



# COVID-19 in the city of Rio de Janeiro: spatial analysis of first confirmed cases and deaths

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## Abstract

**Objective:** to describe the spatial distribution of the first confirmed COVID-19 cases and deaths in Rio de Janeiro. **Methods:** this was an ecological study of confirmed SARS-CoV-2 cases and deaths between March 6<sup>th</sup> and April 10<sup>th</sup>, 2020. Incidence, mortality, lethality, excess risk and global and local Moran rates were calculated. **Results:** 1,808 confirmed cases and 92 confirmed deaths were recorded. The COVID-19 incidence rate was 26.8/100,000 inhab., the mortality rate was 1.36/100,000 inhab. and lethality rate 5%. The incidence rate in eight neighborhoods was 4-12 times higher than the overall rate for the municipality: Joá, in the city's Western Zone; Cosme Velho, Gávea, Ipanema, Jardim Botânico, Lagoa, Leblon and São Conrado, in its Southern Zone. **Conclusion:** high risk of COVID-19 infection and deaths was found in neighborhoods in the Southern Zone of the city of Rio de Janeiro. Neighborhoods in the Northern Zone of the city also stand out in relation to high risk of death.

**Keywords:** Coronavirus; Spatial Analysis; Epidemiology; Brazil.

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## Introduction

In December 2019, a new virus of the *Coronaviridae* family (initially called Novel Coronavirus 2019-nCoV, later renamed SARS-CoV-2), causing a severe acute respiratory syndrome (COVID-19), emerged in Wuhan, in Hubei Province, China.<sup>1,3</sup> In all, seven human coronaviruses (HCoVs) have been identified thus far: HCoV-229E, HCoV-OC43, HCoV-NL63, HCoV-HKU1, SARS-CoV (which causes severe acute respiratory syndrome), MERS-CoV (which causes Middle East respiratory syndrome) and SARS-CoV-2.<sup>3,4</sup>

Transmission is mainly person-to-person by means of respiratory droplets.<sup>4</sup> SARS-CoV-2 infection pattern in humans is similar to that of other coronaviruses, in particular severe acute respiratory syndrome coronavirus (SARS-CoV) and Middle East respiratory syndrome coronavirus (MERS-CoV).<sup>3</sup>

On January 30<sup>th</sup> 2020, the World Health Organization (WHO) declared the novel coronavirus to be a Public Health Emergency of International Concern – the Organization's highest level of alert, as provided for in the International Health Regulations. On March 11<sup>th</sup> 2020, WHO declared COVID-19 to be a pandemic.<sup>4,5</sup> By April 10<sup>th</sup> 2020, 1,521,252 confirmed COVID-19 cases and 92,798 confirmed COVID-19 deaths had been recorded in 210 countries.<sup>6</sup>

*The city of Rio de Janeiro is one of Brazil's largest urban centers and is the city with the second largest number of COVID-19 cases.*

The first COVID-19 case in Brazil, and in South America, was recorded on February 26<sup>th</sup> 2020 in São Paulo.<sup>7</sup> By April 10<sup>th</sup> 2020, 19,638 cases and 1,056 deaths from the disease had been confirmed in Brazil, corresponding to 5.4% lethality.<sup>8</sup> COVID-19 has spread rapidly through the country and community transmission was declared nationwide on March 20<sup>th</sup> 2020.<sup>9</sup>

The city of Rio de Janeiro is one of Brazil's largest urban centers and is the city with the second largest number of COVID-19 cases.<sup>10</sup> The first COVID-19 case in the city of Rio de Janeiro was recorded on March 6<sup>th</sup> 2020, just 11 days after Brazil's first case.<sup>11,12</sup> The city of Rio de Janeiro is highly connected with other urban centers in economic and social terms, contributing to it becoming a hub for dissemination of the disease to

other territories and reinforcing the need to understand its transmission pattern in order to ensure better implementation of mitigation and control measures.<sup>13</sup>

Public Health spatial analysis methods are used principally in ecological studies for detecting spatial and temporal clusters for the purposes of health service planning and use evaluation. In outbreak and epidemic situations spatial analysis is an important tool for identifying areas of greater risk, serving to support control measure implementation.<sup>2,14</sup>

Understanding the spatial distribution of the disease is fundamental for forecasting local outbreaks and developing response strategies during the initial stages of the COVID-19 emergency.

The objective of this study was to describe the spatial distribution of the first confirmed COVID-19 cases and deaths in the city of Rio de Janeiro.

## Methods

An ecological study was conducted, having the neighborhoods of the city of Rio de Janeiro as its units of analysis.

The city is divided into 160 neighborhoods, having an estimated population of 6,752,339 inhabitants in 2020.<sup>15</sup> Rio de Janeiro has well-known social inequalities, due to the large number of people living in extreme poverty, most of whom live in the city's 763 *favelas*, and who have difficulty in accessing quality health services.<sup>15</sup>

All confirmed COVID-19 cases and deaths in the city of Rio de Janeiro between March 6<sup>th</sup> (date of the first confirmed case) and April 10<sup>th</sup> 2020 were included. City Health Department open access panel data on confirmed SARS-CoV-2 cases and deaths by place of residence were used.<sup>12</sup>

Confirmed COVID-19 cases were considered to be individuals with positive SARS-CoV-2 laboratory test results, regardless of signs and symptoms.<sup>16</sup>

The variables studied were sex (female, male, no information), age (average in years), age group (0-9, 10-19, 20-29, 30-39, 40-49, 50-59, 60-69, 70-79, 80-89, 90-100, no information) and neighborhood of residence. This variable was later classified by area (Northern Zone, Central Zone, Western Zone, Southern Zone).

Absolute and relative case and death frequencies were described by sex and age group.

The projected estimate of the number of inhabitants in each neighborhood in 2020 was calculated by means

of interpolation based on 2000 and 2010 Census population data. Incidence and mortality rates per 100,000 inhabitants were calculated, as was lethality (proportion of infected people who die) and excess risk. This information was presented on thematic maps. Excess risk is calculated by determining the overall rates for the municipality, and interpreted by noting which neighborhoods have incidence and mortality rates under or over the overall rates.<sup>17</sup>

The incidence and mortality rates by city neighborhood were also used to calculate the Global Moran Index (Moran's I), which analyzes global spatial autocorrelation, and the Local Indicator of Spatial Association (LISA), to identify local clusters in the city and their statistical significance.<sup>17</sup> The objective of Moran's global and local indices is to identify patterns in the spatial distribution of the indicators presented.<sup>17</sup> The high-high, low-low, high-low and low-high quadrants were presented using scatter plots and cluster maps.<sup>17</sup>

R 3.5.3 software was used for data manipulation and analysis, and Quantum Geographic Information System (QGIS) software version 2.14.8 and GeoDa software version 1.14.0 were used for the spatial analyses.

This study used secondary and aggregated data and was conducted in keeping with research ethics guidelines.

## Results

Between March 6<sup>th</sup> and April 10<sup>th</sup> 2020, 1,808 confirmed COVID-19 cases and 92 confirmed COVID-19 deaths were recorded in the city of Rio de Janeiro. Of the total cases, 47.7% were male, 51.4% were female

and 0.9% had no information as to sex. 56.5% of total deaths were male, 38.0% were female and there was no information as to sex for 5.5% (Table 1). Average case age was 49 years, while average age for deaths was 68 years. Prevalence among cases was highest in the 30-59 years age group, while deaths were more frequent among individuals aged 60-89 years (Table 1). The number of new cases per day can be seen in Figure 1, with an increase in new cases being recorded daily with effect from March 23<sup>rd</sup>.

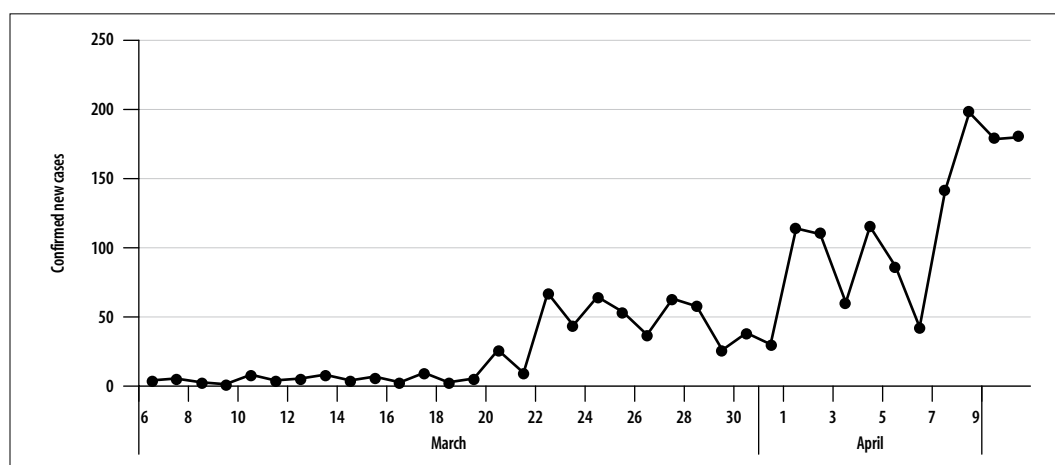
The COVID-19 incidence rate for the city of Rio de Janeiro was 26.8/100,000 inhab., while the mortality rate was 1.36/100,000 inhab. There was 5.0% lethality as at April 10<sup>th</sup>. The city's highest incidence rate was recorded in the Joá neighborhood (300.7/100,000 inhab.), followed by São Conrado (240.6/100,000 inhab.), Leblon (202.6/100,000 inhab.), Jardim Botânico (200.5/100,000 inhab.), Lagoa (193.9/100,000 inhab.), Ipanema (186.2/100,000 inhab.) and Gávea (123.9/100,000 inhab.). With the exception of the first neighborhood, the remainder are located in the Southern Zone of the city (Figure 2A).

The city's highest mortality rate was found in Cosme Velho (14.0/100,000 inhab.), followed by Ipanema (12.9/100,000 inhab.), both of which are located in the Southern Zone; and Vista Alegre (11.2/100,000 inhab.) and Bonsucesso (11.0/100,000 inhab.), both of which are located in the Northern Zone (Figure 2B).

Lethality was highest in Vista Alegre (100,0%), located in the Northern Zone, followed by Vila Valqueire (66.6%), located in the Western Zone; Pilares (50,0%), Maré (50,0%) and Vigário Geral, located in the Northern

**Table 1 – Absolute and relative frequencies of confirmed COVID-19 cases and deaths, by sex and age, in the city of Rio de Janeiro, between March 6<sup>th</sup> and April 10<sup>th</sup> 2020**

Variables		Cases (n)	Cases (%)	Deaths (n)	Deaths (%)
Sex	Female	929	51.4	35	38.0
	Male	862	47.7	52	56.5
	No information	17	0.9	5	5.5
Age (in years)	0-9	15	0.8	-	-
	10-19	12	0.7	-	-
	20-29	141	7.8	2	2.2
	30-39	404	22.3	1	1.1
	40-49	400	22.1	7	7.6
	50-59	294	16.3	10	10.9
	60-69	231	12.8	24	26.1
	70-79	141	7.8	23	25.0
	80-89	88	4.9	20	21.7
	90-100	6	0.3	1	1.1
No information	76	4.2	4	4.3	



**Figure 1 – New confirmed COVID-19 cases in the city of Rio de Janeiro, between March 6<sup>th</sup> and April 10<sup>th</sup> 2020 (N=1808)**

Zone (40,0%); and Inhoaíba (33.3%), located in the Western Zone (Figure 2C).

When applying the excess risk method, it was found that the Joá neighborhood in the Western Zone and Cosme Velho, Gávea, Ipanema, Jardim Botânico, Lagoa, Leblon and São Conrado in the Southern Zone had incidence rates between four and twelve times higher than the overall municipal rate (Figure 3A). In turn, Benfica, Bonsucesso, Vaz Lobo and Vista Alegre (in the Northern Zone), Copacabana, Leme, Cosme Velho, Flamengo, Gávea, Ipanema and Jardim Botânico (in the Southern Zone), and Vila Valqueire, Jardim Sulacap and Gardênia Azul (in the Western Zone) had mortality rates between four and ten times higher than the overall municipal rate (Figure 3B).

Finally, Moran's I showed statistical difference ( $p$ -value=0.001) for COVID-19 global spatial autocorrelation in the city of Rio de Janeiro (Figure 4A). When applying the LISA method, local level autocorrelation and spatial clusters were found. The Alto da Boa Vista, Barra da Tijuca, Joá, Botafogo, Copacabana, Gávea, Humaitá, Ipanema, Jardim Botânico, Lagoa, Leblon, Rocinha and São Conrado neighborhoods were classified as high-high, i.e. where the situation is most serious and where incidence rates will rise increasingly in the following weeks (Figure 4B).

## Discussion

This study analyzed COVID-19 spatial distribution in the city of Rio de Janeiro. The frequency measurements found for the municipality were higher than the national

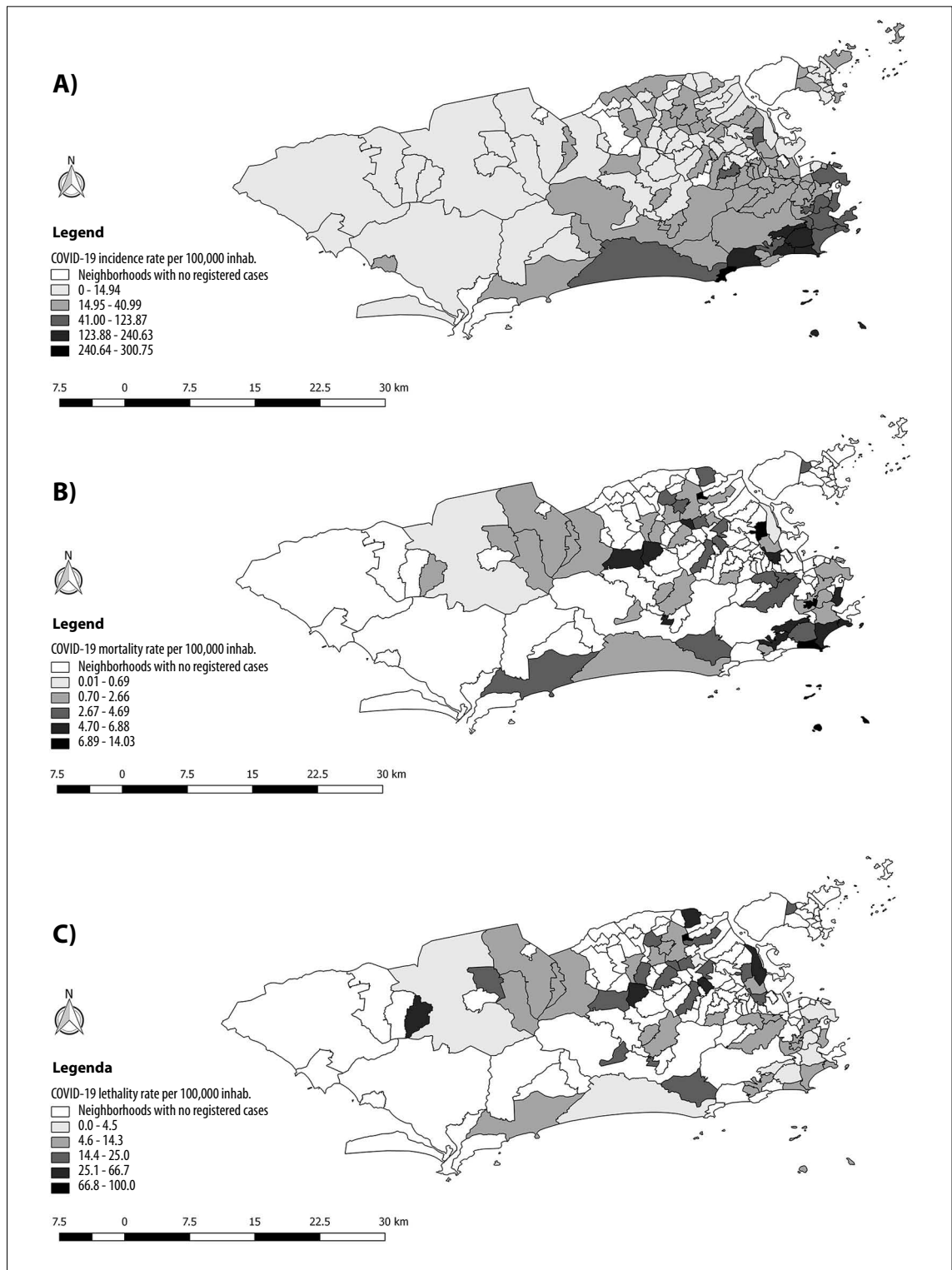
average. The mortality data we found follow the pattern of the national data, with greater risk of death for males and people over 60 years old.<sup>8</sup>

Differently to the national profile, females were predominant among the first cases reported in Rio de Janeiro. The most affected age range was that of young adults and this was similar to the national pattern.<sup>8</sup> Similar patterns were found in the international<sup>1-7</sup> and national literature, suggesting that COVID-19 infects economically active people more, but causes more deaths among the elderly, people with chronic diseases and individuals with a history of immunosuppression.<sup>18</sup> The city of Rio de Janeiro is an important entry point for international travelers, being recognized worldwide as a tourist destination. This fact may have contributed to the virus being introduced in Brazil, since it was the country's second city to register confirmed COVID-19 cases.<sup>19</sup>

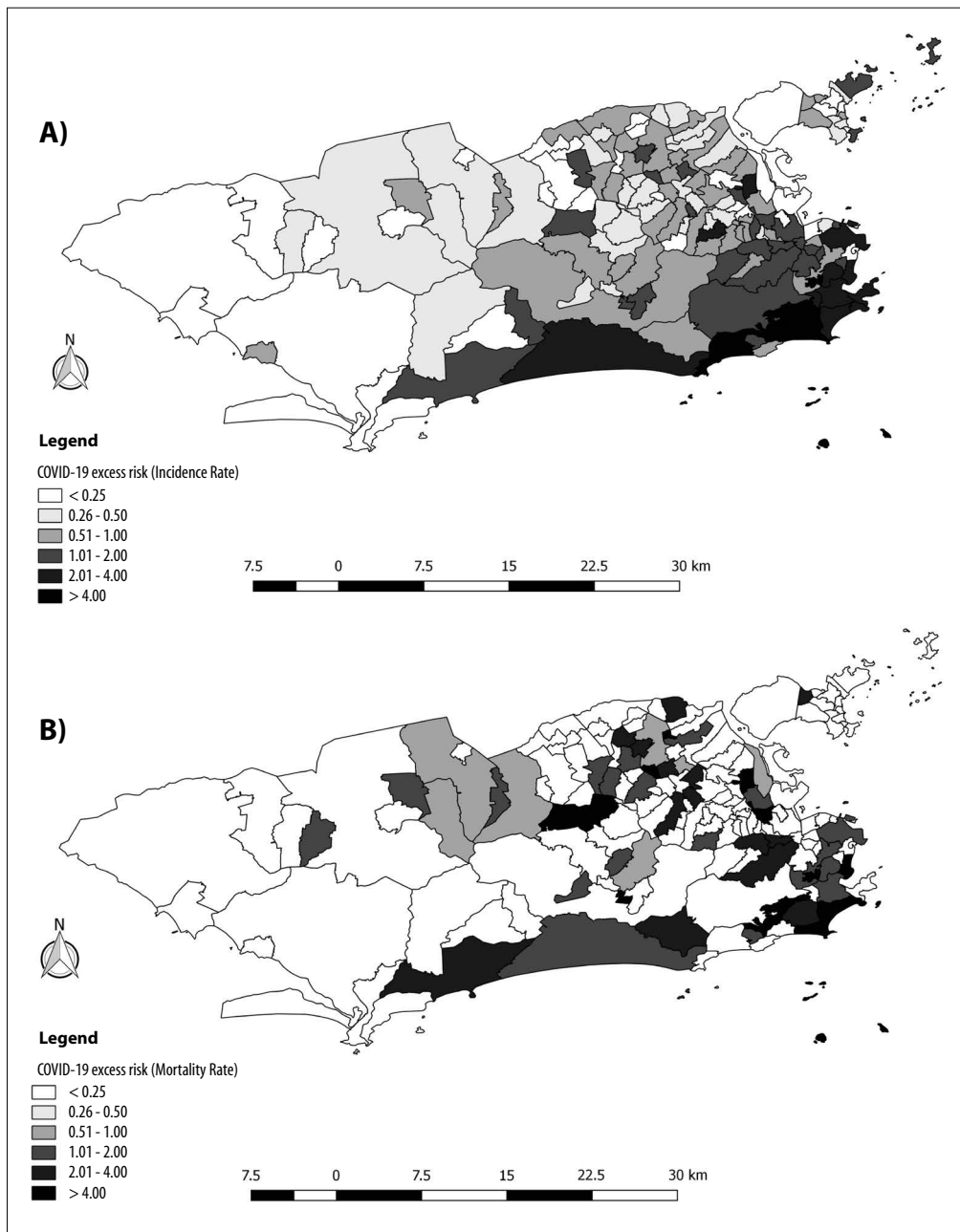
The number of new cases per day in Rio de Janeiro has oscillated, as it has in the rest of the country, given that the network for distributing diagnosis tests to health services is still being implemented.<sup>18</sup>

Based on the spatial distribution of the incidence rate in the municipality, it can be seen that the Southern Zone neighborhoods were the most affected by the disease. Moreover, as the first confirmed cases were registered there, they were potentially the source of the disease spreading to the rest of the city.

Attention is drawn to the fact the neighborhoods in the city's Northern Zone had a higher mortality rate, even when compared to neighborhoods in the Southern Zone where incidence was higher. This may be linked

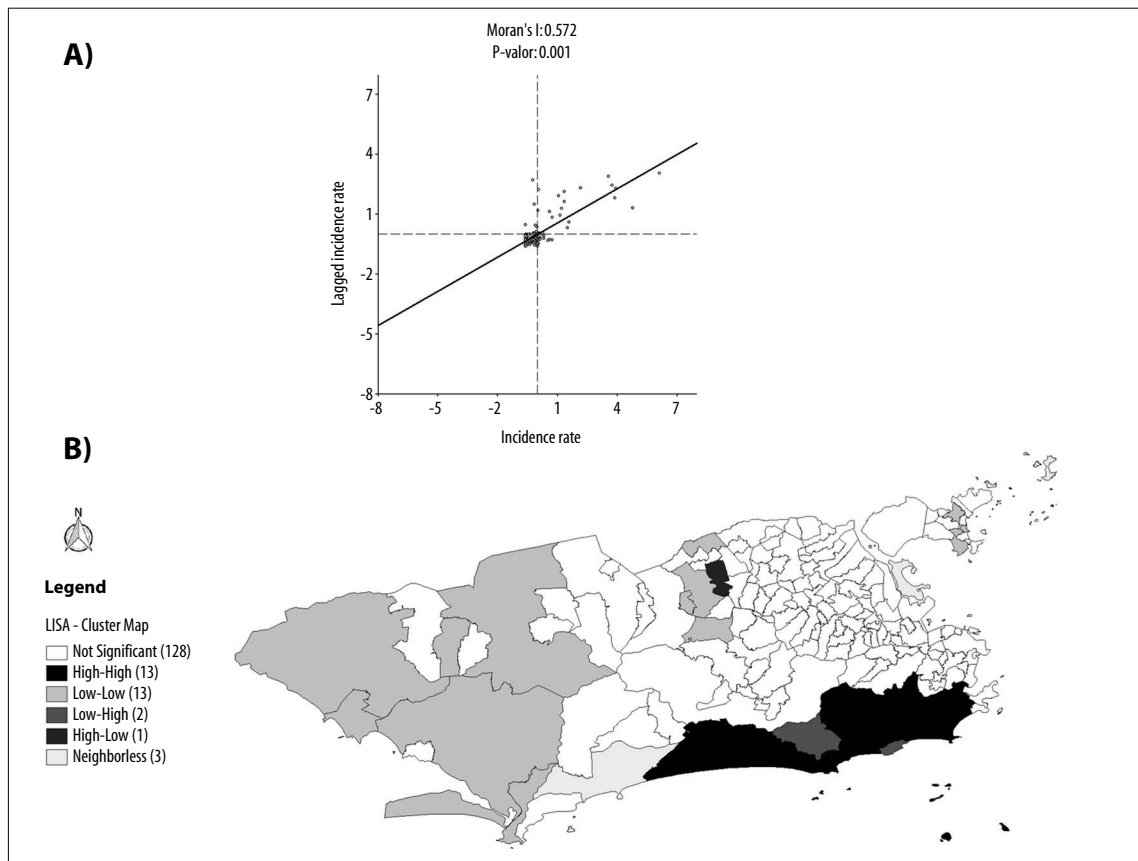


**Figure 2– Spatial distribution of COVID-19 indicators in the city of Rio de Janeiro, between March 6<sup>th</sup> and April 10<sup>th</sup> 2020**



**Figure 3– Spatial distribution of COVID-19 indicators in the city of Rio de Janeiro, between March 6<sup>th</sup> and April 10<sup>th</sup> 2020**





**Figure 4 – Global and local spatial autocorrelation of COVID-19 indicators in the city of Rio de Janeiro, between March 6<sup>th</sup> and April 10<sup>th</sup> 2020**

to access to health services and to the socio-economic and cultural behavior of the population.<sup>20</sup>

The same phenomenon was observed with regard to excess risk. The incidence rate in seven Southern Zone neighborhoods was above the average rate for the municipality. With regard to mortality rate excess risk, this was found in a further four Northern Zone neighborhoods and a further three Western Zone neighborhoods. These are places that concentrate a large agglomeration of middle and low-income people and areas of socially vulnerable populations.<sup>20</sup>

Moran's I and LISA showed global and local spatial autocorrelation, suggesting the need to maintain and intensify control strategies, such as social distancing, in these regions of the city, in order to reduce the speed of SARS-CoV-2 transmission and, consequently, avoid an increase in deaths, given the possibility of health system collapse.<sup>18,21</sup>

This pattern draws attention to the need for a plan to mitigate or suppress the disease taking into consideration

social contexts and realities. The areas of greatest social vulnerability in the city have already begun to suffer the first impacts of the disease, such as the occurrence of deaths in subnormal clusters (*favelas*),<sup>22</sup> thus reinforcing the need for public health policies that incorporate socio-economic and cultural contexts.<sup>20,21</sup>

Certain limitations and considerations are important when interpreting the findings of this study. Firstly, the confirmed case definition is based on laboratory criteria. This fact is intrinsically related to potential underreporting, both for the city of Rio de Janeiro and for Brazil as a whole. The 2020 population used to calculate the rates was an estimate based on the 2000 and 2010 Censuses and, despite being close, they may be different to reality. The incidence and mortality rates, despite being the best way to make comparisons between one place and another, may not reflect well information for neighborhoods with small populations, such as Joá and Cosme Velho, which end up having very high rates. The same is true for lethality, given the neighborhoods with

low numbers of cases and deaths end up having lethality above 50%, as is the case of Vista Alegre for instance.

Furthermore, 215 cases and 2 deaths had no information on neighborhood of residence or were not resident in the city of Rio de Janeiro, and were therefore not included in the spatial analysis. This fact is due to people from cities in the metropolitan region being referred to hospitals in the city of Rio de Janeiro.

This study assessed spatial distribution of the first COVID-19 cases and deaths in the city of Rio de Janeiro. The results of the analyses described high risk of infection and death from the disease in neighborhoods in the city's Southern Zone. Neighborhoods in the Northern Zone also stood out with regard to high risk of death. We assume that this distribution may alter rapidly, due to the high transmissibility of COVID-19, alongside the strong social differences between neighborhoods in Rio de Janeiro. New studies using

spatial analyses of deaths and recovered cases of the disease will contribute to understanding COVID-19 evolution in Rio de Janeiro.

Analyzing the spatial profile of a new disease in the territory is essential for understanding patterns and for adopting control measures. We suggest that COVID-19 emergency plans should be created taking into consideration the socio-economic and cultural characteristics of the different clusters in the territory in order to achieve greater control measure effectiveness.

### Authors' contributions

Cavalcante JR and Abreu AJL contributed equally to drafting the manuscript. Both authors have approved the final version of the manuscript and are responsible for all aspects thereof, including the guarantee of its accuracy and integrity.


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