the state of Pará. Pará, Brazil, 2011 a 2020

Source: Secondary data from SIVEP Malaria, 2021.

Table 2 – Distribution of the Annual Parasitic Incidence of Malaria among Indigenous people, per 1,000 inhabitants, according to the DSEI and the presence of artisanal mining.Pará, Brasil, 2011 to2020

DSEI	Altamira		Guamá-Tocantins		Kaiapó do Pará		Rio Tapajós	
Year	API	N (mining sites)	API	N (mining sites)	API	N (mining sites)	API	N (mining sites)
2011	101.6	5	52.2	0	27.6	7	354.4	280
2012	89.5	6	31.6	0	28.0	21	372.2	363
2013	16.5	6	7.4	0	1.2	23	161.2	370
2014	10.4	6	2.4	0	10.3	26	25.0	383
2015	5.8	6	1.8	0	7.9	37	19.3	420
2016	0.5	6	2.9	0	19.3	40	21.6	459
2017	0.2	9	48.8	0	2.4	45	91.7	559
2018	5.9	10	21.4	0	8.8	49	55.8	662
2019	14.3	10	19.2	0	4.4	54	112.6	765
2020	72.0	11	14.5	0	4.6	66	238.6	904

Source: Secondary data from SIVEP Malaria and the National Mining Agency, 2021.

Table 3 – Correlation of indigenous people working in artisanal mining sites and the Annual Parasitic Incidence of Malaria by DSEI.Pará, Brasil, 2011 a 2020

DSEI	Spearman Correlation Coefficient	p-value
Altamira	-	-
Guamá-Tocantins	-	-
Kaiapó do Pará	-0.069	0.8498
Rio Tapajós	0.8788	0.0008

Source: Secondary data from SIVEP Malaria and the National Mining Agency, 2021.

DISCUSSION

In the period studied, the API showed heterogeneity among the DSEI in Pará. The highest numbers (354.4/1,000 inhabitants, 372.2/1,000 inhabitants and 238.6/1,000 inhabitants) were in the Rio Tapajós DSEI, where a large part of the mining sites that reach indigenous areas are concentrated. However, in the Altamira DSEI, the API values were high, indicating a significant number of patients in the locality, however with significant variation over the years.

Additionally, when analyzing the API variation in the DSEI, it was identified a decrease between 2014 and 2018 in the Rio Tapajós, which may have been caused by the intensification of integrated actions developed between state and municipal management, through surveillance of the endemic disease, viability of access to diagnosis and immediate treatment of suspected/confirmed cases, in addition to fighting the malaria vector[12].

Despite this reduction, the API showed an increase in 2019 and 2020 in the Rio Tapajós and Altamira DSEI. This can be explained by the fact that these Districts unite, mostly, municipalities with a large indigenous population and strong artisanal mining activity, boosted by the government incentive to mineral extraction and prospecting exploration, as well as the lack of inspection[13,14].

The Amazon region includes, in its territory, large mining areas registered and monitored by public authorities, in addition to other illegal mining areas, located mainly in indigenous lands, environmental protection areas and extractive reserves, which reveals the size of the challenge to control the disease[6,15].Malaria is considered a neglected disease, and Brazil has been making efforts and facing difficulties for its elimination, especially in indigenous areas[15].

A study conducted with API data, in mesoregions in Pará, identified that, among indigenous people, the incidence rates presented a high classification, especially in the Southwest mesoregion of the State, where a great indigenous population lives and are geographically located the Rio Tapajós and Altamira DSEI[9].

In another study, carried out with data from the Amazon region, it was identified that, in the municipality of Oiapoque/Amapá, the incidence rate among indigenous people was 67.3% higher than in non-indigenous areas, highlighting, as a conditioning factor, the low level of socioeconomic development[16]. Such findings show that malaria occurs in diverse ways in the territory, manifesting according to the locoregional context and the social, economic and cultural specificity of the region.

The analysis of the variable "gender" shows a predominance of cases among men, similar to the findings of a study that analyzed the epidemiological situation of malaria in a artisanal mining region, in the state of Pará, Brazil, between the years 2011 and 2015, which identified 71, 9% of cases in males[16]. This is explained by the greater exposure, often resulting from unfavorable economic situations, which lead to the search for work in unhealthy environments, such as artisanal mining[17,18].

In this study, there was a significant number of cases of malaria among young people aged between 21 and 40 years, considered a productive age group, indicating a possible relationship with occupation. A study conducted in Boa Vista, Roraima, identified that most patients were male (74.6%), with a mean age of 36 years, and who were affected by malaria in mining activities[5].

Still in the context social profile of the indigenous people, there was confirmation of low education level and people with no schooling, given that, possibly, it is a determining factor for the search for the prospecting activity that does not require professional qualification. It is also noticed that, according to other studies, low schooling has been ratified in indigenous communities[18,19], although they have a constitutional guarantee of access to ethnically different education[20].

However, there are major weaknesses in the planning and implementation of the educational system for this population[20]. This study, points out the high number of notifications without filling in the field about schooling, referring to the little appreciation of this aspect in the indigenous context. The incompleteness of records in the information system hinders to further analyze this variable, limiting knowledge of the real scenario and, consequently, the planning of preventive actions in the health field[8].

In the Amazon, the inclusion of indigenous people in artisanal mining activities has been evidenced in studies on malaria, indicating that it is an occupational disease[18,21]. They are attracted to this practice by the growing scarcity of access to food, combined with the need for labor in the mining sites, located close to the villages. The high number of mining sites, including illegal ones, in the Rio Tapajós DSEI area is noteworthy, where there is intense demand for minerals, especially gold[7].

The prospecting and artisanal mining activities cause environmental changes capable of modifying the diversity and density of malaria vectors, causing an increase in the risk of disease transmission. This reality was evidenced in research that related the occurrence of malaria in mining areas responsible for accelerated and disorderly migration, leading people to exposure to the malarial vector, favoring the perpetuation and, sometimes, increasing incidence[9,21].

Among the species that cause malaria, there was a predominance of infection by *P. vivax*, corroborated by studies conducted in scenarios in the Brazilian Amazon, such as Roraima, where there was a predominance of *P. vivax* (59.2%), followed by *P. falciparum* (36.5%) and mixed infection by *P. vivax* and *P. falciparum* (4.3%)[5]. In the state of Amapá, the most circulating parasite was *P. vivax*, with a trend towards a reduction in cases for the *P. falciparum*. This trend can be explained by some factors, such as the fact that *P. vivax* has a wider territorial distribution, since the vector is able to tolerate several temperature fluctuations and survive at higher altitudes[8].

Indigenous people have been responsible for high incidences of malaria in the Amazon region, due to the geographic and natural characteristics that favor the interaction of plasmodium with the vectors, which represents an important challenge for the implementation of control measures given the context of the villages. The indigenous way of life is, therefore, prone to illness by malaria due to the peculiarities of the territories and the vulnerable conditions of the housing, which sometimes make vector elimination and control measures unfeasible[8,9].

Another important factor to be considered is the low level of indigenous socioeconomic development, with low income and low education level, identified in this specific group, and which have an impact on quality of life and persistence of the disease in the social environment in an endemic way[8,9,18,19].

During the analysis, it became evident that, in these isolated populations, there are many factors that contribute to the increase in the number of malaria cases. Studies have shown that the control of the endemic disease still challenges several countries with specific populations[8,16]. These studies pointed out the occurrence of the disease in indigenous lands adjacent to mining areas in the Brazilian Amazon and in international territories bordering the region, similar to what occurs in northeastern Cambodia.

The constant human mobility, the geographic isolation of villages, and especially the illegality of mining, are determining and constitute important factors for the persistence of the disease, whether due to the distance and difficulty of accessing these communities, or due to poor adherence to treatment and unavailability of medicines[8]. Research complements this idea by indicating a relationship between this mobility behavior in mining areas and illness from malaria, which can lead to an unfavorable outcome in the implementation of control measures[22].

An important issue concerns the environmental damage due to minerals extraction, which disturb the riverbeds and watercourses, resulting in the formation of stagnant water pools, favoring the proliferation of disease vectors. It should be noted that the mining sites are scenarios of disorganized occupation, marked by unhealthy conditions, precarious socioeconomic conditions, lack of health infrastructure and adequate housing, in addition to being located close to the natural habitat of the vector, exposing resident populations to disease[5,22,23].

In the last 20 years, illegal artisanal mining activity has significantly intensified in the Brazilian Amazon, with huge expansion in indigenous territories. From 2010 to 2020, the area occupied by artisanal mining inside indigenous lands grew by around 495%, highlighting the invasions in the Kayapó and Munduruku territories, in Pará. In a survey conducted by government public sources, in 2020, the deforestation of an area of 76,633 hectares was identified in the state of Pará, 89% of which for mineral exploration, with approximately 129 points of illegal mining sites. However, it is expected that this number is underestimated due to the difficulty in locating all areas[13,24,25].

Aware of the complexity of analyzing the malarial indicator in the indigenous context, the results of this study infer that the artisanal mining practice, involving native peoples, has a strong influence on the maintenance of endemicity, confirming that the presence of artisanal mining sites contributes to the high numbers of API in the villages.

Thus, the illness registered among children, women and the elderly corroborates the context of the social ills in which are these people and confirms the disastrous consequences for the community, resulting from the predatory action of man on the environment, since exposure to malaria is not it is restricted to men who go in search for mining activities, as all residents of villages close to deforestation are exposed to the disease[26,27].

The Brazilian State is responsible for preventing and repressing illegal artisanal mining in indigenous lands, through inspection actions. However, despite investigative operations, there is an incentive for illegal mining, as well as the flexibility and even suspension of fines for environmental crimes, favoring economic groups and the invasion of public lands[28,29].

The high rates of malaria among indigenous people in the State are also exacerbated by the difficulty in accessing health care, often determined by the geographical characteristics of entering the villages, the difficulty of accessing villages in some regions, the precariousness of health structures, the limited availability of supplies and the use of obsolete work tools, negatively reflecting on the quality of care provided[1,8]. Stands out that the dynamics and logistics of work in indigenous lands vary according to the DSEI organization and differ in the various villages, resulting, in some cases, from factors that are not always geographical and that compromise the movement and actions of the health teams.

The routine in the villages requires health interventions that consider the indigenous way of life, based on cultural profile. This is, therefore, a challenge for indigenous health teams. There are difficulties in implementing actions that effectively reduce health inequalities among these populations. Such care difficulties can also be explained by the high turnover of health professionals, combined to the discontinuity of actions in other parts of the service network outside the village[30].

CONCLUSION

The API rates among indigenous people were quite high, requiring more effective public policies for malaria control. Its high incidence involves several factors, including economic, social and environmental issues, and must be managed in all its dimensions. Such findings suggest the need to consider the cultural differences that permeate human groups for the implementation of effective control measures. In this sense, it is essential to consolidate institutional partnerships and intersectoral actions, since these are people with low socioeconomic conditions, requiring joint efforts to cope with the problem and revert the endemic indicator.

The study indicates a clear relationship between the impacts of mining and the incidence of malaria among indigenous people. It highlights the need for effort by public agents to combat illegal mining, or even to legalize all areas of mineral exploration in the Amazon, considering that illegal artisanal mining exposes indigenous people even more, substantially contributing to the occurrence of cases.

The results of this study can be applied in four practical dimensions of nursing: teaching, research, assistance, and health management. In teaching, it is understood that it can foster knowledge sharing initiatives in technical education and higher education, raising critical-reflective attitudes and/or improving skills and abilities for qualified intervention with this human group.

In the context of research, the study provides evidence to support the fight against malaria and its repercussions on public health, envisioning greater control of the disease in the ethnic groups most exposed to the vector, and stimulating further studies in the area. In the care dimension, the findings suggest the need to rethink care practices, improving work processes and recognizing the multiple factors that lead to illness from malaria in the indigenous environmental context. Regarding health management, it strengthens the need to invest in intersectoral actions as strategies for greater control of the vector, essentially related to predatory incursions into the environment.

The limitations of this study are related to possible failures in filling out notification forms, attributable to a deficit in training of professionals who made such records.

More stratified research is recommended to identify municipalities, villages, and localities with a higher occurrence of the disease. It is understood that the study presents evidence that contributes to discussing, developing, and/or implementing actions for malaria control among indigenous people, whose sociocultural context must be valued to overcome the conditions of vulnerability that historically imply in health care for these populations.

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Authorship contribution:

Project administration: Rosinelle Janayna Coêlho Caldas, Laura Maria Vidal Nogueira.
Formal analysis: Rosinelle Janayna Coêlho Caldas, Laura Maria Vidal Nogueira.
Conceptualization: Rosinelle Janayna Coêlho Caldas, Laura Maria Vidal Nogueira, Ivaneide Leal Ataíde Rodrigues, Erlon Gabriel Rego de Andrade.
Data curation: Rosinelle Janayna Coêlho Caldas, Laura Maria Vidal Nogueira.
Writing-original draft: Rosinelle Janayna Coêlho Caldas, Laura Maria Vidal Nogueira, Ivaneide Leal Ataíde Rodrigues, Erlon Gabriel Rego de Andrade, Carla Monique Lavareda Costa, Lidiane de Nazaré Mota Trindade.
Writing-review & editing: Rosinelle Janayna Coêlho Caldas, Laura Maria Vidal Nogueira, Ivaneide Leal Ataíde Rodrigues, Erlon Gabriel Rego de Andrade, Carla Monique Lavareda Costa, Lidiane de Nazaré Mota Trindade.
Methodology: Rosinelle Janayna Coêlho Caldas, Laura Maria Vidal Nogueira, Ivaneide Leal Ataíde Rodrigues, Erlon Gabriel Rego de Andrade.
Supervision: Laura Maria Vidal Nogueira.
Visualization: Rosinelle Janayna Coêlho Caldas, Laura Maria Vidal Nogueira, Ivaneide Leal Ataíde Rodrigues, Erlon Gabriel Rego de Andrade, Carla Monique Lavareda Costa, Lidiane de Nazaré Mota Trindade.

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Corresponding author:

Rosinelle Janayna Coêlho Caldas
E-mail: r_janayna@hotmail.com

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