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Incidence of COVID-19 in Paraíba and sociodemographic factors: an ecological and spatial study

Incidência da COVID-19 na Paraíba e fatores sociodemográficos: um estudo ecológico e espacial

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ABSTRACT

Introduction: COVID-19 notification has been growing continuously in Brazil and the study of all related aspects is necessary. **Objective:** To determine the incidence rate of coronavirus, analyze the spatial autocorrelation of reported cases and determine the correlation between the incidence of the disease and sociodemographic variables in the state of Paraíba, in 2020. **Method:** An observational, ecological research was carried out and data were obtained from notifications from cities in Paraíba to the Coronavirus Panel. The outcome variable was the disease incidence rate, and the explanatory variables referred to sociodemographic data, testing the hypotheses using Spearman's correlation. Spatial autocorrelation was verified using Moran's I and Geary's C statistic, using choropleth maps, by means of the R software, at a significance level of 5%. **Results:** Increasing values of incidence rates were observed as the months progressed. There was a statistical correlation for population density, income, and Municipal Human Development Index in most months. In addition, the *Alto-Alto* pattern was observed in the state capital at the beginning of the pandemic and, soon after, a migration of this spatial pattern to the interior cities. **Conclusions:** It was observed, therefore, that the high incidence rates and its spatial behavior negatively impact people's lives and signal the need for a more intense intervention of governmental policies.

KEYWORDS: SARS-CoV-2; Information Storage and Retrieval; Epidemiology

RESUMO

Introdução: A notificação da COVID-19 vem crescendo continuamente no Brasil e o estudo de todos os aspectos relacionados se faz necessário. **Objetivo:** Determinar a taxa de incidência do coronavírus, analisar a autocorrelação espacial dos casos notificados e determinar a correlação entre a incidência da doença e variáveis sociodemográficas no estado da Paraíba, em 2020. **Método:** Foi realizada uma pesquisa observacional, do tipo ecológica e os dados foram obtidos das notificações das cidades paraibanas ao Painel Coronavírus. A variável desfecho foi a taxa de incidência da doença, e as explicativas referiam-se aos dados sociodemográficos, testando as hipóteses por meio da correlação de Spearman. Foi verificada a autocorrelação espacial por meio do Índice de Moran (I) e o Coeficiente de Geary (C), com o uso de mapas coropléticos, através do emprego do *software* R, ao nível significância de 5%. **Resultados:** Valores crescentes das taxas de incidência foram observados com o avançar dos meses. Houve correlação estatística para a densidade demográfica, a renda e o índice de desenvolvimento humano municipal na maioria dos meses. Ademais, observou-se o padrão Alto-Alto na capital do estado no início da pandemia e, logo após, uma migração desse padrão espacial para as cidades interioranas. Conclusões: Observou-se, portanto, que as altas taxas de incidência e o seu comportamento espacial impactam negativamente a vida das pessoas e sinalizam a necessidade de uma intervenção mais intensa de políticas governamentais.

PALAVRAS-CHAVE: SARS-CoV-2; Armazenamento e Recuperação da Informação; Epidemiologia

INTRODUCTION

COVID-19 is a severe acute respiratory infectious disease caused by a virus of the Coronaviridae family, SARS-CoV-2, initially resident in some animal species[1]. The first human cases were identified in the city of Wuhan, China, in December 20192. Since then, due to the high transmissibility with potential global distribution and increased mortality rates, the World Health Organization (WHO) has classified the novel coronavirus pandemic as a global public health emergency[3].

The clinical aspects range from milder symptoms - especially coughing episodes, sore throats, headaches, myalgia - to more serious ones, such as dyspnea, low oxygen saturation (< 93%), to critical cases, such as respiratory failure, septic shock and/or multiple organ dysfunction[4,5]. It is also worth highlighting the importance of certain comorbidities in worsening the clinical picture, such as hypertension, diabetes, chronic kidney disease and cardiovascular disease, as well as smoking and immunosuppression[6].

In the event of a suspected case, a correct diagnosis is necessary for effective control. Therefore, three types of diagnosis are identified for COVID-19: clinical, laboratory and imaging[7]. The Ministry of Health considers the initial clinical picture to be a flu-like syndrome (FS) and its diagnosis is made by clinical-epidemiological investigation, paying attention to the history of close contact in the last 14 days of the onset of signs and symptoms with individuals already confirmed for COVID-19[8]. Laboratory tests can be carried out using reverse transcription polymerase chain reaction (RT-PCR) methodologies, serological testing for IgM, IgA and/or IgG antibodies, or even rapid tests. As for radiology, the standard test is high-resolution computed tomography[9].

Various ways of combating the spread of the virus are reported in the literature, but those considered sovereign include: a measure of social isolation, called quarantine, hygiene actions and mass testing of the population, considering an incubation period of five days on average[10,11]. However, even in the face of successful experiences in developed countries that have managed to test the population on a large scale and determine the levels of infection at subclinical stages, one must consider the potential costs to the public purse when adopting these measures on a national scale and on a compulsory basis[11]. In addition, in Brazil, there is a significant weakness in terms of testing the population, as well as the weakening of social distancing measures to the detriment of a probable risk of economic collapse, increasing social inequalities in economic, ethnic and geographical contexts[12].

According to the database provided by the Ministry of Health's Health Surveillance Secretariat (https://covid.saude.gov.br/), which is updated daily, as of October 2021 Brazil has recorded 21,516,967 confirmed cases of COVID-19, with incidence data of 10,239 per 100,000 inhabitants. In 2020, the country recorded 7,675,973 confirmed cases and 194,949 victims. The Northeast ranks second in reported cases (4,805,521), behind only the Southeast[13].

In Paraíba, the first case of infection occurred in March 2020. There were 166,484 cases in the whole of 2020, behind Bahia with 493,400, Ceará with 335,091, and Pernambuco and Maranhão with 222,166 and 200,938 cases, respectively. In 2021, until October, there were a total of 442,464 cases and 9,329 deaths[13].

Faced with this pandemic emergency in which Brazil is inserted - especially due to the lack of mass testing in order to recognize cases early and, consequently, avoid overcrowding in health services - studies that demonstrate the epidemiological reality through the use of spatial modeling techniques become indispensable for planning and decision-making in Public Health according to the distribution in space-time[14]. Thus, this article aimed to determine the incidence rate of COVID-19, analyze the spatial autocorrelation structure of reported cases and determine the correlation between the incidence of the disease and sociodemographic variables in the state of Paraíba in 2020.

METHOD

This is an epidemiological, observational study, whose design is classified as ecological, panel, as it focuses on comparisons of aggregate data with a longitudinal character, and not at an individual level, in which the numerators correspond to the number of reported events, and the denominators are population estimates[15]. In addition, spatial statistical techniques were used, with area data, normally used when the exact locations of an event are not available, but rather the values of these events per unit area.

To this end, statistical analyses were carried out using secondary data on COVID-19 available on the Ministry of Health's Coronavirus Panel *website* (https://covid.saude.gov.br). This *website* publishes daily incidence bulletins and cumulative case numbers, as well as data on deaths, among other information. The research focused on investigating the distribution of notifications of the disease among the cities in the state of Paraíba, from March to December 2020.

According to the Brazilian Institute of Geography and Statistics (IBGE)[16], Paraíba has an estimated population of 4,059,905 inhabitants in 2021, with a population density of 66.70 inhabitants/km^2. It has 223 municipalities and is divided into four mesoregions: Mata Paraibana, Agreste, Borborema and Sertão Paraibano. In terms of economic aspects, in 2010 the state had a human development index (HDI) of 0.658, a gross domestic product (GDP) *per capita of* 16,108 and a nominal monthly household income *per capita of* R$ 892.00.

The outcome variable was the incidence rate of coronavirus cases reported by the epidemiological surveillance sectors of each municipality in the state of Paraíba to the national information system on GS surveillance. This data comes from the e-SUS Notifica system, which was designed and developed to record suspected and confirmed cases of COVID-19 and contains information related to the patient's place of residence and place of care. Other variables were also tested in relation to the incidence rate in the municipalities: demographic density, *per capita* household income (PDHI), municipal human development index (MHDI), primary care coverage and illiteracy rates. These variables were obtained from the IBGE Automatic Recovery System - SIDRA (https://sidra.ibge.gov.br/home/lspa/brasil).

Statistical analysis

Firstly, the frequency of cases reported for COVID-19 between March and December 2020 was shown. Next, the normality of the data was checked using the Anderson-Darling test to analyze the correlation between reported cases and socioeconomic variables using Spearman's correlation test, adopting a statistical significance level of 5%. After this, case incidence rates were calculated for all the municipalities in Paraíba, taking into account the number of notified cases and the estimated population for the year multiplied, for that municipality, by the population base of 10,000, as shown in the equation:

$$\frac{\textit{Novos casos notificados}}{\textit{População estimada do ano}} \times 10.000\cdot$$

Spatial statistics

In order to apply the area data analysis methodology, it is necessary to draw up a neighborhood matrix which, in turn, is also known as a distance matrix or proximity matrix. This proximity matrix indicates the spatial relationship between the observation areas of the study - in this study, the cities of Paraíba - providing scales of robustness of the interaction between closer cities and the opposite for distant cities. In the matrix, *n* means the number of observations obtained in the W matrix, and each Wij element represents the level of proximity between *Wi* and *Wj*. In this way, the elements of the W matrix are assigned a value of 1 when the areas are considered neighbors and 0 otherwise.

$$W = \begin{bmatrix} W_{11} & W_{12} & \cdots & W_{1n} \\ W_{21} & W_{22} & \cdots & W_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ W_{n1} & W_{n2} & \cdots & W_{n1} \end{bmatrix}$$

Two statistical methods were used to check for possible spatial statistical dependence: the Global Moran's Index, which provides an official indication of the degree of linear correlation between the observation vector of the variable of interest over time and the weighted average of the neighborhood values or spatial lag, and varies between -1 and +1 - this being complemented by the local index which assesses the autocorrelation associated with one or a few specific values for each area - and Geary's C Coefficient, used in locations with little neighborhood, as shown in the following formulas:

I = Moran's index

$$I = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(y_i - \bar{y})(y_j - \bar{y})}{\sum_{i=1}^{n}(y_i - \bar{y})^2}$$

C = Geary coefficient

$$C = \frac{(n-1)}{2\sum_{i=1}^{n}\sum_{j\neq i}^{n} w_{ij}} \times \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(z_i - \bar{z})(z_j - \bar{z})}{\sum_{i=1}^{n}(z_i - \bar{z})^2}$$

Ii = Local Moran's Index

$$I_i = \frac{(y_i - \bar{y})\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(y_j - \bar{y})}{\sum_{i=1}^{n}(y_i - \bar{y})^{\frac{2}{n}}}$$

R statistical *software* was used to calculate incidence rates, bivariate analyses and, finally, to carry out the other spatial analyses[17]. To this end, a table was developed with the values of the Moran Index estimates, as well as descriptive Moran maps and Moran *Maps*, whose function is to indicate the municipalities that are classified in the space-time binomial as significant spatial agglomerations (*clusters*). For interpretative purposes, the cartograms can show four types of *clusters*:

- High-High (Q1): areas built by municipalities with high incidence frequencies of the outcome variable surrounded by other cities with high frequencies;
- Low-Low (Q2): areas built by municipalities with low incidence frequencies of the outcome variable surrounded by other cities with low frequencies;
- High-Low (Q3): areas built by municipalities with high incidence frequencies of the outcome variable surrounded by other cities with low frequencies;
- Low-High (Q4): areas built by municipalities with low incidence frequencies of the outcome variable surrounded by other cities with high frequencies.

Ethical aspects

Regarding ethical precepts, considering the provisions of Resolution 466 of December 12, 2012, submission to the Research Ethics Committee for this type of study becomes optional, since its methodology does not access or manipulate people's individual data, and these are in the public domain[18].

RESULTS

The incidence rate of reported COVID-19 cases in the municipalities of Paraíba between March and December 2020 has, in the vast majority of months, increased since the beginning of the pandemic. From April to May, there was an increase in new cases of around 2,783.42% in relation to the cities with the highest numbers of notifications. In other words, in April, João Pessoa had the highest incidence rate in the state (5.95/10,000). The following month, the town of Riachão de Bacamarte, 97.4 km from the capital, showed a rate of 171.77/10,000, topping the list of towns with the highest numbers of the disease. From August onwards, there was a reduction in new cases until November, when cases began to recur.

With regard to sociodemographic data, Table 1 provides information on demographic density, *per capita* household income, MHDI, primary care coverage and the illiteracy rate and their influence on the behavior of the disease incidence rate. There was a positive correlation (p-value < 0.05) in most of the variables, with the exception of primary care coverage and the illiteracy rate.

Figure 1 shows maps where you can descriptively see the areas with the highest and lowest incidence rates of the disease. The municipalities with the highest incidence rates are identified with stronger shades. On the other hand, those cities with zero (0) incidence are shown in white. Generally speaking, in the first few months of the COVID-19 pandemic, it can be seen that the highest incidence rates were recorded in the cities belonging to the mesoregion of mata paraibana, in the coastal area. After July 2020, there was a gradual increase towards inland areas.

With regard to spatial dependence, the Moran's Index estimate showed significance in some municipalities. Table 2 shows the existence of positive spatial autocorrelation from April to December. In March, there is a dispersion in the distribution of COVID-19 cases, thus justifying the non-significant Moran's I. This confirms the spatial dependence in the spread of notifications between municipalities in the state of Paraíba in those months in 2020.

Using the Moran *Map*, it was possible to see clusters with a High-High pattern between April and December in the mesoregions of Mata Paraibana, Agreste, Borborema and Sertão in the state, with the municipalities of João Pessoa, Campina Grande, Santa Rita and Cabedelo showing this spatial pattern the most (Figure 2). It should be noted that few municipalities showed a Low-Low pattern. In other words, those areas that showed the High-High spatial pattern have positive values and positive averages, influencing their neighbors to have values equal to their own. Furthermore, it is possible to see that, as time progressed, this spatial pattern of influence between cities regarding the incidence of cases tended to migrate towards the mesoregions in the interior of the state.

DISCUSSION

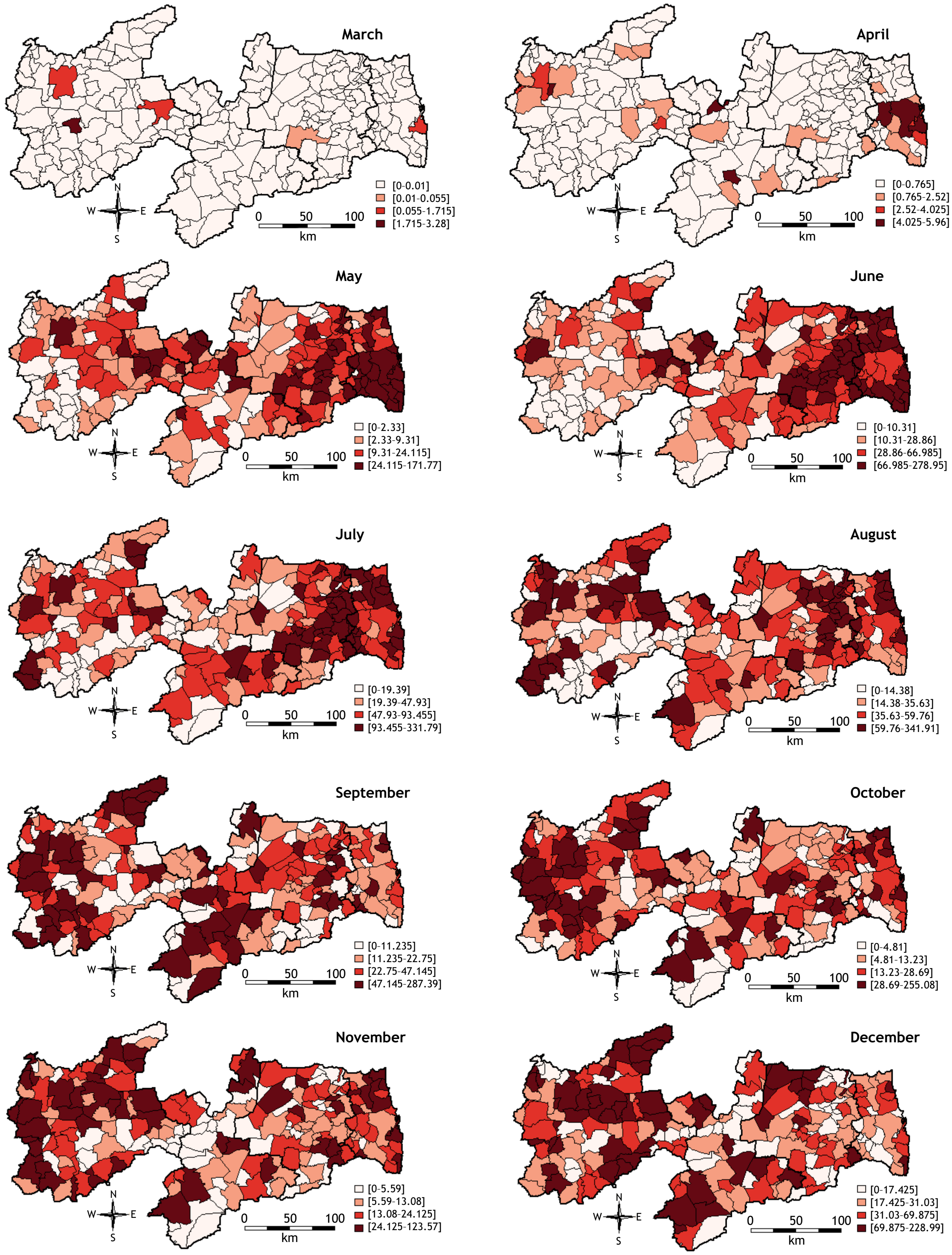
The COVID-19 pandemic has exposed changes related to space, time and the way infectious diseases behave[12]. Several factors have influenced this change in socio-epidemiological paradigms: integration, development and plurality of the world economy, added to the process of globalization, which has culminated in greater and faster movement of people around the world, as well as significant urban population densification. Given this scenario, as it is an infectious pathology, cities tend to behave individually in terms of the appearance of new cases of the disease, as well as influencing the epidemiological picture of neighboring municipalities, and some sociodemographic conditions are capable of interfering in this data.

The analysis of the data obtained in this study made it possible to visualize and understand the pattern of spatial behavior of the incidence of COVID-19 cases among urban agglomerations in the state of Paraíba. It was also possible to establish correlations between sociodemographic variables of interest to the topic and new cases using a spatial-temporal statistical approach. A similar study[19], in the state of Ceará, presented

Table 1. Correlation between sociodemographic variables and the COVID-19 incidence rate between March and December 2020.

Incidence rate/month	Population density		DPRK		MHDI		Primary care coverage		Illiteracy rate	
	Rho	p-value	Rho	p-value	Rho	p-value	Rho	p-value	Rho	p-value
March	0,1640	0,0142	0,2220	0,0008	0,2321	0,0004	-0,1483	0,0268	-0,1772	0,0080
April	0,2807	2,$^{1x10-5}$	0,3343	3,$^{2x10-7}$	0,2510	0,0001	-0,0566	0,4003	-0,2696	0,0453
May	0,4978	2,$^{2x10-15}$	0,1191	0,1047	0,0691	0,3044	-0,0737	0,2729	-0,0170	0,8008
June	0,5352	2,$^{2x10-6}$	0,1090	0,1045	0,0390	0,5628	-0,0447	0,5064	-0,0577	0,3916
July	0,4512	1,$^{4x10-12}$	0,1017	0,1299	0,0174	0,7956	-0,0595	0,3767	-0,0293	0,4418
August	0,2983	0,0057	0,1870	0,0050	0,1489	0,0262	-0,0263	0,6967	0,0140	0,8352
September	0,1430	0,0327	0,2075	0,0018	0,2073	0,0018	0,0371	0,5817	-0,1063	0,1134
October	0,1259	0,0605	0,2551	0,0001	0,2198	0,0009	0,0206	0,7599	-0,1403	0,0363
November	0,2000	0,0027	0,2367	0,0003	0,1856	0,0054	-0,0619	0,3573	-0,0948	0,1583
December	-0,0808	0,2296	0,1046	0,1192	0,1500	0,0250	0,0049	0,9417	-0,1018	0,1296

Source: Prepared by the authors, 2022.
DPRK: Household income *per capita*; MHDI: Municipal human development index; Rho: Spearman correlation coefficient.



Source: Prepared by the authors, 2022.

Figure 1. Descriptive maps of the COVID-19 incidence rate in Paraíba between March and December 2020.

Table 2. Moran's estimate to verify spatial dependence between March and December 2020.

Incidence rate/month	Moran's estimate	Hope	Variance	p-value
March	-0,0036	-4500,0	20,9000	0,4217
April	0,4180	-0,0045	0,0017	2,$^{2x10-16}$
May	0,3513	-0,0045	0,0017	2,$^{2x10-16}$
June	0,4653	-0,0045	0,0018	2,$^{2x10-16}$
July	0,4409	-0,0045	0,0018	2,$^{2x10-16}$
August	0,2223	-0,0045	0,0017	2,$^{5x10-8}$
September	0,1459	-0,0045	0,0017	0,0001
October	0,1046	-0,0045	0,0017	0,0040
November	0,1431	-0,0045	0,0018	0,0002
December	0,2319	-0,0045	0,0018	1,$^{1x10-8}$

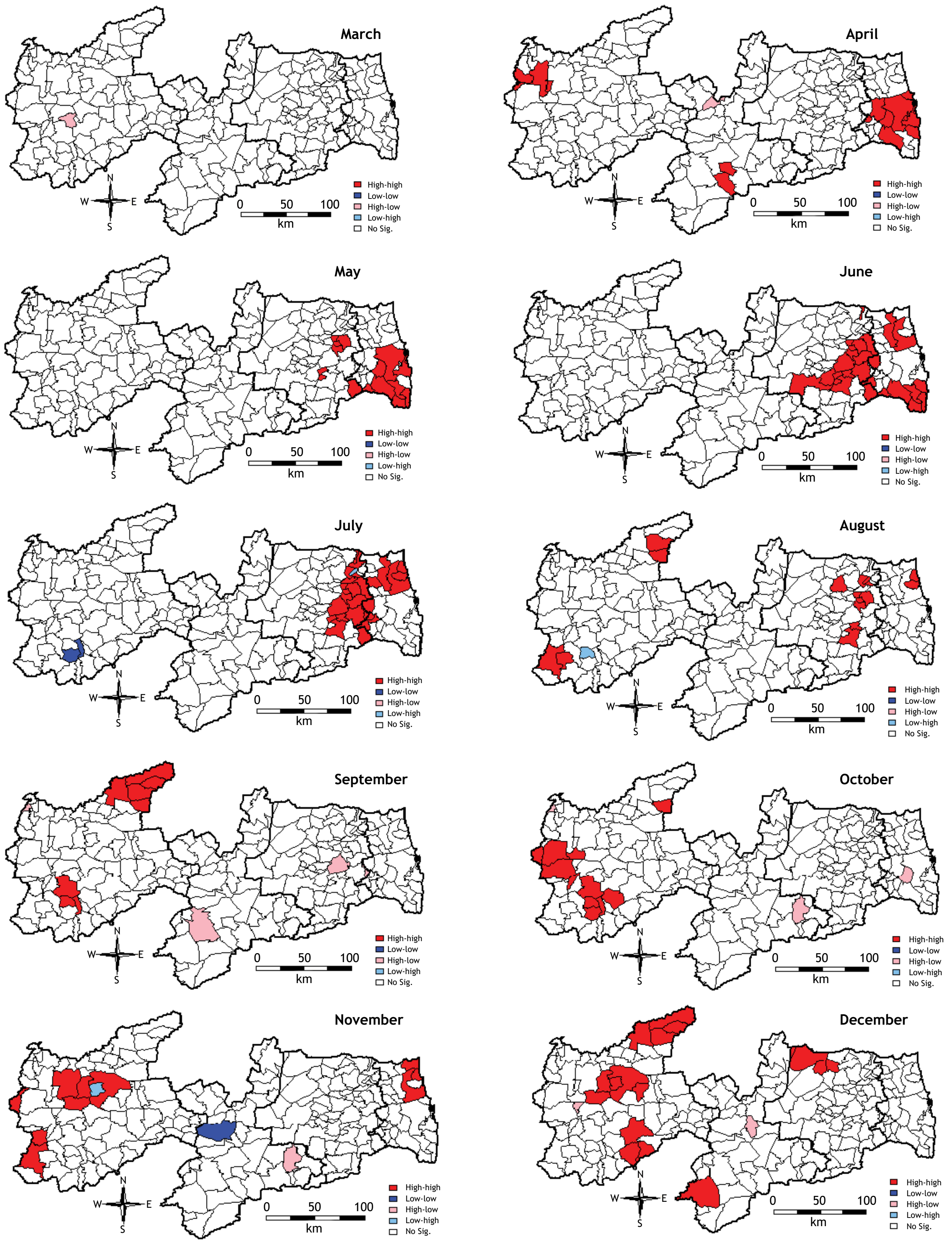
Source: Prepared by the authors, 2022.

a relevant proposal regarding the incidence rate of COVID-19: to verify the spatial correlation between the incidence of the pathology and human development in the municipalities, using Moran's I Index to verify spatial autocorrelation. In the study, the MHDI of all the municipalities in that state was the independent variable analyzed. This highlights the importance and differential of including new sociodemographic variables, such as those used in this study.

Among the policies recommended to contain the spread of COVID-19 in Brazil are social distancing and mandatory notification of suspected and confirmed cases of the disease[20]. On January 22, 2020, the Ministry of Health made immediate notification mandatory - within 24 hours - to the Center for Strategic Health Surveillance Information (CIEVS), in line with the provisions of events of relevance to Public Health[21]. However, it was only in March that confirmed cases were reported in Paraíba. In that month, only five cities reported cases; among these, the municipality of Igaracy, with an estimated population of 6,092 in 2021, had an incidence rate of 3.276/10,000, much higher than the state capital[21]. This information, in particular, is in line with what is mostly observed in the literature: more developed cities initially had a higher frequency of SARS-CoV-2 infection, due to a greater circulation of people[22]. It is possible to justify this dissonance due to the weakness of some cities in implementing surveillance policies for confirmed cases and deaths. In addition, it is important to highlight the accelerated evolution in the number of new cases of the disease in the first half of 2020. During this period, Paraíba ranked second in the northeast region in terms of the number of confirmed cases of the disease[23]. As of August of the same year, there has been a decline in notifications, probably due to greater awareness among the population and, consequently, greater adherence to control measures, namely: the use of masks for facial protection, encouraging hand hygiene, progressive social distancing actions, a ban on public events, discouraging travel and the use of alcohol for hands and surfaces[24].

Descriptive maps are a very efficient alternative for geographical and epidemiological mapping in areas with potential for the spread of SARS-CoV-2[19] infection. By reading and interpreting them over time, it is possible to carry out planning within the scope of epidemiological surveillance, with the aim, firstly, of understanding the behavioral dynamics of the incidence of cases and setting targets for combating the spread of the pandemic, including the allocation of financial resources, especially to those cities with the highest rates of infection.

That said, quintile (March and April) and quartile (May to December) maps were developed in order to visualize the frequencies of COVID-19 rates in all the municipalities in the state of Paraíba. Quantiles were used for the months of March and April, as more than 75% of the data showed zero frequencies. Because of this, in order to be able to differentiate the frequencies of the rates in the municipalities, a new descriptive analysis was carried out with non-zero data. In these choropleth maps, the higher incidence rates are proportionally represented by darker colors. When analyzing them, it is noticeable that, in the initial months of the pandemic, there was a concentration of reported cases in the cities of the Mata and Agreste Paraibano mesoregions, regions that are home to the state's most populous cities, the capital João Pessoa and Campina Grande. A similar finding was observed in the study by Pedrosa and Albuquerque[25], in the state of Ceará, by applying Moran's spatial statistics to identify the distribution of the number of COVID-19 cases. The findings of this study also showed higher initial rates in coastal and more populated cities. As the months went by, there was a considerable spread of the increase in these incidence rates among the cities in the interior of the state. This scenario reflects the influence of the economy, high urban mobility and the greater flow of national and, especially, international travel. From another perspective, the increase in cases in smaller towns confirms the internalization of the infection. Another important factor



Source: Prepared by the authors, 2022.

Figure 2. Moran *Maps of* the incidence rate of reported COVID-19 cases between March and December 2020.

is linked to the fact that the initial geographical spread of COVID-19 tends to be more common in cities with high internet access, confirming the data presented in this research, as well as reinforcing the need for prevention policies in cities with higher population density.

Data on contamination by SARS-CoV-2 tends to be strongly impacted by sociodemographic variables[26], generally inducing a greater risk of contagion because, for example, a certain group has characteristics that potentially predict the spread of the virus. As an example, information in the literature[27] has linked the increase in COVID-19 incidence rates among individuals with fewer years of schooling, either because this type of public usually tends to assume certain behaviours contrary to those recommended by health organizations, mainly due to lack of information, or because of the relationship with older age groups and all the cultural burden involved.

For studies in urban agglomerations, population density has been pointed out as influencing the emergence of notified cases[28]. This study found a positive correlation between the incidence of the disease in the cities of Paraíba and the population density in these areas, with the exception of the month of December. Globally, both absolute population size[29] and population density - more precisely in Japan[30], Italy and Iran[31] - have been found to be related to higher prevalence rates of the disease. This correlation can be interpreted from at least two points of view: greater movement of people in more populous cities and a more active testing policy in these municipalities. According to the evolution of the urban mobility index in the first half of 2020 in Paraíba, a reduction in social distancing was observed, justifying the considerable increase in cases during this period[23].

A relationship has been reported between low socioeconomic status and higher rates of the disease worldwide[32], possibly due to the influence of factors such as adequate sanitary facilities, hygiene practices and the mass distribution of alcohol to the poor for hand hygiene. This research also set out to study a possible relationship between reported COVID-19 cases and *per capita* household income in the municipalities of Paraíba. This data can be verified from the Continuous National Household Sample Survey (PNAD Contínua)[33], which tracks short-, medium- and long-term fluctuations in the labor force and other data necessary for understanding the nation's socioeconomic development. The results obtained here show that some months showed a statistically significant correlation for the DPRK variable. Thus, for the months in which the correlation was significant, the higher the *per capita* household income in the municipality, the higher the infection incidence rate - data confirmed by the correlation coefficient. This information may be related to the fact that cities with a greater number of families belonging to the higher strata of the DPRK tend to have a more active diagnostic testing culture. On the other hand, it should be noted that the PNAD's methodological design only considers permanent households, disregarding those families living on the margins of society, which can lead to confusion bias.

In parallel, the behavior of the variable related to the MHDI was quite similar to the previous one. At the start of the pandemic, cities with higher development indices reported more cases of the coronavirus and most of them were related to people with a recent history of traveling abroad[22]. The study by Maciel et al.[19] also found a correlation between the incidence of COVID-19 and the MHDI, corroborating the present data. Explanatorily, it is possible to establish a link between a high MHDI and greater movement of people, which leads to a greater likelihood of infection. On the other hand, lower levels of MHDI expose social vulnerability and the difficulty of accessing health services. In the context of the pandemic, the testing of this population has been weakened[34] and this has influenced the possible distortion of epidemiological data.

As the organizer of care, Primary Health Care (PHC) plays a crucial role in mitigating the pandemic in Brazil by providing care and guidance at first contact with the user, comprehensive and longitudinal care, as well as family guidance[35]. Although primary care coverage showed no statistically significant correlation over the months studied, with the exception of March, it is possible to observe an inversely proportional relationship between the number of primary care teams and COVID-19 notifications, based on the correlation coefficient. This data draws attention to the potential of PHC to control the spread of new cases. An ecological study carried out in Santa Catarina[36], when assessing the influence of primary care coverage in municipalities, found that those with greater PHC coverage had greater potential for lower lethality rates.

According to the IBGE, illiteracy refers to people over the age of 15 who are unable to articulate reading and writing, even in short texts. However, understanding illiteracy must go beyond reading and writing. It must be linked to an understanding of the socio-economic and political dimensions, as well as an understanding of elementary content aimed at self-care in health. Most of the data analyzed for this variable was not significant. Even so, these results are unprecedented in establishing a certain correlation with incident cases of SARS-CoV-2. Aspects such as culture and religion must be taken into account in this process, since adherence to hygiene measures established by the health authorities is seen as a challenge for most of this public.

With regard to the spatial analysis of the Moran index, areas with a strong positive correlation were found, with a High-High pattern, i.e. a given location with high detection rates and its neighbors showing similarly high numbers. In the first few months, this spatial pattern was observed around the state capital. As time progressed, these areas gradually migrated to the interior regions. The studies by Maciel et al.[19] and Pedrosa and Albuquerque[25] corroborated our results, finding a High-High spatial pattern for the capital of Ceará. The great mobility of people, the dependence and strong socio-economic relations that the cities in the interior establish with the capital[37], as well as the intense intra-state road flow, may be plausible justifications for the migration of this dynamic towards the mesoregions in the interior. Another important finding is the absence of Low-Low *clusters*, revealing a worrying distribution of cases in the state.

This study has limitations that should be considered. The first of these is the ecological fallacy, inherent to the type of study developed using this methodology, from which difficulties arise in establishing causal relationships based on individuals belonging to groups that are quite heterogeneous in terms of exposure[38]. In other words, an association observed between aggregates does not necessarily express the same condition at the level of individuals. Furthermore, testing and, consequently, notification are related to symptomatic cases, leaving an important information gap regarding the number of asymptomatic people in circulation.

On the other hand, this type of content has great potential to provide consistent data for planning actions to combat the spread of the new coronavirus, as well as predictive modeling for appropriate decision-making and public policy construction. Furthermore, the study has considerable internal validity, since the data is representative for urban agglomerations, but caution is needed when analyzing incidence rates due to underreporting.

Even though these data refer to 2020, their magnitude is validated by the need for in-depth analysis on an ongoing basis - including the adoption of georeferencing methodologies - precisely because it can be seen that the epidemiological behavior of cases is constantly fluctuating.

CONCLUSIONS

The spatial analysis carried out, refined with the use of area data techniques, was able to considerably improve the understanding of spatial patterns and behavioral dynamics regarding the COVID-19 incidence rate, since a special positive autocorrelation was observed for some months in 2020 in Paraíba. The study made it possible to verify, through descriptive maps, which areas had the highest rates of notification of the disease. Some cities, therefore, had high incidence rates and, in addition, showed the potential to influence the increase in incidence in neighboring localities, a fact that should be taken into account when planning multi-professional strategies. It is worth noting the influence of some sociodemographic variables on the incidence rate, especially demographic density, MHDI and *per capita* household income. It is therefore necessary to structure permanent health promotion strategies that focus on prevention and self-care.

REFERENCES

1. Sharma A, Lal SK. Zika virus: transmission, detection, control, and prevention. Front Microbiol. 2017;8:1-14. https://doi.org/10.3389/fmicb.2017.00110
2. Wenham C, Smith J, Morgan R. COVID-19: the gendered impacts of the outbreak. Lancet. 2020;395(10227):846-8. https://doi.org/10.1016/S0140-6736(20)30526-2
3. Rothan HA, Byrareddy SN. The epidemiology and pathogenesis of coronavirus disease (COVID-19) outbreak. J Autoimmun. 2020;109:1-14. https://doi.org/10.1016/j.jaut.2020.102433
4. Raoult D, Zumla A, Locatelli F, Ippolito G, Kroemer G. Coronavirus infections: epidemiological, clinical and immunological features and hypotheses. Cell Stress. 2020;4(4):66-74. https://doi.org/10.15698/cst2020.04.216
5. Wu D, Wu T, Liu Q, Yang Z. The SARS-CoV-2 outbreak: what we know. Int J Infect Dis. 2020;94:44-8. https://doi.org/10.1016/j.ijid.2020.03.004
6. Van Doremalen N, Miazgowicz KL, Milne-Price S, Bushmaker T, Robertson S, Scott D et al. Host species restriction of Middle East respiratory syndrome coronavirus through its receptor, dipeptidyl peptidase 4. J Virol. 2014;88(16):9220-32. https://doi.org/10.1128/JVI.00676-14
7. Umakanthan S, Sahu P, Ranade AV, Bukelo MM, Rao JS, Abrahao-Machado LF et al. Origin, transmission, diagnosis and management of coronavirus disease 2019 (COVID-19). Postgrad Med J. 2020;96(1142):753-8. https://doi.org/10.1136/postgradmedj-2020-138234
8. Ministério da Saúde (BR). Saiba como é feito o diagnóstico dos casos de COVID-19 no Brasil. Brasília: Ministério da Saúde; 2021[Acesso em 19 set 2021]. Disponível em: https://www.gov.br/saude/pt-br/coronavirus/diagnostico
9. Lan L, Xu D, Ye G, Xia C, Wang S, Li Y et al. Positive RT-PCR test results in patients recovered from COVID-19. JAMA. 2020;323(15):1502-3. https://doi.org/10.1001/jama.2020.2783
10. Rothe C, Schunk M, Sothmann P, Bretzel G, Froeschl G, Wallrauch C et al. Transmission of 2019-nCoV infection from an asymptomatic contact in Germany. N Engl J Med. 2020;382(10):970-1. https://doi.org/10.1056/NEJMc2001468
11. Moreira RS. Latent class analysis of COVID-19 symptoms in Brazil: results of the PNAD- Covid19 survey. Cad Saúde Pública. 2021;37(1):1-14. https://doi.org/10.1590/0102-311X00238420
12. Lima NT, Buss PM, Paes-Sousa R. A pandemia de COVID-19: uma crise sanitária e humanitária. Cad Saúde Pública. 2020;36(7):1-4. https://doi.org/10.1590/0102-311X00177020

13. Ministério da Saúde (BR). Dados consolidados sobre o COVID-19. Brasília: Ministério da Saúde; 2021.
14. Mendonça FD, Rocha SS, Pinheiro DLP, Oliveira SV. Região norte do Brasil e a pandemia de COVID-19: análise socioeconômica e epidemiológica. J. Health NPEPS. 2020;5(1):20-37. https://doi.org/10.30681/252610104535
15. Merchán-Hamann E, Tauil PL. Proposta de classificação dos diferentes tipos de estudos epidemiológicos descritivos. Epidemiol Serv Saúde. 2021;30(1):1-13. https://doi.org/10.1590/s1679-49742021000100026
16. Instituto Brasileiro de Geografia e Estatística – IBGE. Censo brasileiro de 2010. Rio de Janeiro: Instituto Brasileiro de Geografia e Estatística; 2012.
17. R Core Team. R: a language and environment for statistical computing. Vienna: R Foundation for Statistical Computing; 2021.
18. Guerriero ICZ. Resolução nº 510 de 7 de abril de 2016 que trata das especificidades éticas das pesquisas nas ciências humanas e sociais e de outras que utilizam metodologias próprias dessas áreas. Cien Saúde Colet. 2016;21(8):2619-29. https://doi.org/10.1590/1413-81232015218.17212016
19. Maciel JAC, Castro-Silva II, Farias MR. Análise inicial da correlação espacial entre a incidência de COVID-19 e o desenvolvimento humano nos municípios do estado do Ceará no Brasil. Rev Bras Epidemiol. 2020;23:1-17. https://doi.org/10.1590/1980-549720200057
20. Ministério da Saúde (BR). Plano de contingência nacional para infecção humana pelo novo coronavírus COVID-19. Brasília: Ministério da Saúde; 2020.
21. Ministério da Saúde (BR). Boletim epidemiológico 4: novo coronavírus (2019-nCoV). Brasília: Ministério da Saúde; 2020
22. Silva J, Muniz A. Pandemia do coronavírus no Brasil: impactos no pandemia do coronavírus no Brasil. Espaço Econ. 2020;9(17):1-20. https://doi.org/10.4000/espacoeconomia.10501
23. Kerr L, Kendall C, Silva AAM, Aquino EML, Pescarini JM, Almeida RLF et al. COVID-19 no Nordeste brasileiro: sucessos e limitações nas respostas dos governos dos estados. Cien Saúde Colet. 2020;25(Supl.2):4099-120. https://doi.org/10.1590/1413-812320202510.2.28642020
24. Aquino EM, Silveira IH, Pescarini JM, Aquino R, Souza-Filho JA, Rocha AS et al. Medidas de distanciamento social no controle da pandemia de COVID-19: potenciais impactos e desafios no Brasil. Cien Saúde Colet. 2020;25(Supl.1):2423-46. https://doi.org/10.1590/1413-81232020256.1.10502020
25. Pedrosa NL, Albuquerque NLS. Análise espacial dos casos de COVID-19 e leitos de terapia intensiva no estado do Ceará, Brasil. Cien Saúde Colet. 2020;25:2461-8. https://doi.org/10.1590/1413-81232020256.1.10952020
26. Borges GM, Crespo CD. Aspectos demográficos e socioeconômicos dos adultos brasileiros e a COVID-19: uma análise dos grupos de risco a partir da pesquisa nacional de saúde, 2013. Cad Saúde Pública. 2020;36(10):1-15. https://doi.org/10.1590/0102-311X00141020
27. Rezende LF, Thome B, Schveitzer MC, Souza-Júnior PRB, Szwarcwald CL. Adults at high-risk of severe coronavirus disease-2019 (COVID-19) in Brazil. Rev Saúde Pública. 2020;54:1-9. https://doi.org/10.11606/s1518-8787.2020054002596
28. World Health Organization – WHO. The corona virus disease 2019 (COVID-19). Geneva: World Health Organization; 2020.
29. Cao Y, Hiyoshi A, Montgomery S. COVID-19 case-fatality rate and demographic and socioeconomic influencers: worldwide spatial regression analysis based on country-level data. BMJ Open. 2020;10(11):1-12. https://doi.org/10.1136/bmjopen-2020-043560
30. Bassino JP, Ladmiral G. Socio-economic factors influencing COVID-19 spread in Japan: evidence from the second wave (March-May 2020). ResearchGate Preprint. 2020. https://doi.org/10.13140/RG.2.2.12371.60961
31. Sjödin H, Wilder-Smith A, Osman S, Farooq Z, Rocklöv J. Only strict quarantine measures can curb the coronavirus disease (COVID-19) outbreak in Italy, 2020. Euro Surveill. 2020;25(13):1-6. https://doi.org/10.2807/1560-7917.ES.2020.25.13.2000280
32. Schellekens P, Sourrouille DM. COVID-19 mortality in rich and poor countries: a tale of two pandemics? Policy research working papers. Washington: World Bank Group; 2020.
33. Travassos C, Viacava F, Laguardia J. Os suplementos Saúde na Pesquisa Nacional por Amostra de Domicílios (PNAD) no Brasil. Rev Bras Epidemiol. 2008;11(Supl.1):98-112. https://doi.org/10.1590/S1415-790X2008000500010
34. Ribas RM, Campos PA, Brito CS, Gontijo-Filho PP. Coronavirus disease 2019 (COVID-19) and healthcare-associated infections: emerging and future challenges for public health in Brazil. Travel Med Infect Dis. 2020;37:1-2. https://doi.org/10.1016/j.tmaid.2020.101675
35. Garg S, Basu S, Rustagi R, Borle A. Primary health care facility preparedness for outpatient service provision during the COVID-19 pandemic in India: cross-sectional study. JMIR Public Health Surveill. 2020;6(2):1-7. https://doi.org/10.2196/19927
36. Souza SS, Cunha AC, Suplici SER, Zamprogna KM, Laurindo DLP. Influência da cobertura da atenção básica no enfrentamento da COVID-19. J Health NPEPS. 2021;6(1):1-21. https://doi.org/10.30681/252610104994

37. Silva B. A interiorização da COVID-19 no Nordeste: temos infraestrutura de saúde. Natal: Conselho Regional de Economia-RN; 2020.

38. Costa MFL, Barreto SM. Tipos de estudos epidemiológicos: conceitos básicos e aplicações na área do envelhecimento. Epidemiol Serv Saude. 2003;12(4):189-201. https://doi.org/10.5123/S1679-49742003000400003

Authors' Contribution

Silva GCB, Olinda RA - Conception, planning (study design), analysis, interpretation of data and writing of the paper. Silva GB, Nascimento AA - Conception, planning (study design), data analysis and interpretation. Pachá ASC - Conception, planning (study design). Pamplona YAP, Martins LC - Data analysis and interpretation. All the authors approved the final version of the work.

Conflict of Interest

The authors inform that there is no potential conflict of interest with peers and institutions, political or financial in this study.