HU Revista
Artigo Original

Geospatial distribution and risk factors of COVID-19 in a low-density municipality in Minas Gerais, Brazil

Distribuição geoespacial e fatores de risco da COVID-19 em um município de baixa densidade populacional em Minas Gerais, Brasil

Eduardo David Soares da Silva[1]
Luzivalda Duarte do Couto[2]
Odinéia Amorim[3]
Luciana Maria Ribeiro Antinarelli[4]
Igor Rosa Meurer[5]
Aripuanã Sakurada Aranha Watanabe[4]
Márcio Roberto Silva[6]
Ricardo José de Paula Souza e Guimarães[7]
Elaine Soares Coimbra[4]

[1]Faculdade de Medicina, Universidade Presidente Antônio Carlos (UNIPAC), Juiz de Fora, MG, Brasil.

[2]Hospital Misericórdia de Santos Dumont, Santos Dumont, MG, Brasil.

[3]Departamento de Vigilância Sanitária de Santos Dumont, Santos Dumont, MG, Brasil.

[4]Departamento de Parasitologia, Microbiologia e Imunologia, Instituto de Ciências Biológicas, Universidade Federal de Juiz de Fora, Juiz de Fora, MG, Brasil.

[5]Hospital Universitário da Universidade Federal de Juiz de Fora, Empresa Brasileira de Serviços Hospitalares, Juiz de Fora, MG, Brasil.

[6]Empresa Brasileira de Pesquisa Agropecuária, Unidade Embrapa Gado de Leite, Juiz de Fora, MG, Brasil.

[7]Seção de Epidemiologia, Instituto Evandro Chagas, Ananindeua, PA, Brasil.

✉ **Elaine Coimbra**

Instituto de Ciências Biológicas, Universidade Federal de Juiz de Fora, Campus Universitário, R. José Lourenço Kelmer, s/n, São Pedro, Minas Gerais
CEP: 36036-900
elaine.coimbra@ufjf.br

Submetido: 09/07/2024
Aceito: 06/09/2024

ABSTRACT

Introduction: The human population has faced several pandemics throughout history, with the most recent being COVID-19. Studies on COVID-19 in Brazil, in general, have primarily focused on the country as a whole or on large urban centers. However, prevention measures should also consider smaller municipalities, as the disease has significantly affected these areas as well. **Objective:** To evaluate the geospatial distribution and risk factors associated with SARS-CoV-2 infection in residents of a low-population-density municipality in the state of Minas Gerais, Brazil. **Material and Methods:** This retrospective cross-sectional study collected data from COVID-19 notification forms recorded by the Municipal Health Surveillance in Santos Dumont, Minas Gerais, Brazil, from March 2020 to July 2021. Variables associated with SARS-CoV-2 infections were evaluated using explanatory univariate and multivariate logistic regression models. The occurrence of possible spatial clusters among the reported COVID-19 cases in the municipality was assessed using Kernel Density Estimation (KDE) and Spatial Scan analyses. The main variables explored as explanatory for SARS-CoV-2 infections were race/ethnicity, gender, and health-related occupations. **Results:** Out of 8,271 individuals with suspected COVID-19 in Santos Dumont, 55% (4,595) declared themselves as residents of the municipality. Among these, 4,093 had complete records for spatial analysis, with 1,274 (31%) testing positive for SARS-CoV-2. The choropleth map revealed that infections were concentrated in the central region of the municipality. Univariate analysis showed no statistically significant differences in infection rates based on gender or race/color. However, multivariate analysis indicated that non-health professionals had a significantly higher risk of SARS-CoV-2 infection (OR 2.042; 95% CI 1.41-2.94). **Conclusion:** The central, denser area of the municipality was more susceptible to SARS-CoV-2 transmission. Additionally, non-health professionals faced higher risks of infection. These findings can serve as tools for the development of public health policies to control future pandemics.

Palavras-chave: COVID-19; SARS-CoV-2; Geographic Mapping; Risk Factors; Population Density; Cities, epidemiology.

RESUMO

Introdução: A população humana enfrentou várias pandemias ao longo da história, sendo a mais recente a COVID-19. Estudos sobre a COVID-19 no Brasil têm, na sua grande maioria, se concentrado principalmente no país como um todo ou em grandes centros urbanos. No entanto, as medidas de prevenção também devem considerar municípios menores, uma vez que a doença também afetou significativamente essas áreas. **Objetivo:** Avaliar a distribuição geoespacial e os fatores de risco associados à infecção por SARS-CoV-2 em residentes de um município de baixa densidade populacional no estado de Minas Gerais, Brasil. **Material e Métodos:** Este estudo retrospectivo e transversal coletou dados dos formulários de notificação de COVID-19 registrados pela Vigilância em Saúde do Município de Santos Dumont, Minas Gerais, Brasil, de março de 2020 a julho de 2021. Foram avaliadas variáveis associadas a infecções por SARS-CoV-2 por modelos explicativos de regressão logística uni e multivariados. Também avaliou a ocorrência de possíveis aglomerados espaciais entre os casos notificados de COVID-19 no município, usando a estimativa de densidade de Kernel (EDK) e a varredura espacial (Scan). As principais variáveis exploradas como explicativas para as infecções por SARS-CoV-2 foram raça/etnia, gênero e ocupações relacionadas à saúde. **Resultados:** Dos 8.271 indivíduos com suspeita de COVID-19 em Santos Dumont, 55% (4.595) declararam como residentes do município. Dentre estes, 4.093 apresentaram a ficha completa quanto aos dados para análise espacial; sendo 1.274 (31) positivos para SARS-CoV-2. O mapa coroplético revelou que a infecção estava concentrada na região central do município. A análise univariada não mostrou diferenças estatisticamente significativas nas taxas de infecção com base no gênero ou na raça/cor dos indivíduos. No entanto, a análise multivariada indicou que não profissionais de saúde tinham um risco significativamente maior de infecção por SARS-CoV-2 (OR 2,042; IC 95% 1,41-2,94). **Conclusão:** A área central e mais densa do município foi mais suscetível à transmissão de SARS-CoV-2. Além disso, profissionais que não eram da área da saúde enfrentaram maiores riscos de infecção. Esses achados podem servir como ferramentas para o desenvolvimento de políticas de saúde pública no controle de futuras pandemias.

Keywords: COVID-19; SARS-CoV-2; Mapeamento Geográfico; Fatores de Risco; Densidade Populacional; Cidades, epidemiologia.

INTRODUCTION

Over the years, the human population have had to deal with several pandemics, including viral and non-viral ones, such as influenza, smallpox, falciparum malaria, measles, bubonic plague, and human immunodeficiency virus (HIV).[1] The last one was the COVID-19 disease, caused by SARS-CoV-2, beginning in December 2019 in Wuhan City, Hubei Province, China.[2,3] Currently, 775,678,432 confirmed cases in the world and 7,052,472 deaths by COVID-19 related to World Health Organization (WHO).[4] The mortality rate during the pandemic varied greatly, and factors such as the phase of the pandemic, circulating variant of concern and control measures influenced these values.

The estimate global mortality rate was 120.3 per 100.000 of the population, with high rates found in countries such as Bolivia (734.9/100.000) and negative rates as in New Zealand. On 5th May 2023, with reduction in the number of cases and hospitalizations associated with the increase in people immunized with the vaccine, the WHO announced that the COVID-19 was suppressed in Public Health Emergency of International Concern (PHEIC) list.

Although the brings relief, there is no doubt that the disease was one of the biggest global health problems in the 21st century, and nowadays, millions of infected people around the world suffer with the long-term consequences of SARS-CoV-2 infection.

Regarding the global situation on COVID-19, the Americas had reported the highest number of deaths.[4] In this scenario, Brazil was the second country in number of deaths in the world, being surpassed only by the United States.[4] Brazil is the largest country in Latin America, with continental dimensions and social inequalities.

Brazil was one of the countries with the highest absolute numbers of deaths (619.000) and a mortality rate of 186.9 per 100.000 of the population.[4.5] Minas Gerais State is the 2nd most populous state in Brazil, and the second state in the country with almost number of reported cases, followed by São Paulo. Minas Gerais possesses 853 municipalities and these municipalities present variated heterogeneity in terms of socioeconomic level and democratic access to health, and all of them reported infection by SARS-CoV-2.[5]

Studies on COVID-19 in Brazil were predominantly in large urban centers or using the country as a whole.[6-11] Despite some studies describe the impact of the pandemic in small Brazilian towns, there is still a deficiency of research with this focus. Therefore, there is still a deficiency of clinical, epidemiological, and other types of information.[12-14] Several studies conducted in the United States describe data on the impact of COVID-19 in small American towns, concluding that there is no difference in hospitalization duration and intensive care unit (ICU) admission when comparing populations from large cities with those from less urbanized and/or rural areas. Additionally, these studies raise concerns about the lack of data in small communities.[16-18]

This work used georeferencing to demonstrate how the spread of SARS-CoV-2 infection occurred in a municipality with low density of population in the Minas Gerais state, Brazil. Additionally, epidemiology and risk factors associated with SARS-CoV-2 infection were analyzed.

The research began with the first case registered in the municipality and ended in July 2021, six months after the first dose of vaccination against COVID-19 in Brazil. These data can contribute to the planning of future public health actions, including primary and secondary health care, mainly in smaller municipalities.

MATERIAL AND METHODS

Study area

Santos Dumont (latitude 21°27’24”S/43°33’09”W) is a municipality in the Mesoregion of “Zona da Mata” and microregion of Juiz de Fora, in the state of Minas Gerais, Brazil. Distant, approximately 207 km from Belo Horizonte, the state capital, and 900 km from Brasília, the capital of Brazil. The territorial area unit is 637,373 km^2, with an estimated population of 46,487 people in 2022 (IBGE – https://cidades.ibge.gov.br/).

Study design, sample size and ethics statement

A robust retrospective and cross-sectional study was conducted using the data from the COVID-19 notification by the Municipal Health Surveillance of Santos Dumont, Minas Gerais, Brazil, from March 2020 until July 2021. All analyses were performed considering individual’s residence data. The study used secondary data collected individually by the health service of the patients included.

The inclusion criterion for participation in the study was patients notified by the Santos Dumont Health Surveillance, from the notification of the first case of SARS-CoV-2 in March 31st, 2020 until July 2021, regardless of laboratorial test result. Exclusion criteria for the study were patients with incomplete information regarding diagnostic results, age, home address, or month and year of the diagnostic tests in the Health Surveillance database.

The research project was approved by the Human Ethics Committee of the Federal University of Juiz de Fora, under process number 4.138.128, and conducted in accordance with the ethical and legal aspects of research involving humans established by Resolution no. 466/2012 of the National Health Council.

Epidemiological and clinical data

The information on the SARS-CoV-2 infection, such as home address, age, sex, diagnostic tests date, laboratory results, clinical symptoms and clinical evolution were collected from severe acute respiratory syndrome notification form, organized and archived in the Parasitology, Microbiology and Immunology Department, Federal University of Juiz de Fora. Based on home address, the researchers determined all the georeferenced points used in the spatial analyses.

Diagnostic assays

The diagnostic assays were realized by the Municipal Health Surveillance of Santos Dumont. According the data from the COVID-19 notification by the Municipal Health Surveillance of Santos Dumont, Immunological rapid (SARS-CoV-2-specific antigens and antibodies) or molecular (RT-qPCR*)* tests, distributed by Brazilian Unified Health System (SUS) were performed following the recommendations of the Ministry of Health for detection of SARS-CoV-2 infection.

Study variables

The main outcomes of this study were SARS-CoV-2 infections and confirmed cases of COVID-19, whose explanatory variables were evaluated by explanatory models of logistic regression and spatial analysis, respectively. The main variables explored as explanatory for SARS-CoV-2 infections were race/ethnicity, gender and health-related occupations. The spatial analysis sought to describe the distribution pattern of confirmed cases of COVID-19, whether these cases presented as clusters, and, in the case of clusters, whether they were significant.

Statistical analysis

Descriptive statistics were used to summarize general data about the study individuals. Univariate and multivariate logistic regression analyses were conducted to evaluate putative factors associated with Sars-Cov-2 infections. In the univariate analyses, the χ^2 test was used to assess which explanatory variables were associated with the outcome, with a significance level of 5%.

All variables with P-values <0.20 in the univariate analyses were included in the multiple logistic regression and then adjusted in order to obtain the final model. A backward stepwise method was used to reach a satisfactory fitting level. Crude and adjusted odds ratios (OR) and 95% confidence intervals (CI) were calculated and goodness-of fit was assessed by the Hosmer and Lemeshow's test.

Spatial analysis

Data collection: COVID-19 notification records were obtained from the Health Surveillance of the municipality of Santos Dumont for the period of 2020-2021. These data were processed in Excel (https://www.microsoft.com) to create a COVID-19 database.

The cartographic bases (municipal boundaries, districts, neighborhoods, census tracts, number of residents per tract) and the population of the census tracts were obtained from the Brazilian Institute of Geography and Statistics (IBGE – http://www.ibge.gov.br/).

Data processing: using the fields "Street Type, Street Name, Number, Neighborhood, Municipality, State, and ZIP Code" from the COVID-19 notification record, geocoding/georeferencing of COVID-19 cases was performed in Google Drive. In cases where coordinates were not found or were related to other municipalities, individual geocoding was performed using the following websites: Google Maps (https://www.google.com.br/maps), CEPs of Brazil (https://ceps.io/), and OpenStreetMap (https://www.openstreetmap.org). The obtained coordinates were added to the database, thereby creating a geographic database of COVID-19. COVID-19 Incidence Rate (Rate) was calculated using the number of positive cases by the population of IBGE census tracts multiplied by 1,000.

Data analysis: the spatial analyses performed included: spatial distribution map to visualize the location of confirmed COVID-19 cases; choropleth map to quantify the COVID-19 rate; Global Moran's Index (GMI) to verify the spatial autocorrelation pattern; Nearest Neighbor (NN) to obtain the observed average distance and determine the distribution pattern of cases; Kernel Density Estimation (KDE) to verify the existence and location of clusters of cases and rates; and spatial scan map to identify significant spatial and spatiotemporal clusters.

The choropleth map presents the following classes (colors): no cases (white), low (green), medium (yellow), high (orange), and very high (red) – the classification was based on quartile use. The GMI was applied with a permutation number of 999 times. The KDE used the following parameters: quartic function, density calculation, and adaptive radius. The spatial scan map used the following analyses: space-time of the discrete Poisson model and spatial of the Bernoulli model. The choropleth map, NN, and map creation were performed in ArcGIS software (http://www.arcgis.com/), the spatial scan in SatScan (https://www.satscan.org/), and the GMI and KDE in TerraView (https://www.dpi.inpe.br/terralib5/wiki/doku.php).

RESULTS

From a total of 8,271 individuals investigated to SARS-CoV-2 infection by the public healthcare system in the municipality of Santos Dumont, Minas Gerais, Brazil, during the period of March 2020 to July 2021, 4,595 (55%) declared as residents in the municipality of Santos Dumont, 4,093 of which had complete information regarding diagnostic results and home address were included and the data were used to analyze the spatial distribution of the SARS-CoV-2 infection in the municipality. Among 4,093 individuals, 1,274 cases (31%) were considered positive for SARS-CoV-2, whereas 2,819 cases were considered negative. A choropleth map with the distribution of cases in urban and rural areas was applied and showed in Figure 1, and as can be noted, the distribution of positive individual cases was concentrated in the urban area (Figure 1A). The color gradation (from green to red) quantifies the density of cases by region, areas in red represent the largest prevalence of positive infection of SARS-CoV-2 in the municipality, while green indicates a lower number of infected individuals (Figure 1B). Based it, the highest rates of infected individuals were registered in the central area of the city, mainly in town, and arranged in the vicinity of this area. The rural region has the lowest infection rates.

The Figure 2 shows the result of applying the EDK to specific confirmed cases (a high-density cluster) and the incidence rate of confirmed census tracts (a high-density cluster), both located in the central urban region of the municipality of Santos Dumont. Also, the figure shows the result of the Global Moran Index (0.24 – p-value: 0.009), Average Nearest Neighbor (mean observed distance: 20.5 m; ratio: 0.09; pattern: clustered), and the scan statistic Spatial Scan (Bernoulli – one significant cluster with a radius of 6.46 km and Relative Risk of 1.22) and Space-Time Scan (Poisson – two significant clusters in the year 2021 with r= 6.2 km

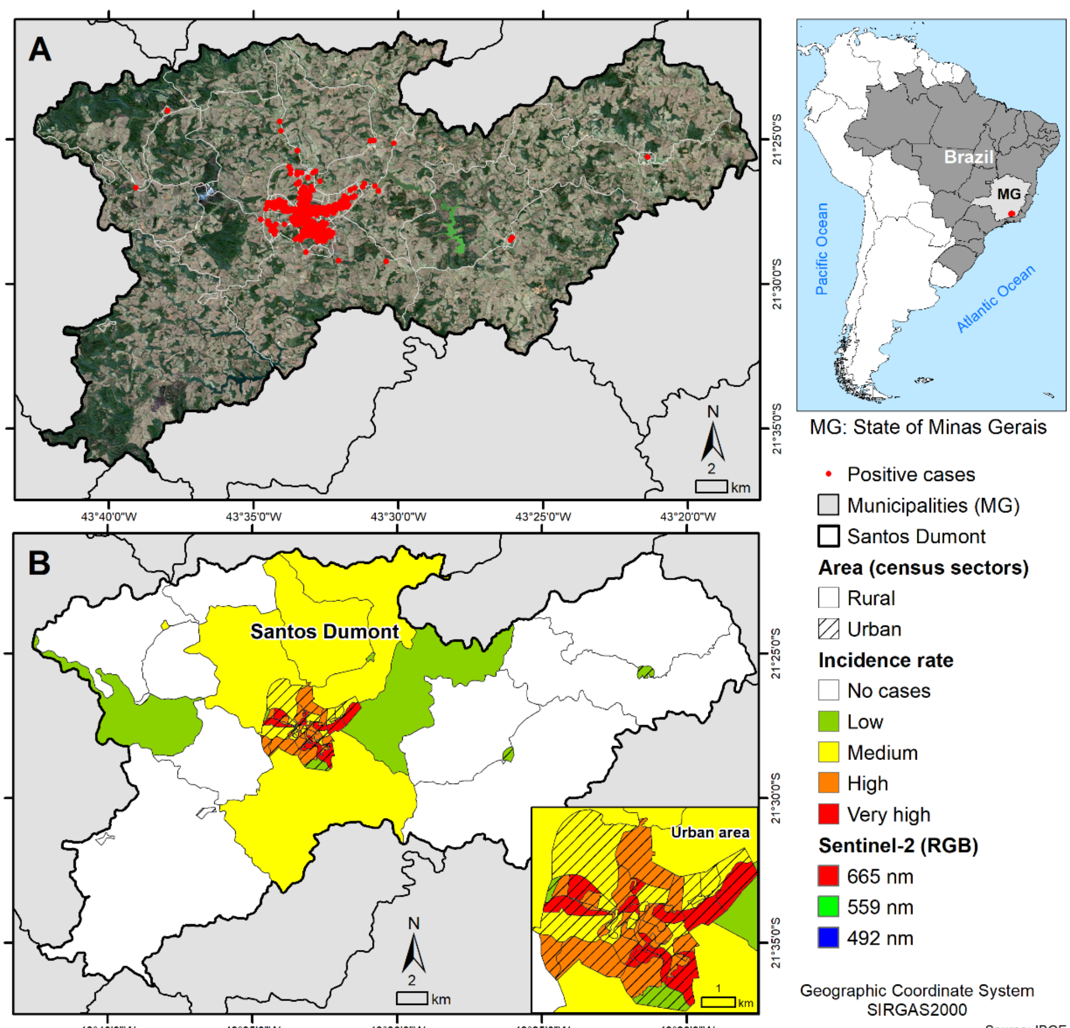

Figure 1: Cases of COVID-19: a) distribution of confirmed cases in the Sentinel-2 image of 09/05/2020, b) choropleth map of the incidence rate in the census sectors in the municipality of Santos Dumont/MG, in the period of 2020-2021 (highlighting the urban center).

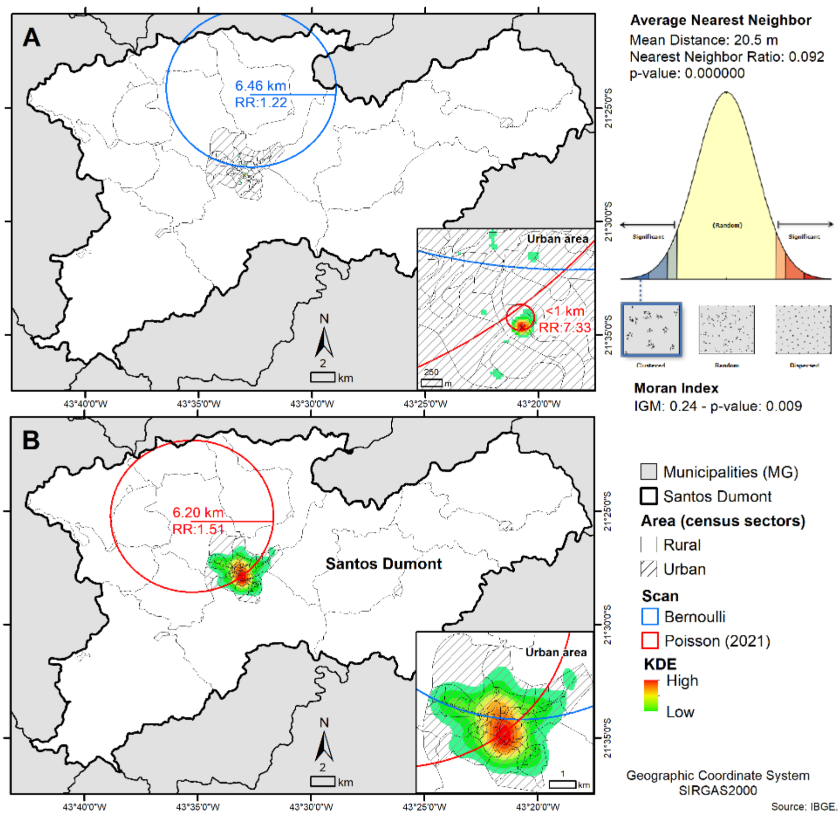

Figure 2: Application of EDK: a) positive cases and spatial scan (Bernoulli), b) incidence rate of the census tracts in the city of Santos Dumont, Minas Gerais, Brazil, and space-time Scan (Poisson) in the period 2020-2021. In the highlight the urban center with the areas indicated by the space and space-time Scan.

/ RR= 1.51 and r <1km / RR= 7.33). It can be seen that the highest risk spatiotemporal scan is located in the same region as the EDK (cases and rate).

Among 8,271 individuals, 4,595 declared as residents in the municipality of Santos Dumont, being 3,446 (75%) individuals were considered positive for SARS-CoV-2, and 1,149 (25%) were negative. Among the infected patients studied, the most prevalent symptoms were cough, sore throat and fever. Regarding the socio-economic and demographic characteristics of individuals positive for SARS-CoV-2, in terms of gender, 32.61% were male and 30.49 female. In the univariate analysis, risk factors associated with gender, race/ethnicity and healthcare workers were evaluated (Table 1). Results revealed that the chances of exposure of SARS-CoV-2 among those with not declared skin color were 2.7 times that of the group characterized as white-skinned people, therefore higher. The chance of SARS-CoV-2 infection among those who were not healthcare workers was 2.04 times that of the group who were healthcare providers, used as a reference group. Multivariate analysis (Table 2) revealed higher odds of SARS-CoV-2 infection associated with race/ethnicity (OR 2.760; CI 2.33-3.26) and not healthcare workers (OR 2.042; CI 1.41-2.94).

DISCUSSION

In this work, the spatial analysis demonstrated a concentration of SARS-CoV-2 infected individuals in the central region of the municipality of Santos Dumont, Minas Gerais, Brazil, indicating that the spread of cases occurred from this region to the outskirts of the municipality. Furthermore, the analysis showed that individuals who are not healthcare professionals were more likely to be infected by SARS-CoV-2 than those working in healthcare.

As SARS-CoV-2 infection is transmitted through the air, it is clear to think that town of the cities, whereas there are denser population, are more vulnerable to infection by this virus.[19] A similar result carried out in the Vellore district, southern India, with a high population density, whose pattern of spread of cases occurred mainly in highly populated urban areas, followed by less populated semi-urban areas and then rural areas.[20] Although Brazil and India are countries with distinct social, economic and cultural characteristics, it is possible to observe a tendency for COVID-19 cases to spread from central to peripheral regions, regardless of the population density of the municipalities. This fact is possibly related to globalization and greater flow of

Table 1: Univariate analysis of associated risk factors for infected SARS-CoV-2 individuals assisted by the public healthcare system, resident in the municipality of Santos Dumont, Minas Gerais, Brazil (March 2020 to July 2021).

Variable	Total	Positive (%)	OR (CI95%)	*P* value
Race/ethnicity				
White[a]	2171	607 (27.96)	1.00	–
Black[b]	519	139 (26.78)	0.94 (0.76-1.16)	0.59
Brown[c]	1094	290 (26.51)	0.92 (0.78-1.09)	0.38
Yelow[d]	21	2 (9.52)	0.27 (0.06-1.16)	0.08
Not declared[e]	790	410 (51.90)	2.78 (2.35-3.28)	<0.001
Healthcare workers				
Yes	203	38 (18.72)	1.00	–
No	4395	1410 (32.08)	2.051 (1.43-2.93)	<0.001
Gender				
Male	2171	708 (32.61)	1.00	–
Female	2427	740 (30.49)	0.90 (0.80-1.02)	0.12

OR: odds ratio. CI: confidence interval. *P* value <0.05. [a]White: are the largest ethnic group in Brazil, most of White-skinned people are either immigrants from Europe or are descendants of earlier European colonists); [b]Black: descendants of African slaves; [c]Brown: mixed" ethnicity; [d]Yelow: ethnic designation for Asian people, mainly Japanese immigrants; [e]Not declared.

Table 2: Multivariate analysis of associated risk factors for infected SARS-CoV-2 individuals assisted by the public healthcare system, resident in the municipality of Santos Dumont, Minas Gerais, Brazil (March 2020 to July 2021).

Variable	OR (CI95%)	P value
Race/ethnicity		<.001
White[a]	1.00	
Black[b]	0.934 (0.75-1.16)	0.538
Brown[c]	0.916 (0.77-1.08)	0.296
Yelow[d]	0.262 (0.06-1.13)	0.073
Not declared[e]	2.760 (2.33-3.26	<0.001
Healthcare workers		
Yes	1.00	<0.001
No	2.042 (1.41-2.94)	

OR: odds ratio. CI: confidence interval. *P* value <0.05. [a]White: are the largest ethnic group in Brazil, most of White-skinned people are either immigrants from Europe or are descendants of earlier European colonists); [b]Black: African descents; [c]Brown: mixed" ethnicity; [d]Yelow: ethnic designation for Asian people, mainly Japanese immigrants); [e]Not declared.

people in the central regions of municipalities.

Also, it is interesting to point out that in addition to the central region, the infection also followed to the north of the territory of the municipality. It is notable that an important tourist attraction is located in this region, since it leads to the Cabangu Museum, dedicated in honor of the Brazilian Santos-Dumont, considered by Brazilian people as the "father of aviation", whose municipality has the same name. Thus, one of the hypotheses for the spread of infection in this direction is the ease of access via paved roads which contribute to the spread of COVID-19. It should also be noted that during the pandemic, many people moved to rural areas, where the lockdown was less strict or because they sought isolation away from large urban centers.[20] Thus, it was possible to verify in this study that demographic density is the determining factor in the rate of transmission of the disease, leading, therefore, to a greater number of infected people and deaths.

Minas Gerais state is the largest southeast state, with a size similar to some European countries like Ukraine, France and Spain. With almost 900 municipalities with roads that favor the displacement of people both internally as well as for those from other states, the COVID-19 pandemic has reached in all of the municipalities.[5] It is emphasized that here a many municipalities present precarious conditions to handle with the COVID-19 pandemic, be it for lack of medics and healthcare professionals, or absence of equipment and supplies. The municipality of Santos Dumont, located approximately 211 kilometers from the state capital of Minas Gerais, Belo Horizonte. This city, despite not having the medical and hospital apparatus of the great urban centers, had to rapidly adapt and became, even precariously, a reference center to support for individuals infected by SARS-CoV-2.

As shown in this work, from a total of 8.271 individuals assisted by the public healthcare system in this municipality, during the period of March 2020 to July 2021, only 4,093 declared as residents. This situation points out the necessity for manager repair responsible for municipalities of high, medium and small populational density for epidemics and outbreaks, with strategies and guidelines to face emergency situations. It is emphasized here that Brazil has a plan to face Influenza virus since 2005, however, as well as other countries, it was not prepared for the COVID-19 pandemic, mainly with regard to municipalities with a smaller population density.

Brazil comprising many races and ethnic groups according by the Brazilian Institute of Geography and Statistics (IBGE), being mainly based on the color skin and self-declared by the people. Unlike what was demonstrated in this work, in Brazil, the infection of SARS-Cov-2 was more prevalent in browns/blacks people in several regions of the country.[21,22] The higher prevalence in these population groups can be explained by multifactorial variables. Notably, factors such as socioeconomic vulnerability, low education level, low family income, malnutrition, low food security, and inadequate access to health services play a significant role. Additionally, poor housing conditions with high crowding make it impossible to promote social distancing, coupled with poor hygiene conditions due to limited access to basic sanitation and potable water. Occupational factors, such as working in essential services or in the informal sector under precarious conditions, also contribute to an increased risk of exposure to infection.[6-8]

The Human Development Index (HDI) is the main measure of human development worldwide through which better public health public policies are developed. The HDI can be a valuable tool for better understanding the impact of the COVID-19 pandemic in different regions and countries. The HDI is calculated based in economic and social variables which are life expectancy, analysis of local health and educations, and gross income per capita. Studies show that there is a strong relationship between the HDI and the quality of local health, in which low HDI locations may be associated with higher vulnerability to acquiring COVID-19 infection as well as the higher mortality.[9,21-22] The municipality of Santos Dumont presents an HDI score of 0.741, on a scale that range from 0 to 1, where regions with HDI between 0.500 and 0.799 is considered to be medium development. Unfortunately, studies showed that areas with this level of HDI tend to have worse access to the health system and diagnostic tools for COVID-19, resulting in an enhanced number of underreports cases and deaths and less detection of asymptomatic and mildly positive cases.[10,21,22]

According to data provided by the Ministry of Health, from the beginning of the pandemic until September 2023, the municipality of Santos Dumont had 8,094 cases and 161 deaths caused by COVID-19.[5] In comparison to large municipalities in Brazil such as Rio de Janeiro and São Paulo, the number of confirmed cases/deaths was, respectively, 1,341,283/38,306 and 1,185,972/45,291. It is important to highlight that the discrepancy in these data occurs due to the difference in population density of these municipalities. However, the number of cases confirmed by death from COVID-19 in Santos Dumont (50.27) is higher when compared to Rio de Janeiro (35.01) and São Paulo (26.18). This data demonstrates that the chances of death in individuals confirmed with COVID-19 were lower in Santos Dumont even though it is a small municipality, a fact that may be linked to efficient management regarding the care of positive cases of the disease.

In a cross-sectional study carried out by Villela et al[23], a high incidence of COVID-19 infection was found among Brazilian healthcare professionals. Healthcare professionals are deemed highly susceptible to SARS-CoV-2 infection because of their direct involvement in clinical roles within healthcare settings. During the early stage of the pandemic, the prevalence of SARS-CoV-2 infection among healthcare workers ranged from 5-10% in several countries around the world.[24-29] In this context, it is important to highlight that in the present study, individuals who are not healthcare professionals were 2.04 times more likely to be infected by SARS-CoV-2 than healthcare professionals. There is no doubt that health professionals' knowledge is essential to contain epidemics and a continuous education action should be prioritized.[28,29] These professionals, despite being more exposed to the virus, have, in general, greater knowledge about forms of prevention than the general population, reflecting the results found in this study.[21,22] Possibly the general population individuals did not receive enough information about ways to prevent the disease. Also importantly, as observed around the world, during the COVID-19 pandemic, there was an information overload associated with misinterpretation, low-quality information, and the rapid spread of incorrect information.[29-31] These data highlighting the need to carry out educational health actions for the general population as well as healthcare professionals.

Our study has some inherent limitations due to record of information system analyzed which may reflect in the underreporting in the number of COVID-19 cases. In addition, the loss of information about variables related to risk factors associated to infection by SARS-CoV-2 must be considered, given the higher percentage of individuals with incomplete information on the analyzed variables, which may reflect on the quality of the analyzed data.

With spillovers increasing more and more frequently, we will probably still have to deal with other pandemics later this century. Since outbreaks can have different characteristics, with different intensities, qualities and forms of aggravation, knowledge of these particularities can favor effective epidemiological surveillance, with collectively and individually measures.

CONCLUSION

The spatial analysis proved that areas with high population density, even in small towns, are more vulnerable to airborne infections such as SARS-CoV-2. Additionally, it highlighted the importance of accurate and high-quality information in controlling pandemics. The data found here can contribute to the construction of a panel and guidelines for public health policies aimed at preventing and controlling future pandemics and other health emergencies.

COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

REFERENCES

1. Morens DM, Fauci AS. Cell emerging pandemic diseases: how we got to COVID-19. Cell. 2020; 182(5):1077-92. doi: 10.1016/j.cell.2020.08.021

2. Lu H, Stratton CW, Tang YW. Outbreak of pneumonia of unknown etiology in Wuhan, China: the mystery and the miracle. J Med Virol. 2020; 92(4):401-2. doi: doi: 10.1002/jmv.25678

3. Huang C, Wang Y, Li X, Ren L, Zhao J, Hu Y et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. The Lancet. 2020; 395:497-506. doi: 10.1016/S0140-6736(20)30183-5

4. World Health Organization. WHO Health Emergencies Programme. WHO COVID-19 dashboard [Internet]. WHO; 2024 [cited 2024 Jul 9]. Available at: https://covid19.who.int/.

5. Ministério da Saúde (BR). COVID-19 no Brasil [Internet]. Brasília: Ministério da Saúde; 2023 [cited 2023 Sep 10]. Available at: https://infoms.saude.gov.br/extensions/covid-19_html/covid-19_html.html.

6. Sousa GJB, Garces TS, Cestari VRF, Moreira TMM, Florêncio RS, Pereira MLD. Estimation and prediction of COVID-19 cases in Brazilian metropolises. Rev Lat Am Enfermagem. 2020; 28:e3345. doi: 10.1590/1518-8345.4501.3345

7. Corrêa PRL, Ishitani LH, Abreu DMX, Teixeira RA, Marinho F, França EB. The importance of surveillance in cases of and mortality from the COVID-19 epidemic in Belo Horizonte, Brazil, 2020. Rev Bras Epidemiol. 2020; 23:e200061. doi: 10.1590/1980-549720200061

8. Bitar S, Steinmetz WA. Scenarios for the Spread of COVID-19 in Manaus, Northern Brazil. An Acad Bras Cienc. 2020; 92(4):e20200615. doi: 10.1590/0001-3765202020200615

9. Santos CVBD, Cavalcante JR, Pungartnik PC, Guimarães RM. Space-time analysis of the first year of COVID-19 pandemic in the city of Rio de Janeiro, Brazil. Rev Bras Epidemiol. 2021; 24:e210046. doi: 10.1590/1980-549720210046

10. Souza ÍVS, Holanda ER, Barros MBSC. Factors associated with covid-19 deaths in the city of Recife, Pernambuco, Brazil, 2020: a cross-sectional study with "Notifique Aqui" system data. Epidemiol Serv Saude. 2023; 32(2):e2022701. doi: 10.1590/S2237-96222023000200014

11. Traebert J, Martins BM, Ferreira PNDSV, Garcia LP, Schuelter-Trevisol F, Traebert E. The burden of disease due to COVID-19 in Florianópolis, Santa Catarina, Brazil, over a one-year period. Cien Saude Colet. 2023; 28(6):1743-9. doi: 10.1590/1413-81232023286.14962022

12. Silva AAPD, Reis RS, Iachecen F, Duarte F, Baena CP, Hino AAF. First year of COVID-19 in Brazil: factors associated with the spread of COVID-19 in small and large cities. PLoS One. 2024; 19(6):e0298826. doi: 10.1371/journal.pone.0298826

13. Ribeiro HV, Sunahara AS, Sutton J, Perc M, Hanley QS. City size and the spreading of COVID-19 in Brazil. PLoS One. 2020; 15(9):e0239699. doi: 10.1371/journal.pone.0239699

14. Sott MK, Bender MS, Silva Baum K. Covid-19 outbreak in Brazil: health, social, political, and economic implications. Int J Health Serv. 2022; 52(4):442-54. doi: 10.1177/00207314221122658

15. Mueller JT, McConnell K, Burow PB, Pofahl K, Merdjanoff AA, Farrell J. Impacts of the COVID-19 pandemic on rural America. Proc Natl Acad Sci U S A. 2021; 118(1):2019378118. doi. 10.1073/pnas.2019378118

16. Hamilton CA, Ayyala D, Walsh D, Bramwell C, Walker

C, Wilson Dib R et al. Small towns, big cities: rural and urban disparities among hospitalized patients with COVID-19 in the Central Savannah River Area. Open Forum Infect Dis. 2022; 9(3):ofac050. doi: 10.1093/ofid/ofac050

17. Karim SA, Chen HF. Deaths from COVID-19 in rural, micropolitan, and metropolitan areas: a county-level comparison. J Rural Health. 2021; 37(1):124-32. doi: 10.1111/jrh.12533

18. Peters DJ. Community susceptibility and resiliency to COVID-19 across the Rural-Urban continuum in the United States. J Rural Health. 2020; 36(3):446-56. doi: 10.1111/jrh.12477

19. Chen J, Chen S, Duan G, Zhang T, Zhao H, Wu Z et al. Epidemiological characteristics and dynamic transmissions of COVID-19 pandemics in Chinese mainland: a trajectory clustering perspective analysis. Epidemics. 2023; 45:100719. doi: 10.1016/j.epidem.2023.100719

20. Murugesan M, Venkatesan P, Kumar S, Thangavelu P, Rose W, John J et al. Epidemiological investigation of the COVID-19 outbreak in Vellore district in South India using Geographic Information Surveillance (GIS). Int J Infect Dis. 2022; 122:669-75. doi: 10.1016/j.ijid.2022.07.010

21. Marinho MF, Torrens A, Teixeira R, Brant LCC, Malta DC, Nascimento BR et al. Racial disparity in excess mortality in Brazil during COVID-19 times. Eur J Public Health. 2022; 32(1):24-6. doi: 10.1093/eurpub/ckab097

22. Santos M, Penteado JO, Brum RL, Bonifácio AS, Ramires PF, Gariboti DF et al. Ethnic/racial disparity in mortality from COVID-19: data for the year 2020 in Brazil. Spat Demogr. 2023; 11(1):1-17. doi: 10.1007/s40980-022-00112-2

23. Villela EFM, Cunha IR, Fodjo JNS, Obimpeh M, Colebunders R, Van Hees S. Impact of COVID-19 on healthcare workers in Brazil between August and November 2020: a cross-sectional survey. Int J Environ Res Public Health. 2021; 18(12):6511-23. doi: 10.3390/ijerph18126511

24. Barrett ES, Horton DB, Roy J, Gennaro ML, Brooks A, Tischfield J et al. Prevalence of SARS-CoV-2 infection in previously undiagnosed health care workers at the onset of the U.S. COVID-19 epidemic. medRxiv. 2020. doi: 10.1101/2020.04.20.20072470

25. Sikkema RS, Pas SD, Nieuwenhuijse DF, O'Toole A, Verweij JJ, van der Linden A et al. COVID-19 in health-care workers in three hospitals in the south of the Netherlands: a cross-sectional study. Lancet Infect Dis. 2020; 20:1273-80. doi: 10.1016/S1473-3099(20)30527-2

26. Ing EB, Xu QA, Salimi A, Torun N. Physician deaths from corona virus (COVID-19) disease. Occup Med. 2020. doi: 10.1093/occmed/kqaa088

27. Zhan M, Qin Y, Xue X, Zhu S. Death from COVID-19 of 23 healthcare workers in China. N Engl J Med. 2020; 382:2267-8. doi: 10.1056/NEJMc2005696

28. Bernardes JM, Magalhães DMS, Alonso MS, Gómez-Salgado J, Ruiz-Frutos, C, Romero A, Días A. Knowledge of COVID-19 among Brazilian health care professionals and associated factors. Medicine. 2022; 101(24):e29067. doi: 10.1097/MD.0000000000029067

29. Deressa W, Worku A, Abebe W, Gizaw M, Amogne W. Risk perceptions and preventive practices of COVID-19 among healthcare professionals in public hospitals in Addis Ababa, Ethiopia. PLoS One. 2021; 16(6):e0242471. doi: 10.1371/journal.pone.0242471

30. Gottlieb M, Dyer S. Information and disinformation: social media in the COVID-19 crisis. Acad Emerg Med. 2020; 27:640-1. doi: 10.1111/acem.14036

31. Klerings I, Weinhandl AS, Thaler KJ. Information overload in healthcare: too much of a good thing? Z Evid Fortbild Qual Gesundhwes. 2015; 109:285-90. doi: 10.1016/j.zefq.2015.06.005