Socioeconomic factors associated with hospital deaths due to COVID-19 in Brazil

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ABSTRACT

The COVID-19 pandemic has raged around the world since the beginning of 2020, and it has affected the population in several ways. Many studies have shown that some individuals are more vulnerable to death from COVID-19 than others, depending on individual characteristics and the location where these individuals live. This study aims to identify the factors associated with the outcome of COVID-19 in Brazil, focusing on economic and social aspects based on the combination of municipal and individual databases. Data were extracted from IBGE and the Ministry of Tourism for municipalities and the Ministry of Health for individuals. The economic and sociodemographic variables of the municipality and the sociodemographic and clinical variables of the individuals were considered. Data analysis was performed based on the estimation of odds ratios through logistic regression. The results show that the probability of an individual hospitalized by COVID-19 dying is greater for those who live in cities with low GDP per capita, high illiteracy rate and high percentage of people in extreme poverty. In addition, individuals over 60 years of age, male, racial and illiterate minorities were more likely to die from COVID-19 compared to their counterparts. This study provides evidence that socioeconomic factors are associated with the outcome of COVID-19 in Brazil.

Keywords: COVID-19 pandemic. Socioeconomic factors. Logistic regression.
JEL Code: C01; C25; I14; I18

RESUMO

A pandemia de COVID-19 assola o mundo desde o início de 2020 e tem afetado a população de diversas formas. Muitos estudos têm apontado que alguns indivíduos são mais vulneráveis à morte por COVID-19 do que outros a depender de características individuais e da localidade em que esses indivíduos residem. Este estudo objetiva identificar os fatores associados ao desfecho do COVID-19 no Brasil, enfocando nos aspectos econômicos e sociais a partir da combinação de bases de dados municipais e individuais. Os dados foram extraídos do IBGE e do Ministério do Turismo para os municípios e do Ministério da Saúde para os indivíduos. Foram consideradas as variáveis econômicas e sociodemográficas do município e as variáveis sociodemográficas e clínicas dos indivíduos. A análise dos dados foi realizada com base na estimativa de *odds ratios* por meio de regressão logística. Os resultados mostram que a probabilidade de um indivíduo hospitalizado pelo COVID-19 morrer é maior para aqueles que vivem em cidades com baixo PIB per capita, alto índice de analfabetismo e alto percentual de pessoas em extrema pobreza. Além disso, indivíduos com mais de 60 anos de idade, minorias do sexo masculino, raciais e analfabetos tinham maior probabilidade de morrer de COVID-19 em comparação com suas contrapartes. Este estudo fornece evidências de que fatores socioeconômicos estão associados ao desfecho do COVID-19 no Brasil.

Palavras-chave: Pandemia COVID-19. Fatores socioeconômicos. Regressão logística.
Área temática 8: Questões urbanas e metrópoles.

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1 INTRODUCTION

Since the beginning of the first semester of 2020, the world has been facing one of its biggest recent challenges in terms of economic, social, and public health due to the new coronavirus (severe acute respiratory syndrome coronavirus 2 or SARS-CoV-2). The disease caused by this new virus (COVID-19) has started in December 2019 after an unknown outbreak of pneumonia in the city of Wuhan, the capital of the Chinese province of Hubei (WHO, 2020a). The advance and severity of the disease led the World Health Organization (WHO) to declare the COVID-19 as a global pandemic, on March 11, 2020 (WHO, 2020b).

From the first death by COVID-19, in January 2020, in China, to September 14, 2020, there were 29 million confirmed cases around the world, including more than 922 thousand recorded deaths worldwide (WHO, 2020c). Since its first death caused by COVID-19, on March 17, to September 14, 2020, Brazil registered more than 4.3 million confirmed cases, including more than 131 thousand deaths (MH, 2020a). According to the Brazilian Ministry of Health (MH), the most populous state in the country, São Paulo, is the one that registered the highest number of cases (892,257) and deaths (32,606), in absolute terms. However, in terms of deaths per million inhabitants, the states with the highest death rates from March 17 to September 14 were Amapá (100.7) and Rio de Janeiro (98.4), respectively. These data suggest that there are elements in addition to the size of the population that impact deaths by COVID-19.

In order to reduce the number of cases and deaths caused by COVID-19, many countries have implemented a set of measures to inhibit the transmission of the new coronavirus, among them social distancing (COHEN; KUPFERSCHMIDT, 2020). In Brazil, the actions are being taken in a decentralized way by state and municipal governments, so that at the end of March 2020, to a greater or lesser extent, all Brazilian states had introduced some measures of social distancing (MORAES; SILVA; TOSCANO, 2020). These measures have contributed significantly to many localities by reducing the transmission of COVID-19, but the magnitude of this reduction and, consequently, the outcome of the disease varies greatly from one locality to another (STOJKOSKI et al., 2020). This indicates that there may be a number of factors related to the outcome of COVID-19, such as economic, social, and demographic factors, in addition to the characteristics inherent to the individual itself.

Although recent, the literature on COVID-19 has sought to identify which factors may contribute more significantly to worsening the disease. Some studies for the United States of America -USA (ABEDI et al., 2020; ALSAN et al., 2020), have found that Afro-descendants

are more likely to contract the new coronavirus when compared to white individuals. These studies also show that male individuals are more likely to be affected by COVID-19 than female individuals. These results are supported by a study developed for patients hospitalized with COVID-19 in China (HOU et al., 2020).

The WHO considers that older individuals (people over 60 years of age) and individuals who have comorbidities (such as cardiovascular disease, diabetes, chronic respiratory diseases, and cancer) are more susceptible to the worsening of the disease (WHO, 2020a). Research carried out on COVID- 19 have shown that of the individuals who were hospitalized with the disease, those with comorbidities, the older ones, and those who are male are the ones who present the greatest complications of the disease when compared to their counterparts (GARG et al., 2020; HOU et al., 2020; HUANG. et al., 2020; LI et al., 2020; LIU et al., 2020; WU et al., 2020).

Few studies on the economic and social factors associated with deaths by COVID-19 have been developed. However, these two factors have the potential to impact the dynamics of an infectious disease (SUK; SEMENZA, 2011), as is the case with COVID-19, and, therefore, must be analyzed. Some studies have sought to identify the association between these factors and deaths by COVID-19 (ABEDI et al., 2020; ALSAN et al., 2020; QIU; CHEN; SHI, 2020; YOU; WU; GUO, 2020). In Brazil, there is evidence that economic inequalities have a positive relationship with the incidence and deaths by COVID-19 (DEMENECH et al., 2020). The Gini coefficient, which measures the income concentration of a population, is positively correlated with the increase of cases and death rates from the new coronavirus in Brazilian states (DEMENECH et al., 2020). Therefore, it is necessary to consider the social and economic aspects of the analysis of deaths by COVID-19.

Given this context, this paper aims to identify the factors associated with the death by COVID-19 in Brazil, with a focus on economic and social aspects, considering the first six months of the pandemic in the country. By doing this analysis, this research brings two important contributions. The first of them is to relate the literature of economics and epidemiology in a single study, showing that these two areas can relate and bring important contributions to analyze the situation of COVID-19 in Brazil. The second contribution is that this study is the first one, until the time of its writing, to take into account in its analysis the association not only of clinical factors but also of socioeconomic factors associated with the outcome of COVID-19. It is important to point out that, with respect to the analysis of the clinical factors associated with the outcome of COVID-19, there is a study for the state of Espírito Santo (MACIEL et al., 2020). There is also a study that relates economic inequality

with the incidence and mortality rates due to COVID- 19 in Brazilian states but does not consider clinical factors in their analysis (DEMENECH et al., 2020). This study differs from these two, as it considers, in addition to clinical factors, socioeconomic factors in its analysis, through a combination of databases at the municipality level and at the individual level.

In general, this paper, by including variables from the municipalities, introduces a component related to the environment in which the individual infected by COVID-19 lives, in order to identify how the characteristics inherent to that environment contribute to the outcome of the disease. This makes understanding and analyzing the progress of COVID-19 becomes more robust. In addition to this introduction, this paper presents three more sections. Section 2 presents the method used in this study and describes the database. Section 3 presents the results. Section 4 presents the discussions. Finally, the references used in this study is presented.

2 METHOD AND DATABASE

This study was carried out using a combination of databases at the municipality and individual level. All municipal variables consider the most up-to-date data possible and are separated into two blocks. The first block incorporates two economic variables: the *ln* of the municipal GDP *per capita* in the year 2017 (the variable was logarithmized to avoid possible biases in the estimates due to the presence of outliers and a high standard deviation), which was extracted from the *Instituto Brasileiro de Geografia e Estatística* - IBGE - (IBGE, 2020a), and a variable of extreme poverty, measured in terms of the percentage of the municipal population living in a situation of extreme poverty ($\leq 1\%$ and $> 1\%$), which was extracted from the 2010 Census data (ATLAS, 2020).

The second block presents the municipalities' sociodemographic characteristics. The variables ln of the population and *ln* of the population density (inhab / km2) were logarithmized for the same reasons as the variable *ln* of GDP *per capita*. The population of the municipalities comes from the last IBGE population estimate (2020b) and the area of the municipalities comes from the last IBGE territorial areas survey (2020c). The variables piped water ($\leq 90\%$ and $> 90\%$), expressed in terms of the percentage of households with running water; garbage collection ($\leq 90\%$ and $> 90\%$), expressed in terms of the percentage of households with garbage collection, and illiteracy rate were extracted from the 2010 Census (ATLAS, 2020).

Also from IBGE the following variables were collected: type of composition (metropolitan region, integrated development regions, urban agglomerations and other compositions) that indicates in which composition the municipality is inserted; border municipality (yes and no) and coastal municipality (yes and no). Finally, the last sociodemographic variable considered is the variable of tourist municipality (yes and no), which was extracted from the Brazilian Ministry of Tourism (2020).

At the individual level, the database refers to individuals hospitalized by COVID-19, from the Severe Acute Respiratory Syndrome (SARS) database, which includes COVID-19 data, made available by OPENDATASUS, on the Brazilian Ministry of Health website (MH, 2020b). The data considered for the present study covers the period from February 21 to August 31, 2020, and considers only cases of SARS classified as COVID-19.

The dependent variable is the outcome of COVID-19, a binary variable in which 0 represents other outcomes, different from death by COVID-19 (hospital discharge, death from other causes, ongoing treatment) and 1 represents death by COVID-19.

The characteristics of the individuals are divided into two sets, the sociodemographic characteristics and the clinical conditions of the individuals. The first set consists of the following variables: age group (in years: < 30, 30 - 60, and ≥60), gender (male and female), race (white, blacks, yellow, *pardos*, indigenous, unidentified, and missing), schooling (illiterate, elementary 1, elementary 2, high school, higher education, and missing), region of residence (North, Northeast, Midwest, Southeast, and South) and area of residence (urban, rural, and missing).

The set of characteristics, in addition to including the variables described in blocks 1, 2, and 3, includes the variables of the individuals' clinical conditions, which contains the following variables: main symptoms (at least one and none), risk group (yes and no), main symptoms and risk groups (yes and no), ICU admission (yes, no, and missing) and ventilatory support (invasive, non-invasive, no, and missing).

For those variables that had more than 10% of missing observations, was created a category called missing to group them in order to avoid generating biased estimates. The main symptom variable takes into account the following symptoms: fever, cough, dyspnea, respiratory distress, and oxygen saturation. The variable risk group considers whether the patient has any comorbidity, such as chronic diseases, immunodeficiency, diabetes mellitus, asthma, puerperal women, obesity, among others.

The binomial logistic regression analysis was used to estimate the values of the crude and adjusted odds ratios (OR), as well as their respective 95% confidence intervals (95% CI),

with the COVID-19 outcome as the dependent binary variable, which 0 represents other outcomes and 1 represents death by COVID-19. Considering that this paper aims to identify the factors associated with the death by COVID-19 in Brazil, with a focus on economic and social aspects, four blocks of logistic regressions were estimated. Block 1 encompasses the municipal economic variables. Block 2 covers the sociodemographic variables of the municipalities. Block 3 presents the estimates of the individuals' sociodemographic characteristics. And, finally, block 4 encompasses, besides the economic and sociodemographic characteristics of the municipality and the individuals' sociodemographic variables, the individuals' clinical characteristics.

Each one of the blocks described above has two analyzes: a univariate analysis to capture the crude odds ratio for each variable and another multivariate analysis to capture the adjusted odds ratios that are adjusted for all variables in the block. Thus, the odds ratios for block 4 are adjusted for all the predictor variables described in this section, which will allow identifying more directly the effect of the association between the death by COVID-19 and the economic and sociodemographic characteristics of the municipalities.

3 RESULTS

From February 21, 2020, to August 31, 2020, 343,071 thousand people were diagnosed and hospitalized with COVID-19, of which 115,212 (33.58%) thousand died and 227,859 (66.42%) had other outcomes (hospital discharge, death from other causes, ongoing treatment).

Table 1 presents the sample distribution as well as the proportion of deaths due to economic, sociodemographic, and health characteristics. Regarding to economics and sociodemographics aspects (the focus of this study), it is observed that the proportion of deaths is higher among individuals who live in municipalities with lower levels of GDP per capita, lower access to piped water, lower garbage collection percentage, lower illiteracy rate, as well for those individuals who live in poorer regions (North and Northeast and rural areas) and in coastal municipalities. Among the individual aspects, the death outcome is higher among older, males, and less educated individuals.

Table 1 - Association distribution between the outcome of COVID-19 and the characteristics of the municipalities and of the individuals hospitalized by COVID-19 in Brazil (to be continued)

	Sample proportion	Deaths proportion	*p-value*
Variables	N=343,071	N=115,212	
Economic characteristics of the municipalities			
***Ln* GDP *per capita* (quartiles)**			
1st Quartile	25.04%	41.86%	
2nd Quartile	26.02%	33.63%	
3rd Quartile	23.99%	33.53%	
4th Quartile	24.95%	25.28%	
Extreme poverty (%)			<0.001
≤ 1%	33.46%	26.86%	
> 1%	66.54%	36.96%	
Sociodemographic characteristics of the municipalities			
***Ln* Population density**			
1st Quartile	25.08%	33.39%	
2nd Quartile	25.31%	31.35%	
3rd Quartile	26.98%	39.62%	
4th Quartile	22.93%	29.10%	
***Ln* Population**			
1st Quartile	25.12%	32.40%	
2nd Quartile	25.15%	34.68%	
3rd Quartile	26.44%	34.79%	
4th Quartile	23.29%	32.31%	
Piped water (%)			<0.001
≤ 90%	14.75%	41.37%	
> 90%	85.25%	32.23%	
Garbage collection			<0.001
≤ 90%	5.56%	42.33%	
> 90%	94.44%	33.07%	
Illiteracy rate			<0.001
1st Quartile	31.27%	30.86%	
2nd Quartile	19.59%	32.29%	
3rd Quartile	24.52%	32.88%	
4th Quartile	24.62%	38.77%	
Type of composition			<0.001
Metropolitan region	67.76%	34.80%	
Integrated development regions	4.62%	25.35%	
Urban agglomerations	1.73%	31.41%	
Other compositions	25.89%	32.00%	
Border municipality			<0.001
Yes	4.11%	28.31%	
No	95.89%	33.81%	
Coastal municipality			<0.001
Yes	24.06%	43.67%	
No	75.94%	30.39%	
Tourist municipality			<0.001
Yes	87.34%	33.28%	
No	12.66%	35.65%	
Sociodemographic characteristics of individuals			
Age group (years)			<0.001
< 30	4.77%	8.28%	
30 - 60	43.07%	18.47%	
≥60	52.16%	48.38%	
Gender			<0.001
Male	56.16%	34.78%	
Female	43.84%	32.06%	

Table 1 - Association distribution between the outcome of COVID-19 and the characteristics of the municipalities and of the individuals hospitalized by COVID-19 in Brazil (conclusion)

Race			<0.001
White	32.66%	31.97%	
Black	4.72%	38.29%	
Yellow	1.14%	33.91%	
Pardos	33.13%	36.92%	
Indigenous	0.31%	40.32%	
Unidentified	16.97%	29.13%	
Missing	11.08%	32.94%	
Schooling			<0.001
Illiterate	2.48%	55.48%	
Elementary 1	9.06%	43.42%	
Elementary 2	6.34%	36.23%	
High school	11.45%	24.40%	
Higher education	5.44%	18.68%	
Missing	65.23%	33.98%	
Region of residence			<0.001
North	8.69%	41.93%	
Northeast	22.43%	42.42%	
Midwest	10.16%	21.19%	
Southeast	49.41%	31.86%	
South	9.31%	27.16%	
Area of residence			<0.001
Urban	84.91%	33.07%	
Rural	3.67%	37.52%	
Missing	11.43%	36.14%	
Clinical and treatment characteristics of individuals			
Main symptoms			<0.001
Yes	98.14%	33.85%	
No	1.86%	19.45%	
Risk group			<0.001
Yes	62.21%	39.75%	
No	37.79%	23.43%	
Main symptoms and risk groups			<0.001
Yes	99.15%	33.78%	
No	0.85%	10.31%	
ICU admission			<0.001
Yes	29.72%	54.28%	
No	51.22%	20.53%	
Missing	19.06%	36.38%	
Ventilatory support			<0.001
Invasive	17.17%	74.59%	
Non-invasive	39.27%	25.11%	
No	24.58%	14.61%	
Missing	18.99%	38.59%	

Source: Elaborated by the authors themselves based on study database.
Notes: The data are presented in terms of mean (standard deviation) for continuous variables and as a percentage for categorical variables.
P-value of the t-test for continuous variables (Ln GDP *per capita*, Ln Population density, and Ln Population) and p-value of Pearson's chi-square test for categorical variables.

Table 2 is displayed the crude and adjusted odds ratios between the variables in block 1 and the deaths by COVID-19. The variable ln of GDP *per capita* in both the crude and adjusted models proved to be statistically significant, with lower likely death for individuals

living in wealthier municipalities. Individuals in the most extreme poverty group (> 1%) are more likely to die.

Table 2 - Association between the economic characteristics of the municipalities and the outcome of COVID-19 in Brazil

Variables	*Odds Ratio* (Crude)	95% CI	*Odds Ratio* (Adjusted)	95% CI
Economic characteristics of the municipalities				
Ln* GDP *per capita	0.704***	(0.696 - 0.713)	0.781***	(0.772 - 0.791)
Extreme poverty (%)				
≤ 1%	1	-	1	-
> 1%	1.597***	(1.572 - 1.622)	1.391***	(1.367 - 1.415)

Source: Elaborated by the authors themselves based on study database.
Notes: All the variables included in the model were adjusted for each other.
Robust confidence interval in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Table 3 presents the crude and adjusted odds ratios between the variables in block 2 - the sociodemographic characteristics of the municipalities - and the deaths by COVID-19. All variables before and after the adjustment were statistically significant. Groups with greater piped water coverage and a higher percentage of garbage collection are less likely to die. Higher population density and higher illiteracy rates are also associated with higher chances of death. Not living in the metropolitan area is associated with lower chances of death when it compares to other areas (except for urban agglomerations in the adjusted odds ratios model). Hospitalized individuals living in non-border municipalities are more likely to die than those living in border municipalities (29% in the crude analysis and 8% in the adjusted analysis). Living in tourist municipalities is associated with lower chances of death while living in coastal counties has a positive relationship with deaths by COVID-19.

Table 3 - Association between the sociodemographic characteristics of the municipalities and the outcome of COVID-19 in Brazil (to be continued)

Variables	*Odds Ratio* (Crude)	95% CI	*Odds Ratio* (Adjusted)	95% CI
Sociodemographic characteristics of the municipalities				
***Ln* Population density**	1.017***	(1.014 - 1.020)	1.012***	(1.005 - 1.020)
***Ln* Population**	0.994***	(0.991 - 0.998)	1.009**	(1.002 - 1.015)
Piped water (%)				
≤ 90%	1	-	1	-
> 90%	0.674***	(0.661 - 0.687)	0.828***	(0.806 - 0.850)
Garbage collection				
≤ 90%	1	-	1	-
> 90%	0.673***	(0.653 - 0.693)	0.949***	(0.915 - 0.984)
Illiteracy rate	1.026***	(1.025 - 1.027)	1.030***	(1.029 - 1.032)
Type of composition				
Metropolitan region	1	-	1	-
Integrated development regions	0.636***	(0.613 - 0.660)	0.760***	(0.731 - 0.791)
Urban agglomerations	0.858***	(0.811 - 0.907)	1.066**	(1.007 - 1.128)
Other compositions	0.882***	(0.867 - 0.896)	0.816***	(0.796 - 0.837)

Table 3 - Association between the sociodemographic characteristics of the municipalities and the outcome of COVID-19 in Brazil (conclusion)

Border municipality				
Yes	1	-	1	-
No	1.293***	(1.246 - 1.343)	1.082***	(1.039 - 1.127)
Coastal municipality				
Yes	1	-	1	-
No	0.563***	(0.554 - 0.572)	0.581***	(0.571 - 0.592)
Tourist municipality				
Yes	1	-	1	-
No	1.110***	(1.087 - 1.134)	1.080***	(1.053 - 1.107)

Source: Elaborated by the authors themselves based on study database.
Notes: All the variables included in the model were adjusted for each other.
Robust confidence interval in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

As it can be seen in Table 4, the crude and adjusted odds ratios between the variables in block 3 - the individuals' sociodemographic characteristics - and the deaths by COVID-19, were statistically significant for all variables. Older individuals are more likely to die while being female has a negative association with this outcome. Blacks, *pardos*, and indigenous individuals are more likely to die when compared to whites. Individuals with higher education levels are less likely to die by COVID-19 when compared to illiteracy individuals. The same occurs for those people who live in rural areas in the adjusted analysis. People who live in the Center-South of Brazil have lower chances of death by COVID-19.

Table 4 - Association between the sociodemographic characteristics of individuals and the outcome of COVID-19 in Brazil (to be continued)

Variables	***Odds Ratio* (Crude)**	**95% CI**	***Odds Ratio* (Adjusted)**	**95% CI**
Sociodemographic characteristics of individuals				
Age group (years)				
< 30	1	-	1	-
30 - 60	2.509***	(2.370 - 2.657)	2.414***	(2.279 - 2.556)
≥60	10.38***	(9.808 - 10.98)	9.441***	(8.918 - 9.994)
Gender				
Male	1	-	1	-
Female	0.885***	(0.872 - 0.898)	0.833***	(0.820 - 0.846)
Race				
White	1	-	1	-
Black	1.320***	(1.276 - 1.366)	1.263***	(1.217 - 1.311)
Yellow	1.092**	(1.021 - 1.168)	0.957	(0.890 - 1.030)
Pardos	1.245***	(1.224 - 1.267)	1.056***	(1.034 - 1.079)
Indigenous	1.437***	(1.272 - 1.624)	1.208***	(1.053 - 1.387)
Unidentified	0.875***	(0.856 - 0.894)	0.810***	(0.790 - 0.831)
Missing	1.045***	(1.019 - 1.071)	0.939***	(0.913 - 0.966)
Schooling				
Illiterate	1	-	1	-
Elementary 1	0.616***	(0.587 - 0.646)	0.811***	(0.770 - 0.853)
Elementary 2	0.456***	(0.433 - 0.480)	0.800***	(0.757 - 0.845)
High school	0.259***	(0.247 - 0.272)	0.612***	(0.580 - 0.644)
Higher education	0.184***	(0.174 - 0.195)	0.425***	(0.400 - 0.451)
Missing	0.413***	(0.395 - 0.432)	0.683***	(0.651 - 0.716)
Region of residence				

Table 4 - Association between the sociodemographic characteristics of individuals and the outcome of COVID-19 in Brazil (conclusion)

North	1	-	1	-
Northeast	1.020	(0.993 - 1.048)	0.963**	(0.935 - 0.993)
Midwest	0.372***	(0.360 - 0.385)	0.467***	(0.450 - 0.484)
Southeast	0.647***	(0.631 - 0.664)	0.633***	(0.615 - 0.651)
South	0.516***	(0.499 - 0.534)	0.494***	(0.475 - 0.514)
Area of residence				
Urban	1	-	1	-
Rural	1.216***	(1.172 - 1.261)	0.914***	(0.877 - 0.952)
Missing	1.146***	(1.121 - 1.171)	1.104***	(1.078 - 1.131)

Source: Elaborated by the authors themselves based on study database.
Notes: All the variables included in the model were adjusted for each other.
Robust confidence interval in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Table 5 presents the estimates of the crude and adjusted odds ratios between the deaths by COVID-19 and the variables in block 4, which includes, in addition to the economic and social variables of the municipality and the individuals' sociodemographic variables, the clinical variables of the individuals. Both in the univariate analysis and in the multivariate analysis of the clinical characteristics of individuals, having none of the main symptoms and not being at risk is negatively associated with deaths by COVID-19, while individuals who were admitted to the ICU and used invasive respiratory support had greater chances of death.

In the multivariate analysis (adjusted for all variables) presented in Table 5, some variables lost statistical significance, namely: piped water, garbage collection, the yellow category of the race variable, and the rural category of the area of residence variable. The other variables remained statistically significant, including the Northeast category, which before adjustment was not statistically significant. For some variables, the magnitude of the odds ratios in the adjusted model was modified, so that the direction of their association with the dependent variable was changed. This occurred for the variables ln of the population and for the category urban agglomerates of the variable type of composition, which started to increase the chances of death by COVID-19. In some cases, the chances of death were reduced after the adjustment, as in the case of individuals hospitalized with the new coronavirus residing in non-tourist municipalities.

Even after adjusting for all variables (Table 5), individuals living in wealthier municipalities (with higher ln of GDP per capita) were less likely to die by COVID-19, while individuals living in municipalities with a higher population density, higher illiteracy rate, as well as individuals in the group of greatest extreme poverty (> 1%) had a higher chance of death by COVID-19. These chances are also greater for individuals residing in urban agglomerations, in coastal municipalities, in non-border municipalities, as well as in tourist municipalities when comparing to their counterparts.

Table 5 - Association between the outcome of COVID-19 and the economic and sociodemographic variables of the municipalities and the sociodemographic and clinical characteristics of individuals hospitalized by COVID-19 in Brazil (to be continued)

Variables	*Odds Ratio* (Crude)	95% CI	*Odds Ratio* (Adjusted)	95% CI
Economic characteristics of the municipalities				
Ln* GDP *per capita	0.704***	(0.696 - 0.713)	0.912***	(0.891 - 0.933)
Extreme poverty (%)				
≤ 1%	1	-	1	-
> 1%	1.597***	(1.572 - 1.622)	1.333***	(1.299 - 1.367)
Sociodemographic characteristics of the municipalities				
***Ln* Population density**	1.017***	(1.014 - 1.020)	1.036***	(1.025 - 1.047)
***Ln* Population**	0.994***	(0.991 - 0.998)	1.012**	(1.002 - 1.021)
Piped water (%)				
≤ 90%	1	-	1	-
> 90%	0.674***	(0.661 - 0.687)	0.995	(0.964 - 1.028)
Garbage collection				
≤ 90%	1	-	1	-
> 90%	0.673***	(0.653 - 0.693)	0.975	(0.934 - 1.018)
Illiteracy rate	1.026***	(1.025 - 1.027)	1.029***	(1.026 - 1.031)
Type of composition				
Metropolitan region	1	-	1	-
Integrated development regions	0.636***	(0.613 - 0.660)	0.837***	(0.794 - 0.881)
Urban agglomerations	0.858***	(0.811 - 0.907)	1.207***	(1.123 - 1.297)
Other compositions	0.882***	(0.867 - 0.896)	0.913***	(0.885 - 0.941)
Border municipality				
Yes	1	-	1	-
No	1.293***	(1.246 - 1.343)	1.145***	(1.090 - 1.204)
Coastal municipality				
Yes	1	-	1	-
No	0.563***	(0.554 - 0.572)	0.668***	(0.651 - 0.686)
Tourist municipality				
Yes	1	-	1	-
No	1.110***	(1.087 - 1.134)	0.931***	(0.902 - 0.960)
Sociodemographic characteristics of individuals				
Age group (years)				
< 30	1	-	1	-
30 - 60	2.509***	(2.370 - 2.657)	2.207***	(2.080 - 2.342)
≥60	10.38***	(9.808 - 10.98)	7.967***	(7.506 - 8.455)
Gender				
Male	1	-	1	-
Female	0.885***	(0.872 - 0.898)	0.844***	(0.829 - 0.858)
Race				
White	1	-	1	-
Black	1.320***	(1.276 - 1.366)	1.177***	(1.129 - 1.227)
Yellow	1.092**	(1.021 - 1.168)	0.967	(0.891 - 1.049)
Pardos	1.245***	(1.224 - 1.267)	1.026**	(1.001 - 1.051)
Indigenous	1.437***	(1.272 - 1.624)	1.217***	(1.052 - 1.410)
Unidentified	0.875***	(0.856 - 0.894)	0.704***	(0.684 - 0.724)
Missing	1.045***	(1.019 - 1.071)	0.883***	(0.855 - 0.912)
Schooling				
Illiterate	1	-	1	-
Elementary 1	0.616***	(0.587 - 0.646)	0.777***	(0.735 - 0.822)
Elementary 2	0.456***	(0.433 - 0.480)	0.700***	(0.659 - 0.743)
High school	0.259***	(0.247 - 0.272)	0.565***	(0.533 - 0.598)
Higher education	0.184***	(0.174 - 0.195)	0.362***	(0.339 - 0.387)
Missing	0.413***	(0.395 - 0.432)	0.549***	(0.521 - 0.578)
Region of residence				

Table 5 - Association between the outcome of COVID-19 and the economic and sociodemographic variables of the municipalities and the sociodemographic and clinical characteristics of individuals hospitalized by COVID-19 in Brazil (conclusion)

North	1	-	1	-
Northeast	1.020	(0.993 - 1.048)	0.518***	(0.494 - 0.543)
Midwest	0.372***	(0.360 - 0.385)	0.534***	(0.509 - 0.561)
Southeast	0.647***	(0.631 - 0.664)	0.630***	(0.604 - 0.658)
South	0.516***	(0.499 - 0.534)	0.512***	(0.485 - 0.540)
Area of residence				
Urban	1	-	1	-
Rural	1.216***	(1.172 - 1.261)	0.980	(0.934 - 1.028)
Missing	1.146***	(1.121 - 1.171)	1.042***	(1.013 - 1.070)
Clinical and treatment characteristics of individuals				
Main symptoms				
Yes	1	-	1	-
No	0.507***	(0.475 - 0.540)	0.829***	(0.760 - 0.905)
Risk group				
Yes	1	-	1	-
No	0.464***	(0.457 - 0.471)	0.655***	(0.643 - 0.668)
Main symptoms and risk groups				
Yes	1	-	1	-
No	0.249***	(0.220 - 0.281)	0.733***	(0.630 - 0.852)
ICU admission				
Yes	1	-	1	-
No	0.218***	(0.214 - 0.221)	0.470***	(0.459 - 0.480)
Missing	0.482***	(0.472 - 0.492)	0.893***	(0.867 - 0.920)
Ventilatory support				
Invasive	1	-	1	-
Non-invasive	0.114***	(0.112 - 0.117)	0.150***	(0.146 - 0.154)
No	0.0583***	(0.0568 - 0.0599)	0.101***	(0.0982 - 0.105)
Missing	0.214***	(0.209 - 0.219)	0.244***	(0.236 - 0.252)

Source: Elaborated by the authors themselves based on study database.
Notes: All the variables included in the model were adjusted for each other.
Robust confidence interval in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

The adjusted model, shown in Table 5, also shows that individuals more educated, female, who was not admitted to the ICU, who did not use invasive ventilatory support and who are not in the risk group were less likely to die by COVID-19 when compared to their counterparts. On the other hand, blacks, *pardo*, and indigenous individuals, when compared to white individuals, were more likely to die from COVID-19. The same occurred for individuals living in the North region and for those who are older.

4 DISCUSSIONS

In Brazil, from February 21 to August 31, 2020, most of the people hospitalized by COVID-19 who died were male, older than 60 years, *pardo*, residents of the Southeast region, and residents in the urban area. In addition, these people lived mostly in municipalities with more than 1% of the population living in an extreme poverty situation, in tourist cities, and in metropolitan regions. Finally, it is also possible to verify that most of the deaths occurred in

municipalities with lower GDP *per capita*, higher population density, and higher illiteracy rates.

The adjusted results of the logistic model for block 1 (Table 2) and block 4 (Table 5) reveal that the chances of an individual hospitalized by COVID-19 dying decrease as the municipal GDP per capita increases. The opposite occurs for those hospitalized in municipalities whose percentage of the population living in extreme poverty is greater than 1% when compared to those who live in cities where this percentage is up to 1%. These results are supported by the recent literature on topic (ABEDI et al., 2020; YOU; WU; GUO, 2020), which has pointed out that low economic development might increase the chances of deaths by COVID-19.

Regarding the adjusted odds ratios in block 2 (Table 3), the results indicate that the chances of death by COVID-19 increase when the population density and the size of the municipal population increase. These results remained in the same direction after adjusting the odds ratios for block 4 (Table 5). The literature has presented different results for the relationship between population variable and the deaths by COVID-19, in some cases diverging results (ABEDI et al., 2020; STOJKOSKI et al., 2020) from those found here, but in others converging (YOU; WU; GUO, 2020). These differences may be related to the behavior, access conditions, and the absorption of information about the new coronavirus by the population of each locality, as well as methodological issues in each study, such as sample size and observed period.

It is also observed that individuals living in coastal, tourist, and non-border municipalities are more likely to die by COVID-19 when compared to their counterparts. These results indicate that the municipalities with the highest flow of people (tourist and coastal) can facilitate the contagion of the new coronavirus and, consequently, increases the chances of death due to COVID-19. On the other hand, individuals who do not reside in border municipalities are more likely to die, which corroborates the fact that Brazil is the epicenter of the disease in South America.

The adjusted estimates of the logistic model in block 3 (Table 4) indicate that individuals over 60 years of age were 9.44 times more likely to die when compared to individuals under 30 years of age. These chances are 7.96 higher when the model is adjusted for all variables (Table 5). These results corroborate with many studies that have shown that individuals affected by COVID-19 with older age are more likely to die when compared to younger people (GARG et al., 2020; GUPTA et al., 2020; HOU et al., 2020; LI et al., 2020; WU et al., 2020). When it comes to gender, hospitalized females were less likely to die when

compared to male individuals, both in the adjusted model in block 3 (Table 4) and in the adjusted model in block 4 (Table 5). This evidence has been documented in research that investigates the factors associated with deaths by COVID-19 (ALSAN et al., 2020; GUPTA et al., 2020; LI et al., 2020).

The adjusted odds ratios for block 3 (Table 4) and block 4 (Table 5) indicate that more educated individuals, affected by COVID-19, were less likely to die compared to illiterate individuals. This result may be indicating that the way information arrives and how it is processed by individuals may vary according to the level of education. Regarding the race, blacks, *pardo*, and indigenous individuals who were hospitalized by COVID-19 had a higher chance of death when compared to white individuals. This result may be linked to the level of exposure to COVID-19, which may be higher for racial minorities especially blacks and *pardos* due to a less favored economic situation than white individuals (ABEDI et al., 2020; ALSAN et al., 2020).

Regarding the region in which the individual hospitalized by COVID-19 lives, the adjusted odds ratios for both block 3 (Table 4) and block 4 (Table 5) indicate that when compared to the North region, the chances of death by COVID-19 are lower for those hospitalized in other regions of the country. This result may be linked to the high incidence and mortality rates of COVID-19 in the North region when compared to other regions of the country and to its high percentage of the population of the municipalities living in extreme poverty, which is 12.14%, the highest percentage average of the country, according to the calculations of this research.

Block 4 (Table 5) shows that the odds ratios adjusted for clinical characteristics reveal that those individuals hospitalized by COVID-19 who did not present the main symptoms, who are not in the risk group, and who did not present any of the main symptoms and are not at risk, simultaneously, had a lower chance of death by COVID-19 when compared to their counterparts (GARG et al., 2020; GUPTA et al., 2020; HOU et al., 2020; HUANG et al., 2020; LI et al., 2020; LIU et al., 2020; WU et al., 2020). It is also observed that hospitalized individuals who were not hospitalized in ICUs and those who did not receive invasive respiratory support were less likely to die by COVID-19 compared to those who were hospitalized in ICUs and those who received invasive respiratory support. These results may reflect a possible delay between the time of worsening of symptoms and the required intervention (admission to the ICU or use of ventilatory support) to alleviate them in time to prevent death.

In general, the results found in this study for the clinical and sociodemographic factors of individuals hospitalized by COVID-19 are widely supported in the literature on the subject. Individuals over 60 years of age, male, blacks, *pardos* and indigenous, illiterate, who are part of the risk group, who had at least one of the main symptoms, who needed ICU admission and the use of invasive ventilatory support greater chances of death by COVID-19 when compared to their counterparts. The same is true for hospitalized individuals living in municipalities with a high population and a high population density.

Caution is necessary when interpreting the estimates for municipalities' socioeconomic characteristics as they are estimates at the municipal level, not at the individual level. Therefore, what can be stated from the results found here is that the chances of death by COVID-19 are higher for those who live in cities with low GDP *per capita*, high illiteracy rate, and a high percentage of people in extreme poverty.

From the results of this study, it is possible to state that the characteristics of the local in which the individual hospitalized by COVID-19 lives are important factors for the outcome of the disease. The chances of death by COVID-19 are higher for places with the worst socioeconomic indicators and for places with higher population density and higher population. In addition, other municipalities' aspects, such as where they are located (coastal, border) and their composition are factors that are significantly associated with the deaths by COVID-19. This indicates that the factors (economic, social, and demographic) inherent to the place of residence of individuals hospitalized with the disease are important channels in the progress of COVID-19 that may increase or decrease the chances of death due to COVID-19. Thus, the planning of actions to combat health crises such as that caused by the new coronavirus may not ignore the influence of local aspects especially socioeconomic ones on the worsening of the crisis.

As in this study, some studies using different methodologies and with different objectives have highlighted those economic inequalities in Brazil can aggravate the COVID-19 pandemic for individuals living in less developed cities (DEMENECH et al., 2020; PIRES; CARVALHO; XAVIER, 2020). The fact is that these economic inequalities can compromise the ability to react to the disease both on the part of the individual and on the part of the municipality (DEMENECH et al., 2020).

Thus, the better the socioeconomic conditions, ceteris paribus, the lower the chances of death due to COVID-19. This points out the importance of developing public policies that aim to improve socioeconomic conditions in Brazil in order to increase the power of reaction to COVID-19 or another disease with similar characteristics that may affect the Brazilian

population again. These policies should focus on reducing extreme poverty and expanding the population's education level, with the aim of improving access and absorption of important information to combat a pandemic. In addition, policies aimed at increasing the income of individuals must be formulated in order to increase the capacity to react to the disease. These policies are structural and long-term, therefore, they should be discussed and put into practice as soon as possible in order to reduce the impact on Brazilians of a future pandemic or health crisis along the lines of COVID-19.

Although this paper has achieved its objective, it is important to highlight the presence of some limitations regarding to the use of the data in this study. As the database at the individual level is built from records filled out by the reporting health units, its quality depends on the proper filling in by those who do it. As a result, some information has not been filled out, generating for some variables high percentages of missing data, such as the schooling variable, in which 66.01% of the observations are missing. However, regarding the dependent variable – the outcome of COVID-19 - was completely filled out. Considering the data at the municipality level, the main limitation relates to the time lag of some variables especially those from the 2010 Census.

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