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Article

A decomposition analysis for socioeconomic inequalities in health status associated with the COVID-19 diagnosis and related symptoms during Brazil's first wave of infections

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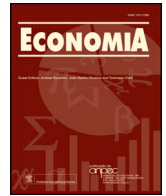
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A decomposition analysis for socioeconomic inequalities in health status associated with the COVID-19 diagnosis and related symptoms during Brazil's first wave of infections[☆]

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ABSTRACT

Recent studies have shown that COVID-19 affects different population groups asymmetrically. This work uses data from the National Survey of Households—PNAD COVID-19/IBGE—to quantify the socioeconomic inequality in health during the first wave of COVID-19 infections in Brazil. We use the concentration curve, the concentration index, and a decomposition analysis to verify the factors that most influence the inequalities in the specified health variables. We find a positive concentration index for the incidence rate, indicating a greater concentration of diagnoses (number of tests) among groups with higher income levels. When considering symptoms similar to a COVID-19 infection, inequality practically disappears. Among people with higher income, a pre-existing disease has a more significant contribution to the concentration of COVID-19 in the presence of correlated symptoms than in its diagnosis. Tests of dominance support the findings. Moreover, the decomposition results show that if the inequalities were explained only by race (non-white) and place of living (North and Northeast), there would be a concentration of COVID-19 among the poorest.

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1. Introduction

The distribution of health and disease in a society is related to its socioeconomic, cultural, and environmental conditions, which can cause health disparities (Dahlgren and Whitehead, 1991). The COVID-19 pandemic devastates many health systems and the global economy, significantly affecting ethnic minorities and lower socioeconomic status (SES) groups, as poverty and income inequality tend to increase the infection rate (Brown and Ravallion, 2020; Liao and De Maio, 2021).

A large international body of evidence that deals with the problem of health inequities and the outbreak of the SARS-CoV-2 show social inequalities in the incidence of COVID-19 by age group, gender, geographic location, and income. Such studies find that populations classified as non-white, residing in areas of low SES, less educated, and those living in poverty were associated with a more significant number of confirmed cases and deaths (Abedi et al., 2020; Cifuentes et al., 2021; Davillas and Jones, 2021; Gutiérrez, Inguanzo and Orbe, 2021; Khanijahani, 2021; Marí-dell'olmo et al., 2021; Mena et al., 2021; Nwosu and Oyenubi, 2021; Shahbazi and Khazaei, 2020).

Latin America currently has some of the world's highest mortality rates from the new coronavirus. In addition, it faces a humanitarian crisis fueled by multiple social, economic, educational, ethnic-racial, labor, and gender inequalities. Thus, lower SES is directly related to the mortality rate of the pandemic, and existing socioeconomic inequalities affect the course of the infection rate, with a disproportionate adverse burden on states and municipalities with high vulnerability (Mena et al., 2021; Rocha et al., 2021).

In this context, it is necessary to understand how disparities in health and its socioeconomic determining factors affect the ones with the double burden of a COVID-19 infection and a pre-existing noncommunicable disease (NCD) (Henry, 2020).

Unfortunately, the national literature still lacks addressing the uneven impact of the new coronavirus by a comprehensive socioeconomic analysis focusing on the effects of income inequality, over the number of COVID-19 tests realized and appearance of related symptoms, given pre-existing conditions of an NCD. Most findings determined a disproportionate impact of the pandemic on black and poor populations. These studies focused on specific indicators of poverty, income, and the prevalence of antibodies (Baqui et al., 2020; Hallal et al., 2020; Tavares and Betti, 2021) or contributed to the investigation over socioeconomic aspects, infection incidence, risk of hospitalization, and mortality rate (Demenech et al., 2020; Martins-Filho et al., 2021; Li et al., 2021).

We aim to contribute to the literature by analyzing the factors that determine socioeconomic inequality in diagnosing and related symptoms of COVID-19 during the first wave of infection in Brazil. Therefore, we use available data from the National Survey of Households—PNAD COVID-19/IBGE—for July and November 2020, considering this period, the first wave. The methodology adopted uses the concentration curve (CC) and the concentration index (CI). In addition, we use a decomposition analysis based on Wagstaff, Doorslaer, and Watanabe (2003) to identify the participation of the different elements.

The empirical results corroborate the literature that emphasizes that race, education, income-poverty ratio, and employment are the main contributing factors for socioeconomic inequalities during Brazil's first wave of COVID-19 pandemic. Concerning the regional context, residing in the Northeast and North contributes to the concentration of the diagnosis of COVID-19 in the portion of the population most vulnerable socioeconomically, as these regions present a lower average household income per capita (HIPC), a higher percentage of beneficiaries for emergency aid, and a reduced possibility of a home office. In addition, a pre-existing disease (PED) contributes to the concentration of COVID-19 (both diagnosis and correlated symptoms) among people with greater purchasing power. In this sense, the elimination of socioeconomic inequalities in these PEDs would cause a reduction in disparities for the coronavirus pandemic.

In the next section, we present the evolution of the pandemics in Brazil, followed by the methods and data description. Finally, along with the fourth session, the reader faces the research results, and the fifth section highlights the final remarks and ends this paper.

2. Evolution of the pandemic in Brazil

In March 2020, the World Health Organization (WHO) declared that COVID-19 had its first registrations in China in December 2019 (Zhu et al., 2020). In March 2020, the World Health Organization (WHO) declared a pandemic state. It recommended the suppression strategy (social distancing, massive testing, and isolation of cases) due to the exponential transmission of the disease (Li et al., 2020).

The pandemic of the new SARS-CoV-2 coronavirus starts in Brazil in a context of profound social inequality with internal and regional cultural differences and structural problems in the economy. Furthermore, the population lives in precarious housing and primary sanitation conditions with social agglomeration and without clean water.

Data from the Continuous PNAD Survey indicated that in 2019, the Gini index of per capita household income in the country was 0.543. This number increased compared to 2012, when the index reached 0.540, according to the Synthesis of Social Indicators of the IBGE (2020). Regarding the regional aspects, the Northeast Region presents the most significant inequality of income, and the South Region presents the smallest, with Gini indices of 0.559 and 0.467, respectively. Additionally, the report highlights the disparities concerning essential sanitation services, considering the population as a whole: 90.6% lived in households with direct or indirect garbage collection, 84.7% in homes with water supply by the public network, and 65.8% in households with sewage drainage. The North Region had the worst results for the three services:

- 78.7% of the population living in homes with garbage collection
- 58.3% in households with water supply by the public network
- 26.1% with the sewage collection system

In this context of socioeconomic and regional inequalities, the pandemic of the new SARS-CoV-2 coronavirus begins in Brazil. This absence of uniformities translates into a more significant risk of exposure and severity of the coronavirus outbreak, disproportionately affecting disadvantaged populations.

The first confirmed case in Latin America in February 2020 was in the state of São Paulo. Brazil monitored the pandemic by the National Health Surveillance System (NHSV) of the Unified Health System (SUS) with universal access, which performs the notification of COVID-19 cases, operating throughout the national territory in an articulated manner among states and health secretariats.

Despite the effort given, the disease that began in capitals and large urban centers gradually progressed to the states' interior. [Nicoletis et al. \(2021\)](#) noted that approximately 30% of the initial COVID-19 infections were linked to 26 federal highways. During the first weeks of the pandemic, São Paulo alone was responsible for 85% of the spreading throughout the country. Small towns are at a disadvantage in health parameters and social indicators, as in rural areas, only 39% of the population live in households with direct or indirect garbage collection. In comparison, in urban areas, it represents 99%. The water supply through the public distribution network in rural areas comprises 33.5%, while it comprises 92.9% in urban areas. Sewage collection by the network is minimal in rural areas, 9.4%, while it represents 75% in urban areas. The economic and health services' dependence on small cities created "the boomerang effect" described by [Nicoletis et al. \(2021\)](#)—namely, the flow from infected sizeable urban population to the small towns, and the bounce back from severely ill patients from interiors to larger capitals of Brazil. Although the spread pattern did not have a homogeneous distribution, it changed with the region, state, or city ([Galvan et al., 2021](#)).

According to [Noronha et al. \(2020\)](#), Brazil's health care supply is quantitatively similar to OECD countries, but it differs in its spatial segmentation and composition. First, most hospitals are concentrated in capitals, and there is an average distance to travel to the following health care facility with ICU beds, which varies from 98 km to 615 km. Therefore, private facilities are primarily responsible for the health supply composition of the country. For instance, without the private beds, the cities of São Paulo and Rio de Janeiro would present an excess of health service demands from 202% and 245%, respectively.

In the first months of 2020, the most severe evidence of COVID-19 was manifested in the age group of over 60 years old due to the expressive increase in the incidence rate of the Severe Acute Respiratory Syndrome (SRAG) ([Bastos et al., 2020](#)). In the absence of a vaccine or specific treatment, non-pharmacological measures (such as social distancing, masks, and hand hygiene) were the main available coping strategies adopted in the country ([R.M. Anderson et al., 2020](#); [G. Anderson et al., 2020](#)).

The seasonal character of the pandemic is defined as waves of infections. Although the term is not based on scientific parameters, it is related to the progressive increase or decrease in disease cases. Most studies consider the first wave of the pandemic in the country in the period from March to November 2020. There was an epidemiological peak from July to September 2020, and, subsequently, there was a decrease in the number of new cases per week. However, the number of patients returned to grow, especially from December 2020, starting the second wave ([Tang et al., 2021](#); [Pêgo et al., 2021](#); [Moraes, 2021](#)). For our paper, we define the first wave in Brazil as the period between July and November in 2020.

The national literature in the area reports the difficulty of diagnosing COVID-19 cases in the first wave, mainly due to the complexity of the country's high population density, the lack of inputs due to the increased worldwide demand for molecular tests, and the scarcity of quick tests. What contributed to the case's underreporting, number of deaths, and advance in the transmission of the disease, explaining the top positions of states in vulnerable social regions, such as North and Northeast Brazil in the ranking of lethality ([Souza et al., 2020](#); [De Oliveira and Araújo, 2020](#); [Pêgo et al., 2021](#)).

Additionally, in an analysis of the first wave, [Pêgo et al. \(2021\)](#) verified an upward evolution of the pandemic in almost all Brazilian federation units. The most critical periods vary according to the regions aggravating social disparities together with the economic crisis. In July, the highest death rates came from the states of Mato Grosso, Sergipe, and Roraima; respectively, 32.97, 31.84, and 31.70 cases by 100,000 inhabitants.

[Moraes \(2021\)](#) emphasizes that state governments initially adhered to strict social distancing measures before and during the first wave of COVID-19. However, with the reduction in the number of cases, this policy began to be relaxed using complementary prevention measures. At the end of October 2020, efforts consisted of the prohibition of events with a high number of people, the total (or partial) suspension of onsite teaching activities, and the rules for operating various types of establishments.

The literature results referring to the first wave corroborate the findings found in this study, which highlights that in July 2020, of the total tests performed, 21.17% had a positive result, while this item corresponded to 23.08% in November 2020. Among the poorest 20% of the Brazilian population, only 4.07% and 8.75% performed any test to diagnose the new coronavirus in July and November, respectively. The latter numbers highlight the inequality experienced by the low-income population, who have difficulty paying for the test and less access to health services. Thus, it is likely that there is an underreporting of cases of the disease among the poorest.

In this context, given the appearance of a new pathogen, the development of public policies requires evidence-based actions to protect the most vulnerable groups from the adverse consequences of the pandemic. Given the heterogeneity of the Brazilian population and the fragility of the world situation, this study aims to analyze the determining factors for socioeconomic inequality in the diagnosis and symptoms of the new coronavirus based on data from PNAD-COVID-19/IBGE for July and November 2020.

3. Methods and data

3.1. Inequality measures

This study uses the CC and the CI to verify socioeconomic inequality linked to COVID-19 in Brazil. For the CC construction, we plot the cumulative percentage of the measure referring to COVID-19 (*y-axis*) on a Cartesian axis versus the cumulative

percentage of the population ranked in ascending order by household living standards variable (x -axis). "In other words, it plots shares of the health variable against quantiles of the living standards variable" (Wagstaff et al., 2007).

This paper uses the derivation of the CC according to Kakwani (1977). According to the author, x represents income, and $F(x)$ is the cumulative distribution function, expressing the proportion of income for individuals with income less than or equal to x . If the mean of the distribution exists, then the ratio of total income received by individuals with income less than or equal to x also exists and is called $F_1[x]$.

Let $g(x)$ be a function of x such that the first derivative exists and $g(x) \gg 0$. If the mean $E[g(x)]$ exists, then it is possible to define (1):

$$F_1[g(x)] = \frac{1}{E[g(x)]} \int_0^x g(x)f(x)dx \tag{1}$$

where $f(x)$ is the probability density function (PDF) of x , such that $E[g(x)]$ increases monotonically, taken that $F_1[g(0)] = 0$ and $F_1[g(\infty)] = 1$. The ordinate of the curve is given by $F_1[g(x)]$, the abscissa by $F(x)$ and the ratio between them determines the CC.

CC can occupy any position on the graph. For example, suppose the curve is below the equality line, as shown in the example in Fig. 1. In that case, there is a concentration of the variable of interest in the wealthiest part of the population. On the other hand, the concentration is among the poorest when the curve is above the 45° line. Furthermore, the farther the CC is from the equality line, the greater the degree of inequality in the analyzed variable.

CC provides a visual analysis of the distribution of the variable of interest and the income distribution, which is insufficient to verify the relationship between the variables. In this sense, we perform dominance tests with the concentration curves, as presented in Wagstaff et al. (2007). The test has as a null hypothesis the non-dominance between the CC and the line of perfect equality; there are no statistically significant differences between them. When this hypothesis is rejected, social inequality in the variable of interest is statistically significant. This same test can be performed by comparing CC with the Lorenz curve of the variable that reflects socioeconomic status. In this context, we perform a dominance test that helps analyze whether the inequality verified in the health variable reflects the disparity observed in the socioeconomic status distribution (we use the per capita household income for the related measure).

We use the algorithm developed by Wagstaff et al. (2007) to implement the dominance test. From CC, we obtain CI as a measure that indicates the degree of inequality in the variable of interest. Its algebraic formalization consists of the areas above and below the equality line delimited by the CC. The CI is defined as one minus twice the area under the CC of $g(x)$.

$$CI = 1 - 2 \int_0^{\infty} F_1[g(x)]f(x)dx \tag{2}$$

This index can assume values in the $[-1, 1]$ interval. The CI will be negative when the concentration curve is above the equality line, showing that COVID-19 is concentrated among the poorest. Conversely, the values of this measure will be positive when the WC is below the 45° line, indicating a concentration of the infection among the wealthiest part of the population. If the concentration curve coincides with the diagonal, the CI will be null; the closer to the line of equality the concentration curve is, the smaller the index will be. However, as Khaled et al. (2018) highlighted, values very close to zero deserve some caution, as they may indicate that CC crosses the equality line (and not a low level of inequality).

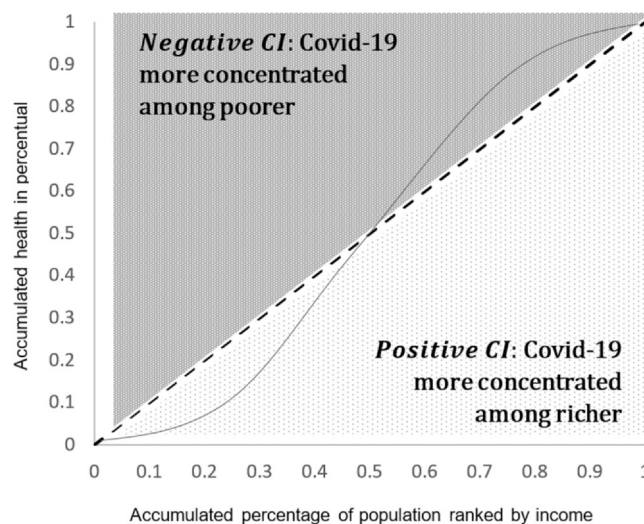


Fig. 1. Health concentration curve
Source: Adaptated from Khaled et al. (2018).

In cases where the variable of interest is a binary variable, the conventional CI assumes values in the range between $(\mu-1)$ and $(1-\mu)$, where μ is the mean of the variable of interest. In this sense, Wagstaff (2005) suggested a normalization so that the measure assumes values in the $[-1$ to $1]$ interval. As a result, the normalized index follows:

$$\bar{I}C = \frac{1}{1 - \mu} IC \quad (3)$$

3.2. Inequality decomposition

One of the objectives of our work is to provide information about the determinants of socioeconomic inequality in COVID-19 in Brazil. Thus, we break down the CI into contributions made by factors correlated with COVID-19 and with income. We implement the method of Wagstaff, Doorslaer Watanabe (2003) to investigate the extent to which inequality in a given variable affects inequality concerning the infection. We do not intend to reveal causal effects between variables but rather to generate relevant information about the simultaneously correlated factors with income and the variable of interest (Bilger et al., 2017).

We obtain the decomposition when the variable of interest is expressed as a linear function of its determining factors, as shown by the expression (4):

$$Y_i = \delta + \sum_{k=1}^K \beta_k z_{ki} + \varepsilon_i \quad (4)$$

where z_{ki} are the determinants of the dependent variable Y_i , δ and β_k , the parameters, and ε_i the econometric error. The Wagstaff et al. (2003) decomposition method is expressed as (5):

$$CI = \frac{\bar{z}_k}{\mu} \left[\sum_{k=1}^K \beta_k CI_k \right] + \frac{CG_\varepsilon}{\mu} \quad (5)$$

where μ is the mean of Y_i , \bar{z}_k is the mean of z_k , CI_k is the CI for z_k , and CG_ε is the generalized CI for the econometric error. According to Eq. (5), we decompose the CI into two parts. First, the deterministic components, given by the weighted sum of the explanatory variables' concentration indices, indicate the degree of social inequality in the determining factors. We estimate in the first part the elasticity of the dependent variable in relation to the independent variable. A positive elasticity shows a direct relationship between the measure referring to COVID-19 and the explanatory variable. Second, the residual component captures the part of the inequality not explained by the independent variables.

3.3. Database

This work uses data from the National Household Sample Survey—PNAD-COVID-19—which began to be carried out in May 2020 by the Brazilian Institute of Geography and Statistics – IBGE. The research aims to investigate health aspects, the symptoms of the new coronavirus, and the socioeconomic impacts of the pandemic in the Brazilian territory. The questionnaire includes questions about demography, health, work, income, and assistance benefits. PNAD COVID-19 relies on telephone interviews in approximately 48,000 households per week.

To measure families' standard of living, per capita household income was used, a measure widely used in the empirical literature and easy to obtain. It is worth mentioning that the results in terms of CC depend on the implemented socioeconomic status variable. Two other variables capture the standard of living families' average of living options and years of education. However, this information is not present in the PNAD COVID-19. Concerning education, the research reveals the levels of education but does not show the individuals' years of schooling.

Since the beginning of the household survey in May 2020, information has been collected on symptoms related to COVID-19 too. However, data on the performance of tests to diagnose the disease began to be made available from July 2020. Therefore, this study refers to July and November 2020, which we define as the first wave of infections.

Regarding the treatment of the database, we exclude the following:

- Pensioners, domestic workers, and relatives of domestic workers.
- Observations that had some information missing for the variables used in the analyses.
- People under 14 years of age.

The choice to consider only individuals aged 14 years or older is because this is the minimum age allowed to work in Brazil (Constitutional Amendment No. 20/1998). In addition, in constructing the variable income-poverty, the threshold of a monthly per capita household income of R\$178.00 was used. This amount is one of the criteria for registering beneficiaries in the “Bolsa Família” Program (a federal government initiative created in 2003 as a way to alleviate poverty).

For the construction of per capita household income, we add all household members' sources of income (both labor income and other income). Here, we consider both people over 14 years of age and those under this level.

To verify the factors that most contribute to inequality to the infection, the dependent variables, namely diagnosis and symptoms related to COVID-19, and independent variables, which include demographic and socioeconomic factors, are defined in [Chart 1](#).

Chart 1

Variable description.

Variable	Description
Dependent Variables	
COVID-19 Diagnosis	1, if there is a positive result in one of the tests – exam collected with a cotton swab in the mouth and/or nose (SWAB), exam of blood collection through a hole in the finger or exam of blood collection through the arm vein; 0, otherwise
COVID-19 related symptoms	1, one of the following symptoms was reported to have felt, in the week prior to the survey – fever, cough, sore throat, difficulty breathing, headache, chest pain, nausea, stuffy/runny nose, fatigue, eye pain, loss of smell/taste, muscle pain or diarrhea; 0, otherwise
Independent Variables	
Age	Age in years
Gender	1, if female; 0, otherwise
Place	1, if person lives in rural area; 0, if urban
Race	1, if white; 0, otherwise
Education*	
None	1, assigned to persons without any education, or the one who did not complete the primary education; 0, otherwise
Primary	1, assigned to persons who completed until the primary education; 0, otherwise
Secondary	1, assigned to persons who completed until the secondary education; 0, otherwise
University	1, assigned to persons who achieved a university degree; 0, otherwise
Income-poverty ratio**	Household income per capita (HIPC) divided by the poverty line of R\$ 178
Job	1, if during the week before the survey, the person worked (formally or informally) for at least 1 hour; 0, otherwise
Pre-existing disease (PED)	1, if the person previously was diagnosed with diabetes, and/or hypertension, and/or asthma/bronchitis/emphysema/ chronic respiratory and/or lung disease, and/or heart disease, and/or depression, and/or cancer; 0, otherwise
Region**	
North	1, if the person lives in the North region of Brazil; 0, otherwise
Northeast	1, if the person lives in the Northeast region of Brazil; 0, otherwise
Southeast	1, if the person lives in the Southeast region of Brazil; 0, otherwise
South	1, if the person lives in the South region of Brazil; 0, otherwise
Midwest	1, if the person lives in the Midwest region of Brazil; 0, otherwise

Source: Own elaboration. * The base category corresponds to individuals with no education and incomplete primary education.

** This variable shows the HIPC of a household relative to the HIPC of a household whose income coincides with the poverty line ([Bilger et al., 2017](#)). *** The base category corresponds to individuals residing in the South.

4. Results

4.1. Descriptive statistics

We perform all statistical and econometric results in Stata MP 16.0 software®. As shown in [Table 2](#), the total sample considered (aged 14 or over) represents 80.66% of the Brazilian population, both in November 2020 and in July of the same year, which is the first wave of infections. [Table 1](#) shows that among the people considered, 2,572,597 people had tested positive for the new coronavirus in July 2020, which represents 1.51%. Thus, the volume of diagnoses more than doubled in the period analyzed, reaching 6,067,510 people in November 2020, which indicates 3.56% of the population assessed. In turn, there was a drop in the share of individuals who reported some type of symptom related to the flu syndrome. This contingent was 12,539,790 people in July 2020 (7.37% of the population) and went to 7,016,844 in November of the year in question (4.11%). Note that data for November on the number of tests is cumulative for the whole period of the analysis, while data for November on the presence of related COVID-19 symptoms refer only to the last week before the phone call interview in November.

With low testing capacity, the country has a high percentage of positive results in the total number of tests performed compared to the incidence of the disease in the general population. In July, of the complete tests performed, 21.17% were positive, while this item corresponds to 23.08% in November 2020 ([Fig. 2](#)). All that may indicate that symptomatic people primarily search for the diagnosis of COVID-19. In addition, it is essential to emphasize that at the beginning of the pandemic, the tests were aimed at professionals who worked on the front lines in combating the new pathogen. In this context, mass testing is essential to be carried out on the Brazilian population to show the actual situation experienced in this pandemic. According to the data available, in July 2020, only about 7% of the population considered had undergone some test to diagnose the new flu syndrome, rising to 15.41% in November of the same year.

When analyzing the performance of these tests by income quintile, the difference is alarming ([Fig. 3](#)). Among the poorest 20% of the Brazilian population, only 8.75% underwent any examination to diagnose the new coronavirus until the end of the first wave of infections. This value is almost three times lower than observed among the wealthiest 20%, namely 25.62%. Unfortunately, another facet of inequality is experienced by the poor, who have less access to health services. Thus, it is likely an underreporting of cases of the disease among the poorest.

Table 1
 COVID-19 diagnosis and related symptoms during the first wave of infections in Brazil.
 Source: Own elaboration based on PNAD COVID19 Survey.

Period	COVID-19 Diagnosis	COVID-19 Symptoms	Total
July	2,572,597 (1.51%)	12,539,790 (7.37%)	170,119,985 (100%)
November	6,067,510 (3.56%)	7,016,844 (4.11%)	170,650,012 (100%)



Fig. 2. Cumulated percentage of population who performed at least one COVID-19 test and results during the first wave of infections in Brazil.
 Source: Own elaboration based on PNAD COVID19 Survey.

We consider socioeconomic and demographic factors of the Brazilian population when implementing the decomposition of inequality in COVID-19. One of these variables concerns the person's race, classified as white and non-white (black, yellow, brown, and indigenous). Regarding the non-white population, note that it is composed almost exclusively of blacks and browns, representing a total of 98.07%¹. Thus, when mention is made of non-whites, the focus will be on the black population².

Table 2 presents the descriptive statistics of the independent variables used in this study, considering the total sample and disaggregating according to people who had a positive diagnosis for COVID-19 or had symptoms related to the disease. Overall, for all subsamples analyzed, the relative participation of men and women is quite similar; the same is happening between whites and blacks, and most reside in urban areas.

As for the educational level, the relative participation of people with higher education is higher among those who tested positive for COVID-19. Similarly, the income-poverty ratio was higher among this group of individuals, which may be associated with the high price of the tests, making it difficult to diagnose the disease among the most vulnerable people. Another interesting result is the higher percentage of people with PED among those who reported some type of symptom related to COVID-19 (41.13%). Finally, it is worth noting that the South and Southeast, the two wealthiest regions in the country, represent 57.42% of the sample considered. In turn, evaluating the COVID-19 diagnosis, this participation drops to 47.95%, indicating that the new coronavirus affects more, in relative terms, less developed regions. Again, the results found are from the specialized literature (Abedi et al., 2021; Clouston et al., 2021; Baqui et al., 2020).

When analyzing aspects related to COVID-19 in Brazil, it can be of interest to consider the age distribution between the country's regions. Therefore, we present in Table 3 remarkable data related to age group and symptoms associated with COVID-19. Note that despite the higher proportion of the younger population in North and Northeast regions, correspondingly 53.44 and 47.28%, a similar distribution is not found for diagnosis and symptoms. Indeed, the proportion of symptoms related to COVID-19 is higher among young people from North and Northeast, 43.66 and 40.31%, compared to the same age group in South and Southeast regions, 33.76 and 34.73%, respectively.

4.2. Health measures by income quintile

Fig. 4 shows the distribution, by income quintile, of people diagnosed positive for COVID-19 (cumulated value for the first wave of infections) and with symptoms related to the flu-like illness (reported in November 2020, related to one week before the phone interview). The prevalence of positive tests for the new coronavirus grows with income. In turn, the share of individuals who reported some symptom is more even among the income distribution quintiles, being slightly higher among the richest.

¹ Data relate information from November 2020.

² As stated in the Racial Equality Statute (Law 12 288/2010), the black population is made up of people who declare themselves black and brown, according to the color or race item used by the IBGE, or who adopt a similar self-definition.

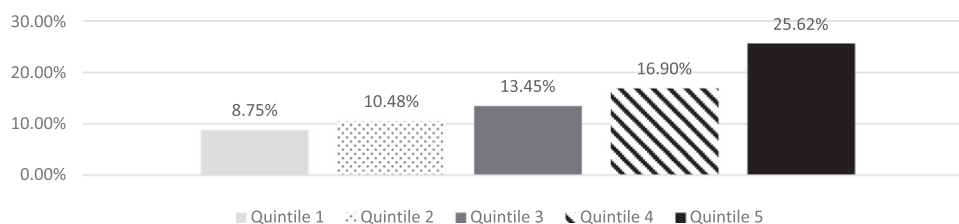


Fig. 3. Percentage of tests performed by income quintile during the first wave of infections in Brazil.

Source: Own elaboration based on PNAD COVID19 Survey.

Table 2

Descriptive statistics for independent variables.

Source: Own elaboration based on PNAD COVID19 Survey.

Variable	Total		COVID-19 Diagnosis		COVID-19 Symptoms	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
	(n = 170 650 012; 80.66%)		(n = 6 067 510; 3.56%)		(n = 7 016 844; 4.11%)	
Age	41.39	18.02	40.96	15.17	43.11	17.88
Gender						
Male	0.4840	0.4997	0.4607	0.4985	0.4168	0.4930
Female	0.5160	0.4997	0.5393	0.4985	0.5832	0.4930
Place						
Urban	0.8607	0.3463	0.9225	0.2674	0.8820	0.3226
Rural	0.1393	0.3463	0.0775	0.2674	0.1180	0.3226
Race						
White	0.4414	0.4966	0.4438	0.4968	0.4400	0.4964
Black	0.5586	0.4966	0.5562	0.4968	0.5600	0.4964
Education						
None	0.2734	0.4457	0.1613	0.3678	0.2785	0.4482
Primary	0.1961	0.3970	0.1400	0.3470	0.1812	0.3852
Secondary	0.3677	0.4822	0.4206	0.4937	0.3508	0.4772
University	0.1628	0.3692	0.2781	0.4481	0.1895	0.3919
Income-poverty ratio	13.17	18.62	19.22	27.02	14.63	21.78
Job						
Unemployed	0.5190	0.4996	0.3941	0.4887	0.5466	0.4978
Employed	0.4810	0.4996	0.6059	0.4887	0.4534	0.4978
Health						
With PRD	0.2627	0.4401	0.3003	0.4584	0.4113	0.4921
Without PED	0.7373	0.4401	0.6997	0.4584	0.5887	0.4921
Region						
North	0.0820	0.1188	0.1188	0.3235	0.0773	0.2670
Northeast	0.2668	0.4423	0.2758	0.4469	0.2668	0.4423
Southeast	0.4287	0.4949	0.3615	0.4804	0.4230	0.4940
South	0.1455	0.3526	0.1180	0.3226	0.1602	0.3668
Midwest	0.0769	0.2665	0.1258	0.3317	0.0727	0.2597

Table 3

Percentage distribution of population according to age groups by region.

Source: Own elaboration based on PNAD COVID19 Survey.

Region	14–29			30–59			60+		
	Total	Positive diagnosis	Related Symptoms	Total	Positive diagnosis	Related Symptoms	Total	Positive diagnosis	Related Symptoms
North	53.44	33.02	43.66	37.65	57.26	44.95	8.91	9.72	11.39
Northeast	47.28	30.20	40.31	39.95	58.23	43.94	12.77	11.57	15.75
Southeast	41.18	26.90	34.73	42.57	60.32	46.56	16.25	12.78	18.70
South	41.30	30.87	33.76	41.87	58.61	45.29	16.83	10.51	20.96
Midwest	45.44	32.66	35.86	42.41	56.47	48.56	12.16	10.87	15.59
Brazil	44.25	29.74	36.91	41.32	58.69	45.66	14.43	12.16	17.43

4.3. Concentration Indices

The results in [Table 8](#) highlight that the CI is statistically significant both for the diagnosis and the symptoms related to the new coronavirus in the analyzed period. Both indices indicate a pro-rich inequality; there is a higher prevalence of positive tests

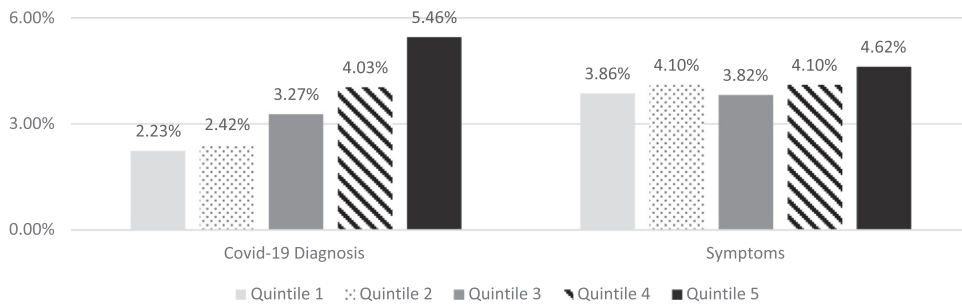


Fig. 4. COVID-19 Diagnosis and related symptoms by income quintile during the first wave of infections in Brazil. Source: Own elaboration based on PNAD COVID19 Survey.

for COVID-19 and people with some type of symptom among the groups with greater purchasing power. Such evidence corroborates the results obtained by Davillas and Jones (2021). The extent of this inequality is much more accentuated when considering the people who tested positive than when evaluating those who reported some symptom (the CI of this last variable is very close to zero, indicating that there is almost no inequality in its distribution).

The positive sign of the CI for the diagnosis of the new coronavirus is consistent with the results of Shahbazi and Khazaei (2020), which show a concentration of the incidence of COVID-19 in countries with a higher human development index (in general, these places have higher income level). According to the authors, this may be associated with better health systems in wealthier nations, with a better structure for mass testing and early detection of the disease, even in asymptomatic cases. They also highlight that in countries with a low HDI, poor access to diagnostic services means low rates of disease incidence. In the Brazilian context, the high cost of testing for COVID-19, combined with the lack of mass testing carried out by the government, contributes to the underreporting of disease cases among the poorest people.

In addition to these aspects considered, it is noteworthy that the COVID-19 cases spread more quickly in large urban centers, mainly in capitals, due to different factors. Huang and Brown (2021) show a positive association between poor air quality and COVID-19 incidence for larger cities in Germany. Furthermore, income level and income inequality play a positive role in the COVID-19 incidence, according to the evidence found at the beginning of the pandemic among USA states (Mollalo et al., 2020). In July 2020, the date considered to mark the beginning of the first wave of infections in Brazil, the incidence of flu syndrome in Brazilian capitals was 2.20%. In other areas of the country, 1.29% of the population were diagnosed. With the advance of the virus to the nation’s interior, this difference between the locations is reduced. In November 2020, there was 4.62% of people diagnosed with the new coronavirus in Brazilian capitals, while this participation rose to 3.21% in other country areas.

4.4. Concentration curves

Fig. 5 shows the CC for the diagnosis of COVID-19 and flu-related symptoms in November 2020. Again, the coronavirus incidence is concentrated in the wealthiest part of the population, as CC lies below the equality line. And, as expected, social inequality practically disappears when the symptoms of the disease are considered (CC very close to the 45° line).

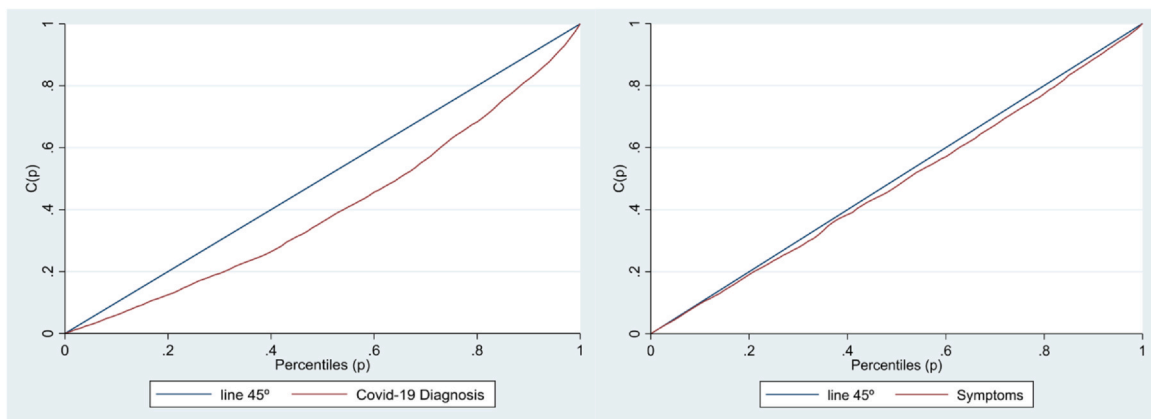


Fig. 5. COVID-19 diagnosis and related to COVID-19 symptoms concentration curves during the first wave of infections in Brazil, Source: Own elaboration based on PNAD COVID19 Survey., Source: Own elaboration based on PNAD COVID19 Survey.

Table 4

Dominance tests for COVID-19 diagnosis and related to COVID-19 symptoms concentration curves.
Source: Own elaboration based on PNAD COVID19 Survey.

Variable	Line of perfect equality	Lorenz Curve
COVID-19 diagnosis	45° line dominates*	CC dominates*
COVID-19 symptoms	45° line dominates*	CC dominates*

* 5% significance level.

As shown in [Table 4](#), the results of the dominance tests confirm that the CC of the two variables of interest is dominated (located below) by the line of perfect equality. Compared with the Lorenz curve for per capita household income, this curve is dominated by the respective concentration curves.

Thus, the inequality in the two health attributes considered has a minor extent compared to the disparity in the income distribution (given that the CC lies closer to the line of perfect equality). In other words, as the Lorenz curve is located further away from the line of perfect equality, compared to the respective CC, there is greater inequality of COVID-19 incidence and income distribution, which favors the wealthiest part of the Brazilian regions.

4.5. Decomposition of socioeconomic inequality in COVID-19

We performed a decomposition analysis to investigate the factors that contribute to socioeconomic inequality in diagnosing COVID-19 and the symptoms related to the disease. [Table 8](#) shows the CI for each explanatory variable, capturing socioeconomic disparities itself. In addition, we present the estimated coefficients, elasticity, and the absolute and relative contribution of each factor to the analyzed health variables' concentration indices.

As shown in the second column of [Table 8](#), a point that deserves emphasis is the high concentration of people living in rural areas and black people in the poorest part of the income distribution. Thus, we find evidence of racial inequality in Brazil as a negative CI, which confirms racial inequality in Brazil, disadvantaging black people ([Campante et al., 2004](#); [Chadarevian, 2011](#)). Similarly, individuals with complete primary education are concentrated in the lower part of the income distribution (CI = -0.1844). On the other hand, as expected, there is a high concentration of people with complete higher education and people employed in the labor market among the wealthiest sections of the population (the respective concentration indices were positive). Concerning social inequality between Brazilian regions, the data highlight the vulnerability of the North and Northeast. Both areas had negative CI, indicating a concentration of people residing in the lower-income distribution (poorest population). This fact is evidenced in [Rocha et al. \(2021\)](#) and [Baqui et al. \(2020\)](#).

The results in the sixth column of [Table 8](#) show that the factors that most contributed to socioeconomic inequalities with the diagnosis of the new coronavirus were level of education (completed higher education), the income-poverty ratio, and employment. Considering the symptoms related to the disease, the data in the last column of [Table 8](#) indicate that, in addition to the factors mentioned above, the person's race also plays an essential role in socioeconomic inequalities.

According to the data in the last column of [Table 8](#), race explains -39.96% of the inequality in symptoms related to COVID-19. Thus, if disparities associated with the new coronavirus symptoms were determined only by race, there would be a concentration of COVID-19 in the poorest part of the population. This evidence is in line with studies that show a greater probability of poor and black people dying victims of COVID-19 due to difficulty accessing quality health services, the more incredible difficulty in maintaining social isolation, and the higher prevalence of comorbidities ([Abedi et al., 2021](#); [Baqui et al., 2020](#); [Khanijahani, 2021](#); [Li et al., 2021](#); [Liao and De Maio, 2021](#); [Nwosu and Oyenubi, 2021](#)).

The data used in this work corroborate the greater social vulnerability among black people. [Table 5](#) shows descriptive statistics of some socioeconomic indicators for the Brazilian population disaggregated by race. As shown in [Table 5](#), the average per capita household income is much lower among blacks than whites (blacks' income is practically half that of whites). In addition, among blacks and browns, a more significant portion benefits from emergency aid (which assists people in vulnerable situations). Finally, the remote work perspective is less plausible among the black population, making social isolation difficult among this population group. These factors make black people more exposed to the coronavirus infection. However, the high prices of diagnostic tests may be causing an underreporting of the disease in this group.

Also, according to [Table 8](#), the positive contributions of education and income weighted by the poverty line indicate that inequalities with COVID-19 diagnosis and related symptoms would decrease in the absence of disparities in these variables. In turn, the employment variable affects inequality in these two variables differently. As shown in the sixth column of [Table 8](#), it

Table 5

Socioeconomic indicators by race in Brazil, November 2020.

Source: Own elaboration based on PNAD COVID19 Survey. Standard deviations in parentheses.

Race	HIPC (BRA RS)	Emergency Aid (%)	Home Office (%)
White	3 087.75 (4 139.50)	35.87 (0.4863)	82.56 (0.4804)
Black	1 756.78 (2 201.37)	52.81 (0.4951)	60.65 (0.3613)

Table 6

Home office by income quintile among employed population, November 2020.

Source: Own elaboration based on PNAD COVID19 Survey. Standard deviations in parentheses.

Income Quintile	Home Office (%)
1	12.72 (0.4090)
2	28.07 (0.4668)
3	47.79 (0.4999)
4	67.93 (0.4625)
5	89.79 (0.2783)

has a positive effect on the CI for the diagnosis of COVID-19, showing that having an occupation contributes to a slight concentration of positive tests among the wealthiest part of the population. Having a job in the labor market contributes to the individual being more able to pay for the diagnostic test.

Nevertheless, results in the last column of [Table 8](#) indicate that the person's occupation in the labor market explains -22.10% of the inequality in symptoms related to COVID-19. It means that if social disparities in the symptoms of the disease were defined only by occupation in the labor market, there would be a concentration among the poorest Brazilians. Reinforcing this result seen above, [Table 6](#) shows some descriptive statistics of home office among employed population according to income distribution quintiles. Thus, the possibility of remote work is much less in the portion of the low-income population, making it more difficult for them to maintain social distance, becoming more susceptible to being infected by the virus and developing symptoms of the disease.

Examining [Table 8](#), we infer that if the only determinants of inequality in the incidence of COVID-19 were to reside in the Northeast and the North, there would be a concentration of the disease among the poor population. [Table 7](#) below shows descriptive statistics of some socioeconomic indicators by region in Brazil. Northeast and North are more vulnerable in the sense of having a lower average per capita household income, a higher percentage of beneficiaries for emergency assistance, and a lower possibility of remote work. These factors further aggravate the situation in the North and Northeast regions in the current pandemic.

In turn, as shown in the last column of [Table 8](#), the impact of living in the North and Northeast regions for inequality in terms of symptoms related to the disease is favorable, contributing to a concentration among the wealthiest part of the population. This result may be influenced by the lower educational level observed in these regions. With less education, people do not adequately report COVID-19-related symptoms (either because of lack of knowledge or confusion with flu symptoms), so there may be underreporting among the poorest portion of the population.

Finally, the decomposition analysis results in [Table 8](#) show that the variables age, gender, and race have very discrete effects on the CI for the incidence of the new coronavirus. Concerning symptoms related to the disease, if inequalities were explained only by age and gender (female), there would be a rapid concentration of people with some symptoms in the poorest part of the population. A PED contributes to the attention of COVID-19 in the number of tests realized and the presence of correlated symptoms among people with higher income. In the absence of socioeconomic inequalities in these pre-existing diseases, there would be a reduction in disparities concerning the coronavirus. In relative matters, the impact of the PED on the inequality decomposition is significantly higher in the case of the variable related symptoms to COVID-19, 20.70%, than for the dependent variable COVID-19 diagnosis, just 1.62%. The residuals in [Table 8](#) show the unexplained sources of the inequalities.

5. Concluding remarks

This article presents evidence on socioeconomic inequality in diagnosis and symptoms related to COVID-19 using concentration indices. Additionally, we used the decomposition of the CI by Wagstaff, Doorslaer, and Watanabe (2003), which

Table 7

Socioeconomic indicators by region in Brazil, November 2020.

Source: Own elaboration based on PNAD COVID19 Survey. Standard deviations in parentheses.

Region	HIPC (BRA RS)	Emergency Aid (%)	Home Office (%)	Without Education (%)
North	1 594.35 (2 081.03)	61.35 (0.4749)	43.33 (0.4945)	29.58 (0.4569)
Northeast	1 501.55 (2 189.44)	59.79 (0.4791)	59.30 (0.4800)	35.19 (0.4775)
Southeast	2 752.39 (3 797.29)	38.71 (0.4925)	80.41 (0.3784)	22.41 (0.4171)
South	2 901.85 (3 255.88)	30.85 (0.4742)	76.57 (0.4032)	26.80 (0.4425)
Midwest	2 737.64 (3 572.24)	42.45 (0.4980)	72.98 (0.4306)	26.17 (0.4409)

Table 8

Decomposition of inequality in COVID-19 diagnosis and disease-related symptoms during the first wave of infections in Brazil.

Source: Own elaboration based on PNAD COVID19 Survey.

Variable	C _I	COVID-19 Diagnosis				Related COVID-19 Symptoms			
		Coefficient	Elasticity	Absolute	%	Coefficient	Elasticity	Absolute	%
Age	0.0505*	0.0000*	-0.0533	-0.0027	-1.32	-0.0002*	-0.1520	-0.0077	-21.53
Gender (base: male)									
Female	-0.0416*	0.0041*	0.0595	-0.0025	-1.21	0.0086*	0.1076	-0.0045	-12.54
Place (base: urban)									
Rural	-0.4049*	-0.0130*	-0.0510	0.0207	10.12	-0.0054*	-0.0184	0.0075	20.90
Gender (base: white)									
Non-white	-0.3020*	0.0009*	0.0138	-0.0042	-2.04	0.0035*	0.0472	-0.0143	-39.96
Education (base: no education)									
Primary	-0.1844*	0.0043*	0.0238	-0.0044	-2.15	-0.0014*	-0.0066	0.0012	3.39
Secondary	0.0639*	0.0162*	0.1676	0.0107	5.25	0.0003*	0.0025	0.0002	0.45
University	0.6145*	0.0273*	0.1250	0.0768	37.64	0.0058*	0.0228	0.0140	39.32
Education Total					40.74				43.15
Income-poverty ratio	0.5252*	0.0004*	0.1493	0.0784	38.43	0.0002*	0.0483	0.0254	71.09
Job	0.4422*	0.0120*	0.1620	0.0717	35.13	-0.0015*	-0.0178	-0.0079	-22.10
PED	0.0347*	0.0129*	0.0951	0.0033	1.62	0.0333*	0.2126	0.0074	20.70
Region (base: South)									
North	-0.2407*	0.0299*	0.0689	-0.0166	-8.13	-0.0035*	-0.0071	0.0017	4.76
Northeast	-0.3671*	0.0162*	0.1212	-0.0445	-21.81	-0.0026*	-0.0171	0.0063	17.62
Southeast	0.2011*	0.0000***	-0.0006	-0.0001	-0.05	-0.0058*	-0.0608	-0.0122	-34.23
Mideast	0.1380*	0.0289*	0.0624	0.0086	4.22	-0.0072*	-0.0135	-0.0019	-5.23
Region Total					-25.77				-17.08
Total observed				0.1952				0.0152	
Residuals				0.0088				0.0205	
CI (Dependent variables)^{iv}				0.2040*				0.0357*	
				(0.0056)				(0.0052)	

* Significant at 1% level.

*** Not significant. iv Standard error in parentheses.

allows the generation of relevant information on the determining factors. Understanding the nature and main generators of these inequalities during the pandemic is essential to design and implement effective policies to tackle health disparities.

The results found show accelerated growth in the incidence of the new pathogen during the analyzed period. Furthermore, inequality in the diagnosis of COVID-19 is concentrated among the richest, corroborating empirical evidence in the literature for the first wave of infections in different countries. However, this higher concentration of the disease among the richest may be influenced by the high prices of the tests, making diagnosis difficult in the poorest population. We analyze social inequalities concerning the symptoms of the flu syndrome to get around this possible bias. The results indicated a very low inequality in the two months studied, considering the value of the CI is very close to zero. We explain inequalities mainly by race and socio-economic factors (education, income weighted by the poverty line, and employment). If disparities in COVID-19 symptoms were determined only by race, there would be a concentration among the poorest population. This fact is consistent with the empirical studies that reveal the greater probability that poor and black people to die as victims of COVID-19. Regarding the regional context, living in the Northeast and the North contributes to the concentration of the COVID-19 diagnosis in the most socioeconomically vulnerable portion of the population, in which it is highly exposed to the risk of contamination by the virus, mainly due to the difficulty in maintaining the social isolation, and the drastic fall in income levels caused by the social isolation policies. A pre-existing disease contributes to the concentration of COVID-19 in the number of tests realized among people with higher income, especially in the presence of correlated symptoms.

These conclusions are essential to provide relevant information to public managers to direct resources efficiently to the most vulnerable subgroups of the population. Identifying disproportionately affected population groups can help fill disparities and guide policymakers in designing and implementing specific interventions. Efforts to contain the spread of the disease require the development and implementation of public health interventions that take into account equity and social justice.

Even with the beginning of the immunization system, we highlight the importance of testing strategies on a large scale to detect cases, the tracking of new variants, relaxation of the lockdown, and control of the virus outbreak. Additionally, the continuity of social protection measures (emergency assistance) is essential for combating and preventing future health crises and tackling structural social determinants of health. When people have the means to meet their basic vital needs, such as food and housing, they will be encouraged to practice healthy behaviors, such as physical distance, wearing masks, and hygienic practices that will reduce their vulnerability to the disease.

Some limitations of this study are noteworthy. First, there are different decomposition methodologies, so that the results may differ depending on the method used. In addition, due to the lack of mass testing, there may be an underreporting of COVID-19 cases among the poorest part of the population, harming the work results. Second, we base this work on the available information for the first wave of infections; we point out the need to extend the temporal analysis to check for robustness of

findings during the second wave of infections. Finally, the space can be an essential variable to explain much of the infection rate and related symptoms. Therefore, we suggest space statistical/econometrical models capture the strength and extension of the neighborhood impact among municipalities. Future work is essential for monitoring individuals with the post-COVID-19 syndrome and determining the infection's long-term health and social consequences.

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Competing interests statement

The authors have no competing interests to declare.

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