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SPECIAL ARTICLE / *ARTIGO ESPECIAL*

Space-time analysis of the first year of COVID-19 pandemic in the city of Rio de Janeiro, Brazil

Análise espaço temporal do primeiro ano da pandemia de COVID-19 no município do Rio de Janeiro

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ABSTRACT: ***Objective:*** To describe the space-time evolution of cases and deaths due to COVID-19 in the Rio de Janeiro municipality, Brazil, during the first year of the pandemic. ***Methods:*** An ecological study was carried out. The units of analysis were the neighborhoods of the city of Rio de Janeiro. Incidence and mortality rates, excess risk, Global Moran's Index (Moran's I), local indicator for spatial association, standardized incidence ratio, and standardized mortality ratio were estimated for neighborhoods in the municipality of Rio de Janeiro. ***Results:*** Over the first year of the pandemic, registries in the city of Rio de Janeiro included 204,888 cases and 19,017 deaths due to COVID-19. During the first three months of the pandemic, higher incidence rates were verified in the municipality compared with the state of Rio de Janeiro and Brazil, in addition to higher mortality rates compared with the state of Rio de Janeiro and Brazil from May 2020 to February 2021. Bonsucesso was the neighborhood with the highest incidence and mortality rates, and throughout the neighborhoods and months, there is no synchrony between the worst moments of the COVID-19 pandemic. ***Conclusion:*** The authors emphasize the need for implementing more rigid control and prevention measures, increasing case detection, and accelerating the COVID-19 immunization campaign.

Keywords: COVID-19. SARS-CoV-2 infection. Spatial analysis. Epidemiology. Public health.

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RESUMO: ***Objetivo:*** Descrever a evolução espaço temporal de detecção de casos e mortalidade por COVID-19 no município do Rio de Janeiro durante o primeiro ano da pandemia. ***Métodos:*** Foi realizado um estudo ecológico cujas unidades de análise foram os bairros do município do Rio de Janeiro. Calcularam-se as taxas de incidência e mortalidade, excesso de risco, índice de Moran global (I de Moran), indicador local de associação espacial, razão de incidência padronizada e razão de mortalidade padronizada para bairros do município do Rio de Janeiro. ***Resultados:*** Foram notificados 204.888 casos e 19.017 óbitos por COVID-19. O município apresentou durante os três primeiros meses de pandemia taxas de incidência superiores às do estado do Rio de Janeiro e do Brasil e taxas de mortalidade superiores às do estado do Rio de Janeiro e Brasil de maio de 2020 até fevereiro de 2021. Bonsucesso foi o bairro com maiores taxas de incidência e mortalidade, e ao longo dos bairros e dos meses não há sincronia entre os piores momentos da pandemia de COVID-19. ***Conclusão:*** Ressaltamos a necessidade de implantação de medidas mais rígidas para controle e prevenção da COVID-19, aumento na detecção de casos e aceleração da campanha de imunização.

Palavras-chave: COVID-19. SARS-CoV-2. Análise espacial. Epidemiologia. Saúde coletiva.

INTRODUCTION

The 2019 novel coronavirus disease, known as COVID-19, caused by the SARS-CoV-2 virus, was first notified to the World Health Organization (WHO) on December 31, 2019, by China[1]. With the rapid spread of the virus, on January 30, 2020 the WHO declared a Public Health Emergency of International Concern (PHEIC)[2]. On March 11, the spread of the disease was classified as a pandemic[3]. Until February 28, 2021, over 113 million cases and 2.5 million deaths were registered worldwide[4].

In Brazil, COVID-19 was declared a Public Health Emergency of National Concern (PHENC) on February 3, 2020, even before the confirmation of the first case, which occurred on February 26, 2020 in the state of São Paulo[5,6]. One year later, on February 28, 2021, over 10.5 million cases and 254 thousand deaths were registered in the country. The Southeast region has 36% of cases and 46% of deaths in Brazil, and the state of Rio de Janeiro is the fifth with the highest number of cases (583,044) and the second in deaths (33,080) in the country[6].

The first case of COVID-19 in the municipality of Rio de Janeiro was registered on March 6, 2020, 11 days after the first case in Brazil. As the second most populous city in the country, until April 9, 2021, it was the third city with the highest number of cases (235,005) and the second in number of deaths (21,436)[7,8].

The city of Rio de Janeiro has an economic and social dynamic of high connectivity with other urban centers, in addition to having one of the highest concentrations of slums in the country, which favors the spread of the disease in the territory[9]. In addition, the percentage of social distancing of the state of Rio de Janeiro has decreased in the last months, and the challenges faced by the Brazilian Unified Health System (SUS), such as the historical inequality in access to health care and scarcity of resources, favor the rapid spread of COVID-19[10,11].

The objective of the present study was to describe the space-time evolution of cases and deaths due to COVID-19 in the city of Rio de Janeiro, Brazil, during the first year of the pandemic.

METHODS

This is an ecological study whose units of analysis were the neighborhoods of the municipality of Rio de Janeiro. The city has 163 neighborhoods, divided into 10 planning areas. These areas have important differences regarding social indicators and characteristics of occupation of the geographic space (Supplementary Material #1). In 2020, the municipality had an estimated population of 6,752,339 inhabitants[12,13]. Data on cases and deaths from COVID-19 per neighborhood were collected from the Rio COVID-19 Panel of the Municipal Department of Health of Rio de Janeiro (*Secretaria Municipal de Saúde do Rio de Janeiro* – SMS-RJ) for the period from March 6, 2020 to March 6, 2021 (one year)[7]. Data on deaths from COVID-19 for the state of Rio de Janeiro and Brazil were collected, respectively, from the COVID-19 Panel of the Rio de Janeiro State Department of Health and the Coronavirus Panel of the Brazilian Ministry of Health for the period from March 6, 2020 to March 6, 2021, comprising a period of one year[6,14].

The incidence and mortality rates (per 100 thousand inhabitants) due to COVID-19 in the municipality of Rio de Janeiro, in the state of Rio de Janeiro, and in Brazil were calculated based on population estimates provided by the Brazilian Institute of Geography and Statistics (IBGE)[15]. In addition, the 2020 population for each neighborhood in the city of Rio de Janeiro was estimated based on populations from the 2000 and 2010 IBGE Censuses by interpolation[15].

The standardized incidence ratio (SIR) and the standardized mortality ratio (SMR) according to neighborhood in the municipality of Rio de Janeiro, per month, were estimated using as standard the COVID-19 incidence and mortality coefficients of the municipality in the period from March 2020 to February 2021. These measures estimate the occurrence of cases and deaths due to COVID-19, in the neighborhoods of the city of Rio de Janeiro, in relation to what would be expected if the same rates observed in the city were applied to the neighborhoods. Such methods have been previously used to investigate the current COVID-19 pandemic, as well as the occurrence of other diseases, such as tuberculosis, in Brazil and in other countries[8,16,17]. 95% confidence intervals (CI) were considered based on the method proposed by Vandenbroucke (1982)[18].

Incidence and mortality rates per neighborhoods in the city were also used to calculate the Global Moran's Index (Moran's I), which analyzes global spatial autocorrelation, and the local indicator of spatial association (LISA), to locally identify clusters in the municipality and their statistical significance. Moran's global and local indices aim to identify patterns of spatial distribution of the presented indicators. The high-high, low-low, high-low, and low-high quadrants were presented using a scatterplot and a cluster map[19].

Analyses were performed using the R 3.6.1 software, and the thematic maps were created using QGIS 3.14 and GeoDa 1.14.0 software. The scripts of the analyses performed in the R software are presented in the Supplementary Material. The study was carried out with aggregated secondary data and, therefore, there was no need for approval by a Research Ethics Committee.

RESULTS

During the first year of the pandemic, 204,888 confirmed cases and 19,017 confirmed deaths due to COVID-19 were registered in the municipality of Rio de Janeiro. The incidence rate was lower on July 2020 (180.41 cases/100 thousand inhab.) and February 2021 (142.86 cases/100 thousand inhab.) and higher on November (313.82 cases/100 thousand inhab.) and December 2020 (392.90 cases/100 thousand inhab.). In turn, the mortality rate was lower on March (0.36 cases/100 thousand inhab.) and April 2020 (10.58 cases/100 thousand inhab.) and higher on May (47.02 deaths/100 thousand inhab.) and June 2020 (40.72 deaths/100 thousand inhab.) (Figure 1). In the state of Rio de Janeiro, the incidence rate was lower on March (18.17 cases/100 thousand inhab.) and April 2020 (164.54 cases/100 thousand inhab.) and higher on December 2020 (562.56 cases/100 thousand inhab.) and January 2021 (425.68 cases/100 thousand inhab.). The mortality rate was lower on March 2020 (0.70 deaths/100 thousand inhab.) and February 2021 (7.98 deaths/100 thousand inhab.) and higher on May (41.62 deaths/100 thousand inhab.) and December 2020 (24.48 deaths/100 thousand inhab.) (Figure 1). Brazil

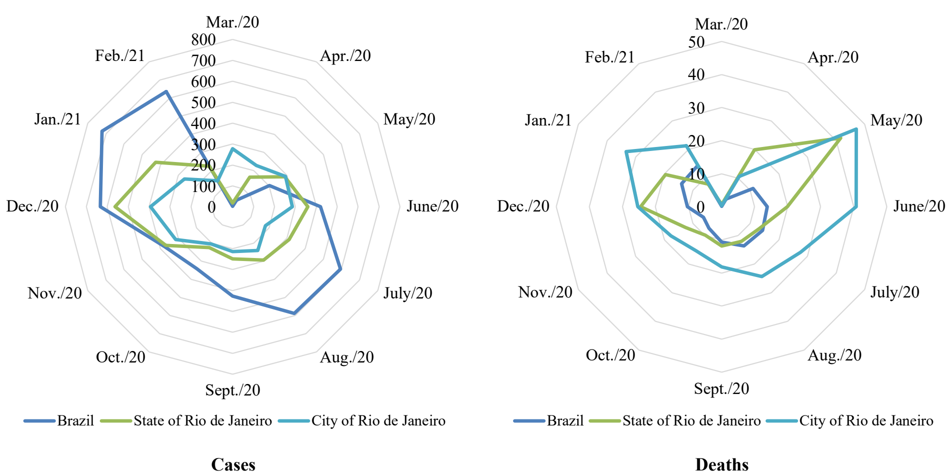


Figure 1. Incidence and mortality rates (per 100 thousand inhabitants) of COVID-19 in the city of Rio de Janeiro, in the state of Rio de Janeiro, and in Brazil between March 2020 and February 2021.

had the lowest incidence rates on March (2.70 cases/100 thousand inhab.) and April 2020 (37.62 cases/100 thousand inhab.) and the highest rates on January (721.94 cases/100 thousand inhab.) and February 2021 (635.89 cases/100 thousand inhabitants). Conversely, the mortality rate was lower on March (0.09 deaths/100 thousand inhab.) and April 2020 (2.69 deaths/100 thousand inhab.) and higher on January (13.96 deaths/100 thousand inhab.) and February 2021 (14.37 deaths/100 thousand inhab.) (Figure 1). The incidence rate in the city of Rio de Janeiro was considered low when compared with those in the state of Rio de Janeiro and Brazil, but a high mortality rate was verified in the city during the first year of the pandemic.

The incidence rate of COVID-19 found in the city of Rio de Janeiro, for the entire period, was 3,063 per 100 thousand inhabitants. The highest incidence rate in the municipality was verified in Bonsucesso neighborhood (13,071.1/100 thousand inhab.), followed São Cristóvão (9,968.7/100 thousand inhab.), Gávea (9,779.1/100 thousand inhab.), Jacaré (7,921.1/100 thousand inhab.), Centro (7,742.9/100 thousand inhab.), São Conrado (7,552.1/100 thousand inhab.), and Humaitá (7,466.6/100 thousand inhab.) neighborhoods (Figure 2A).

The mortality rate due to COVID-19 verified in the city of Rio de Janeiro was 279 per 100 thousand inhabitants. The highest mortality rate in the city was also verified in Bonsucesso neighborhood (960.1/100 thousand inhab.), followed by São Cristóvão (844.3/100 thousand inhab.), Camorim (665.8/100 thousand inhab.), Campo dos Afonsos (658.4/100 thousand inhab.), Vista Alegre (618.2/100 thousand inhab.), Jacaré (609.3/100 thousand inhab.), and Vila da Penha (556.3/100 thousand inhab.) neighborhoods (Figure 2B). It is worth emphasizing that the spatial distribution of the mortality rate differs from the spatial analysis of the incidence rate, as they are concentrated in different areas of the city.

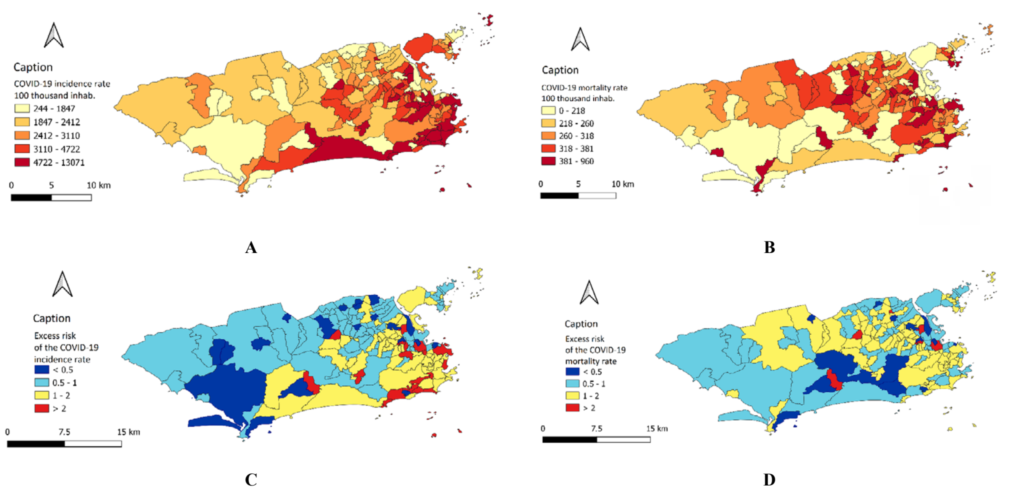
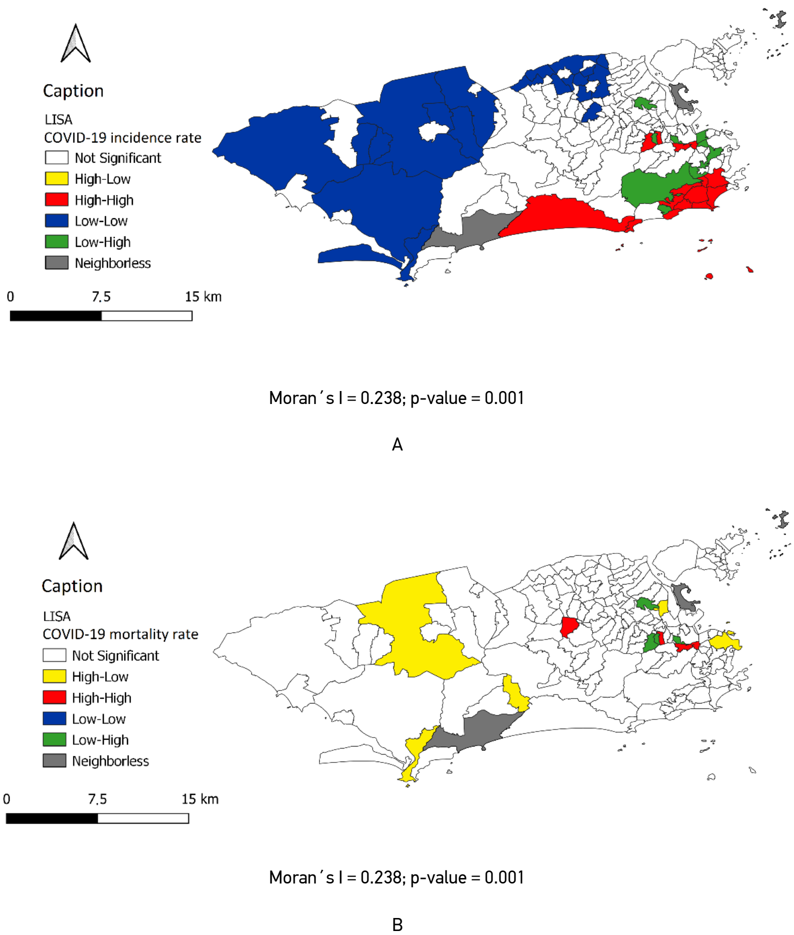


Figure 2. Spatial distribution of the incidence rate (A), the mortality rate (B), excess risk of the incidence rate (C), and excess risk of the mortality rate (D) of COVID-19. City of Rio de Janeiro, March 2020 to February 2021.

With the excess risk, it was possible to verify that Bonsucesso, São Cristóvão, Gávea, Jacaré, Centro, São Conrado, Humaitá, Joá, Jardim Botânico, Leblon, Ipanema, Praça da Bandeira, Camorim, Flamengo, Rocha, Campo dos Afonsos, Vila Isabel, and Anil neighborhoods have an incidence rate between two and four times higher than that of the municipality (Figure 2C). In turn, Bonsucesso, São Cristóvão, Camorim, Campos dos Afonsos, Vista Alegre, and Jacaré neighborhoods have a mortality rate between two and four times higher than that of the municipality (Figure 2D). The spatial analysis of the excess risk of incidence rate and the excess risk of mortality rate demonstrated the neighborhoods with the most outliers in relation to the general rates of the municipality.

Moran Index of incidence and mortality rates showed statistical significance (p=0.001 and p=0.02, respectively) for global spatial autocorrelation of COVID-19 in the city of Rio



LISA: local indicator of spatial association.

Figure 3. Global and local spatial autocorrelation index for incidence (A) and mortality (B) rates of COVID-19. City of Rio de Janeiro, March 2020 to February 2021.

de Janeiro (Figures 3A and 3B, respectively). Moran Index of incidence and mortality rates are different from each other (and significant), which reinforces the idea that there are pockets of incidence and mortality clustered in different places in the city of Rio de Janeiro.

By adopting the LISA method for incidence and mortality rates, autocorrelation at the local level and spatial clusters were observed. Jardim Botânico, Barra da Tijuca, Botafogo, Lagoa, Engenho Novo, Leblon, Vidigal, Riachuelo, Maracanã, Humaitá, Copacabana, Joá, Praça da Bandeira, Gávea, and Ipanema neighborhoods were classified as high-high for incidence rates (Figure 3A). In turn, Vila Valqueire, Praça da Bandeira, Riachuelo, and Maracanã neighborhoods were classified as high-high for mortality rates (Figure 3B). The high-high classification indicates where the situation is more severely spatially-dependent and where incidence and mortality rates are likely to increase in the coming months.

The frequency measures (SIR and SMR) found for the neighborhoods mostly exceeded the rates observed in the city of Rio de Janeiro during the first year of the COVID-19 pandemic.

When comparing the situation of the neighborhoods in the city of Rio de Janeiro with that of the city itself, according to the SIR, it is observed that, even for neighborhoods belonging to the same municipal planning areas (PA), there is not always synchrony between the worst moments of the COVID-19 pandemic (Supplementary Material #2). In PA 1.0, apparently there is no pattern of synchronous SIR concentration or peaks. In PA 2.1, it is observed that, for most neighborhoods, the highest SIR values occurred between June and October 2020. Conversely, in PA 2.2, the most worrisome SIR values were mostly verified between November 2020 and February 2021. In PA 3.1, apparently there is a concentration of high SIR values between April and November 2020. In PA 3.2, heterogeneity in the SIR values is evident, and it is not possible to highlight peaks or concentrations of high values of this measure. In PA 3.3, a concentration of high SIR values was observed, comprising the period from April to November 2020. PA 4.0 presented high SIR values at two different times, between June and August 2020, and in the period between November 2020 and February 2021. In PA 5.1, the worst SIR values are concentrated between March and June 2020. In PA 5.2, the worst SIR values were observed between March and May 2020 and from October 2020 to February 2021. Conversely, in PA 5.3, the worst moment of the pandemic comprised the months of March and April 2020 and also from December 2020 to February 2021.

When comparing the mortality rates of the neighborhoods with those of the city of Rio de Janeiro according to SMR, the same pattern is verified, and even neighborhoods belonging to the same PA have different disease burdens and worse asynchronous moments (Supplementary Material #3). In PA 1.0, the highest SMR values were verified between April and June 2020, similar to those observed in PA 2.1. Conversely, in PA 2.2, the most worrisome SMR values were mostly verified between November 2020 and February 2021. In PA 3.1, the concentration of SMR values apparently follows the same pattern presented in the SIR. In PA 3.2, heterogeneity in the SMR values is also evident, and it is not possible to highlight peaks or concentrations of high values. In PA 3.3, a concentration of high SMR values was observed, comprising the period from April to November 2020. In PA 4.0, 5.1, 5.2, and 5.3, no trends or patterns were observed.

DISCUSSION

The current COVID-19 pandemic presents itself, so far, as the greatest health challenge of this century. In a municipality such as Rio de Janeiro, marked by its great intra-urban inequality — especially in the social, economic, and demographic dimensions —, the challenges have even been greater.

The city of Rio de Janeiro receives a large flow of people from other countries. It is a tourist city and one of the main mobility hubs in Latin America[20]. In this sense, it was expected that, at the beginning of the pandemic, the city would present high incidence rates of COVID-19, when compared with those in the state of Rio de Janeiro and Brazil[21]. The high mortality rate, together with the low rate of reported cases in the city of Rio de Janeiro, when compared with the state of Rio de Janeiro and Brazil, suggests that the underreporting of cases in the city can have substantial values[22]. Similar patterns of high incidence in more densely populated cities and mobility hubs were observed in the state of São Paulo[23].

The city of Rio de Janeiro follows a pattern of excess mortality similar to that of other Brazilian cities that are also deemed hubs as for the movement of people, whether for tourism or commercial routes. The study conducted by Orellana et al.[24] describes, at the beginning of the pandemic, that the four main cities with this excess were Manaus, with 112% (95%CI 103–121), followed by Fortaleza, with 72% (95%CI 67 –78); Rio de Janeiro, with 42% (95%CI 40–45); and São Paulo, with 34% (95%CI 32–36).

The difference in the spatial distribution of incidence and mortality rates in the neighborhoods can be explained by the socioeconomic heterogeneity and intra-urban inequality present in the city of Rio de Janeiro. The achieved results corroborate the spatial analyses carried out by Cavalcante et al.[25] and Santos et al.[26], also concerning incidence and mortality rates due to COVID-19 in the city of Rio de Janeiro. According to these studies, the highest incidence rates were concentrated in the richest neighborhoods, whereas the highest mortality rates were concentrated and growing among the poorest neighborhoods. Similar patterns were also reported on both geographic and socioeconomic issues in the distribution of other diseases strongly related to social vulnerability such as tuberculosis[27] and dengue[28].

There is, in fact, a marked spatial heterogeneity in the distribution of excess deaths from COVID-19 in Brazil, with a similar relation to that found for the city of Rio de Janeiro. In the country, the most affected regions were the Southeast, Northeast, and North. In addition, in capitals, the excess deaths are proportionally greater, although there is a tendency for the pandemic to become more internalized in the most recent scenario. It is speculated that factors related to socioeconomic status, urban segregation, occupation, and poor remuneration, as well as limited access to health services and ethnicity/color, may be determinants of the excess deaths in state capitals[29]. Furthermore, it is worth recognizing that COVID-19 is not necessarily the direct cause of excess mortality. Deaths caused by the overload or collapse of health services, the interruption of treatment for chronic diseases, or the resistance of patients to seek health care due to the fear of being infected by the new coronavirus make the situation in these places even more delicate[30].

In addition to the spatial analyses, the variation in SIR and SMR values between neighborhoods indicates that the spread and burden of COVID-19 during the pandemic does not uniformly occur along the CAs. It is worth mentioning that geographic and socioeconomic inequality presents itself as a differential for a greater or lesser chance of surviving or dying from infection by the same virus. This evidence has been demonstrated by several other studies, which highlight a notable difference in access to health services, notably in the waiting time to meet healthcare demands and referral to more complex care[31-37]. Another equally relevant aspect is that social vulnerability also presents itself in the possibility of social distancing. Individuals who live in extreme poverty reside in slums, with a high rate of household density; they have more precarious jobs and inadequate income, which forces them to look for alternatives to complement their household income[33,36,38].

Another aspect worth emphasizing is health management in the municipality. This division, which encompasses primary health care (PHC), has been praised for several years and has been used as a model for health management in other municipalities, especially in the fight against infectious diseases such as dengue, tuberculosis, and leprosy[39]. However, as of 2017, PHC has been dismantled in the city of Rio de Janeiro, with major cuts in funding and a consequent reduction in coverage by the Family Health Strategy, which decreased from 62% in 2017 to 55% in 2019[39].

The authors of the present study emphasize that mitigating the pandemic, considering the context of inequality discussed in this study, requires the implementation of strict measures of social distancing, as well as non-pharmacological measures at the individual level, such as the correct use of masks. These measures have had a positive impact on reducing the spread of the virus[40,41]. Moreover, the implementation of these strategies requires broadening inspection to avoid noncompliance with the rules, a phenomenon considerably observed and reported in the municipality[10,42,43]. Definitely, such control measures should be primarily accompanied by the creation of social protection measures for the vulnerable population such as the regularity of emergency aid and concessions to small producers and/or small businesses[44]. Finally, the authors emphasize the need for accelerating the immunization campaign for proper control of the COVID-19 pandemic, by increasing the purchase of vaccines together with the organization of the vaccination flow, allowing everyone to quickly and safely receive the vaccine and avoiding overcrowding and poor distribution of vaccines[44-47].

The study has limitations. Underreporting should be considered, as the number of cases and deaths is directly dependent on the implemented testing policy and control measures. Brazil, as a whole, does not have a uniform and well-defined testing policy or control plan, which results in the country having one of the lowest testing rates in the world[4,8]. Even with the possibility of using the clinical-epidemiological criterion, which allows notification of COVID-19 without the laboratory test, it is evident that an individual with COVID-19 is only notified when seeking healthcare services; therefore, people with mild or asymptomatic cases who did not sought for medical care were not considered in this study. Furthermore, the population considered to calculate the rates was an estimate calculated based on the 2000 and 2010 Censuses, as the the Demographic Census, initially planned for 2020, has not been conducted yet. All in all, incidence and mortality rates, despite being the best alternatives to make comparisons between different locations, may not accurately reflect information concerning neighborhoods with small populations. Therefore, the authors recommend for systematic studies to be carried out to monitor the evolution of the pandemic in the city of Rio de Janeiro, seeking to collaborate on the formulation of health policies that protect people with the same characteristics in possible new public health emergencies.

REFERENCES

1. World Health Organization. Novel Coronavirus (2019-nCoV) situation report – 1. Geneva: World Health Organization; 2020. [cited on Apr. 30, 2021]. Available at: https://apps.who.int/iris/handle/10665/331475
2. World Health Organization. Novel Coronavirus(2019-nCoV) situation report – 11. Geneva: World Health Organization; 2020. [cited on Apr. 30, 2021]. Available at: https://apps.who.int/iris/handle/10665/330761
3. World Health Organization. Coronavirus disease 2019 (COVID-19) Situation Report – 51. Geneva: World Health Organization; 2020. [cited on Apr. 30, 2021]. Available at: https://apps.who.int/iris/handle/10665/331475
4. Roser, M., Ritchie, H., Ortiz-Ospina, E., Hasell J. Coronavirus pandemic (COVID-19) [Internet]. 2020 [cited on Apr. 9, 2021]. Available at: https://ourworldindata.org/coronavirus
5. Brasil. Ministério da Saúde. Portaria Nº 188, de 3 de fevereiro de 2020. Declara Emergência em Saúde Pública de importância Nacional (ESPIN) em decorrência da infecção humana pelo novo Coronavírus (2019-nCoV). Brasil; 2020.
6. Brasil. Ministério da Saúde. Coronavírus Brasil: painel coronavírus. [Internet]. 2021 [cited on Apr. 9, 2021]. Available at: https://covid.saude.gov.br/
7. Prefeitura do Rio de Janeiro. Secretaria Municipal de Saúde do Rio de Janeiro. Painel Rio COVID-19 [Internet]. 2021 [cited on Apr. 9, 2021]. Available at: https://experience.arcgis.com/experience/38efc69787a346959c931568bd9e2cc4
8. Silva GAE, Jardim BC, Santos CVBD. Excesso de mortalidade no Brasil em tempos de COVID-19. Cien Saude Colet 2020; 25 (9): 3345-54. https://doi.org/10.1590/1413-81232020259.23642020
9. Instituto Brasileiro de Geografia e Estatística. Quase dois terços das favelas estão a menos de dois quilômetros de hospitais [Internet]. 2012 [cited on Apr. 9, 2021]. Available at: https://agenciadenoticias.ibge.gov.br/agencia-noticias/2012-agencia-de-noticias/noticias/27728-quase-dois-tercos-das-favelas-estao-a-menos-de-dois-quilometros-de-hospitais
10. InLoco. Mapa brasileiro da covid-19 [Internet]. 2021 [cited on Apr. 30, 2021]. Available at: https://mapabrasileirodacovid.inloco.com.br/pt/
11. Castro MC, Massuda A, Almeida G, Menezes-Filho NA, Andrade MV, Noronha KVMS, et al. Brazil's unified health system: the first 30 years and prospects for the future. Lancet 2019; 394 (10195): 345-56. https://doi.org/10.1016/S0140-6736(19)31243-7
12. Prefeitura da cidade do Rio de Janeiro. Lei nº 5.407, de 17 de maio de 2012. Cria o Bairro da Lapa, pela subdivisão do Bairro de Fátima e do Centro, área da AP 1, II Região Administrativa. Brasil; 2012.
13. Prefeitura da cidade do Rio de Janeiro. Lei nº 3852, de 23 de novembro de 2004. Cria e delimita o bairro de Gericinó, e altera a delimitação do bairro de Bangu. Brasil; 2004.

14. Secretaria de Estado de Saúde do Rio de Janeiro. Painel Coronavírus COVID-19 [Internet]. 2020 [cited on Apr. 30, 2021]. Available at: https://www.saude.rj.gov.br/
15. Instituto Brasileiro de Geografia e Estatistica. Estimativas da população residente para os municípios e para as unidades da federação brasileiros com data de referência em 1º de julho de 2020 [Internet]. 2021 [cited on Apr. 9, 2021]. Available at: https://biblioteca.ibge.gov.br/index.php/biblioteca-catalogo?view=detalhes&id=2101747
16. Kayano T, Nishiura H. A Comparison of Case Fatality Risk of COVID-19 between Singapore and Japan. J Clin Med 2020; 9 (10): 3326. https://doi.org/10.3390/jcm9103326
17. Antunes JLF, Waldman EA. Tuberculosis in the twentieth century: time-series mortality in São Paulo, Brazil, 1900-97. Cad Saude Publica 1999; 15 (3): 463-76. https://doi.org/10.1590/s0102-311x1999000300003
18. Vandenbroucke JP. A shortcut method for calculating the 95 percent confidence interval of the standardized mortality ratio. Am J Epidemiol 1982; 115: 303-4. https://doi.org/10.1093/oxfordjournals.aje.a113306
19. Anselin L. GeoDa: an introduction to spatial data analysis [Internet]. Chicago: GeodaCenter; 2018 [cited on Mar. 16, 2021]. Available at: https://geodacenter.github.io/workbook/3b_rates/lab3b.html#excess-risk
20. Codeço CT, Villela D, Coelho F, Bastos LS, Carvalho LM, Gomes MFC, et al. Estimativa de risco de espalhamento da COVID-19 no Brasil e avaliação da vulnerabilidade socioeconômica nas microrregiões brasileiras [Internet]. 2020 [cited on May 5, 2021]. Available at: https://www.arca.fiocruz.br/bitstream/icict/40509/4/Relatorio_tecnico_COVID-19_procc-emap-covid-19-reporte2_resultados.pdf
21. Coelho FC, Lana RM, Cruz OG, Villela DAM, Bastos LS, Pastore Y, et al. Assessing the spread of COVID-19 in Brazil: Mobility, morbidity and social vulnerability. PLoS One 2020; 15 (9): e0238214. https://doi.org/10.1371/journal.pone.0238214
22. Werneck GL, Porto LC, Sena A, Ferreira Júnior OC, Cavalcanti AC, Santos AMG, et al. The incidence and geographical spread of SARS-CoV-2 in Rio de Janeiro, Brazil based on RT-PCR test results. Rev Soc Bras Med Trop 2021; 54: e07792020. http://doi.org/10.1590/0037-8682-0779-2020
23. ardim VC, Buckeridge, MS. Análise sistêmica do município de São Paulo e suas implicações para o avanço dos casos de Covid-19. Estud Av 2020; 34 (99): 157-74. https://doi.org/10.1590/s0103-4014.2020.3499.010
24. Orellana JDY, Cunha GM, Marrero L, Moreira RI, Leite IC, Horta BL. Excesso de mortes durante a pandemia de COVID-19: subnotificação e desigualdades regionais no Brasil. Cad Saude Publica 2021; 37 (1): e00259120. https://doi.org/10.1590/0102-311X00259120
25. Cavalcante JR, Abreu AJL. COVID-19 no município do Rio de Janeiro: análise espacial da ocorrência dos primeiros casos e óbitos confirmados. Epidemiol Serv Saude 2020; 29 (3): e2020204. https://doi.org/10.5123/S1679-49742020000300007
26. Santos JPC, Siqueira ASP, Praça HLF, Albuquerque HG. Vulnerabilidade a formas graves de COVID-19: uma análise intramunicipal na cidade do Rio de Janeiro, Brasil. Cad Saude Publica 2020; 36 (5): e00075720. https://doi.org/10.1590/0102-311x00075720
27. Vicentin G, Santo AH, Carvalho MS. Mortalidade por tuberculose e indicadores sociais no município do Rio de Janeiro. Ciênc. Saúde Coletiva 2002; 7 (2): 253-63. https://doi.org/10.1590/S1413-81232002000200006
28. Xavier DR, Magalhães MAFM, Gracie R, Reis IC, Matos VP, Barcellos C. Difusão espaço-tempo do dengue no Município do Rio de Janeiro, Brasil, no período de 2000-2013. Cad Saude Publica 2017; 33 (2): e00186615. https://doi.org/10.1590/0102-311X00186615
19. França EB, Ishitani LH, Teixeira RA, Abreu DX, Corrêa PRL, Marinho F, Vasconcelos AMN. Deaths due to COVID-19 in Brazil: how many are there, and which are being identified? Rev Bras Epidemiol 2020; 23: e200053. https://doi.org/10.1590/1980-549720200053
30. CONASS. Painel de análise do excesso de mortalidade por causas naturais no Brasil. [cited on Apr. 24, 2021]. Available at: https://www.conass.org.br/indicadores-de-obitos-por-causas-naturais/.
31. Albuquerque MV, Ribeiro LHL. Desigualdade, situação geográfica e sentidos da ação na pandemia da COVID-19 no Brasil. Cad. Saúde Pública 2020; 36 (12): e00208720. https://doi.org/10.1590/0102-311x00208720
32. Fortes A, Oliveira LD, Sousa GM. A COVID-19 na Baixada Fluminense: Colapso e apreensão a partir da periferia metropolitana do Rio de Janeiro. Espaço e Economia 2020; 9 (18). https://doi.org/10.4000/espacoeconomia.13591
33. Escola Nacional de Saúde Pública. Boletim socioepidemiológico da COVID-19 nas favelas [Internet]. 2020 [cited on May 5, 2021]. Available at: http://www.ensp.fiocruz.br/portal-ensp/informe/site/arquivos/anexos/36c528bb42327a6fd1e4f53f98aa716524db35e9.PDF
34. Souza LPS, Souza AG, Tirelli C. COVID-19 no Brasil: seguimos no mesmo mar, mas não nos mesmos barcos. Com Ciências Saúde 2021 [cited on May 5, 2021]; 31 (3): 41-8. Available at: http://www.escs.edu.br/revistaccs/index.php/comunicacaoemcienciasdasaude/article/view/787

35. Rocha J. Farias V. Covid-19 potencializou diferenças sociais nos estados [Internet]. 2020 [cited on May 5, 2021]. Available at: https://oglobo.globo.com/sociedade/covid-19-potencializou-diferencas-sociais-nos-estados-24407617
36. Silva BZ. Pela DesCrivelização da saúde: reflexões sobre a crise da saúde no Rio de Janeiro-RJ e seu agravo na pandemia. Physis 2020; 30 (3): e300308. https://doi.org/10.1590/S0103-73312020300308
37. Rodrigues NCP, Andrade MKN, Monteiro DLM, Lino VTS, Reis IN, Frossard VC, et al. COVID-19 morbidity and mortality in 2020: the case of the city of Rio de Janeiro. J Bras Pneumol 2020; 46 (5): e20200341. https://doi.org/10.36416/1806-3756/e20200341
38. Rianelli E. Passageiros enfrentam filas enormes e ônibus lotados com janelas fechadas no Rio [Internet]. 2021 [cited on May 5, 2021]. Available at: https://g1.globo.com/rj/rio-de-janeiro/noticia/2021/01/26/passageiros-enfrentam-filas-enormes-e-onibus-lotados-com-janelas-fechadas-no-rio.ghtml
39. Fernandes L, Ortega F. A atenção primária no rio de janeiro em tempos de Covid-19. Physis 2020; 30 (3): e300309. https://doi.org/10.1590/s0103-73312020300309
40. Crokidakis N. COVID-19 spreading in Rio de Janeiro, Brazil: do the policies of social isolation really work? Chaos Solitons Fractals 2020; 136: 109930. https://doi.org/10.1101/2020.04.27.20081737
41. Volpatto D, Resende AC, Anjos L, Silva J, Dias C, Almeida R, et al. Avaliação de estratégias de relaxamento do distanciamento social para o Brasil e estado do Rio de Janeiro [Preprint]. 2020 [cited on May 2, 2021]. Available at: https://preprints.scielo.org/index.php/scielo/preprint/download/595/840/872
42. Aquino EML, 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. Ciênc Saúde Coletiva 2020; 25 (suppl 1): 2423-46. https://doi.org/10.1590/1413-81232020256.1.10502020
43. Amorim D. Rio registra menor taxa de isolamento social desde o início da pandemia de Covid-19; Botafogo lidera índices - Jornal O Globo [Internet]. 2021 [cited on May 3, 2021]. Available at: https://oglobo.globo.com/rio/rio-registra-menor-taxa-de-isolamento-social-desde-inicio-da-pandemia-de-covid-19-botafogo-lidera-indices-24909045
44. Barreto ML, Barros AJD, Carvalho MS, Codeço CT, Hallal PRC, Medronho RA, et al. O que é urgente e necessário para subsidiar as políticas de enfrentamento da pandemia de COVID-19 no Brasil? Rev Bras Epidemiol 2020; 23: e200032. https://doi.org/10.1590/1980-549720200032
45. Leal A. Vacinação na Uerj tem aglomeração e fila de até 1 hora nesta segunda-feira – Jornal O Globo [Internet]. 2021 [cited on May 3, 2021]. Available at: https://oglobo.globo.com/rio/vacinacao-na-uerj-tem-aglomeracao-fila-de-ate-1-hora-nesta-segunda-feira-1-24956087
46. Castro MC, Kim S, Barberia L, Ribeiro AF, Gurzenda S, Ribeiro KB, et al. Spatiotemporal pattern of COVID-19 spread in Brazil. Science 2021; 372 (6544): 821-6. https://doi.org/10.1126/science.abh1558
47. Domingues CMAS. Desafios para a realização da campanha de vacinação contra a COVID-19 no Brasil. Cad Saúde Pública 2021; 37 (1): e00344620. https://doi.org/10.1590/0102-311X00344620

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