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REGIONAL AND SOCIAL INEQUALITIES RELATED TO COVID-19 MORTALITY IN BRAZIL

INIQUIDADES REGIONAIS E SOCIAIS NA MORTALIDADE POR COVID-19 NO BRASIL

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Abstract

This study explored the relationship between regional characteristics and epidemiological and social factors and Covid-19 mortality in Brazil. Uncertainties surrounding the response to the pandemic include the speed at which the disease spreads, unfavorable economic and social indicators across a large part of the population, lack of leadership on the part of the federal government, and tensions between different levels of government, resulting in an unprecedented political and economic crisis. Using logistic regression, we conducted a quantitative analysis of data combined with a documentary analysis of technical and scientific evidence on the Covid-19 pandemic, public health system governance structure, and fiscal federalism related to health funding. The findings reveal differences across regions, confirming inequalities in access to intensive care services. The results also show that epidemiological and social factors contribute to increased mortality in the North and Northeast regions of the country. It is concluded that Covid-19 mortality is distributed unevenly across regions, indicating the need to adopt effective measures to reduce regional inequalities.

Keywords: Covid-19; SUS; Mortality; Fiscal federalism; Public governance.

Resumo

O presente estudo teve como objetivo identificar a relação entre as características regionais e fatores epidemiológicos e sociais na mortalidade por Covid-19 no Brasil. As incertezas quanto ao

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enfrentamento da pandemia no Brasil residem em diversos fatores, desde a velocidade de propagação da doença, dos indicadores econômicos e sociais desfavoráveis para grande parte da população, perda de protagonismo da união e tensionamento entre os entes federativos que, além da crise sanitária instalada, desencadeiam uma crise política e econômica sem precedentes no país. Utilizou-se de abordagem quantitativa para análise dos dados, Regressão Logística (RL), combinada com análise documental de evidências técnico-científicas sobre a Covid-19 pandemia, aspectos da governança do Sistema Único de Saúde e do federalismo fiscal relacionado ao financiamento da saúde. Os resultados demonstram diferenças entre as regiões do país, com desigualdade em termos de acesso aos serviços de cuidados intensivos, e ainda, que o perfil epidemiológico e social contribuí para aumentar a mortalidade nas regiões Norte e Nordeste do país. A principal contribuição da pesquisa está em evidenciar que a mortalidade por Covid-19 ocorre de maneira distinta nas diferentes regiões do país, indicando necessidade de adoção de medidas efetivas para a redução das desigualdades regionais.

Palavras-chave: Covid-19; SUS; Mortalidade; Federalismo fiscal; Governança pública.

Introduction

One of the main difficulties in tackling the coronavirus pandemic in Brazil is the speed at which the disease spreads throughout the country due to the complexity of adherence to preventive measures and social isolation in a society historically marked by inequality, with most of the population showing unfavorable economic and social indicators.

In turn, Brazil's latest National Household Survey shows that concentration of income, measured by the Gini index, was stable in 2019, with an average coefficient of 0.543 and reductions across all regions except the Northeast, where income inequality rose from 0.545 in 2018 to 0.559 in 2019 (IBGE, 2020). The Northeast and North regions continued to show the highest concentration of income and pronounced social inequalities, with the highest rates in the Northeast.

In addition, Brazil has experienced a certain amount of tension in relation to Ministry of Health and World Health Organisation social distancing guidelines (COLBOURN, 2020; COHEN; KUPFERSCHMIDT, 2020; JIN *et al.*, 2020), which has been aggravated by a lack of national coordination in the country's pandemic response. Furthermore, the government has adopted an economic policy that demands a swift resumption of business activities to minimize the impact of the crisis on economic indicators such as employment.

The challenge of flattening the coronavirus infection curve involves the arduous task of improving the organization of public health systems to ensure treatment for patients with severe cases of Covid-19 in the face of uncertainties surrounding the control of the pandemic, especially in developing countries.

To ensure more effective decision-making, it is vital to develop a pandemic response plan to help define resource allocation, particularly in countries with geographical disparities. It is important to highlight that low levels of national preparedness for early case detection and reporting, limited health care capacity, and population characteristics such as advanced age, obesity and higher unemployment rates have been shown to be key factors associated with increased viral spread and overall mortality (CHAUDHRY; DRANITSARIS; MUBASHIR, 2020). In this direction, the aim of this study was to identify the relationship between regional characteristics and epidemiological and social factors and Covid-19 mortality in Brazil.

Finally, it is important to highlight that the country's public health care system, the *Sistema Único de Saúde* (SUS) or Unified Health System, has a three-tiered, single command and control governance structure, and relations between each level of government are marked by power struggles. These tensions hamper the approval of resource allocation measures, demanding a new approach to secure equity and ensure that resources reach the most affected regions. This presents an additional challenge to meeting health care needs during the pandemic, especially considering current tax revenue shortfalls triggered by the crisis.

Theoretical-empirical frame of reference

Historically, the pursuit of health equity across regions has been indicated as a way of guaranteeing the constitutional right to health and meeting health care needs. However, questions related to the federal pact and model of governance suggest that SUS funding needs to be restructured to address specific social determinants and epidemiological characteristics that have an impact on the health of vulnerable populations across different regions of the country.

Covid-19 and mortality

A large percentage of patients with severe cases of Covid-19 need intensive care (WALKER *et al.*, 2020; REMUZZI; REMUZZI, 2020; RONCO *et al.*, 2020; LIEW *et al.*, 2020). According to the World Health Organisation (WHO), 40% of people with Covid-19 develop only mild disease and do not require hospitalization, 40% develop moderate disease, requiring hospital treatment, 15% develop severe disease, requiring oxygen therapy or other hospital interventions, and 5% have critical disease and need mechanical ventilation (WHO, 2020).

On this point, it is important to highlight that Brazil faces a number of challenges: shortage of hospital beds (PEREIRA *et al.*, 2020), high concentration beds in more developed regions in the South and Southeast (BEDOYA-PACHECO *et al.*, 2020), greater shortage of beds in the Northeast and North regions (NORONHA *et al.*, 2020), and bed regulation problems (MENDES; AGUIAR, 2017).

In addition to questions related to access to public health services, the following factors may show significant differences in relation to Covid-19 mortality rates: beds per 1,000 people (LIANG *et al.*, 2020; BANIK *et al.*, 2020); population age structure (CHAUDHRY, DRANITSARIS, MUBASHIR, 2020; SHAMS, HALEEM, JAVAID, 2020; LIANG *et al.*, 2020); sex, skin color and race; level of poverty and per capita GDP (CHAUDHRY; DRANITSARIS; MUBASHIR, 2020); specific immunization campaigns, such as vaccination against H1N1; and comorbidities like diabetes and obesity (CHAUDHRY; DRANITSARIS; MUBASHIR, 2020). National studies have also shown similar differences (MACIEL *et al*., 2020; ESTRELA *et al.*, 2020; MACHADO *et al.*, 2020; SEVERO-SANTOS; SANTOS, 2020; OLIVEIRA *et al.*, 2020).

Addressing the above problems requires improved management capacity to minimize regional differences and, more especially, the allocation of more resources to areas with care gaps to address questions related to the federal pact and SUS funding model, which have not be able to reduce regional differences.

From fiscal federalism to the SUS funding logic in times of pandemic

The underfunding of the SUS a widely discussed and recurring theme in Brazil. Constitutional Amendment No. 29 (BRAZIL, 2000), regulated by Complementary Law No. 141 (BRAZIL, 2012), requires the government to allocate a set percentage of government tax revenue to health actions and services provided by federal, state and local governments. However, despite leading to an increase in overall spending on public health, this has not resulted in a reduction in regional inequalities in per capita spending (PIOLA, FRANÇA, NUNES, 2016).

SUS funding arrangements (for both outpatient and hospital care services) take into account installed capacity for the purposes of determining the allocation of financial resources. Based on this assessment, SUS transfers to subnational governments are allocated to inputs, based on the number of hospitals, equipment and staff, although part of the transfers are also directed to outputs, such as appointments, surgeries and procedures performed (DUARTE *et al.* 2009).

Governed by a variety of normative mechanisms, funding transfer arrangements within the context of Covid-19 do not differ from this preexisting logic, which is based on inequality and political considerations (FERNANDES; PEREIRA, 2020). A practical example of this is the allocation of new resources for tackling Covid-19 under Ministerial Order No. 774 (BRAZIL, 2020), which fails to set objective criteria for the transfer of resources to state and local governments.

Thus, due to the persistence of this funding logic, the resources allocated by the federal government to tackling the Covid-19 pandemic have tended not contribute to reducing regional inequalities.

Finally, in addition to fiscal questions, combined with the competing interests of public and private health providers, the SUS's three-tiered governance structure has a long history of conflict between different levels of government.

Federal government disarrangement as a potential driver of regional governance

A striking feature at the beginning of the pandemic in Brazil was the difficulty experienced by the government in aligning and coordinating national actions to tackle this public health emergency, especially social distancing measures and care protocols. As the government shied away from its role, state and local governments assumed the leadership in the adoption of temporary pandemic control measures.

This situation is particularly relevant because of the historical importance of the federal government as the main driver of public health policy within a predominantly top-down model, due to its fundraising power and public sector financing mechanisms, such as the issuing of government bonds and currency production. In this regard, the reduction of the role of states in regional planning and coordination has been dealt with in the literature (OUVERNEY, FLEURY, 2017). However, when it comes to spending on health as percentage of overall budget, studies have shown that state and local governments have increased expenditure as a share of Gross Domestic Product (SALDIVA; VERAS, 2018).

At the same time, the capacity of institutions to adapt to change is notable, for example the management of public health policies through the introduction of constitutional regulatory frameworks, which, under a three-tier approach, determine roles, structures and financial resources for the implementation of public policy. This resilience in the face of institutional change is only broken by critical situations, sparked by wars, deep economic crises and shifts in political regimes. Viewed from this perspective, significant institutional changes require the participation of all three levels of government in the process (OUVERNEY, FLEURY, 2017).

Within this context, the shift from national to regional coordination led to the creation of regional mechanisms or negotiation forums. An example of regional coordination in the context of the coronavirus crisis is the Northeast Consortium, created to promote dialogue and equity in the response to the Covid-19 pandemic.

This type of effort leads to improvements in shared regional decision-making and ensures resource optimization in bulk purchases. However, it fails to reduce inequalities across major regions since, although it increases the bargaining power of states over the federal government, it does not result in the allocation of a greater volume of resources.

Procedures, methods and data

Using logistic regression (Hosmer & Lemeshow, 2000; Gujarati, 2004), we analyzed data on hospitalizations, available from Open DataSUS, the national health information system's information portal, and ICU beds, mechanical ventilators, and doctors per 100,000 inhabitants, obtained from the Brazilian Institute of Geography and Statistics (IBGE).

In addition, using descriptive statistics, we analyzed the number of ICU beds by IBGE micro region between August 2019 and August 2020 based on data extracted from the National Register of Health Facilities (CNES) using the software TabWin. The selection encompassed the following types of SUS and non-SUS ICU beds: Adult Covid-19 ICU II, Pediatric Covid 19 ICU II, Adult ICU, Child ICU, Neonatal ICU, Adult ICU - Type I, Adult ICU - Type II, Adult ICU - Type III, Pediatric ICU - Type I, Pediatric ICU - Type II, Pediatric ICU - Type III, Neonatal ICU - Type I, Neonatal ICU - Type II, Neonatal ICU - Type III, and Burns ICU.

Data collection and selection of variables for inclusion in the logistic regression model

The data were obtained from the IBGE (2019 up to August 2020) and Severe Acute Respiratory Syndrome Database including information on Covid-19 at the Open DataSUS portal (on September 9, 2020), resulting in a sample of 41,200 cases of individuals hospitalized for Covid-19 treatment across Brazil's five regions.

Based on the theoretical-empirical frame of reference, we selected 12 variables to build the logistic regression model (Box 1).

Box 1: Variables included in the logistic regression model

Dependent variable		Source
Death	Categorical (dummy) variable - value = 1 for deaths from Covid-19 and 0 for recoveries.	Open DataSUS (2020)
Explanatory variables		Source
Man	Categorical variable - value = 1 for men and 0 for women.	Open DataSUS (2020)
Black	Categorical variable - value = 1 for black people (black and brown) and 0 for whites.	Open DataSUS (2020)
Education level	Variable represents education level as follows: i) 0, illiterate; ii) 1, primary education; iii) 2, secondary education; iv) 3, higher education.	Open DataSUS (2020)
Age	Continuous variable representing the individual's age.	Open DataSUS (2020)
Diabetic	Categorical variable - value = 1 if the patient has diabetes and 0 if the patient does not.	Open DataSUS (2020)
Obesity	Categorical variable - value = 1 if the patient is obese and 0 if not.	Open DataSUS (2020)
Vaccinated	Categorical variable - value = 1 for individuals vaccinated against flu during the last campaign and 0 for those who were not.	Open DataSUS (2020)
Region	Ordinal categorical variable that captures regional effects.	Open DataSUS (2020)
Ventilators_100,000	Ventilators per 100,000 inhabitants.	IBGE (2019/2020)
Doctors_SUS_100,000	SUS doctors per 100,000 inhabitants.	IBGE (2019/2020)
ICU_beds_100,000	SUS ICU beds per 100,000 inhabitants.	IBGE (2019/2020)

Source: Authors' elaboration.

The variables were chosen estimate logistic regression models in the context of a qualitative dataset. Logistic regression (HOSMER; LEMESHOW, 2000; GUJARATI, 2004) is suitable for many research situations because it allows researchers to determine the effects of one or more discrete, continuous or ordinal variables on a dependent dichotomous variable. It was therefore possible to estimate the probability of death in individuals who tested positive for Severe Acute Respiratory Syndrome Coronavirus-2, thus facilitating the identification of possible effects of regional characteristics and epidemiological and social factors on mortality.

Logistic regression

Logistic regression aims to generate a mathematical function whose response establishes the probability that an observation belongs to a previously determined group due to the behavior of a set of independent variables (SUCUPIRA; BRAGA, 2010). The logit model is therefore based on the cumulative logistic probability function, which can be expressed as follows:

$$p_i = E\left(Y = \frac{1}{x_i}\right) = \frac{1}{1+e^{-zi}} = \frac{e^{zi}}{1+e^{zi}} \qquad (1)$$

According to Greene (2008) and equation (2), P_i is the probability of the occurrence of a particular event given the occurrence of X and n, the coefficient of independent variable X, and the base of natural logarithms with an approximate value of 2.718.

Where $z_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n$ (2)

$1 - p_i = \mathrm{E}(\mathrm{Y}=0/X_i) = \frac{1}{1+e^{zi}}$ (3)

To determine the impact of the probability of the parameters on the probability of the occurrence of the event, the covariate is transformed using an antilogarithm. An algebraic manipulation in equations (1) and (3) expressed as follows:

$$L_i = L_n\left(\frac{P_i}{1-p_i}\right) = z_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n \quad (4)$$

Where P_i is the probability of occurrence of a given event, $1 - P_i$ is the probability of the event not occurring, X is the set of explanatory variables, and β_i is the coefficient to be estimated. The dependent variable of the regression equation is the logarithm related to the probability of occurrence of one of the two possible events. Thus, for the purposes of this study, the estimated logistic regression model is defined by following subset of variables:

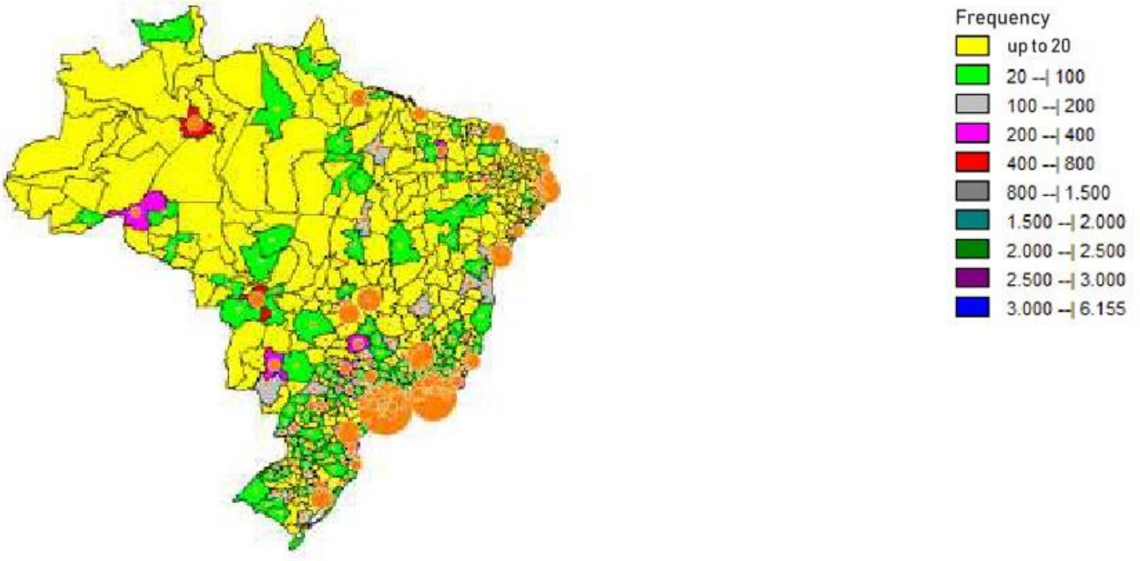
$$y = \alpha + \beta_1 man + \beta_2 black + \beta_3 \sum_{j=i}^{4} edu + \beta_4 age + \beta_5 diabetic + +\beta_6 obesity + \beta_7 vaccinated + \beta_8 \sum_{j=i}^{5} region + \beta_9 ventil + \beta_{10} doct + \beta_{11} beds$$

Results

Exploratory analysis of the variation of ICU beds

The benchmark explored by this study was regional inequalities in SUS structure and funding. The results of the exploratory analysis show differences in the distribution of ICU beds across micro regions, as shown in Figures 1 and 2.

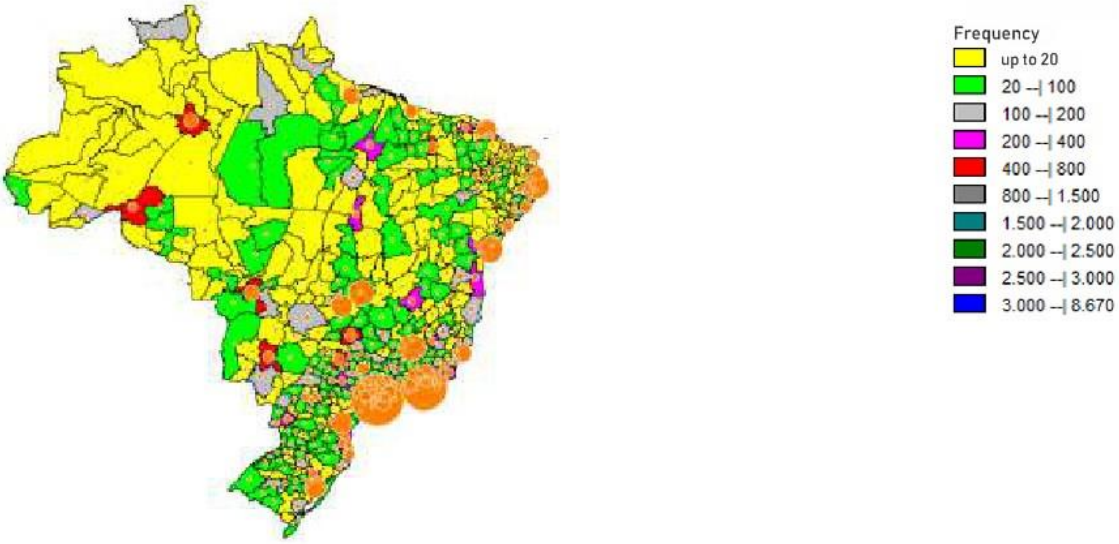
Figure 1: Map showing the distribution of SUS and non-SUS ICU beds by Micro region - August/2019



Source: Prepared using Tabwin45 based on data obtained from the CNES in August/2019

In Figure 1, the regions with the lowest numbers of ICU beds are highlighted in yellow, while the orange circles indicate areas with a high concentration of ICU beds, clearly showing that the concentration of ICU beds in August 2019 was highest in the Southeast and South regions. Although this trend persisted in August 2020, Figure 2 shows that there was a slight increase in the concentration of ICU beds in micro regions in the North and Northeast regions.

Figure 2: Map showing the distribution of SUS and non-SUS ICU beds by Micro region - August/2020



Source: Prepared using Tabwin45 based on data obtained from the CNES in August/2020

Figure 2 shows that there was a reduction in the number of micro regions highlighted in yellow and an increase in the number of regions in green, reflecting the overall increase in ICU beds across the country (51.31%). However, although there was real growth in the number of ICU beds in the North (69.54%) and Northeast (63.15%), the disparities persist because there was also an increase in the Southeast (45.41%), South (47.49%) and Center-West (55.95%) regions, where the number of SUS and non-SUS ICU beds increased from 24,313 (53.08%) in August 2019 to 35,353 (77.19%) in August 2020, as shown in Table 1.

Table 1: Variation in the distribution of SUS and non-SUS ICU beds in August/2019 and August/2020.

Region/State	Aug/2019 (N)	Distrib. Aug/2019	Aug/2020 (N)	Distrib. Aug/2020	Variation in beds created		
					Non-Covid-19	Covid-19	% Non-Covid-19
NORTH	2387	5.21%	4047	5.84%	242	1418	17.07%
.. RO	345	0.75%	581	0.84%	18	218	8.26%
.. AC	77	0.17%	198	0.29%	17	104	16.35%
.. AM	533	1.16%	748	1.08%	2	213	0.94%
.. RR	48	0.10%	111	0.16%	8	55	14.55%
.. PA	1046	2.28%	1768	2.55%	179	543	32.97%
.. AP	91	0.20%	198	0.29%	0	107	0.00%
.. TO	247	0.54%	443	0.64%	18	178	10.11%
NORTHEAST	8527	18.62%	13912	20.09%	89	5296	1.68%
.. MA	784	1.71%	1263	1.82%	24	455	5.27%
.. PI	394	0.86%	764	1.10%	21	349	6.02%
.. CE	1259	2.75%	2165	3.13%	8	898	0.89%
.. RN	580	1.27%	1018	1.47%	8	430	1.86%
.. PB	663	1.45%	987	1.43%	73	251	29.08%
.. PE	1925	4.20%	2964	4.28%	-8	1047	-0.76%
.. AL	485	1.06%	747	1.08%	-22	284	-7.75%
.. SE	350	0.76%	533	0.77%	7	176	3.98%
.. BA	2087	4.56%	3471	5.01%	-22	1406	-1.56%
SOUTH	24313	53.08%	35353	51.05%	792	10248	7.73%
.. MG	4384	9.57%	6841	9.88%	205	2252	9.10%
.. ES	1141	2.49%	1889	2.73%	113	635	17.80%
.. RJ	6407	13.99%	8573	12.38%	154	2012	7.65%
.. SP	12381	27.03%	18050	26.06%	320	5349	5.98%
SOUTHEAST	6458	14.10%	9525	13.75%	143	2924	4.89%
.. PR	2848	6.22%	3890	5.62%	87	955	9.11%
.. SC	1198	2.62%	2152	3.11%	28	926	3.02%
.. RS	2412	5.27%	3483	5.03%	28	1043	2.68%
CENTER-WEST	4116	8.99%	6419	9.27%	570	1733	32.89%
.. MS	510	1.11%	833	1.20%	52	271	19.19%
.. MT	906	1.98%	1287	1.86%	-37	418	-8.85%
.. GO	1440	3.14%	2134	3.08%	82	612	13.40%
.. DF	1260	2.75%	2165	3.13%	473	432	109.49%
Total	45801	100.00%	69256	100.00%	1836	21619	8.49%

Source: Prepared using Tabwin45 based on data obtained from the CNES in August/2019 and August/2020

It is worth noting that only 1,836 (8.49%) of the beds were non-Covid-19 beds, demonstrating that existing SUS ICU beds were converted to Covid-19 beds. This situation suggests a focus on input measures, such as temporary SUS beds, rather policies to improve the overall organization and structure of the health care system (DUARTE *et al.*, 2009).

Despite an increase in ICU beds in both public and private providers, the results suggest that care gaps and the concentration of ICU beds in the most developed regions of the country persist (NORONHA *et al.*, 2020; PEREIRA *et al.*, 2020).

Descriptive statistics

Table 2 shows the distribution of the data used in the estimation of the logit model. It is important to note that, although there was a large amount of missing data for the variables included in the model, this did not distort the results.

Table 2: Descriptive analysis of Covid-19

Variables	Hospitalizations		Deaths		Recoveries	
Sex	N	%	N	%	N	%
Male	22,406	0.544	10,242	0.249	12,164	0.295
Female	18,794	0.456	7,546	0.183	11,248	0.273
Total	41,200	100	17,788	0.4320	23,413	0.5680
Race	N	%	N	%	N	%
Black	23,575	0.572	9,437	0.229	14,138	0.343
White	17,625	0.428	8,351	0.203	9,274	0.225
Total	41,200	100	17,788	0.4320	23,412	0.5680
Education level	N	%	N	%	N	%
Illiterate	3,587	0.0871	2,190	0.0532	1397	0.0339
Primary education.	21,423	0.520	10,322	0.251	11,101	0.269
Secondary education	11,332	0.275	3,928	0.0953	7,404	0.180
Higher education	4,858	0.118	1,348	0.0327	3,510	0.0852
Total	41,200	100	17,788	0.4322	23,412	0.5681
Vaccination	N	%	N	%	N	%
Vaccinated	11,940	0.290	4,577	0.111	7,363	0.179
Not Vaccinated	29,260	0.710	13,211	0.321	16,049	0.390
Total	41,200	100	17,788	0.4320	23,412	0.5690
Comorbidity	N	%	N	%	N	%
Diabetic	16,410	0.398	7,729	0.188	8,681	0.211
Non-diabetic	24,790	0.602	10,059	0.244	14,731	0.358
Total	41,200	100	17,788	0.4320	23,412	0.5690
Comorbidity e	N	%	N	%	N	%
Obese	3,605	0.0875	1,469	0.0357	2,136	0.0518
Non-obese	37,595	0.912	16,319	0.396	21,276	0.516
Total	41,200	100	17,888	0.4317	23,412	0.5678
Region	N	%	N	%	N	%
North	3,513	0.0853	1,839	0.0446	1,674	0.0406
Northeast	6,528	0.158	3,739	0.0908	2,789	0.0677
Center-West	2,629	0.0638	989	0.0240	1,640	0.0398
Southeast	21,521	0.522	8,648	0.210	12,873	0.312
South	7,009	0.170	2,573	0.0625	4,436	0.108
Total	41,200	100	17,713	0.4319	23,412	0.5681

Source: Ministry of Health (2020)

The results shown in Table 2 show that infection and mortality rates were higher among men than in women and in blacks than in whites.

People with only primary or secondary education accounted for the largest number of cases of infection and deaths (32,755 or 79.5% and 14,250 or 34.6%, respectively).

The rate of hospitalization and mortality was greater in individuals with diabetes and obesity. Finally, infection and mortality rates showed disparities across regions.

Estimation results

The results of the logistic regression model showed how various factors can affect the probability of death of individuals who tested positive for Covid-19, as shown in Table 3:

Table 3: Logistic regression model where the outcome was death of hospitalized Covid-19 patient.

Variables	B	Z	OR	Lower limit	Upper limit
Man	0.2916984*** (0.0204912)	14.235	1.34	1.29	1.39
Black	0.1502007*** (0.0232103)	6.471	1.16	1.11	1.22
Education level	-0.2223704*** (0.0136564)	-16.283	0.80	0.78	0.82
Age	0.0466125*** (0.0007323)	63.652	1.05	1.05	1.05
Diabetic	0.1556469*** (0.0205373)	7.579	1.17	1.12	1.22
Obesity	0.5233127*** (0.0352320)	14.853	1.69	1.58	1.81
Vaccinated	-0.4277563*** (0.0231403)	-18.49	0.65	0.62	0.68
Northeast	0.5539192*** (0.0476382)	11.628	1.74	1.58	1.91
North	0.6208195*** (0.0521648)	11.901	1.86	1.68	2.06
Southeast	0.0469646 (0.0425461)	1.104	1.05	0.96	1.14
South	-0.1878390*** (0.0494942)	-3.795	0.83	0.75	0.91
Ventilators_100	0.0015851*** (0.0007058)	2.246	1.00	1.00	1.00
Doctors_SUS_100	0.0001927 (0.0001570)	1.228	1.00	1.00	1.00
Beds_ICU_SUS_100	0.0034498*** (0.0010652)	3.239	1.00	1.00	1.00
Constant	-3.146838*** (0.0803998)	-39.11	0.04	0.04	0.05

Source: Authors' elaboration.

The goodness of fit of the logistic regression model was measured using "*Pseudo* R^2", as stipulated by *CoxSnell* (0.1536) and *Nagelkerke* (0.2056) residuals. The ability of the model to explain variance was between 15% and 20%. The test to assess multicollinearity did not show any changes in the model. We adopted the following p-values: *p-value <0.1, **p-value <0.05 and ***p-value <0.01. The results of the estimated model show significant differences in Covid-19 deaths across regions, with mortality rates being higher in the North and Northeast regions.

The findings also show that the probability of death from Covid-19 was greater among men than in women, with the odds ratio indicating that men had a 34% greater chance of dying than women when the other variables were maintained constant.

The probability of death from Covid-19 was also greater among black people than in whites, with the odds ratio indicating that black people had a 16% greater chance of mortality than whites.

The probability of death from Covid-19 was lower in individuals with a higher education level, while increasing age indicated a greater probability death.

With regard to comorbidities, the findings show that patients with diabetes had a 17% greater chance of dying, while obese individuals had a 69% greater chance. Probability of death from Covid-19 was lower in patients who had been vaccinated in the last vaccination campaign than in those who had not. It is worth highlighting that the flu vaccine immunizes individuals against the H1N1 virus.

The analysis of Covid-19 deaths across regions shows that the probability of death was greatest in the North (86%) and Northeast (74%) regions and lowest in the South region. These results were statistically significant for all regions except the Southeast.

Having ventilators and ICU beds was shown to have a significant association with mortality. This may be explained by the fact that severe Covid-19 cases are sent to hospitals equipped with ventilators and ICU beds.

In short, the variables man, black, obese, diabetic, older age, lower level of education, and living in poorer regions of the country showed greater probability of death from Covid-19. On the other hand, being vaccinated, having access to mechanical ventilators and ICU beds, a higher level of education, and living in the South region was associated with a reduction in probability of death.

Discussion

There is no doubt that there is a concentration of ICU beds in the more developed regions of the country. However, this is not the only obstacle to be considered in developing a pandemic response plan. The age structure of the population, presence of comorbidities and questions related to the social determinants of health are also relevant.

Our findings show increased mortality among patients who are male, black, aged over 65 years, and obese. These results are supported by evidence from international studies. An exploratory analysis involving 50 countries reported that prevalence of obesity and per capita GDP were significantly associated with increased Covid-19 mortality per million. In contrast, reduced income dispersion within the nation was negatively associated with increased mortality. Mortality rates were also higher in those counties with an older population upon univariate analysis. Higher caseloads and overall mortality were associated with comorbidities such as obesity and advanced population age (CHAUDHRY, DRANITSARIS, MUBASHIR, 2020).

A comparative analysis of the 18 countries most affected by Covid-19 cases found that the top four countries with the highest deaths per million population (United Kingdom (623), Spain (580), Italy (571), and France (454)) belonged to Western Europe and have an average life expectancy of over 80 years. In a first analysis, the authors found a positive relationship between higher average life expectancy and deaths per million population. In a subsequent analysis, they observed a positive correlation between average life expectancy and mortality rates (SHAMS, HALEEM, JAVAID, 2020).

Another comparative study involving 200 countries found that Covid-19 mortality was negatively associated with number of hospital beds (RR = 0.85, p-value <0.001). Conversely, the authors observed that Covid-19 mortality was positively associated with the proportion of the population aged 65 and over (RR = 1.12, p-value <0.001) and the mean transport infrastructure quality score (RR = 1.08, p-value = 0.002). In addition, the findings showed that the negative association between test numbers and Covid-19 mortality was stronger among low-income countries and countries with lower government effectiveness scores, younger populations and fewer hospital beds. Predicted mortality rates showed a strong association with observed mortality rates (r = 0.77 and p-value <0.001) (LIANG *et al.*, 2020).

It is also important to consider social determinants of health and socioeconomic disparities across regions and within the context of Brazilian society. The public and private health systems should be restructured to reduce regional inequalities, particularly those related to the SUS, considering the principle of equity as a component of the development process, which in turn is a crucial element of human and social activity (SOUZA, NUNES, 2019).

In light of our findings related to the effects on mortality – which are consistent with those of other recent studies – and those concerning the SUS funding model and governance, it is evident that the pandemic may exacerbate the historic concentration of health care resources in regions of the country with better socioeconomic indicators and living conditions. However, from a health equity perspective, capitalizing on the potential technological legacy that should be left by the pandemic to reduce disparities in access to health care across regions may prove to be a possible path towards improvement.

Conclusion

Our findings suggest that the historical neglect of health care in Brazil resulting from fiscal federalism, which is incapable of reducing regional inequalities, is aggravating Covid-19 mortality.

Combined with this, the SUS funding crisis, complex governance structure, and conflicting public and private sector health policy interests, mean that the health system does not have the necessary capacity to absorb the increased pressure placed on services by the coronavirus pandemic, especially in less developed regions of the country.

In this respect, the main contribution of this study are the findings relating Covid-19 mortality in Brazil to regional characteristics and epidemiological and social factors. Our findings suggest that it is necessary to implement a fiscal federalism and SUS governance model that is capable of reducing health inequalities, including mortality in disadvantaged contexts, which is severely exacerbated by the pandemic.

It is important to mention that there are signs of change with regard to SUS governance. Prompted by the lack leadership shown by the federal government in conducting Covid-19 response measures, states have been forced to collaborate and cooperate to tackle this grave crisis putting subnational governments to the test. However, it appears that these efforts do not go far enough, given the growing demand for resources and current fiscal crisis.

Study limitations include the large amount of missing data on hospitalized Covid-19 cases, which were excluded from the dataset, and possible problems related to the lack of uniformity of data collection across the various public and private health service providers, which may have compromised the quality of the information. It is also important to mention that this study did not intend to examine cause-and-effect relationships between the selected variables and Covid-19 mortality.

Directions for future research include the investigation of the performance of macro health regions in Brazil in tackling the pandemic using other combinations of the Generalized Linear Model.

In conclusion, our findings provide strong evidence that regional inequalities tend to have an impact on Covid-19 mortality among hospitalized patients, despite the existence of other actors that play a role in the health of these individuals.

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