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SPECIAL ARTICLE / *ARTIGO ESPECIAL*

Initial analysis of the spatial correlation between the incidence of COVID-19 and human development in the municipalities of the state of Ceará in Brazil

Análise inicial da correlação espacial entre a incidência de COVID-19 e o desenvolvimento humano nos municípios do estado do Ceará no Brasil

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ABSTRACT: ***Objective:*** To analyze the spatial distribution of the incidence of COVID-19 and its correlation with the municipal human development index (MHDI) of the municipalities of Ceará. ***Methods:*** This is an ecological study with data recovered from the 15th epidemiological week and the 19th one of the year 2020 using the MHDI and the COVID-19 incidence coefficient for each municipality as variables. The univariate spatial correlation and the bivariate one were analyzed using the TerraView and GeoDa softwares. ***Results:*** The incidence of COVID-19 has spatial dependence with moderate positive correlation and the formation of high-high clusters located in the metropolitan region of Fortaleza and municipalities in the north region. The lowest incidence was a low-low cluster in the south and west regions. There was a positive bivariate correlation between MHDI and the incidence of COVID-19 with the formation of a cluster in the metropolitan region of Fortaleza. ***Conclusion:*** The uneven mapping of COVID-19 and its relationship with MHDI in Ceará can contribute to actions to regional combat the pandemic.

Keywords: Coronavirus. SARS virus. Development indicators. Geographic mapping.

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RESUMO: ***Objetivo:*** Analisar a distribuição espacial da incidência de Covid-19 e sua correlação com o índice de desenvolvimento humano municipal (IDHM) dos municípios do Ceará. ***Métodos:*** Trata-se de um estudo ecológico com dados recuperados da 15ª e da 19ª semana epidemiológica do ano de 2020 utilizando como variáveis o IDHM e o coeficiente de incidência de Covid-19 para cada município. Foi analisada a correlação espacial uni e bivariada por meio dos *softwares* TerraView e GeoDa. ***Resultados:*** A incidência da Covid-19 possui dependência espacial com correlação positiva moderada e formação de *clusters* do tipo alto-alto localizados na região metropolitana de Fortaleza e municípios da região norte. As menores incidências foram *cluster* tipo baixo-baixo na região sul e na região oeste. Houve correlação bivariada positiva entre IDHM e incidência de Covid-19 com formação de *cluster* na região metropolitana de Fortaleza. ***Conclusão:*** O mapeamento desigual de Covid-19 e sua relação com IDHM no Ceará podem contribuir com ações de enfrentamento regional à pandemia.

Palavras-chave: Coronavírus. Vírus da SARS. Indicadores de desenvolvimento. Mapeamento geográfico.

INTRODUCTION

On December 31, 2019, the World Health Organization (WHO) headquarters, in China, was informed about cases of pneumonia, of unknown etiology, detected in the city of Wuhan, province of Hubei. A new type of coronavirus was isolated on January 7, 2020, and new cases were confirmed in Thailand, Vietnam, Japan, and South Korea. On January 30, 2020, the WHO declared an international public health emergency, due to the fast dissemination of the coronavirus, after a meeting with specialists. At that point, there were 7.7 thousand confirmed cases and 170 deaths in China, main location of the virus dissemination, besides 98 cases in 18 other countries[1].

The disease is highly contagious and its main clinical symptoms include fever, dry cough, fatigue, myalgia and dyspnea. The severe cases are characterized by acute respiratory distress syndrome, septic shock, metabolic acidosis, which is difficult to treat, and blood and coagulation disorders[2].

On March 11, 2020, the WHO classified the disease caused by coronavirus 2019 (Covid-19) as a pandemic. This means that the virus is circulating in all continents, and that there are oligosymptomatic cases, or with unspecific clinical and imaging presentation, which makes it difficult to identify it, and facilitates the fast transmission, with a very high level of severity[3,4].

A global systematic review evaluated the epidemiological profile of Covid-19 and verified that the mortality rate reaches 0.3% of the population, especially affecting elderly men[4]. The first case of Covid-19 was confirmed in Brazil on February 26, 2020, in an elderly man who had come from Italy[5]. Until May 7, 2020, the country had 135,106 confirmed cases and 9,146 deaths. The Northeast region has 31.2% of the cases in Brazil, and the state of Ceará is the third with the highest number of confirmed cases in the country[6]. In May, 2020, the transmission rate of Covid-19 in Brazil was considered as one of the 11 highest rates in the world. The estimation was that each infected person could favor the contamination of three other people, being the country with the third highest absolute lethality, after the United States and the United Kingdom[7].

Studies about Covid-19 have been increasing fast in the country; there were 162 observational studies and 37 clinical trials until May 1st, 2020. The Northeast region had only one clinical trial approved by the National Research Ethics Commission, located in Ceará, including 300 patients with pneumonia caused by Covid-19, treated with new pharmacological agents[8].

Since until the present moment there is no scientific evidence that ensures the therapeutic efficacy of antiretroviral drugs to fight the pandemic, the non-pharmacological interventions are being prioritized in Brazil. The objective is to postpone the peak of the epidemic curve, reduce the demand for health care and decrease the number of cases and effects on the health of the population[9]. The most recommended strategies to control the dissemination of Covid-19 are social distancing and frequent hand washing; however, these actions are not feasible for the millions of people who live in highly dense communities or precarious households, without basic sanitation and access to drinkable water[10]. It is believed that, in the initial stages of the epidemic process of Covid-19 in the state of Ceará, there was a spatial correlation between the coefficient of incidence of Covid-19 and its different municipalities.

Brazil is one of the countries in which Covid-19 is progressing, alongside with Canada, Colombia, Dominican Republic, Equator, India, Mexico, Pakistan, Peru, Russia and South Africa. This reinforces the fact that contamination is higher in emerging countries, even though nations with continental proportions and heterogeneous economy represent a new epidemiological profile for the disease[7]. In this sense, it is important to verify the ecological association between human development and the Covid-19 pandemic.

Therefore, the objective of this study was to analyze the spatial distribution of the incidence of Covid-19 and its correlation with the municipal human development index (HDI-M) in the municipalities of Ceará.

METHODS

This is an ecological, exploratory and analytical study whose analysis units were the 184 municipalities in the state of Ceará. We used the coefficients of incidence of Covid-19 in the municipalities in 2020. The social information about the cities were collected in the Atlas of Human Development in Brazil[11], systematized by the United Nations Development Programme (UNDP) in 2010. The official estimation of the population of each municipality in Ceará, as well as this federative unit, was obtained for 2019 after consulting the Unified Health System computing department (DATASUS/Health information (TABNET), on May 12, 2020[12].

The incidence rates of Covid-19 were obtained based on the confirmed cases made available by the Secretariat of Health in the State of Ceará (SESA), through the electronic platform Integra SUS[13]. To calculate the coefficient of incidence of each municipality with cases, the number of confirmed cases was divided by the resident population and multiplied by the population base of 100 thousand inhabitants. The coefficients were calculated in two moments: the first considered the cases made available until 2 p.m., on April 12, 2020, enabling the inference of risk of impact in each municipality until the 15th epidemiologic week; and the second moment collected data until 6:11 p.m. on May 7, 2020 (19th epidemiologic week).

Social development was used as an independent variable, and the HDI-M estimated for each municipality in 2010 was used, according to the data by the UNDP. HDI-M can be classified as very low (0 to 0.499), low (0.500 to 0.599), medium (0.600 to 0.699), high (0.700 to 0.799) and very high (0.800 to 1). HDI-M synthetizes a mean of three sub-indexes calculated in the base of a few indicators, easily collected in the different nations; three basic and universal dimensions of life, which are the conditions for the choices and opportunities of individuals to be amplified: access to knowledge (education), right to a long and healthy life (longevity) and right to a worthy life pattern (income). Because of its simplicity, HDI-M does not deeply analyze any of these dimensions particularly, but allows to compare the general level reached by the units of analysis in the assistance of these basic needs, so that individuals can develop their capacities and choices[14].

The Statistical Package for the Social Sciences (SPSS, version 20.0, IBM, United States) was used for the descriptive data analysis. Descriptive statistics was carried out with the data about the cases and the population of each municipality, followed by the calculation of the coefficient of incidence. The HDI-M variable was presented by the respective arithmetic mean values referring to the three sub-indexes. Techniques were used for a spatial analysis of area data considering the digital mesh of the cities in the state of Ceará, using two geographic information programs.

The spatial analysis was carried out using TerraView 4.1.0, from the National Institute for Space Research[15]. For the estimation of spatial self-correlation, we used the Global Moran's I (GMI), which ranges between -1 and +1 and provides its statistical significance (p). After this analysis, the presence of spatial clusters was assessed based on the indicators of spatial association (LISA), with the construction of boxmaps related to the dependent variable and to each one of the independent variables. The cartograms showed the spatial cluster design in four types:

- high-high: regions formed by cities with high frequencies of the variable, and surrounded by high-frequency regions;
- low-low: regions formed by cities with low frequencies of the variable, and surrounded by low-frequency regions;
- high-low: regions formed by cities with high frequencies of the variable and surrounded by low-frequency regions;

- low-high: regions formed by cities with low frequencies of the variable, and surrounded by high-frequency regions.

The GeoDa 0.9.9.10 (Spatial Analysis Laboratory, University of Illinois, Urbana Champaign, United States) software was used to conduct the bivariate LISA analysis, to evaluate the spatial correlation between the dependent variable (coefficient of incidence of Covid-19) and the independent variable (HDI-M). This analysis generated the Local Moran's index (LMI), and the spatial correlation maps (LISA). For the bivariate spatial correlation, the clusters were interpreted in one of the five types:

- non-significant: territories that did not enter the cluster formation, because the differences were not significant;
- high-high: regions formed by municipalities with high frequencies of the dependent variable and high frequencies of the independent variable;
- low-low: regions formed by municipalities with low frequencies of the dependent variable and low frequencies of the independent variable;
- high-low: regions formed by municipalities with high frequencies of the dependent variable and low frequencies of the independent variable;
- low-high: regions formed by municipalities with low frequencies of the dependent variable and high frequencies of the independent variable.

The correlation values generated by GMI and LMI could be assessed as positive or negative, and as weak (< 0.3), moderate (0.3–0.7) or strong (> 0.7), as used in the Pearson's correlation evaluation[16].

All of the data used were secondary, without personal identification and of public domain, which, according to Resolution n. 510/2016, from the National Health Council, does not require the previous approval of the Human Research Ethics Committee[17].

RESULTS

The state of Ceará has a population of 9,178,363 inhabitants projected for 2020, with a population density of 56.76 residents/km^2 and HDI-M of 0.682, considered as medium. On April 12, 2020, there were 5,520 confirmed cases and 137 deaths; the coefficient of incidence of Covid-19 was 60.14 cases per 100 thousand inhabitants, and the cities with the highest incidence rates were Fortaleza (54.88), Aquiraz (36.13) and Senador Sá (13.12).

On May 7, 2020, there were 16,440 cases and 1,056 deaths, and the coefficient of incidence increased to 179.11 cases per 100 thousand inhabitants; the cities with the highest incidence rates were Fortaleza (362.22), Eusébio (350.63) and Ibicuitinga (199.60), for a population base of 100 thousand inhabitants, referring to the 166 cities with cases. The data of all municipalities with cases in the first collection were summarized with their respective HDI-M, and containing the sub-divisions of coefficient of incidence in time 1 (I1) and coefficient of incidence in time 2 (I2) for the dates April 12 and May 7, respectively (Table 1).

In the spatial correlation analysis of I1 for Covid-19, the cities presented significant and weak spatial self-correlation (GMI = 0.28; $p < 0.05$), with indication of low-low spatial clusters formed by the majority of cities, including Paracuru, Paraipaba, Trairi, Itapipoca, Tururu, Umirim, Itapipoca, Uruburetama, Pentecoste, Apuiarés, Tejuçuoca, Canindé, Caridade, General Sampaio, Paramoti, Pacoti, Mulungu, Guaramiranga, Baturité, Caridade, Palmácia, Capistrano, Aratuba, Itapiana, Ibaretama, Aracoiaba, Acarape, Barreira, Chorozinho, Ocara, Beberibe and Morada Nova. The high-high clusters were formed by the cities of Fortaleza, Caucaia, Maranguape, Maracanaú, Pacatuba, Eusébio, Aquiraz, Pindoretama, Horizonte and Itaitinga (Figure 1A).

In I2, the spatial self-correlation of Covid-19 remained positive and moderate (GMI = 0.47; $p < 0.05$), with formation of a high-high cluster in cities of the metropolitan region of Fortaleza, reaching the cities of Aquiraz, Beberibe, Morada Nova, Ibicuitinga, Banabuiú, Quixeramobim, Choró and Quixadá. There were high-high clusters in cities of the North coast (Jijoca de Jericoacoara, Cruz, Bela Cruz, Acaraú and Itarema), and in municipalities of the North region (Sobral, Coreaú, Moraújo, Frecheirinha, Cariré, Mucambo, Alcântaras, Massapê and Meruoca) (Figure 1B).

The low-low clusters for Covid-19 included most of the cities in the Cariri region (South of Ceará), as well as municipalities in the Southwest area, such as Sobral, Boa Viagem, Independência, Ocara, Novo Oriente, Quiterianópolis, Poranga, Ipueiras, Ararendá, Tamboril, Nova Russas, Hidrolândia e Catunda, Varjota, Reriutaba, Ibiabina, Carnaubal, São Benedito and Guaraciaba do Norte (Figure 1B).

Regarding HDI-M, the values concentrated between 0.540 (Salitre) and 0.754 (Fortaleza) (Table 1). The spatial self-correlation analysis of HDI-M was moderate and significant (GMI = 0.36; $p < 0.05$). There were spatial clusters formed by most of the cities in the central Brazilian "outback" and the South of the state, which were low-low. Most municipalities in the east coast formed high-high spatial clusters for this index (Figure 1C).

In the first period of bivariate data analysis of the study, it was observed that the coefficient of incidence of Covid-19 had a positive and weak spatial self-correlation with HDI-M (LMI = 0.20); however with a bivariate spatial high-high cluster in cities that are part of the metropolitan region of Fortaleza (Figure 1D). This scenario presented a slight increase in the second period of the analysis (LMI = 0.25), that is, the municipalities with the highest coefficients of incidence of Covid-19 had higher HDI-M. Low-low spatial relations were present in municipalities with lower HDI-M, and lower coefficients of incidence of Covid-19, however, without cluster formation (Figure 1E).

Table 1. Distribution of the municipal human development index (HDI-M) and coefficient of incidence* of Covid-19 per municipality of Ceará on April 12 and May 7, 2020. Sobral, Ceará, 2020.

Municipaliry	HDI-M	I1**	I2***
Abaiara	0.628	0	8.52
Acarape	0.606	0	60.29
Acaraú	0.601	0	180.39
Acopiara	0.595	0	14.74
Aiuaba	0.569	0	5.75
Alcântaras	0.600	0	110.98
Alto Santo	0.601	0	40.83
Amontada	0.606	2.30	13.81
Antonina	0.599	0	13.60
Apuiarés	0.618	0	68.49
Aquiraz	0.641	36.13	124.58
Aracati	0.655	2.68	48.29
Aracoiaba	0.615	0	71.78
Ararendá	0.590	0	9.14
Araripe	0.564	0	4.63
Aratuba	0.622	0	16.88
Arneiroz	0.618	0	191.33
Assaré	0.600	0	4.27
Aurora	0.605	0	4.06
Banabuiú	0.606	0	120.90
Barbalha	0.683	0	13.16
Barreira	0.616	0	17.84
Barro	0.599	0	8.82
Barroquinha	0.571	6.66	46.61
Baturité	0.619	0	22.38
Beberibe	0.638	1.87	52.27
Bela Cruz	0.623	0	122.73
Boa Viagem	0.598	0	27.54
Brejo Santo	0.647	0	14.15
Camocim	0.620	0	1.57
Campos Sales	0.630	0	18.23
Canindé	0.612	1.30	110.39
Capistrano	0.611	0	50.74

Continue.

Table 1. Continuation.

Municipaliry	HDI-M	I1**	I2***
Caridade	0.592	0	39.92
Cariré	0.596	0	65.05
Caririaçu	0.578	0	7.42
Cariús	0.597	10.70	10.70
Carnaubal	0.593	0	39.76
Cascavel	0.646	1.39	76.66
Catarina	0.618	4.83	9.66
Catunda	0.609	0	9.67
Caucaia	0.682	7.19	165.47
Cedro	0.627	0	3.91
Chaval	0.586	0	7.65
Choró	0.585	0	66.56
Chorozinho	0.604	0	88.83
Coreaú	0.610	0	133.99
Crateús	0.644	1.33	39.96
Crato	0.713	0.76	11.35
Croatá	0.590	5.54	5.54
Cruz	0.632	0	52.36
Deputado Irapuan Pinheiro	0.609	0	41.56
Ererê	0.610	0	69.46
Eusébio	0.701	7.46	350.63
Farias Brito	0.633	5.14	10.28
Forquilha	0.644	0	8.26
Fortaleza	0.754	54.88	362.22
Fortim	0.624	0	30.34
Frecheirinha	0.604	0	49.74
General Sampaio	0.568	0	39.38
Graça	0.570	0	62.50
Granja	0.559	0	20.09
Groaíras	0.633	0	153.60
Guaiuba	0.617	0	103.59
Guaraciaba	0.609	2.46	14.76
Guaramiranga	0.637	0	115.54
Hidrolândia	0.597	0	30.03

Continue.

Table 1. Continuation.

Municipaliry	HDI-M	I1**	I2***
Horizonte	0.658	10.40	136.63
Ibaretama	0.577	0	22.47
Ibiapina	0.608	0	8.00
Ibicuitinga	0.606	0	199.60
Icapuí	0.616	5.02	80.26
Icó	0.606	4.41	13.23
Iguatu	0.677	7.81	43.90
Independência	0.632	7.64	15.28
Ipaporanga	0.579	8.63	69.01
Ipaumirim	0.606	0	16.05
Ipu	0.618	0	16.68
Ipueiras	0.573	5.24	13.10
Iracema	0.652	0	55.96
Irauçuba	0.605	0	37.26
Itaiçaba	0.656	12.78	12.78
Itaitinga	0.626	7.90	208.00
Itapagé	0.623	1.90	28.48
Itapipoca	0.640	0.77	122.14
Itapiúna	0.604	0	63.78
Itarema	0.606	2.39	66.94
Itatira	0.562	0	50.82
Jaguaretama	0.612	0	38.54
Jaguaribara	0.618	0	96.48
Jaguaribe	0.621	11.53	63.43
Jaguaruana	0.624	0	20.77
Jardim	0.614	0	3.68
Jijoca	0.652	0	65.60
Juazeiro do Norte	0.694	1.09	8.39
Jucás	0.598	0	20.13
Lavras	0.613	3.17	15.87
Limoeiro	0.682	5.04	57.10
Madalena	0.610	0	45.71
Maracanaú	0.686	9.22	126.82
Maranguape	0.659	2.33	83.74

Continue.

Table 1. Continuation.

Municipaliry	HDI-M	I1**	I2***
Marco	0.612	0	14.62
Martinópole	0.599	0	8.90
Massapê	0.616	0	85.19
Mauriti	0.605	2.08	8.34
Meruoca	0.618	0	53.13
Milagres	0.628	0	7.27
Milhã	0.626	0	38.01
Miraíma	0.592	0	7.24
Missão Velha	0.622	0	5.65
Mombaça	0.582	4.57	25.12
Monsenhor Tabosa	0.610	0	52.22
Morada Nova	0.610	0	72.71
Moraújo	0.581	0	103.16
Morrinhos	0.588	0	35.50
Mucambo	0.607	0	68.79
Mulungu	0.607	0	36.96
Nova Olinda	0.625	0	44.97
Nova Russas	0.614	0	9.28
Novo Oriente	0.605	6.99	10.49
Ocara	0.594	0	77.81
Orós	0.636	0	46.67
Pacajus	0.659	0	88.64
Pacatuba	0.675	2.40	154.62
Pacoti	0.635	0	48.94
Paracuru	0.637	0	28.51
Paraipaba	0.634	0	76.35
Parambu	0.570	0	15.86
Paramoti	0.583	0	16.36
Pedra Branca	0.603	2.31	50.86
Pentecoste	0.629	0	34.44
Pereiro	0.601	0	24.53
Pindoretama	0.636	4.86	145.86
Poranga	0.581	0	48.64
Porteiras	0.622	0	6.67
Potiretama	0.604	0	46.74

Continue.

Table 1. Continuation.

Municipaliry	HDI-M	I1**	I2***
Quiterianópolis	0.594	0	23.71
Quixadá	0.659	7.96	98.03
Quixelô	0.591	0	6.18
Quixeramobim	0.642	4.93	87.57
Quixeré	0.622	9.03	27.09
Redenção	0.626	0	75.72
Reriutaba	0.601	0	32.45
Russas	0.674	2.56	57.55
Salitre	0.540	0	6.04
Santa Quitéria	0.587	4.58	29.75
Santana do Acaraú	0.612	3.08	30.81
São Benedito	0.611	0	10.44
São Gonçalo	0.665	0	192.06
São João do Jaguaribe	0.654	0	39.24
São Luís do Curu	0.620	7.69	38.46
Senador Pompeu	0.619	7.84	31.38
Senador Sá	0.603	13.12	78.71
Sobral	0.714	6.70	112.95
Solonópole	0.625	0	49.12
Tabuleiro	0.645	3.26	22.80
Tamboril	0.580	0	15.24
Tauá	0.633	0	79.85
Tejuçuoca	0.584	0	78.18
Tianguá	0.657	3.95	38.19
Trairi	0.606	0	44.71
Tururu	0.606	0	30.73
Ubajara	0.648	0	5.75
Umirim	0.587	0	50.44
Uruburetama	0.639	0	82.38
Uruoca	0.566	0	28,90
Varjota	0.611	0	32.57
Várzea Alegre	0.629	2.46	19.65
Viçosa	0.571	0	54.20
Ceará	0.682	60.14	179.11

*Population base: 100 thousand inhabitants; I1: incidence in period of time 1: April 12, 2020; I2: incidence in period of time 2: May 7, 2020. Source: Brazil[11,12] and State Government of Ceará[13].

Figure 1. Analysis of spatial correlation in the state of Ceará. Sobral, Ceará, 2020: (A) spatial self-correlation of Covid-19 in incidence in period of time 1 (April 12, 2020); (B) spatial self-correlation of Covid-19 in incidence in period of time 2 (May 7, 2020); (C) spatial self-correlation of the municipal human development index (HDI-M) (2010); (D) bivariate analysis (spatial association indicators — LISA) of the coefficient of incidence of Covid-19 and HDI-M in Ceará in period of time 1 (April 12, 2020); (E) bivariate analysis (LISA) of the coefficient of incidence of Covid-19 and HDI-M of Ceará in period of time (May 7, 2020).

DISCUSSION

The spatial distribution of the coefficient of incidence of Covid-19 in the municipalities of the state of Ceará shows inequalities in the coefficient of incidence of this pandemic, with spatial dependence and high-high positive correlation associated with HDI-M, and cluster formation in the cities that are close to the metropolitan region of Fortaleza. Therefore, this study has confirmed the association between Covid-19 and human development, pointing to the importance of geographic screening in locations with a potential for local infectious transmission as a fundamental aspect to coordinate better actions against the pandemic.

In case of Covid-19, it is necessary to conduct a critical evaluation of epidemiological data referring to human mobility to understand the dynamics of the transmission of the virus in local, regional and global scales. The continuous integration of these flow of data helps to guide the use of resources in order to mitigate the transmission of Covid-19[18].

The recent literature has been focusing on the generation of evidence, considering the following influencing factors of the Covid-19 outbreak: endemicity for other infections, immune regulation with other coinfections, bacillus Calmette-Guérin (BCG) vaccine, age of the population and quantitative data transposable for epidemiological predictions[19]. The understanding of the spatial distribution of Covid-19 in Ceará, third most affected state in Brazil[6], is urgent in the country, given its high morbidity and mortality magnitude, absence of any available and effective immunization and its pandemic character, which has not yet reached its maximum peak[18]. Georeferencing has shown to be a useful tool for the epidemiological surveillance of communicable diseases and for the association of social determinants, in micro or macro spatial analyses[20].

The positive spatial correlations found between the coefficient of incidence of Covid-19 and the social development measured by the HDI-M, even if weak, are unprecedented in Brazil, which can also be a limiting factor considering the comparison with only a few initial studies about the approached theme. In general, epidemiological studies of communicable diseases find an indirect indicator for health in HDI-M, since its highest constitutive values are related to longevity, income and education[21].

From the socioeconomic perspective, it is important to point out that the elderly population represents one of the groups that are more prone to the infection and symptomatology by Covid-19, with higher risk of causa mortis for men after the seventh decade of life, in China and in the United States[22]. The pandemic caused by Covid-19 has raised a red flag in many big cities, which present high densities and facilitate the propagation of the disease. This was also observed in the high coefficient of incidence in Fortaleza and surrounding municipalities, with a tendency for a less concentrated diffusion in the other cities of the state, even though the decisions made by the State government contribute to limit the speed of occurrences, since Ceará had a burst of cases of Covid-19 in the end of March and the beginning of April[23]. The first cases of contamination occurred in the neighborhoods with the best HDI-M in Fortaleza, and all of the infected subjects had been abroad. The virus already circulates in the suburbs of the city, with high population density and worsened sanitary conditions, which raises the concern about the fast transmission[23]. The metropolitan region of Fortaleza generates income and services, is a tourist pole, has high demographic density and urban mobility[24]. Even though in Brazil international air traffic is more intense in the Southeast region, where most of the travelers coming from the United States, France and Italy arrive[18], the airport of Fortaleza is a potent national hub for Europe[25]. This set of factors can corroborate this study, suggesting that a high HDI-M can also facilitate the conditions of intense viral circulation, transmission and recrudescence of the clinical status of Covid-19.

The distribution of the variables in the territory of the state of Ceará points to the existence of a geographic space that seems to in a stage of epidemic dissemination to the cities in the countryside. Even though Ceará presents a 1.03% lethality rate in relation to its population, which is equivalent to the tenth position of deaths caused by coronavirus in the country, the state is the fifth in Brazil with the highest level of underreporting of Covid-19, with 18,857 estimated cases[26]. In addition, the population living in the countryside, despite having less contact with individuals who tested positive for coronavirus, is less isolated than individuals in the capital[27].

The low levels of HDI-M reveal that not only the vulnerability of the population, but also the difficulties in health services concerning diagnosis and treatment of the condition in the cities of Ceará, similarly to the overview of fragility expected from health services in Brazil[28] and in the countries of Latin America to face the pandemic[5].

Given the great mobility of the population and the intense social and economic relations that the countryside cities have with their respective capitals, the dissemination of Covid-19 should strongly affect the infrastructure in the countryside[29]. Unlike other diseases in other moments, this time there may not be enough time to transfer to other capitals, or the capacity of service for all of the severe patients, which can reflect in different coefficients of lethality associated to social inequalities.

Likewise, there is a concern about the maintenance of jobs, considering the already ongoing fragile work relations due to the current economic crisis in Brazil, which is being exacerbated by the pandemic. In this sense, the number of people who are invisible to the social policies, especially the homeless population, tends to increase, and ways to protect the entire society against the new coronavirus need to be reconsidered[30].

Despite the evolution of the Brazilian public health system, it is worth to mention that diseases that are neglected or associated to health care in low-income populations may emerge in a secondary manner, after Covid-19, and have an even darker impact on the healing prognosis[28].

This study presents some limitations regarding the methodology used, and its results should be carefully interpreted due to the possible existence of a aggregation bias or ecological fallacy[31]. In ecological studies, the observation of a relationship between two variables in the aggregated level does not necessarily imply the fact that this relationship remains in the individual level[16]. The study presents good internal validity, because the data are representative of the analyzed geographic strata; however, it is important to be careful in the incidence analysis due to the possibility of data underreporting[26], which could be influenced by the unequal access to diagnostic testing and the variability in the quality of health services[3,18,27].

The study is valid because it shows the need for articulation in epidemiological surveillance services in the private health services and SUS, being the former mostly attended by population groups with higher purchasing power. The findings contribute with the knowledge about the epidemic process of Covid-19 in the state of Ceará, as well as make the way for constant analyses that indicate the behavior of the disease.

Data transparency coming from SESA enabled this analysis and discussion about social aspects and the occurrence of Covid-19 in the state, generating products that allow the planning of more effective actions, which are coherent and resolutive for the problems that interfere negatively in the health-disease process experienced by the population.

The conclusion is that the occurrence of the coefficient of incidence of Covid-19 was unequally distributed in the municipalities of the state of Ceará, and was associated with HDI-M. The unequal mapping of Covid-19 and its relationship with HDI-M in Ceará can contribute with regional actions against the pandemic.

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