Original Article

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COVID-19 em Jundiaí/SP: dinâmica temporal de notificaciones y análisis espacial de prevalencia seroepidemiológica

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RESUMO

Justificativa e Objetivos: A pandemia pela COVID-19 trouxe um cenário desafiador para a saúde pública em todo o mundo, devido ao pouco conhecimento sobre a infecção e seu aumento exponencial. O objetivo é analisar a tendência temporal e a distribuição espacial dos casos positivos para COVID-19 na cidade de Jundiaí/SP, Brasil, bem como sua correlação com a renda e densidade populacional dos bairros. **Métodos:** Estudo transversal, conduzido no período de fevereiro a junho de 2020. Os dados foram obtidos a partir dos casos confirmados pela Vigilância Epidemiológica e por levantamento soroepidemiológico realizado em duas etapas: 1) com usuários sintomáticos para Síndrome Respiratória Aguda Grave que buscaram atendimento nas Unidades de Saúde; 2) amostragem probabilística dos domicílios. Realizou-se análise da série temporal dos casos confirmados pela Vigilância Epidemiológica e foram elaborados mapas com a densidade de Kernel e Índice de Moran Local ($p < 0,05$) dos casos diagnosticados no levantamento soroepidemiológico. **Resultados:** Houve aumento do número de casos no período estudado (2,35%), bem como distribuição heterogênea no território, com concentração em áreas periféricas da cidade. Houve autocorrelação espacial fraca entre média da renda *per capita* (I = 0.11; valor de $p < 0,001$) e densidade populacional por bairros (I = 0.05; valor de p = 0,03). **Conclusão:** A análise do comportamento da infecção no tempo e espaço podem contribuir com ações de enfrentamento com base nas necessidades locais.

Descritores: *Infecções por Coronavirus. Epidemiologia. Saúde Pública. Estudos Transversais*

ABSTRACT

Background and Objectives: The COVID-19 pandemic brought a challenging scenario for public health worldwide, due to little knowledge about the infection and the exponential increase in new cases. This study aims to analyze the temporal trend and the spatial distribution of the positive cases for COVID-19 in the city of Jundiaí/SP, Brazil, as well as its correlation with the income and population density of the neighborhoods. **Methods:** Cross-sectional study, conducted from February to June 2020. Data were obtained from cases confirmed by the Epidemiological Surveillance and by a seroepidemiological survey carried out in two stages: 1) with symptomatic users for Severe Acute Respiratory Syndrome who sought care in Basic Health Units; 2) probabilistic sampling of households. An analysis of the time series of the cases confirmed by the Epidemiological Surveillance was carried out and maps with Kernel density and Local Moran Index ($p < 0.05$) of the cases diagnosed in the seroepidemiological survey were prepared. **Results:** There was an increase in the number of cases in the period studied (2.35%), as well as the heterogeneous distribution in the territory, with a concentration in peripheral areas of the city. There was weak spatial autocorrelation between average per capita income ($I = 0.11$; p value <0.001) and population density by neighborhood ($I = 0.05$; p value $= 0.03$). **Conclusion:** The analysis of infection behavior in time and space can contribute to coping actions based on local needs.
Keywords: *Coronavirus Infections. Epidemiology. Public Health. Cross-Sectional Studies*

RESUMEN

Justificación y Objetivos: La pandemia por COVID-19 trajo un escenario desafiante para la salud pública a nivel mundial, debido al escaso conocimiento sobre la infección y su aumento exponencial. El objetivo es analizar la tendencia temporal y la distribución espacial de casos positivos para COVID-19 en la ciudad de Jundiai/SP, Brasil, así como su correlación con el ingreso per cápita y la densidad poblacional de los barrios. **Métodos:** Estudio transversal, realizado de febrero a junio de 2020. Se obtuvieron datos de casos confirmados por la Vigilancia Epidemiológica y por encuesta seroepidemiológica realizada en dos etapas: 1) con usuarios sintomáticos por Síndrome Respiratorio Agudo Severo que acudieron a las Unidades de Salud; 2) muestreo probabilístico de hogares. Se realizó un análisis de la serie temporal de los casos confirmados por la Vigilancia Epidemiológica y, se elaboraron mapas con densidad de kernel e índice de Moran local ($p < 0.05$) de los casos diagnosticados en la encuesta seroepidemiologica. **Resultados:** hubo un incremento en el número de casos en el período estudiado (2,35%), así como una distribución heterogénea de casos en el territorio, con concentración en áreas periféricas de la ciudad. Hubo una autocorrelación espacial débil entre el ingreso per cápita promedio ($I = 0.11$; valor de $p < 0.001$) y la densidad de población por vecindario ($I = 0.05$; valor de $p = 0.03$). **Conclusión:** El análisis del comportamiento de la infección en el tiempo y el espacio puede contribuir a acciones de afrontamiento basadas en las necesidades locales.
Palabras clave: *Infecciones por Coronavirus. Epidemiología. Salud pública. Estudios Transversales*

INTRODUCTION

Six months after the dissemination and declaration of an international public health emergency, more than 200 countries and regions had confirmed cases of COVID-19, with 20,439,814 infections and 737,417 recorded deaths[1]. In the face of this challenging context for health and for the entire world population, characterized by an infection of little-known nature, it is necessary to conduct epidemiological investigations based on monitoring mechanisms, for decision-making consistent with the urgency and complexity of the situation[2]. Accordingly, the development of temporal and spatial analysis methods as tools for evidence-informed management is of great relevance.

In Brazil, the first confirmed case was registered in the city of São Paulo and, since then, the numbers have increased exponentially, encompassing the cities of the state of São Paulo, with a trend of advancing toward less urban, more rural areas[3]. This trend of rapid spread of COVID-19 transmission toward some less urban municipalities has occurred due to a scarcity of available health services and, consequently, the increased demand for service in the main health care units in larger urban areas, which leads to rapid overcrowding in health care units in these localities, making this situation concerning[4]. Currently, according to data released by the Ministry of Health, until February 15, 2021, Brazil had 9,834,513 cases and 239,245 deaths, and the state of São Paulo had 1,913,598 confirmed notified cases and 56,266 deaths. In the state of São Paulo, the city of Jundiaí has 24,143 confirmed cases and 587 deaths[1].

The COVID-19 dissemination in Brazilian cities in 2020 occurred at three different times: the first, beginning from February to March 2020, showed a higher prevalence of infection in large capitals, favoring the spread of the virus from downtown areas to districts in the outskirts. Then, there was the process of spread within metropolitan areas, through the commute and interaction of the infected population (asymptomatic or not) between municipalities, and the travel of people to less urban remote cities of the states, characterizing the second and third moment respectively[5]. This flow of dissemination is maintained in both directions – large central urban areas and remote less urban areas – due to the greater concentration of health care services and infrastructure. Thus, the movement and circulation of people and the consequent increase in cases makes the situation concerning not only because of individual health conditions and capacity to meet the demand for health services, but also due to the presence of inequalities and vulnerabilities characteristic of each Brazilian population and municipality[6].

Recent studies show that the virus can have two main types of spread: hierarchical spread – from urban hubs with available services and infrastructure – and by contagion, from one city to others in its surroundings[7,8]. In this pandemic conjuncture, it is essential to monitor the spread of the virus and its behavior in time and space. It is important to emphasize that the dissemination of SARS-CoV-2 does not occur homogeneously, and knowing its spatial and temporal behavior enables tracing areas of greater risk, providing support for decision-making by health managers[9]. Considering these needs, this study aims to analyze the temporal trend and spatial distribution of positive cases for COVID-19 in the city of Jundiaí/SP, Brazil, and their correlation with the income and population density of the districts.

METHODS

Study design

This is an epidemiological investigation conducted in the city of Jundiaí, state of São Paulo, Brazil, from March to June 2020. Data collection for this study was carried out in three stages: 1) survey of positive cases confirmed by the Epidemiological Surveillance (ES); 2) seroepidemiological survey with users that presented with symptoms for Severe Acute Respiratory Syndrome (SARS) who sought service in Basic Health Units (UBS); 3) seroepidemiological survey in households in the city.

Jundiaí has a territory of 431,207 km^2 and an estimated population, in 2019, of 409,497 inhabitants[10], with its territory divided into 74 districts and four main health regions (Figure 1). During the pandemic, the city has three sentinel UBS, which are the main health care units for service geared toward flu-like illnesses.

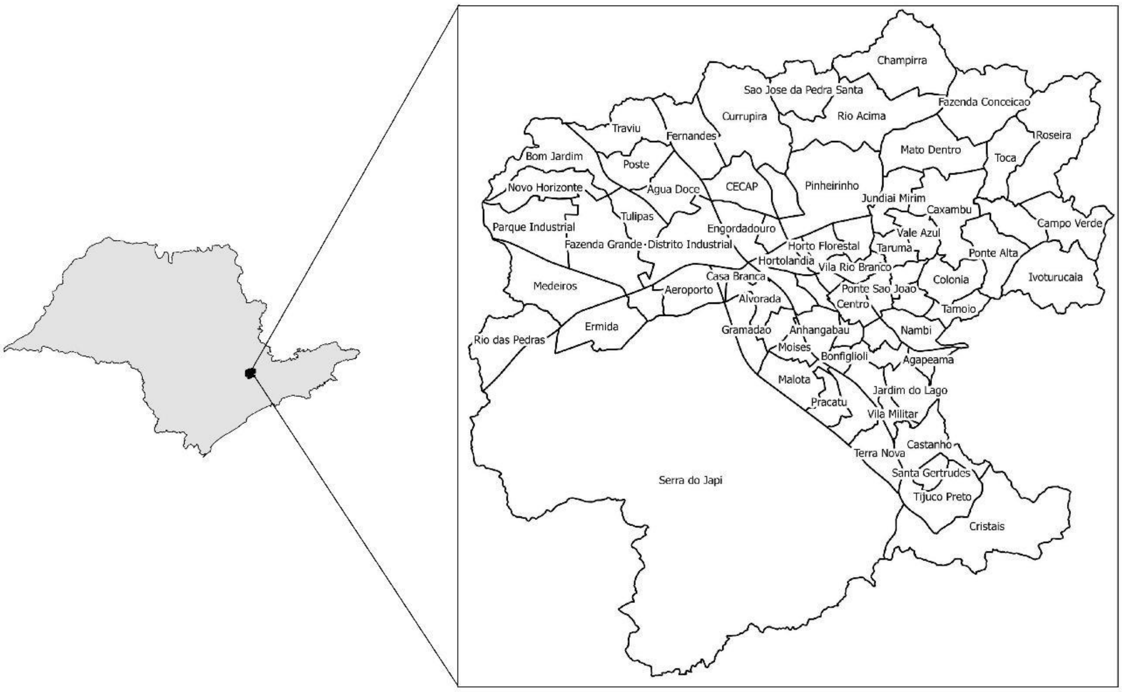

Figure 1. Location of the city of Jundiaí in the metropolitan area of São Paulo and its administrative division into 74 districts, 2020.

Study participants

For step 1, all positive cases notified and confirmed in the period from March to June 2020 were obtained from the municipal ES. At this step, notified cases (regardless of age group) were considered and only the number of cases per day was obtained – according to the onset of first symptoms –, with no other information referring to the notifications. For step 2, there was participation of individuals with symptoms who resided in the city and sought service at UBSs and, in step 3, of residents of selected households who agreed to participate in the seroepidemiological survey, regardless of age group.

Study variables

The variables used for analysis of the time series were: date of first symptoms; number of notified and confirmed cases per day; and moving average (two days) of the number of cases. We decided to adopt the date of first symptoms for the time series because this information is more reliable than the date the case was notified to the ES.

For spatial analysis, we adopted as variables the geographic coordinates of the household (participants in steps 2 and 3), average per capita income of the districts in 2019, and number of residents per district, updated in 2016 by the Department of Social Surveillance of the Municipality.

Sample size and selection

For step 1, sample calculation was not necessary, as it was composed of all positive cases notified in the period. The total sample consisted of 4,727 cases.

Sample calculation for step 2 considered a 10% prevalence of positive diagnoses in the tests, an alpha of 0.05, power of 95%, Odds Ratio (OR) = 3.0. In the sample of 940 participants, 20% of the sample size was added to offset any losses, reaching a total of 1,175 individuals. In this step, participants were selected randomly, through the participation of patients with symptoms who sought service at the UBS. We established a target number of individuals based on the weekly average number of quick tests, which resulted in a total of 1,181 participants.

For step 3, sample calculation considered a margin of error of 3%, prevalence of 50%, population estimated at 400,000 inhabitants and alpha of 5%, reaching a sample size of 1,067 households. We added 20% to the minimum size in order to offset any sample losses, totaling 1,333 households. Participants were selected through a probability sampling of households in two stages: in the first, considering the total number of neighborhoods, the sample size was determined with a probability proportional to the number of households. In the second stage, the main households and two substitutes were randomly selected. With the exception of seniors and individuals with risk comorbidities, the number of selected participants was, at most, five per household and, in case of a larger number, a drawing was carried out. At this stage, there was a total of 1,251 participants.

Data collection instrument

In step 1, the numbers of positive cases per day were tabulated by ES members in a Microsoft Excel® spreadsheet and periodically forwarded to the researchers. For steps 2 and 3, data were obtained from the result of the quick test (Smart Test Covid-19 Vyttra®

and AdvaGen®) of the selected individuals. The professionals responsible for applying and reading the quick tests underwent training with a total time of 16 hours.

Data collection

In step 1, data were obtained from spreadsheets with the count of positive cases according to the date of first symptoms. The count was periodically made available by the ES and the researchers did not have access to the notification forms.

In step 2, those with SARS symptoms who sought service at the UBSs had their quick test scheduled for 14 days from the first symptoms and, upon accepting to participate in the study, were included. Participants underwent quick testing and answered a questionnaire comprising aspects related to sociodemographic information, health behaviors – based on the World Health Organization Behavioral Insights for COVID-19[11] – and clinical data, such as the presence of comorbidities, signs and symptoms of flu syndrome.

For step 3, participants from previously selected households were approached by the health team. The team had a vehicle equipped to perform the quick tests and, after the initial approach and upon acceptance, the participants were referred to the vehicle to undergo quick testing and be applied the same questionnaire used in step 2 of this study. In this approach, only one resident was designated to answer the questionnaire with information from other family members. In case of a positive result, the participant was instructed to seek service at the nearest UBS, in order to follow the municipal protocol. It should be noted that all team members were properly dressed and the material used was stored under WHO recommendations.

Data analysis

The time series was initially analyzed by preparing a line graph between the number of confirmed cases notified to the ES (dependent variable) and the days of the first symptom (independent variable), in order to obtain a visual analysis of the relation and behavior of the data. In order to reduce the noise (irregularities) of the time series from the numbers of positive cases, smoothing was performed through the moving average centered on two periods (k = 2). To estimate the trend, increment rate, and confidence intervals, statistical analysis was performed according to the methodology proposed by Antunes and Cardoso[12]. We considered a significance level of 95% (p-value < 0.05) .

For spatial analysis, initially the locations of positive cases confirmed via serological testing (performed in steps 2 and 3) were georeferenced using the geographic coordinates, obtaining the distribution of cases in the territory. Based on these points, Kernel density maps were prepared using QGIS software version 2.18. To estimate the radius, we used the Kernel density estimator of QGIS , which takes into account the size of the area covered by the points. Thus, the adopted radius was 800 meters. To assess the presence of spatial autocorrelation between positive results for COVID-19, average per capita income, and population density per district, the Moran Global Index (I) was calculated and, in case of presence of clusters, the intensity of these clusters was analyzed using the Local Moran Index (LISA), considering a significance level of 5%. Both indices range from -1 to 1, in which positive values indicate direct autocorrelation and negative values indicate inverse autocorrelation. The Moran spread diagram was used to trace the areas of autocorrelation and these data were presented through the Box Map in order to trace districts with high values close to districts in the same condition (high-high cluster), districts with low values close to districts in the same condition (low-low cluster), and districts with values opposite to the values of their neighbors (high-low and low-high). Correlation analysis, spread diagrams and maps were produced in the GeoDA program, version 1.14.0.

Ethical aspects

The research was approved by the Research Ethics Committee (opinion 4,040,674) and then by the municipal Department of Health. The study was conducted in compliance with all the guidelines of Resolution 466/2012 and volunteers who agreed to participate signed the Free and Informed Consent Form.

RESULTS

At the end of data collection with the ES, the city of Jundiaí had 2,951 notified and confirmed cases of COVID-19. The time series was prepared from March 5 to June 30th, 2020, totaling 114 days.

For confirmed cases (Figure 2), visual analysis of the line shows the existence of stretches with different trends; however, based on the statistical analysis, we found a daily increment rate of 2.35% (95% CI: 1.48 to 3.23). These values indicate an increasing trend for this series. It is also observed that the city had two peaks in the occurrence of symptoms, one in May, followed by another in June/2020.

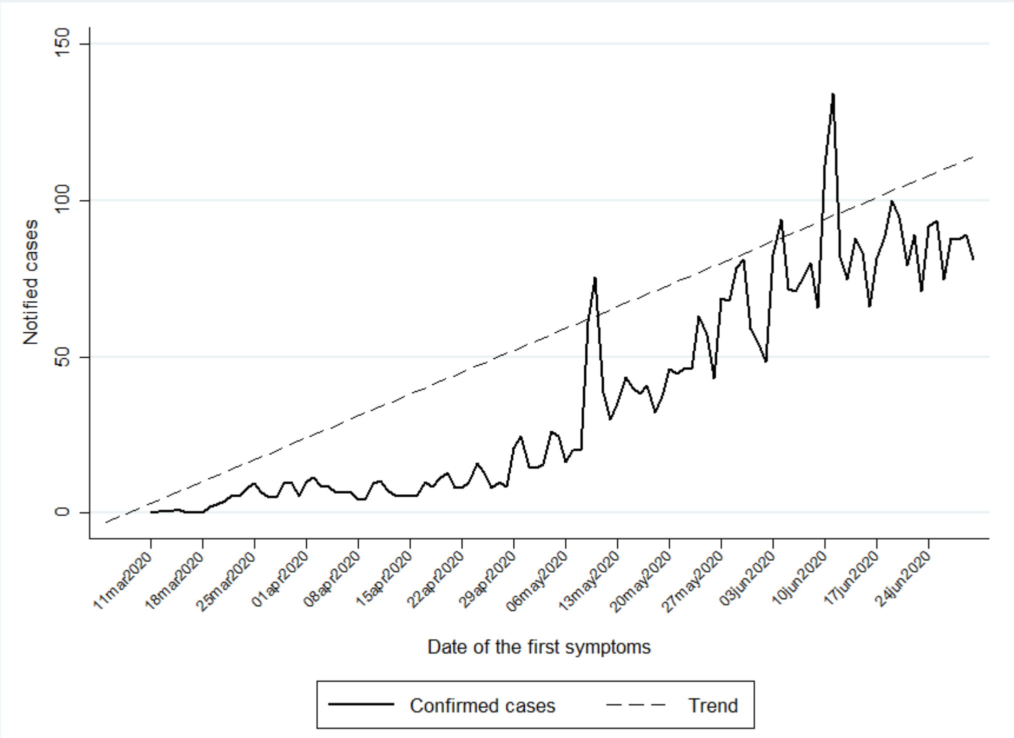

Figure 2. Time series of confirmed COVID-19 cases, according to the date of the individuals' first symptoms. Jundiaí/SP, 2020.

Data from steps 2 and 3 were obtained from June 1–19, totaling 16 days of collection. During this period, the questionnaire was applied to 1,181 participants who sought service at the UBSs (step 2) and in 1,260 households, with a total of 3,065 people tested (step 3). The total number of positive cases found in this sample was 364 individuals in the UBSs (incidence rate of 30.81%) and 66 in the households (incidence rate of 2.15%). During the investigation in households, the response rate was 94.52%, with a 5.47% loss related to refusal to take the test.

The spatial distribution of the total number of positive cases traced by the seroepidemiological survey showed that, although the city had cases throughout its territory, the districts of Fazenda Grande, Jardim do Lago, Bonfiglioli, Cecap, Novo

Horizonte and Maringá had high Kernel density, that is, areas in red showed higher concentration of COVID-19 cases within the established radius (Figure 3).

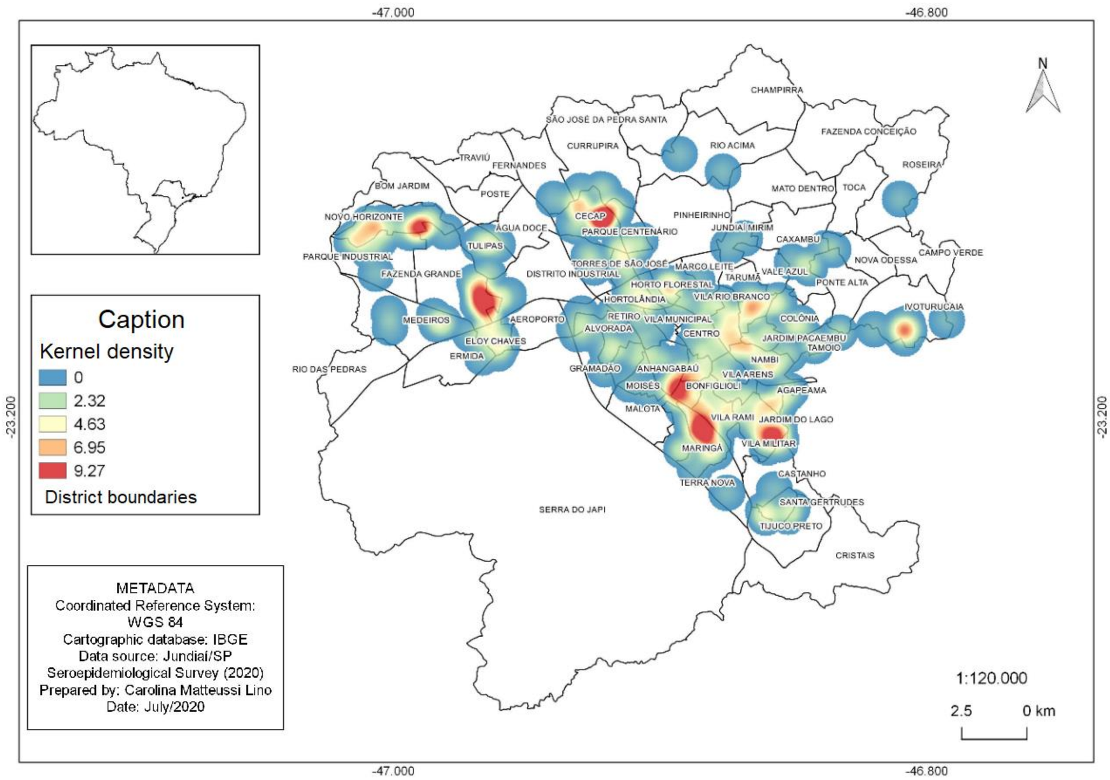

Figure 3. Kernel density to trace the concentration of positive cases for COVID-19 in the city of Jundiaí/SP, Brazil, 2020.

Spatial analysis using the Moran Global Index showed statistical significance for spatial autocorrelation (albeit weak) between positive cases of COVID-19 diagnosed in this study and average per capita income by district (I = 0.11; p-value < 0.001), and for the number of residents (I = 0.05; p-value = 0.03). Through the LISA method (Table 1), we observed local autocorrelation and presence of local clusters both correlated variables.

Table 1. Results of local autocorrelation (LISA) and presence of local clusters according to district, population, and average per capita income in the city of Jundiaí/SP, Brazil, 2020.

District	Cases	Population	Average Income	per capita income LISA		Residents LISA	
				Index	p-value	Index	p-value
Aeroporto	0	407	R$ 1,568.59	-0.0952131	0.009	-0.09386	0.293
Agapeama	9	8,066	R$ 1,449.63	-0.0427473	0.236	0.15574	0.031
Água Doce	1	3,065	R$ 1,166.72	0.18623294	0.033	-0.06707	0.201
Alvorada	12	18,182	R$ 1,784.55	-0.0374902	0.001	0.372994	0.058
Anhangabaú	13	9,347	R$ 3,159.74	0.36475632	0.001	0.203171	0.018
Bom Jardim	0	655	R$ 994.04	0.42292673	0.009	-0.10123	0.36
Bonfiglioli	10	6,706	R$ 2,976.05	0.27459265	0.004	0.098247	0.006
Campo Verde	0	168	R$ 2,115.77	-0.0616348	0.139	0.192721	0.25
Casa Branca	0	488	R$ 1,177.83	-0.3062228	0.001	-0.12322	0.2
Castanho	0	680	R$ 1,394.28	0.07261865	0.19	-0.3258	0.063
Caxambu	6	4,824	R$ 1,819.10	0.00217926	0.376	0.003715	0.255
Cecap	28	14,063	R$ 1,597.19	-0.0236102	0.276	-0.21731	0.266
Centro	8	9,865	R$ 3,254.02	0.36569461	0.002	0.23051	0.01
Chácara Urbana	0	3,472	R$ 4,370.60	0.6261385	0.001	-0.09676	0.003
Champirra	0	2,482	R$ 989.07	0.55690558	0.008	0.350321	0.016
Colônia	9	7,589	R$ 1,641.49	-0.0410045	0.061	0.116287	0.062
Cristais	0	567	R$ 1,301.19	0.26084407	0.084	0.375885	0.2
Currupira	1	4,359	R$ 1,293.93	0.12469498	0.127	0.031643	0.164
Distrito Industrial	1	665	R$ 1,156.43	-0.1424235	0.066	-0.03138	0.451
Eloy Chaves	7	11,561	R$ 2,440.80	0.08979843	0.162	-0.0236	0.482
Engordadouro	6	5,029	R$ 3,349.31	0.30597987	0.031	0.000447	0.294
Ermida	3	1,712	R$ 2,932.76	-0.0893034	0.416	0.102363	0.313
Fazenda Conceição	0	556	R$ 00.00	0.67178464	0.065	0.47236	0.043
Fazenda Grande	55	12,509	R$ 1,017.10	0.12690715	0.177	-0.22153	0.29
Fernandes	0	1,552	R$ 1,355.48	0.14818613	0.054	0.054736	0.378
Gramadão	2	391	R$ 3,529.36	0.81735211	0.001	-0.13128	0.185
Horto Florestal	9	4,176	R$ 1,574.81	-0.0976126	0.001	-0.02446	0.101
Hortolândia	16	9,904	R$ 1,314.42	-0.2063865	0.001	0.139419	0.094
Ivoturucaia	13	5,970	R$ 1,403.26	0.04724409	0.358	0.019491	0.338
Jardim Botânico	0	312	R$ 1,217.42	-0.2319405	0.001	-0.15855	0.089
Jardim Do Lago	26	19,750	R$ 1,367.99	-0.089392	0.098	0.822598	0.008
Jardim Pacaembu	4	8,556	R$ 1,781.02	-0.0229016	0.006	0.209286	0.002
Jundiaí Mirim	2	7,103	R$ 1,012.34	-0.0579597	0.309	0.002676	0.48
Malota	2	909	R$ 5,828.52	0.70511781	0.023	-0.1893	0.059
Marco Leite	3	176	R$ 6,537.38	0.79246492	0.01	-0.20922	0.057
Maringá	39	16,230	R$ 1,774.15	-0.0358206	0.014	0.75682	0.005
Mato Dentro	1	1,143	R$ 1,351.36	0.09565584	0.106	0.259688	0.039
Medeiros	9	6,649	R$ 1,996.91	-0.0248556	0.176	0.01049	0.436
Moisés	0	614	R$ 00.00	-0.6769226	0.001	-0.22353	0.032
Nambi	11	9,039	R$ 1,341.71	-0.1403495	0.005	0.153433	0.04
Nova Odessa	0	1,091	R$ 1,155.17	0.19067411	0.053	-0.02934	0.461

(continuation)

Novo Horizonte	11	14,137	R$ 829.70	0.50463802	0.013	-0.23898	0.386

Parque Centenário	5	3,107	R$ 2,403.15	0.08165061	0.087	-0.0034	0.487
Parque Industrial	0	0	R$ 00.00	0.19900823	0.313	-0.15798	0.305
Pinheirinho	0	770	R$ 1,170.24	-0.1148145	0.137	-0.08572	0.281
Ponte Alta	0	1,340	R$ 1,577.96	-0.0020764	0.471	-0.10309	0.259
Ponte São João	20	8,134	R$ 2,267.37	0.09796486	0.003	0.137895	0.021
Poste	0	1,277	R$ 1,124.91	0.2030126	0.059	-0.07166	0.341
Pracatú	0	97	R$ 2,047.70	0.05608405	0.008	-0.36455	0.015
Retiro	3	7,694	R$ 4,439.21	0.79668686	0.001	0.106317	0.053
Rio Acima	2	954	R$ 1,429.53	0.04517803	0.276	0.291107	0.044
Rio Das Pedras	0	928	R$ 3,516.52	-0.2176937	0.383	-0.25253	0.255
Roseira	1	1,668	R$ 1,154.47	0.22902384	0.126	0.507031	0.007
Samambaia	4	3,020	R$ 4,913.03	0.86293804	0.001	-0.11026	0.015
Santa Gertrudes	6	8,745	R$ 1,078.28	0.2202959	0.088	0.165609	0.191
São Camilo	12	13,774	R$ 847.43	-0.1738932	0.04	0.508851	0.004
São José Da Pedra Santa	0	785	R$ 00.00	0.59243549	0.076	0.185822	0.261
Serra Do Japi	0	2,759	R$ 1,832.34	-0.1237751	0.011	0.383162	0.252
Tamoio	4	12,557	R$ 1,326.79	-0.0960242	0.089	0.44723	0.01
Tarumã	1	4,279	R$ 1,135.02	-0.1601328	0.013	-0.02643	0.076
Terra Nova	1	255	R$ 1,234.74	-0.0098632	0.496	-0.25899	0.126
Tijuco Preto	0	2,205	R$ 1,068.48	0.29590523	0.05	-0.17753	0.145
Toca	0	387	R$ 1,776.86	0.03043798	0.045	0.410939	0.016
Torres De São José	6	7,591	R$ 2,137.81	0.0599799	0.014	0.047272	0.237
Traviú	0	1,879	R$ 1,782.96	0.05241237	0.003	-0.07362	0.32
Tulipas	7	8,965	R$ 1,105.43	0.13593419	0.132	0.073122	0.297
Vale Azul	0	992	R$ 3,250.45	0.18539972	0.091	-0.0909	0.21
Vianelo	10	6,673	R$ 2,399.02	0.14367045	0.001	0.091827	0.011
Vila Arens	6	5,746	R$ 2,632.92	0.19525327	0.003	0.040735	0.008
Vila Militar	0	140	R$ 00.00	-0.2867541	0.172	-0.4763	0.004
Vila Municipal	0	2,587	R$ 2,899.95	0.27317738	0.001	-0.15076	0.002
Vila Progresso	0	7,346	R$ 2,116.81	0.06708088	0.006	0.146452	0.006
Vila Rami	18	10,689	R$ 2,323.84	0.07613284	0.05	0.384544	0.002
Vila Rio Branco	6	8,064	R$ 1,811.35	-0.0204495	0.001	0.147124	0.01

For the average per capita income (Figure 4A), the districts of Anhangabaú, Bonfiglioli, Centro, Engordadouro, Gramadão, Malota, Marco Leite, Ponte São João, Retiro, Samambaia, Torres De São José, Vianelo, Vila Arens, and Vila Rami showed weak positive association (statistically significant) and neighbors with similar condition, that is, districts with a higher number of diagnosed cases and a higher per capita income. The low-low pattern can be seen in the districts of Água Doce and Novo Horizonte, implying the presence of few positive cases associated with low income, with low-income neighbors.

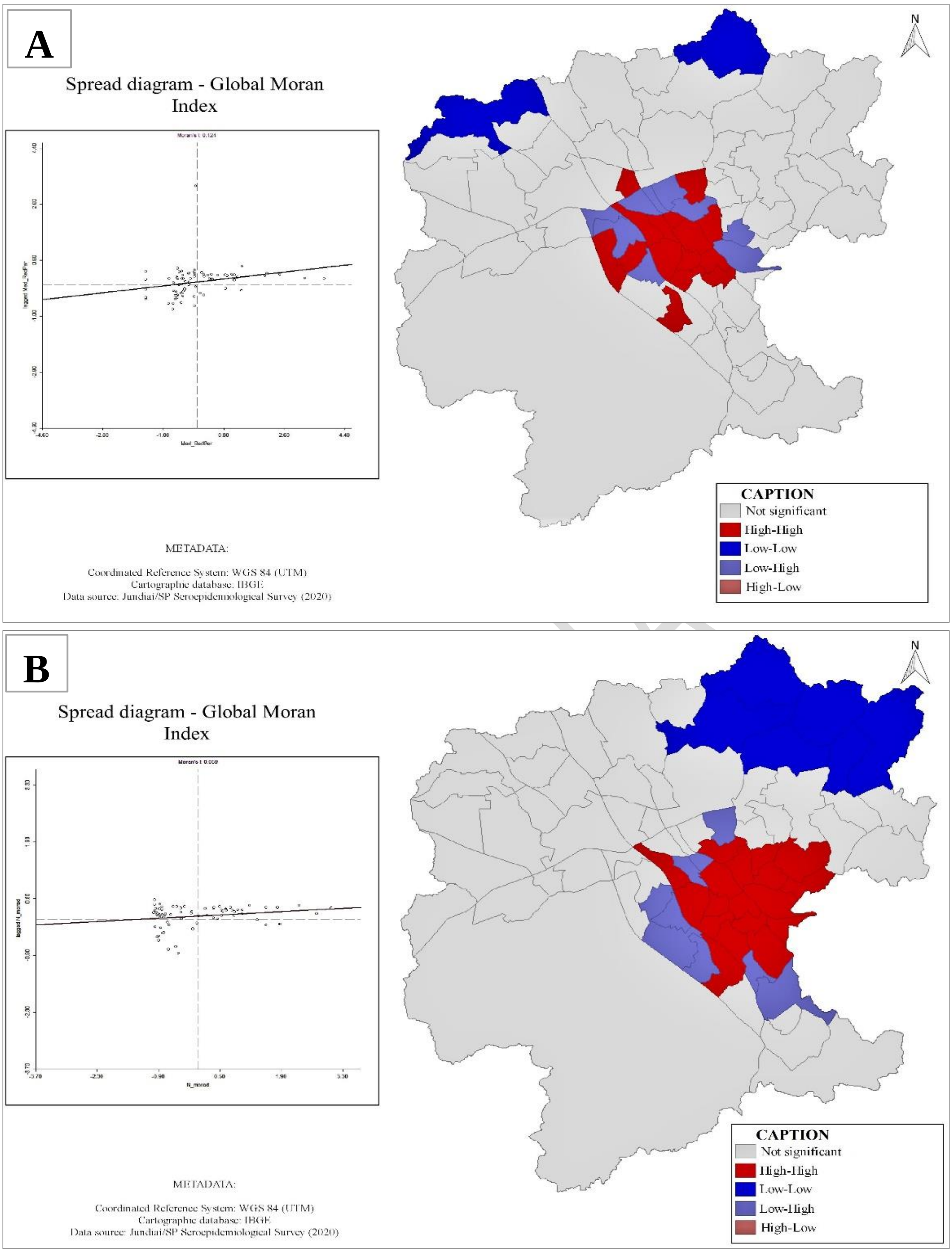

Figure 4A. Local autocorrelation (LISA) of positive cases for COVID-19 and average per capita income by district in Jundiaí/SP, Brazil, 2020. **Figure 4B.** Local autocorrelation (LISA) of positive cases for COVID-19 and number of residents by district in Jundiaí/SP, Brazil, 2020

For the number of residents (Figure 4B), the districts of Agapeama, Anhangabaú, Bonfiglioli, Centro, Jardim Do Lago, Jardim Pacaembu, Maringá, Nambi, Ponte São

João, São Camilo, Tamoio, Vianelo, Vila Arens, Vila Progresso, Vila Rami, and Vila Rio Branco showed a positive association (statistically significant) and neighbors with a similar condition, that is, districts with a higher number of cases in relation to the number of inhabitants in the district. The low-low pattern (low number of cases – from zero to two – and low population density – less than 2,500 inhabitants) can be seen in the districts of Champirra, Fazenda Conceição, Mato Dentro, Rio Acima, Roseira, and Toca.

DISCUSSION

The municipality of Jundiaí/SP showed a progressive increase in the number of positive cases for COVID-19, mainly from late April, peaking in early June. Data obtained from the seroepidemiological survey in the UBSs and households showed a heterogeneous spatial distribution of cases, with the largest number of positive cases among those who sought service in the main UBSs. There was correlation between positive cases by district – traced by seroepidemiological survey – and per capita income above two minimum wages, and by the number of residents per district, observing a spatial dependence between the variables.

The sharp increase in the number of cases detected corroborates the findings in other localities of the country, such as Rio de Janeiro and Fortaleza[9,13] and in other parts of the world, such as Italy, Germany, Turkey[14] and the United States[15,16]. After the first peak of infection, the number of daily cases in Jundiaí fluctuated; however, they remained high until June – the highest peak of infection. These data differ from those found in Rio de Janeiro and Fortaleza, which showed peaks between April and May, respectively[9,13]. This difference may be related to the fact that Jundiaí is a less urban city, located 59 kilometers from the city of São Paulo, which has high infection rates in the state of São Paulo and in Brazil.

Currently, Brazilian states undergo a process of spread of the infection to regions outside metropolitan areas, that is, the migration of cases to cities close to the capital and neighboring municipalities. This reality is not unique to Brazil, being observed in China[17] and the United States,[15] where small metropolitan areas and rural areas showed an increase in the number of cases. This migration of cases can be explained by issues related to access to health care services and population movement, as observed in the United States[15]. Despite the spread to non-metropolitan areas and the peaks of positive cases, the city of Jundiaí is expected to see a reduction in the daily increment rate or reduction in this trend, which is observable by analyzing the trend line and the reduction in increment rate found in the present study.

The infection information found through the time series reinforces the importance of measuring the behavior of COVID-19 and evaluating epidemiological data in order to understand the dynamics of the infection. According to Hallal et al.[18], statistics related to the evolution of the coronavirus are susceptible to several factors, including the lack of information on prevalence in the population. Considering the context of a new infection, whose behavior is still under investigation and with the speed of spread over time and space, studies that go beyond the issue of number of cases and address the population and social inequalities involved – such as the case of georeferencing and spatial analysis – contribute to trace vulnerabilities and possibilities for action/intervention[19].

Spatial analysis demonstrated that positive cases traced by seroepidemiological survey showed a strong concentration in peripheral regions, as evidenced by Kernel density. Although spatial autocorrelation was not positive for all locations where a concentration of cases was traced, there was autocorrelation (albeit weak) between positive cases with higher average per capita income and higher population density by district, corroborating the findings in the literature[13,15]. A study carried out in Fortaleza showed that the first confirmed cases of COVID-19 came from districts with better economic conditions; however, this pattern has changed and it reached the outskirts of the city and areas with high population density[13]. The coronavirus entered the country through people from higher classes; however, it has been spreading to areas with a higher population concentration and is directly associated with economic transformations and unequal social development[20].

Although this study found the presence of positive cases in districts with lower average per capita income, the number of diagnosed cases was positively correlated with districts with higher per capita income. This situation can be explained by the fact that the municipality adopted early containment measures, such as the distribution of masks to the population at strategic points – such as the central bus terminal –, as well as awareness-raising initiatives in districts with a higher incidence of cases and, also, through the expansion and decentralization of population testing. It should be noted that the new coronavirus has a high contagion rate and the difficulty of adherence to isolation, related to population concentration, living and working conditions, represents increased spread of the virus throughout the territory and increased risk of contagion, mainly for the most socially vulnerable regions[21].

In addition to issues involving the circulation of the virus in the territory, the difference between the concentration of positive cases in peripheral areas of the city, traced by Kernel density and spatial autocorrelation between these cases, per capita income, and number of residents by district, can be a consequence of the presence of irregular houses not yet identified by the local authorities (communities), which can impact the data referring to the number of residents and the per capita income of the districts. Moreover, the lack of information about these houses may indicate the presence of social vulnerability, and require greater attention due to the lack of sanitary conditions and the presence of clusters, consequently increasing the chances of spreading and transmitting the virus.

In addition to the socioeconomic issue, it is noted that the positive cases that constituted the spatial analysis are mostly of participants who sought service at the UBSs, that is, who presented with symptoms suggesting COVID-19. The seroepidemiological survey also traced – in the household investigation stage – positive participants who did not go to health care services, which demonstrates the importance of testing the entire population, as there may be cases with mild symptoms or no symptoms that often end up unnoticed. The presence of individuals without symptoms contributes to increase the number of cases and the difficulty in controlling the infection. For this reason, the wide-ranging testing of the population has been one of the important measures adopted to control the coronavirus, being effective in some countries such as China[22] and Italy[23].

Despite the difficulties to expand the testing of the population observed in Brazil, a Unified Health System and a comprehensive Health Surveillance System enable governments and local authorities to adopt quick measures as to identified needs[24], often through the decentralization and expansion of testing in available Primary Health Care (PHC) services. PHC is an important support in emergency situations and, based on data on its area of coverage, multidisciplinary team, relations, comprehensive care, monitoring of vulnerable families, and joint work with the ES, mild cases can be managed, which is essential to contain the infection and coordinate care with services from other levels of care, if necessary[24,25].

The findings of this study presented as a limitation the spatial analysis only of the participants in the seroepidemiological survey, since the accelerated and exponential growth of COVID-19 cases rapidly changes the epidemiological situation of the infection, preventing a complete and current spatial analysis. Regardless of this limitation, it is important to emphasize that carrying out the investigation through a probabilistic sample reduced the selection bias, enabling the study to have a population-based nature.

The methodological resource employed, based on a population-based epidemiological survey and the use of spatial analysis tools, can be used for the management and allocation of resources. Through the results presented here, the municipality received technical-scientific evidence-based support for planning and decision-making to deal with COVID-19, in order to monitor positive cases and social distancing, and for the adoption of measures, such as intensified inspection in areas of concentration of cases and reorganization of health care services.

Based on the data obtained through the seroepidemiological survey, it can be concluded that there was an increase in the number of cases in the period studied, and heterogeneous distribution of positive cases in the territory, with concentration in peripheral regions of the city. There was spatial autocorrelation between average per capita income and population density by district. These data suggest that attention should be directed to areas with higher population density, both in higher-income buildings and condominiums and in areas with sub-housing, since these can have greater clustering and, consequently, be more prone to an increase in the number of cases of COVID-19. Analyzing the behavior of the infection in time and space is relevant and contributes to the planning of actions to address the issue based on local needs.

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Marília Jesus Batista contributed to research conception and planning, data collection and organization, article design, data analysis and interpretation, article writing, and final review.

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