Original Article

Social inequalities associated with COVID-19 case fatality rate in Fortaleza, Ceará state, Brazil, 2020*

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Abstract

Objective: To analyze the association among social and health inequalities, socioeconomic status, spatial segregation and Case Fatality Rate (CFR) due to COVID-19 in Fortaleza, the state capital of Ceará, Brazil. **Methods:** This was an ecological study of confirmed cases and deaths due to COVID-19. The 119 neighborhoods of Fortaleza were used as units of analysis. Incidence, mortality and apparent CFR indicators due to COVID-19 were calculated between January 1 and June 8, 2020. Socioeconomic indicators were obtained from the 2010 Brazilian Demographic Census. Spatial analysis was performed and local and global Moran's indexes were calculated. **Results:** There were 22,830 confirmed cases, 2,333 deaths and the apparent CFR was 12.7% (95% CI 11.6;13.9). Significant spatial autocorrelations between apparent CFR (I=0.35) and extreme poverty (I=0.51), overlapping in several neighborhoods of the city, were found. **Conclusion:** The apparent CFR due to COVID-19 is associated with the worst socioeconomic and health status, which shows the relationship between social inequalities and health outcomes in times of pandemic.

Keywords: SARS-CoV-2; Socioeconomic Factors; Social Inequity; Case Fatality Rate; Mortality; Spatial analysis.

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Introduction

The first pneumonia cases of unknown origin were identified in Wuhan, Hubei Province, China, in December, 2019. The pathogen has been identified as a novel enveloped RNA betacoronavirus, that has currently been named *severe acute respiratory syndrome coronavirus 2* (SARS-CoV-2), and the disease caused by this pathogen is called *Coronavirus disease* 2019 (COVID-19).[1,2] By February 4, 2021, the disease had caused 2,260,259 deaths of the 103,989,900 confirmed cases worldwide.[3] Brazil was the world's second leading country in terms of COVID-19 deaths, 225,099, with 9,229,322 confirmed cases and 24,591 new cases.[4]

> *There are knowledge gaps regarding transmission characteristics of COVID-19 in a context of great social inequality.*

Northeastern Brazil, one of the poorest regions in the country,[5] has been severely affected by the COVID-19 pandemic. By February 4, 2021, the region accounted for 23.6% of national cases and had the second highest incidence of new cases: 526.7 per 100,000 inhabitants.[6] In Ceará, one of the nine states in the Northeast region, the first case was reported on March 15, 2020, with a COVID-19 incidence rate of 1,209.83 cases per 100,000 inhabitants. The state is second with the highest number of cumulative deaths: 94.2 per 100,000 inhabitants.[4,7]

Fortaleza, the capital of Ceará, also experienced an increase in the number of deaths, which gained speed and lasted until mid-May, with an exponential increase in the daily average (36.6 deaths). Fortaleza was one of the most affected capitals in the country, following São Paulo and Rio de Janeiro.[8]

Retrospective analyses of severe acute respiratory syndrome (SARS) cases, performed in laboratories, showed that in Ceará, there were cases of COVID-19 on January 1, 2020, shortly after the first official case had been reported by Wuhan authorities to the World Health Organization (WHO).[9,10] It can be shown that, when the first case was identified, there had already been 1,303 cases reported in Fortaleza and two thirds of municipalities in the state had already cases of COVID-19.

Brazil is one of the most unequal countries in the world in terms of concentration of wealth. These inequalities have been determinants for the way the epidemic has spread around the country, making the poorest regions, such as the North and Northeast, respectively, those with the first and second highest prevalence of COVID-19 cases in the country.

The epidemic, both in Brazil and in the world, highlights the inequalities related to gender,[11,12] socioeconomic status[13] and race or ethnicity.[14,16] In general, in the country, there are knowledge gaps regarding transmission characteristics of COVID-19 in a context of great social inequality, with the population living in precarious housing and sanitation conditions, poor access to safe drinking water and in a situation of extreme crowding.[17]

In order to understand how social inequalities influence health and risk production in the epidemic context, the objective of this study was to analyze the association among social inequalities related to health conditions, socioeconomic status, spatial segregation and apparent case fatality rate (CFR) due to COVID-19 in neighborhoods of the city of Fortaleza.

Methods

This was an ecological study, whose units of analysis were comprised of the 119 neighborhoods of the municipality of Fortaleza. The capital of the state of Ceará had an estimated population of 2,669,342 in 2020,[5] and the highest population density among all Brazilian capitals, 7,786.44 inhabitants per km^2. According to data from the 2010 Brazilian Demographic Census, regarding social inequality, the city had a Gini coefficient of 0.62 and a large proportion of the population living in precarious conditions: 26% with inadequate sanitation, and a total of 508 favelas, home to 396,370 people, corresponding to 16% of the total population of the municipality which is 4% higher than the national average.[5,18]

The study population was comprised of all positive and reported cases of COVID-19. Data of reported cases and laboratory test results were obtained from open data repositories, managed by the Government of the state of Ceará, related to reported and confirmed cases and deaths of the disease in Fortaleza, whose database was accessed on June 9, 2020 via the Integrated-health Information Platform of the Health Department of the

state of Ceará.[9] Data of reported cases between January 1 and June 8, 2020 were included, a total of 53,389 cases reported in the period, when mortality from COVID-19 in the municipality reached its first peak.[9] Social and health indicators were obtained from the 2010 Brazilian Demographic Census.

The study variables included were:

a) Individual

- Sex (female; male);
- Age group (in years: less than 1; 1 to 9; 10 to 19; 20 to 29; 30 to 39; 40 to 49; 50 to 59; 60 to 69; 70 or older);
- Neighborhood of residence (by the name of the 119 neighborhoods of Fortaleza).

These variables were used to characterize the cases and deaths analyzed.

b) Aggregated by neighborhood

1) Epidemiological indicators

- Number of cases confirmed by Reverse Transcription-Polymerase Chain Reaction (RT-PCR) and number of deaths due to COVID-19. Confirmed positive cases refer to cases that meet the case definition recommended by the WHO and the Ministry of Health: those investigated epidemiologically and laboratory-confirmed SARS-CoV-2 regardless of the case definition criteria (laboratory, epidemiological or clinical);
- Number and types of comorbidities;
- Calculation of epidemiological indicators: (i) covid-19 incidence rate was calculated from the number of confirmed cases, between January 1 and June 8, 2020, divided by the population of the neighborhoods multiplied by 10,000 inhabitants; (ii) cause-specific mortality rate due to COVID-19 was calculated by neighborhood, from the number of deaths divided by the population of the neighborhoods and multiplied by 10,000 inhabitants; and (iii) CFR due to COVID-19 was estimated by the ratio of the number of deaths by the total number of confirmed cases of COVID-19.

2) Socioeconomic status and sanitation conditions in the neighborhoods

- Home ownership; households with access to proper sewage disposal; households with septic tanks; households with 2 or more bathrooms for exclusive use; households with elderly 65 years or older as the head of family; household with elderly (≥65 years old) who does not help with household expenses and is financially dependent; households with an illiterate person over 15 years of age; households with monthly income of less than 1 minimum wage; and households headed by women;
- Median monthly family income *per capita* of households, in Reais (R$);
- Median monthly income of women over 10 years of age, in Reais (R$).

3) Demographics

- Households with elderly (≥65 years); households without water supply system; households without waste collection; households without access to electricity; households with more than 4 residents; and households in extreme poverty;
- Infant mortality rate;[5]
- Average number of residents per household;
- Human Development Index (HDI-B) by neighborhood, calculated by the Municipal Secretariat for Economic Development (SDE), Fortaleza, state of Ceará;[18]
- Population density (inhabitant/km^2).

4) Spatial segregation indicator

The socioeconomic index of the geographic context for health studies (GeoSES index), validated in Brazil, was used. The index is based on data from the 2010 Demographic Census to measure inequalities in health conditions at territorial levels, at three aggregation scales: national, Federative Unit and intra-municipal (neighborhoods). The GeoSES was developed using principal component analysis, starting with 41 variables, resulting in interval scores ranging from -1 (worst socioeconomic situation) to 1 (best socioeconomic situation). GeoSES constructs the socioeconomic status by considering seven parameters: education; poverty; wealth; income; segregation (education and income criteria); mobility; and lack of resources and services.[19]

Descriptive statistics of relative frequencies of individual variables of confirmed cases and deaths due to COVID-19 were calculated by sex, age group and comorbidities, for the period during which the study was conducted. Numerical data were expressed as mean and standard deviation (SD), and in the absence of normal distribution, as median and interquartile range (25º-75º). The normal distribution of numerical variables was evaluated using the Shapiro-Wilk test.

Count data were expressed as cases and percentages, presented with confidence intervals. The Moran index (I) was used as a measure of spatial autocorrelation in order to verify whether there is a spatially conditioned pattern by the epidemiological indicators of CFR, specific mortality and incidence of COVID-19, and socioeconomic, sanitation, sociodemographic and spatial segregation indicators. The first-order queen contiguity matrix (neighborhood) was used, at significant spatial pattern <5%. Local Indicators of Spatial Association (LISA) were also used to identify clusters in the municipality and their statistical significance, with graphical representation (LisaMap). Clusters were defined and thus presented as – high-high; low-low; high-low; low-high – scatterplots for socioeconomic, sociodemographic and spatial segregation variables that resulted statistically significant, <5%.

The organization, cleaning and descriptive analysis of data were performed using Stata software, version 16. Quantum Geographic Information System (QGIS), version 3.12.1, and GeoDa software, version 1.14.0, were used for spatial analysis.

Results

Between January 1, when the first confirmed case of COVID-19 was reported, and June 8, 2020, 22,830 confirmed cases and 2,333 deaths due to the disease were reported in the city of Fortaleza. There was a higher proportion of confirmed cases in women (54%); and deaths among men (57.4%) (Table 1).

The majority of confirmed cases of COVID-19 were among the age group 40 to 59 (35.1%), followed by 30 to 39 (21.9%) and those aged 70 years or older (15.7%).

Deaths due to COVID-19 were concentrated in the age group over 60 years of age, which represented approximately 75% of all deaths, followed by 40 to 59 years of age (19.8%). There was also a lower number of deaths under 19 years of age, representing 0.5% of the total. Among the confirmed cases, a lower proportion of people with comorbidities, such as cardiovascular disease (5.3%) and diabetes *mellitus* (4.7%) was found, compared to fatal cases, of which 34.9% had cardiovascular disease and 31.9% had diabetes. Women's and children's health status also stood out: Fortaleza recorded 25 postpartum women with COVID-19, of these, 4 died (0.2%) (Table 1).

The incidence rate of confirmed COVID-19 cases in the municipality was 66.4(95%CI 59.2;73.6) per 10,000 inhabitants (Table 2). It was more concentrated in neighborhoods in northern and eastern zones of the city, the same neighborhoods showed the worst socioeconomic status and sanitation conditions, ranging from 76 to 236 cases per 10,000 inhabitants followed by neighborhoods in the northern and southern zones, with 54 to 75 cases per 10,000 inhabitants (Figure 1A).

The city presented a specific mortality rate due to COVID-19 of 7.6(95%CI 6.8;8.5) per 10,000 inhabitants (Table 2). Among the neighborhoods that recorded higher mortality, there was a trend of concentration in those in the northern zone of the city, with rates ranging between 6.8 and 26.5 deaths per 10,000 inhabitants. It is worth pointing out the high mortality rate in the southern zone of the city, a region of high social vulnerability such as poverty, illiteracy and low income. Lower mortality rates – below 6.7 per 10,000 inhabitants. – were found in areas of the city where the population presented the highest income and most favorable sanitation conditions (Figure 1B).

CFR due to COVID-19 in Fortaleza was 12.7% (95%CI 11.6;13.9), and the average of confirmed cases per neighborhood was 125.5 (95%CI 106.9;146.1), and the average of deaths per neighborhood was 16.1 (95%CI 13.4;18.6) (Table 2). The neighborhoods with the highest CFR (Figure 1C) also had the worst living conditions, presenting (i) a high percentage of households in poverty, (≥ 39%) (Figure 2A), (ii) low monthly income, up to R$ 600 (Figure 2B), (iii) a higher proportion of households headed by women, ranging from 31.2% to 36.8% (Figure 2C), (iv) a lower proportion of people aged 65 years or older (Figure 2D) and (v) a higher proportion of illiteracy, between 5.1% and 11.7% (Figures 2E and 2F).

The GeoSES index shows that the neighborhoods with the highest CFR were also those with higher proportions of poverty and the worst education level, household income and access to health services, ranging from -1 to -0.5 (Figure 2G).

The distribution of CFR due to COVID-19 according to the LISA clusters showed the existence of high-high statistically significant neighborhood clusters in the northwest region of the city (p-value<0.001), and low-low in neighborhoods in the eastern region (p-value<0.05) (Figure 3A).

Table 1 – Absolute and relative frequencies of confirmed cases and deaths confirmed due to COVID-19, according to sex, age group and comorbidities, Fortaleza, Ceará, Brazil, January 1 - June 8, 2020

Variables	Cases (n) N=22,830	Cases (%)	Deaths (n) N=2,333	Deaths (%)
Sex				
Female	12,334	54.0	1,046	42.5
Male	10,493	45.9	1,411	57.4
Age group (years)				
<1	19	0.1	3	0.1
1-9	194	0.9	3	0.1
10-19	342	1.5	6	0.3
20-29	2,474	10.8	27	1.2
30-39	4,999	21.9	76	3.3
40-59	8,008	35.1	462	19.8
60-69	2,865	12.5	440	18.8
≥70	3,584	15.7	1,308	56.1
Not informed	345	1.5	8	0.3
Comorbidities				
Cardiovascular	1,230	5.3	815	34.9
Diabetes *mellitus*	1,089	4.7	799	31.9
Obesity	69	0.3	40	1.7
Kidney disease	161	0.7	105	4.5
Pulmonary disease	80	0.3	54	2.3
Neurological	147	0.6	117	5.2
Immunodeficiency	93	0.4	45	1.3
Postpartum	25	0.1	4	0.2
Asthma	69	0.3	39	1.7
Hematological	24	0.1	19	0.8

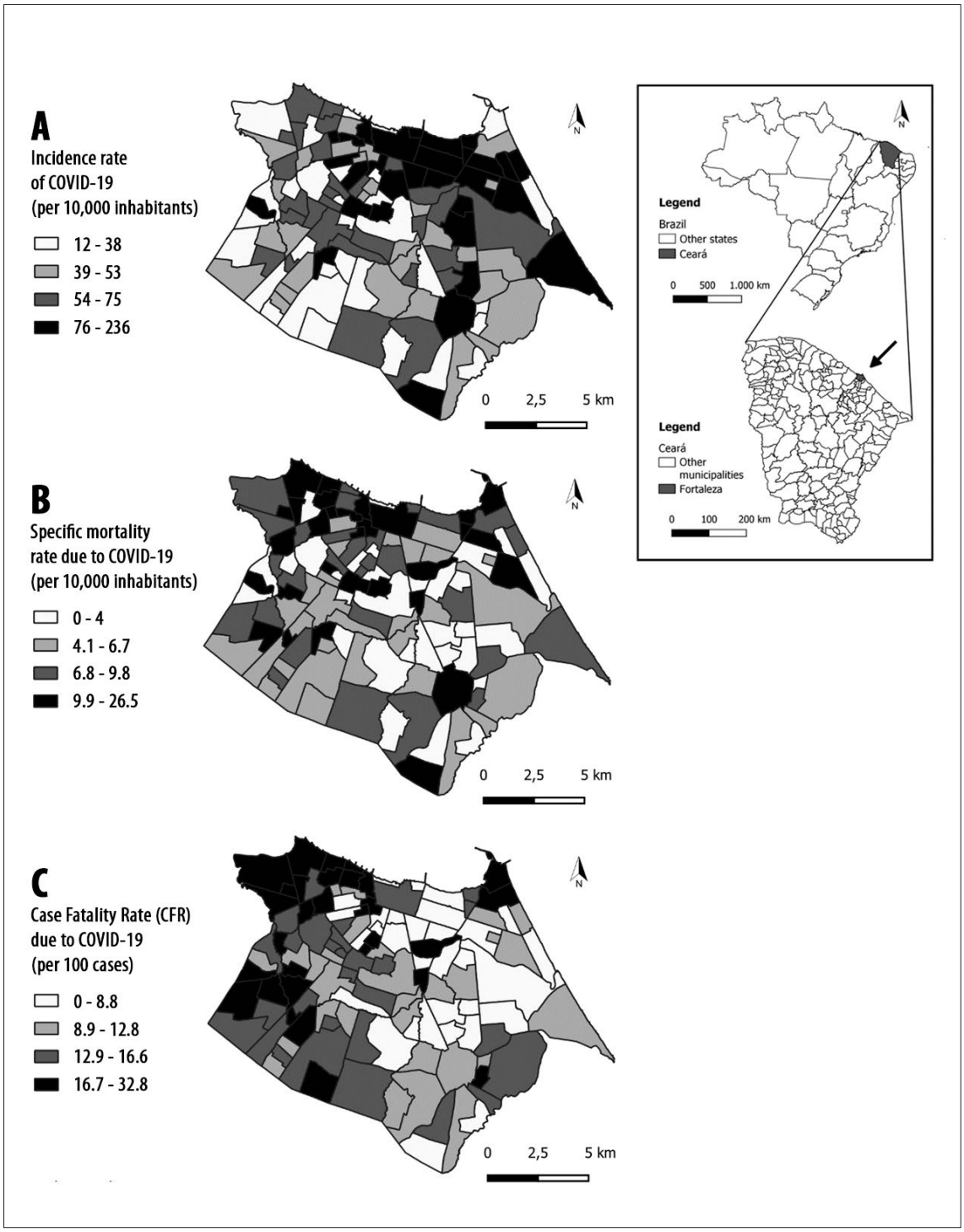
Source: Health Department of the state of Ceará, 2020.

Table 2 – Epidemiological indicators of COVID-19 in neighborhoods of Fortaleza, Ceará, Brazil, January 1 - June 8, 2020

Variables	Average	95%IC		Median	IQR	Standard deviation	p-value[a]
		LL	UL				
Incidence rate	66.4	59.2	73.6	57.5	40.3	39.6	<0.01
Mortality rate	7.6	6.8	8.5	6.7	5.9	4.4	<0.01
Apparent case fatality rate	12.7	11.6	13.9	12.5	8.1	6.1	0.550
Deaths	16,1	13,4	18,6	12,0	18,0	14,3	<0.01
Cases	125.5	106.9	146.1	109.0	18.0	14.3	<0.01

Source: Health Department of the state of Ceará, 2020.

a) Shapiro-Wilk test of normality; 95%IC: 95% confidence interval; LL: lower limit of 95%CI (average); UL: upper limit of 95%CI (average); IQR: interquartile range.



Source: Health Department of the state of Ceará, 2020.

Figure 1 – Spatial distribution of deaths, apparent Case Fatality Rate (CFR), and mortality rates due to COVID-19, Fortaleza, Ceará, Brazil, January 1 - June 8, 2020

Regarding the proportion of households in poverty, there were also clusters of high-high neighborhoods in the northwest and low-low neighborhoods in the eastern region (Figure 3B). With regard to Moran's index, CFR presented, and I value of 0.35 (Figure 3E), and 0.51 in the evaluation by households in poverty conditions (Figure 3F).

Discussion

The results show a great disparity in the distribution of deaths due to COVID-19 in the neighborhoods of Fortaleza, demonstrating that the epidemic in the city disproportionately impacts the poorest populations. The unequal characteristics of the distribution and dispersion of SARS-CoV-2 in the city of Fortaleza show an unequal structure in risk exposure, strongly associated with social exclusion and precarious living conditions.[20] It is noteworthy the fact that there is a progressive dispersion of the epidemic, from areas with higher concentration of wealth to poorer neighborhoods.[21]

Segregation by socioeconomic class and race/skin color is a strong determinant of health. Studies have shown that highly segregated African-American communities in the United States have been experiencing a disproportionate burden of mortality due to SARS-Cov-2 infection .[15,22] These findings were similar to those identified in a study conducted in Rio de Janeiro.[23]

Evidence from a population-based survey conducted in the city of Fortaleza in June 2020 found a seroprevalence of 14% and an estimated 370,000 people who developed antibodies to SARS-CoV-2.[24] However, most of the population was still susceptible to SARS-CoV-2 infection. According to the same research, among the neighborhoods most affected by COVID-19, those in the northwest region stood out – Barra do Ceará, Pirambu and Cristo Redentor – the prevalence was 20%, 3.5 fold higher than that in neighborhoods with the highest household income, showing health disparities. These results corroborate the findings of this study, which found high apparent CFR in these neighborhoods.

CFR due to COVID-19 reflects another pattern of social stratification: the highest proportion of households headed by low-income women, most of whom work in central areas of the city, in informal employment relationships, with greater exposure to the virus. This pattern could have favored the spread of the virus in the poorest neighborhoods, thus, justifying the high percentage of apparent CFR rate in low-income population – and greater poverty – living in these neighborhoods.

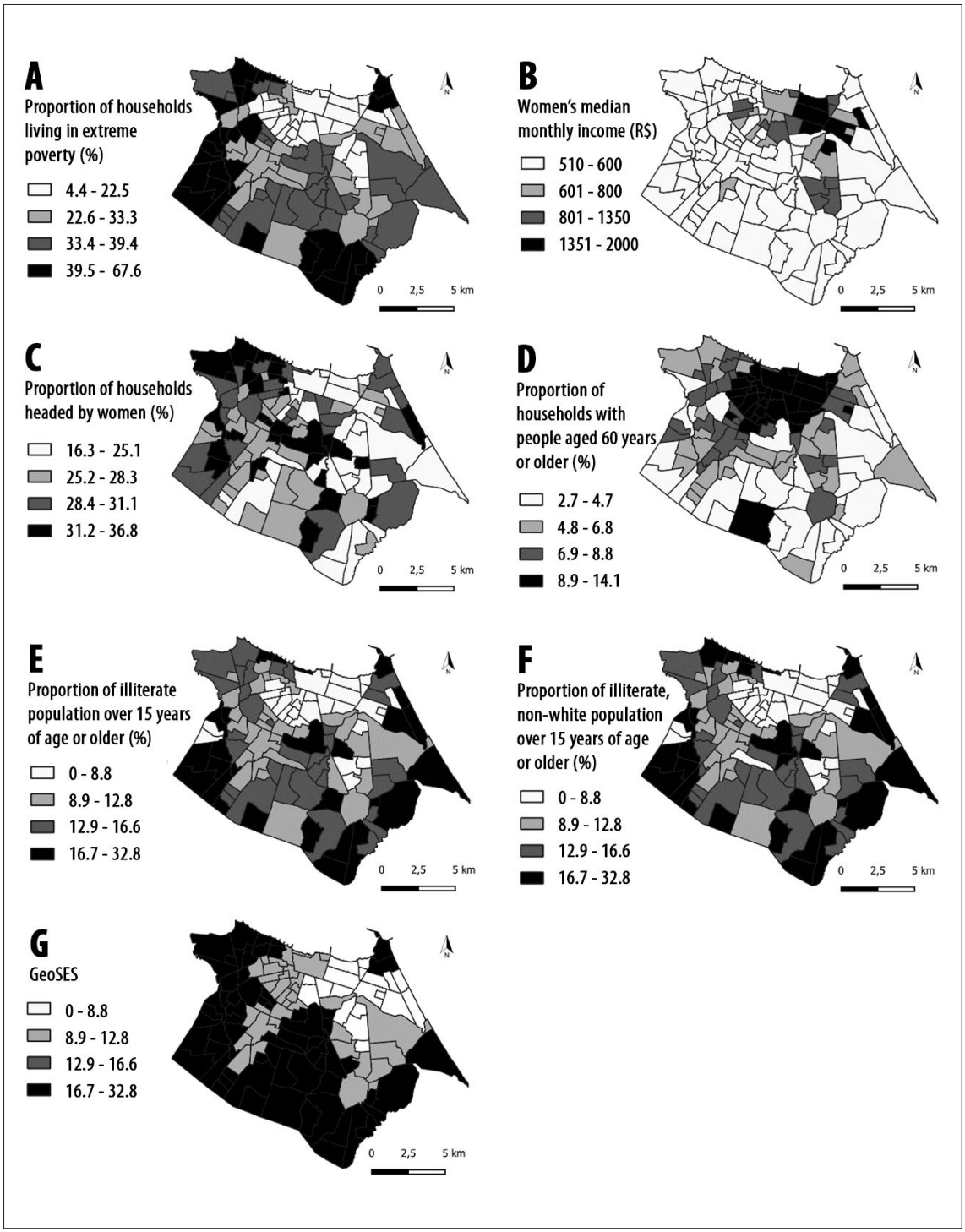
CFR due to COVID-19 also involves access to health care. In the areas with higher CFR, there is greater difficulty in accessing tertiary health care (of greater complexity), due to spatial segregation and distance to Primary Healthcare Centers (PHC).

The Brazilian case draws attention. The neoliberal political measures adopted aggravated the pandemic in Latin America.[25-27] The country's recent experience with other epidemics – such as chikungunya fever, Zika fever, dengue fever and yellow fever – demonstrated the intersection between these infections and demographic, socioeconomic and health indicators of pockets of poverty, home to a significant proportion of the population.[28]

It is worth considering, among the limitations of this study, the fact that the demographic and socioeconomic variables used were obtained from the 2010 Demographic Census, and, therefore they may not correspond to the reality of 2020. However, data with the same level of disaggregation and reliability are not available, considering the lack of an updated demographic census.

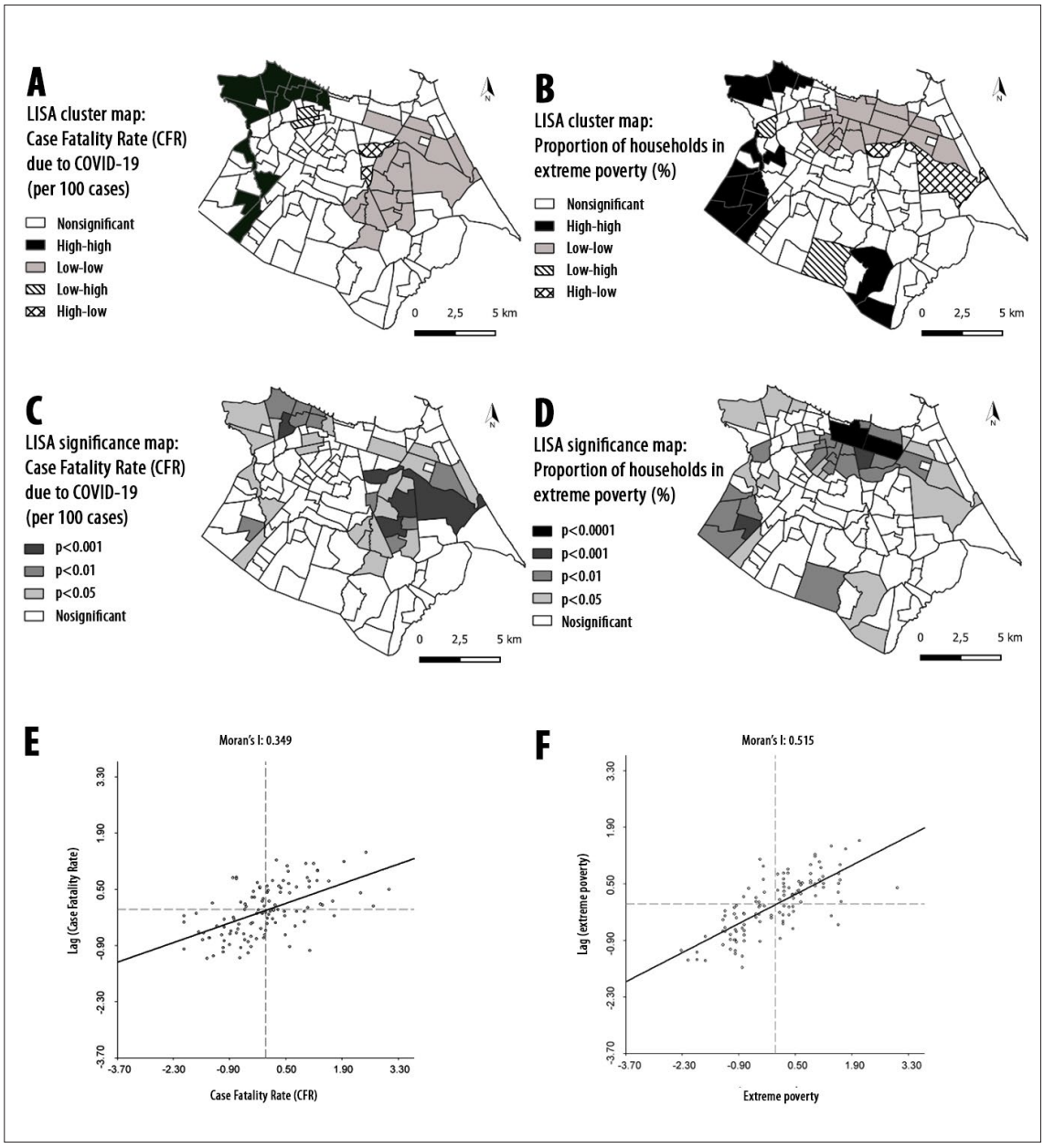
It can be seen that, neighborhoods with high CFR due to COVID-19 also present precarious socioeconomic conditions, which are reflected in a high spatial segregation of the population, associated with the worst disease outcomes. Such conditions make it difficult a successful implementation of preventive measures. The population of these areas should have accessible testing and contact tracing, quarantine and physical distancing. In the medium and long term, it is crucial to implement policies to improve the general living conditions of the population, enhanced access to health care to prevent adverse effects of emerging and reemerging infectious diseases.

This study also presents some limitations related to the calculations performed for epidemiological indicators, given a considerable number of new cases and deaths due to COVID-19 underreported in the period during which the pandemic was being evaluated, in addition to the methods used in this analysis. The delay in the release of results and limited



Source: Brazilian Institute of Geography and Statistics (IBGE), 2010 Demographic Census.

Figure 2 – Spatial distribution of socioeconomic indicators by neighborhoods of Fortaleza, Ceará, Brazil, 2010



Source: Health Department of the state of Ceará, 2020.

Figure 3 – Spatial autocorrelation between apparent Case Fatality Rate (CFR) due to COVID-19 and extreme poverty, according to neighborhoods of Fortaleza, Ceará, Brazil, January 1 - June 8, 2020

testing capacity for tracing infected individuals by health services in Fortaleza represent another bias for the emergence of different indicators in the real pandemic scenario in the city.

Authors' contribution

Sanhueza CS and Aguiar IWO collaborated with the study design, analysis and interpretation of the results, drafting and critical reviewing of the manuscript content. Kerr LRFS, Kendall C and Almeida RLF collaborated with the interpretation of the results and critical reviewing of the manuscript content. Mendes A collaborated with the drafting and critical reviewing of the manuscript. All authors have approved the final version of the manuscript and have declared themselves to be responsible for all aspects of the work, including ensuring its accuracy and integrity.

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