Journal Health NPEPS

http://dx.doi.org/10.30681/2526101010825 ORIGINAL ARTICLE

Demographic and socioeconomic factors in impacts of COVID-19 by regions in Brazil

Factores demográficos y socioeconómicos en impactos del COVID-19 por regiones en Brasil

Fatores demográficos e socioeconômicos nos impactos da COVID-19 por regiões do Brasil

Amaury de Souza[1], Débora Martins de Souza[2], Marcel Carvalho Abreu[3], José Francisco de Oliveira-Júnior[4], Elania Barros da Silva[5], Ivana Pobocikova[6], Raquel Soares Casaes Nunes[7]

ABSTRACT

Objective: assess which demographic and socioeconomic factors contribute to the different impacts of COVID-19 by regions in Brazil. **Method**: descriptive study with mathematic modeling (USA) were use to assess deaths and COVID-19 cases and also establish a standard relational relationship with demographic and socioeconomic factors across the country and by regions (2020 to 2023). The factors analyzed in the study: i) deaths and cases of COVID-19, ii) total population density per thousand kilometers, iii) isolation index, iv) population, v) Human Development Index - HDI, vi) population density, vii) average water tariff, viii) urban water service tariff, ix) total water tariff, x) urban sewage service tariff referring to municipalities served with water, xi) service tariff of total sewage, referring to the municipalities served with water, xii) Gini index (income concentration level), xiii) 1st and 2nd dose of vaccine, and xiv) Gross Domestic Product. **Results**: the study reveals that COVID-19 cases/deaths are significantly correlated with GDP and inversely correlated with the vaccination rate. **Conclusion**: this study shows scientific evidence that supports the use of vaccination as a protective measure against COVID-19 mortality in Brazil.

Descriptors: COVID-19; Demography; Mortality; Brazil.

[1]Physicist. PhD in Environmental Technologies. Federal University of Mato Grosso do Sul (UFMS). Campo Grande, Mato Grosso do Sul, Brazil. E-mail: amaury.de@uol.com.br ORCID ID: https://orcid.org/0000-0001-8168-1482 **Corresponding author** – address: Av. Costa e Silva, s/nº – Bairro Universitário, Campo Grande, Mato Grosso do Sul, Brasil. CEP: 79070-900.

[2]Physiotherapist. Master in Health Sciences. Federal University of Mato Grosso do Sul (UFMS). Campo Grande, Mato Grosso do Sul, Brazil. ORCID ID: https://orcid.org/0000-0003-2955-1036

[3]Forest Engineer. Doctor in Agronomy. Federal Rural University of Rio de Janeiro (UFRRJ). Rio de Janeiro, Rio de Janeiro, Brasil. ORCID ID: https://orcid.org/0000-0002-6457-421X

[4]Weatherman. PhD in Atmospheric Sciences. Federal University of Alagoas (UFAL). Maceió, Alagoas, Brazil. ORCID ID: https://orcid.org/0000-0002-6131-7605

[5]Nurse. Master's student in Biosystems Engineering. Federal Fluminense University (UFF). Niterói, Rio de Janeiro, Brazil. ORCID ID: https://orcid.org/0000-0003-3943-9769

[6]Mathematics. PhD in Statistics.University of Žilina. Žilina, Eslováquia. ORCID ID: https://orcid.org/0000-0003-4357-260X

[7]Biologist. PhD in Food Science. Federal Rural University of the Amazon (UFRA). Belém, Pará, Brazil. ORCID ID: https://orcid.org/0000-0002-5250-7466

RESUMEN

Objetivo: *evaluar qué factores demográficos y socioeconómicos contribuyen a los diferentes impactos del COVID-19 en Brasil.* ***Método****: estudio descriptivo utilizaron modelo matematico para evaluar las muertes y los casos de COVID-19 y establecer una relación con los factores demográficos y socioeconómicos en todo el país y por región (2020 al 2023). Los factores analizados en el estudio: i) muertes y casos de COVID-19, ii) densidad de población total por mil kilómetros, iii) índice de aislamiento, iv) población, v) Índice de Desarrollo Humano - IDH, vi) densidad de población, vii) tarifa total de agua, viii) tarifa del servicio de agua urbana, ix) tarifa total del agua, x) tarifa del servicio de alcantarillado referida a los municipios atendidos con agua, xi) tarifa total del servicio de alcantarillado, referida a los municipios atendidos con agua, xii) índice de Gini (nivel de concentración de ingresos), xiii) 1ra y 2da dosis de vacuna, xiv) Producto Interno Bruto.* ***Resultados:*** *los casos/muertes por COVID-19 están significativamente correlacionados con el PBI y inversamente correlacionados con la tasa de vacunación.* ***Conclusión****: presenta evidencia científica que apoya el uso de la vacunación como medida de protección contra la mortalidad por COVID-19 en Brasil.*
Descriptores*: COVID-19; Demografía; Mortalidad; Brasil.*

RESUMO

Objetivo*: avaliar os fatores demográficos e socioeconômicos que contribuem para os diferentes impactos da COVID-19 por regiões do Brasil.* ***Método****: estudo descritivo com modelo matemático (USA) foi utilizado para avaliar óbitos e casos de COVID-19 e também estabelecer uma relaçao padrão com fatores demográficos e socioeconômicos em todo o país e por regiões (2020a 2023). Os fatores analisados no estudo: i) óbitos e casos de COVID-19; ii) densidade populacional total por mil quilômetros; iii) índice de isolamento; iv) população; v) Índice de Desenvolvimento Humano; vi)densidade demográfica; vii) tarifa média de água; viii) tarifa de serviço de água urbana; ix) tarifa de água total; x) tarifa de serviço de esgoto urbano referente aos municípios atendidos com água; xi) tarifa de serviço de esgoto total referente aos municípios atendidos com água; xii) índice de Gini; xiii) 1ª e 2ª dose de vacina; e xiv) Produto Interno Bruto.* ***Resultados****: o estudo revela que casos/óbitos por COVID-19 são significativamente correlacionados com o PIB e inversamente correlacionados com a taxa de vacinação.* ***Conclusão****: este estudo mostra evidências científicas que apoiam o uso da vacinação como medida de proteção contra a mortalidade por COVID-19 no Brasil.*
Descritores*: COVID-19; Demografia; Mortalidade; Brasil.*

INTRODUCTION

On March 11, the World Health Organization (WHO) declared the 2019 outbreak of coronavirus disease (COVID-19) caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), a pandemic[1]. Currently, the deadly COVID-19 has little therapy and three different vaccines against Covid-19 are being applied in the Brazilian population: Comirnaty (Pfizer/BioNTech), Coronavac (Butantan/Sinovac) and Covishield (AstraZeneca/Oxford. In addition, symptoms caused by COVID-19 are non-specific or may be absent, adding challenges to disease control and prevention[2]. As COVID-19 spreads rapidly, many available data sources were based on case series or small cuts, limiting your conclusions.

The current pandemic has highlighted the marked variation in patient demographics, access to healthcare, healthcare infrastructure and preparedness across regions, and these, in turn, have significantly impacted outcomes[3]. These factors are important for health policy, not just for the current pandemic, but for future global events of endemic outbreaks and new pandemics. In Brazil, the COVID-19 pandemic began on February 26, 2020, and quickly spread across the country, starting in the states of São Paulo and Rio de Janeiro (Southeastern region of Brazil) and spreading to other Brazilian states within a few weeks later. Three months after the 1st COVID-19 case, several Brazilian states are already in critical condition, with their health systems overloaded, most of them with occupations above 80% or even collapsing. Currently, Brazil is considered the epidemic center in Latin America, occupying the 2nd place in total number of cases and, more recently, in total number of deaths.

The situation in Brazil is critical and the authorities demand a general scenario and development trend for COVID-19. Based on a simple mathematical[4], the Sars-Cov-2 epidemiology by regions in Brazil is shown in this study. The results obtained are important for understanding the COVID-19 outbreak, estimating the size of the affected population and the temporal evolution of the disease. This knowledge can help authorities make critical decisions and direct new strategies to control the COVID-19 pandemic, as well as predict when life can safely return to normal, at least in part.

The objective is to assess which demographic and socioeconomic factors contribute to the different impacts of COVID-19 by regions of Brazil.

METHOD

Descriptive study with exponential decay methodology proposed by Tang and Wang [4] was applied in the study. Infected numbers, including cumulative number and daily moving number, were collected from the Ministry of Health[5] and publicly available online. Then, the decay factors for each location were obtained and simulating the growth rate. Finally, the cumulative number and daily change number predictions were calculated, and the numbers were plotted.

Data from 02/28/2020 to 01/25/2023 were used for COVID-19 total deaths, total confirmed cases, population density per thousand kilometers, isolation index, population, HDI, population density, average water rate , urban water service index, total water, average water tariff, urban sewage service index referred to municipalities served with water, total sewage service index, referred to municipalities served with water, Gini index (degree of income concentration), 1st dose of vaccine, 2nd dose of vaccine and GDP.

For statistical analyses, the MATLAB function was used to calculate Pearson's correlation coefficients (*r*) for statistical relationships between independent variables. The r coefficient was used to measure statistical relationships between independent variables that are continuous and approximately normally distributed. The MATLAB 'corrcoef' function returns a matrix of coefficients of r calculated from an input matrix whose rows are observations (states) and whose columns are variables (e.g., cases, vaccination rates, etc.). A generalized linear model regression (MRLG) with the MATLAB® 'glmfit' function was used for multivariate analysis. The bilateral significance limit was set at $p<0.05$.

Principal Component Analysis (PCA) is a multivariate data reduction technique in which the objective is to build a linear combination of the original variables, generating new orthogonal components that represent and capture the variability of the original set of variables. This method was used in order to reduce the number of variables generating new components by capturing the dependencies between the variables[6], thus seeking a natural relationship, with independence analysis or dependence, between the variables.

In addition, PCA consists of calculating the eigenvalues and respective eigenvectors of a matrix of variances and covariances or a matrix of correlation coefficients between variables. The latter matrix being more appropriate for the present study, due to the unequal measurement units and the variance, presenting a great difference between the variables[6]. Its application occurs through a linear transformation of "m" original variables into "n" new variables, so that the first new variable (1st component) is responsible for the greatest variation in the data set, and so on, until that all the variation of the set has been captured[6].

The present study is based on secondary, publicly available data, which do not constrain groups of populations and/or individuals in the presentation of the results found, ensuring the confidentiality of the information collected. Thus, the ethical aspects of research with human beings were respected, according to Resolution 466/2012.

RESULTS

Table 1 shows the number of cases, deaths, incidence per 100,000 inhabitants and number of deaths per 100,000 inhabitants, with the highest number of cases and deaths in the Southeast, incidence in the South and mortality in the Midwest.

Table 1 - Synthesis of cases, deaths, incindence and mortality for COVID 19 by regions of Brazil.

Regions	Midwest	South	North	Northeast	Sudeste
Cases	4.239.305	7.824.998	2.859.574	7.272.724	14.572.076
Deaths	65.799	110.338	51.454	134.174	334.838
Incidence/100 thousand inhab.	26012,7	26104,2	15515,0	12743,1	16489,6
Mortality/100 thousand inhab	287,4	368,1	279,2	235,1	378,9

Although the COVID-19 pandemic has spread to every country in the world, different countries have been impacted differently, for example, the US recorded the highest number of cases and deaths due to COVID-19, while in other countries, numbers obtained were lower. The numbers of cases and deaths were highly correlated, that is, in general, the greater the number of cases, the greater the number of deaths in a country, although there are outliers with a high number of cases. The uneven distribution of deaths from COVID-19 and numbers of cases in different countries raises the question of what factors are important for a population's susceptibility to SARS-CoV-2 infection.

Although three vaccines or specific treatment against COVID-19 are available, the best strategy to fight the disease is preventive measures and social distance. The Brazilian Government, as far as possible, is taking important decisions to prevent the spread of Sars-CoV-2. Different mechanisms and levels of social distancing have been imposed, including 1.5 m distance between people (in queues, public spaces and transport), quarantine and, finally, lockdown.

Most Brazilian cities have adopted quarantine with only essential services authorized to function. In some critical cities, the blockade was imposed. Other preventive measures include hand, personal and public space hygiene, use of a face mask, complete isolation of infected people and flu vaccination. Currently, according to our results, Brazil and its states are going through the worst moment of the COVID-19 epidemic and any flexibilization of preventive measures and/or social distancing will likely have a negative impact on the disease curve.

To understand which demographic or socioeconomic factors are important for the impact of COVID-19, multivariate statistical analyzes were employed in the study. First, a pairwise r coefficient analysis was performed for several factors listed above. Since the number of cases and deaths from COVID-19 are highly correlated.

The *r* coefficients were calculated from an input table assembled from publicly available data from 02/28/2020 to 01/25/2023. ([5]) When these factors were analyzed as independent variables, it was found that cases/ COVID-19 deaths more significantly (negatively) correlate with state vaccination coverage rates (*r* = -0.49). (*r* = 0.30) - (Figure 1) COVID-19 cases/death is negatively correlated with water and sewage index (Table 2) Thus, fewer deaths from COVID-19 were found in countries with rates higher vaccination rates.

Table 2 - Pearson correlation coefficients (r) between confirmed cases of COVID-19 and the studied variables.

Variables	cases	deaths	pop	IDH	density	IS	IN005	IN023	IN055	IN006	IN024	IN056	Gini	v1	v2	PIB
cases	1.00	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
deaths	0.96	1.00	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Pop	0.97	0.98	1.00	---	---	---	---	---	---	---	---	---	---	---	---	---
IDH	0.24	0.24	0.18	1.00	---	---	---	---	---	---	---	---	---	---	---	---
density	0.00	0.07	-0.01	-0.20	1.00	---	---	---	---	---	---	---	---	---	---	---
IS	0.65	0.65	0.64	0.02	0.28	1.00	---	---	---	---	---	---	---	---	---	---
IN005	0.00	0.00	0.00	0.00	0.00	0.00	1.00	---	---	---	---	---	---	---	---	---
IN023	-0.28	-0.24	0.23	0.08	-0.03	0.02	0.00	1.00	---	---	---	---	---	---	---	---
IN055	-0.38	-0.37	0.35	0.24	-0.05	0.15	0.00	0.95	1.00	---	---	---	---	---	---	---
IN006	-0.04	-0.06	0.00	0.06	0.32	0.45	0.00	0.36	0.44	1.00	---	---	---	---	---	---
IN024	-0.55	-0.54	0.54	0.40	0.03	0.08	0.00	0.64	0.71	0.24	1.00	---	---	---	---	---
IN056	-0.58	-0.58	0.57	0.47	0.06	0.13	0.00	0.60	0.70	0.27	0.99	1.00	---	---	---	---

Gini	-0.59	-0.56	-0.26	-0.38	0.18	0.02	0.00	-0.25	-0.29	-0.03	-0.28	-0.29	1.00	---	---	---
v1	-0.59	-0.58	0.21	-0.42	0.11	0.00	0.00	-0.23	-0.29	-0.13	-0.20	-0.21	0.54	1.00	---	---
v2	-0.59	-0.57	0.20	-0.22	0.12	0.07	0.00	-0.13	-0.14	-0.04	0.02	0.02	0.66	0.88	1.00	
PIB	0.95	0.98	0.96	0.29	0.09	0.13	0.00	0.25	0.38	0.04	0.56	0.61	-0.26	0.15	0.17	1.00

Using the Fisher's F test at 5% significance, the aim was to determine, through the p-value, whether there is a statistically significant linear relationship between the dependent variable Y and one or more of the independent variables X1 and X2 [6,7]. Similarly, after obtaining the regression equations and the respective analysis of variance, the adjustment of the models was analyzed by interpreting the coefficient of determination (R^2).

As for the equations obtained from regression, as well as the respective coefficients of determination of multiple regression (Table 3).

The *F* test was used at 5% significance, a regression p-value less than 0.05 means that the null hypothesis (H_0) that the dependent variable (in this case, incidence or mortality by COVID-19) is not linearly influenced by any of the independent variables considered: IN023, IN024, IN055 and IN056 [7]. In cases of such rejection, the implication is that incidence or mortality rates, depending on the scenario considered, are significantly affected in a linear fashion by the population's access to sanitation services [8]. In turn, the R^2 coefficient is a statistical measure of how close the data are to the adjusted regression and, therefore, represents the proportion of the data variance that is explained by the model. Their values range from 0 to 1, between a complete lack of fit and a perfect fit, respectively [9].

It can be observed from the p-values obtained that the equation influence of access to water supply and sanitary sewage services on the incidence of COVID-19 was statistically significant by the *F* test, as they presented p-values below 0.05. On the other hand, the influence of these health variables on mortality resulted in equations with p-value > 0.05, and therefore, the equations obtained by multiple linear regression were not significant.

Thus, it appears that, in the context of the data analyzed in this research, the access of both the urban population and the rural population to water supply and sanitary sewage services has a significant linear influence on the incidence rate of COVID-19. Furthermore, as can be seen from the negative signs of the coefficients of the dependent variables, this influence is inversely proportional, that is: the greater the proportion of the population with access to these sanitation services, the lower the incidence rate of the disease caused by SARS- CoV-2.

The MRLG was used for a multivariate statistical analysis of cases and deaths from COVID-19. Here, deaths and COVID-19 cases, respectively, in each state were used as observed responses, and all other factors were used as predictors. The results obtained from the multivariate analysis with MRLG are similar to the results of the r coefficient, although with peculiar differences. Specifically, the most significant predictor of deaths from COVID-19 was, again, immunization rates (Figure 1), consistent with the r-coefficient analysis. Also consistent with the r coefficient is that the Gini index significantly correlates with COVID-19 deaths and water and sewage indicators. However, 1st vaccine immunization rates are negatively correlated with cases/death by COVID-19. Thus, two different statistical methods suggest that vaccination reduces deaths from COVID-19 in Brazil.

Table 3 presents analysis of the main components of the variables studied. For the data mentioned, the PCA was performed, where the total explained variance, based on the PCA, three PC's were obtained, in which, through the total explained variance, the values were truncated above 3, where the inertia test showed which were the groups of variables chosen and the first three components explain 70.2% of the variance.

Table 4 presents the results of the regression analysis for the model with intercept values (constant), population, HDI, population density, social isolation, IN23, INO55, INO06, INO24, INO56, vaccine 1, vaccine 2 and GDP. Table 5 demonstrated the Statistical analysis of regression equation variables.

Figure 1 shows the spatial projection of the ordering of the vectors of the variables of confirmed cases in the two main components for the study period. Figure 2 shows the residual deviations and values observed as a function of the adjusted values, histogram of the response variable for the adjustment model of deaths as a function of the variable.

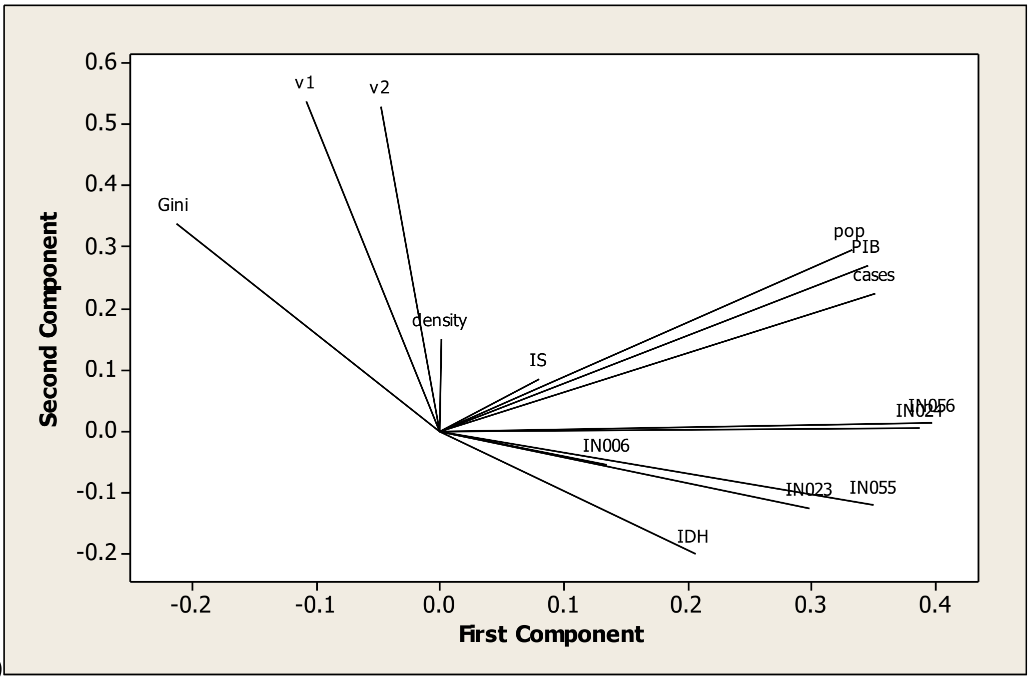
Table 3 - Factors extracted by PCA on the data, which represented 70.2% of the total explained variance.

Variables	PC1	PC2	PC3
Cases	0.652	0.226	-0.249
Pop	0.632	0.297	-0.246
IDH	0.206	-0.202	0.596
Density	0.001	0.05	0.357
IS	0.58	0.085	0.338
IN023	0.298	-0.126	0.593
IN055	0.35	-0.121	0.575
IN006	0.135	-0.054	0.532
IN024	0.388	0.003	0.591
IN056	0.398	0.012	0.583
Gini	-0.214	0.538	0.276
v1	-0.108	0.538	0.015
v2	-0.048	0.529	0.118
PIB	0.745	0.27	-0.219
Eigenvalue	5.125	2.761	1.94
Proportion	0.366	0.197	0.139
Cumulative	0.366	0.563	0.702

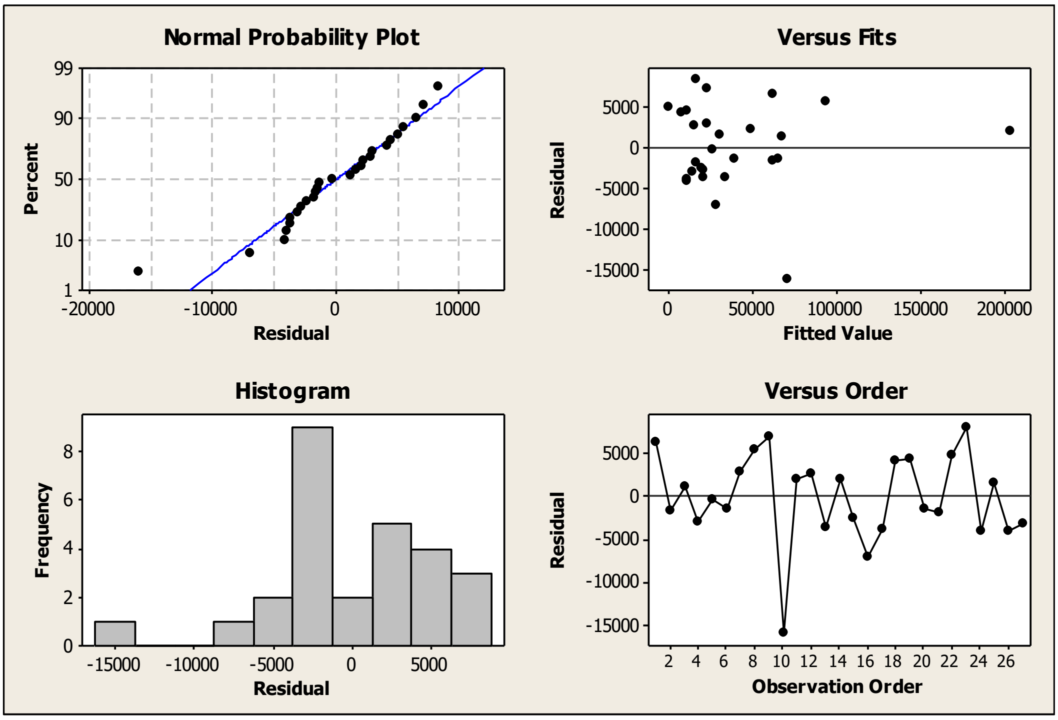
Table 4 - Linear regression model for prediction of confirmed cases of Covid 19 using the original independent variables.

Predictor	Coef	SE Coef	T	P
Constant	86152	75267	1.14	0.003
pop	0.003357	0.0007108	4.72	0
IDH	30242	51919	0.58	0.004
density	8.243	8.967	0.92	0.003
IS	266.2	467.3	0.57	0.001
IN023	-60.7	626	-0.1	0.004
IN055	12.6	627.4	0.02	0.004
IN006	2346	2077	1.13	0.002
IN024	1778.3	819.8	2.17	0.004
IN056	-2150.8	938.2	-2.29	0.003
Gini	-197186	67800	-2.91	0.002
v1	-990.3	390.9	-2.53	0.002
v2	2502	1117	2.24	0.004
PIB	46.39	26.55	1.75	0.004

S = 7234.62 R-Sq = 98.4% R-Sq(adj) = 96.8%



1)



2)

Figure 1 - Spatial projection of the ordering of the vectors of the confirmed cases variables in the two main components for the study period. Figure 2 - Residual deviations and observed values as a function of adjusted values, histogram of the response variable for the adjustment model of deaths as a function of variables.

Table 5 - Statistical analysis of regression equation variables.

Analysis	of	Variance			
Source	DF	SS	MS	F	P
Regression	13	42227611066	3248277774	62.06	0.000
Residual Error	13	680416982	52339768		
Total	26	42908028048			

DISCUSSION

Using the PCA extraction method with Varimax rotation and Kaiser normalization, and Cluster analysis obtained by the Ward method, 3 PC's were obtained that explained 70.2% of the total variance and three homogeneous groups by clustering. Factor 1/group 1 (36.6% of explained variance and R^2 = 94.3%) consisted of confirmed cases of COVID-19, population, isolation and GDP, with positive intercorrelations. Factor 2/group 2 (19.7% of explained variance and R^2=31.5%) groups the parameters GINI, v1 and v2. Factor 3/group 3 (13.9% of explained variance and R2=28.0%) groups the parameters HDI, INO23, INO55, INO06, INO24 and INO56.

The time period covered was from 28 February 2020 to 25 January 2023 for this time period, we identified 12 studies which estimated the basic reproductive number for COVID-19 from China and overseas. The estimates ranged from 1.4 to 6.49, with a mean of 3.28, a median of 2.79 and interquartile range (IQR) of 1.16[12]. The harmonic mean of the arithmetic mean doubling time estimates ranged from 1.4 (Hunan, 95% CI, 1.2–2.0) to 3.1 (Xinjiang, 95% CI, 2.1–4.8), with an estimate of 2.5 days (95% CI, 2.4–2.6) for Hubei[13].

Based on international experience, it is possible deduce that the percentage of asymptomatic SARS-CoV-2 infections among populations tested and with confirmed COVID-19, the combined percentage of asymptomatic infections was 0.25% among the population tested and 40, 50% among the confirmed population. The high percentage of asymptomatic infections highlights the potential risk of transmission of asymptomatic infections in communities[15].

It is necessary to continue to follow hygiene and safety recommendations, as well as to keep an eye out for possible outbreaks and variants of the virus that may arise. In addition, it is necessary to ensure that vaccination is widespread and effective throughout the country, in order to protect the greatest possible number of people and prevent the emergence of new outbreaks.

In the future, it is also essential that the public authorities maintain support for policies to contain the pandemic, such as carrying out mass tests. In addition, continue emphasizing the importance of vaccination on social media and contact tracing and offering adequate treatment to confirmed cases.

Correlation analyzes between deaths from COVID-19 and the variables were carried out in order to assess which factors are important for the impact of COVID-19 in the regions of Brazil. The study identified the second dose of vaccination as the most significantly inversely correlated with mortality from COVID-19. Other factors significantly correlate with deaths from COVID-19, the Gini index. This factor is highly correlated with each other, which is known to affect susceptibility to COVID-19, it is probably a confounding factor[15].

As an infectious disease transmitted by human contacts, it can be assumed that the greater the human density would result in more cases of COVID-19 and deaths. Social distancing works by reducing effective human density. However, this study found that COVID-19 cases and deaths did not significantly correlate with population density. Therefore, the most densely populated counties or regions, such as Monaco, Singapore, and Hong Kong, do not have the highest number of cases or deaths of COVID-19, even on a population basis[16]. Likewise, it was surprising that deaths from COVID-19 did not correlate significantly with factors such as the rigor of government disease control. However, there are reservations in this interpretation, as some data are incomplete, affecting the statistical analysis. This is information corroborates with other studies[5,15].

Contrary to the perception that low standard of living and poverty can incur a high number of COVID-19 victims, it was found that high numbers of COVID-19 cases/deaths are correlated with the Gini index, a general measure of concentration. It is believed that the reason that the elderly was more susceptible to COVID-19 is the decline of the immune system[17]. Thus, the correlation between the Gini index and COVID-19 is probably confounded by age.

Although it is also argued that countries with a low Gini index may lack testing capacity and thus underestimate the impacts of COVID-19. While this may be true in the first days or months of the pandemic, testing capacity has increased to levels comparable to high-income countries[18]. This study concluded that deaths from COVID-19 are not significantly correlated with the total number of tests performed by countries, although understandably the cases of COVID-19 do have a significant correlation with the tests[15].

According to previous studies[19],

populations were more likely to not intend to be vaccinated when vaccines against COVID-19 were first made available between January and December 2021. Possible reasons for this hesitation among the white population could be the presence of negative beliefs regarding vaccines against COVID-19.

Some evidence suggests that people living in Latin America mainly, in rural areas of Colombia, Ecuador and Venezuela are more likely to believe that the vaccine is ineffective, and that COVID-19 is not dangerous [20], in addition to having conspiracy beliefs and distrust of vaccines[19,21]. Although the risk of misinformation and lack of adequate coverage of health promotion activities contribute to resistance to immunization and community mitigation strategies in rural areas[21].

Although education and higher economic levels might be thought to positively influence the intention to vaccinate against COVID-19[19]. In addition, people with higher household incomes are more likely to look for vaccination against COVID-19 [22], in a free vaccine scenario; willingness to vaccinate tends to be higher among low-income groups[23]. The influence of each factor on COVID-19 vaccine hesitancy is complex, context-specific, and varies across time, location, and vaccine type[24,25].

Study limitations may be related to the lack of access to accurate and up-to-date data on COVID-19, as well as the difficulty in assessing the impact of interventions implemented to control the epidemic. Other possible limitations in studies related to COVID-19 may include, as COVID-19 affects specific groups of people in different ways, there may be selection bias in studies involving certain population groups. This may affect the generalizability of the results to other populations. COVID-19 can have mild or even asymptomatic symptoms, which can lead to underreporting of cases. Additionally, people may not accurately report their experiences with the disease, which can affect the quality of data collected. COVID-19 can be affected by external factors, such as climate change, which can affect the effectiveness of implemented interventions.

CONCLUSIONS

The analyses indicates that, the most significant predictor of deaths from COVID-19 was, again, immunization rates, consistent with the r-coefficient analysis. It identified the second dose of vaccination as the most significantly inversely correlated with mortality from COVID-19. The study reveals that COVID-19 cases/deaths are significantly correlated with GDP and inversely correlated with the vaccination rate.

It is priority preventive measure in some epidemics is to reduce susceptible individuals through vaccination. Currently, specifically in the case of the disease COVID-19, so far there aren't adequate immunobiologicals to reduce these susceptibles, leaving us only interventions in the social structure as a priority measure for its containment.

REFERENCES

1. Cucinotta D, Vanelli M. WHO declares COVID-19 a pandemic. Acta bio-medica: Atenei Parmensis. 2020; 91:157-60.
2. Young BE, Ong SWX, Kalimuddin S, Jenny GL, Seow YT, Jiashen L, et al. Epidemiologic features and clinical course of patients infected with SARS-CoV-2 in Singapore. JAMA. 2020; 323(15):1488-1494.
3. Baloch S, Baloch MA, Zheng T, Pei X. The coronavirus disease 2019 (COVID-19) pandemic. Tohoku J Exp Med. 2020; 250(4):271-278.
4. Tang Y, Wang S. Mathematic modeling of COVID-19 in the United States. Emerg Microbes Infect. 2020; 9(1):827–829.
5. Ministério da Saúde (BR). Secretaria de Vigilância Epidemiológica, Departamento de Vigilância Epidemiológica. Guia de Vigilância em Saúde. Brasília, DF: Ministério da Saúde; 2021.
6. Johnson RA, Wichern DW. Applied Multivariate Statistical Analysis. 5. ed. Prentice Hall: Upper Saddle River; 2002.
7. Bonamente M. Statistics and analysis of scientific data. 2. ed. New York: Springer; 2017.
8. Dekking FM. A modern introduction to probability and statistics: understanding why and how. New York: Springer; 2005.
9. Von Sperling M. Introdução à qualidade das águas e ao tratamento de esgotos. 4. ed. Belo Horizonte: UFMG; 2014.
10. Hozé N, Paireau J, Lapidus N, Kiem CT, Salje H, Severi G, et al. Monitoring the proportion of the population infected by SARS-CoV-2 using age-stratified hospitalisation and serological data: a modelling study. The Lancet. 2021; 6(8):546.

11. Jewell NP, Lewnard JA. On the use of the reproduction number for SARS-CoV-2: Estimation, misinterpretations and relationships with other ecological measures. J R Stat Soc Series A. 2022; 185(Suppl. 1):S16–S2.7
12. Gomes MGM, Ferreira MU, Corder RM, King JG, Souto-Maior C, Penha-Gonçalves C, et al. Individual variation in susceptibility or exposure to SARS-CoV-2 lowers the herd immunity threshold. medRxiv [Preprint]. J Theor Biol. 2022.
13. Liu Y, Gayle AA, Wilder-Smith A, Rocklöv J. The reproductive number of COVID-19 is higher compared to SARS coronavirus. J Travel Med. 2020; 13; 27(2):taaa021.
14. Wu JT, Leung K, Leung GM. Nowcasting and forecasting the potential domestic and international spread of the 2019-nCoV outbreak originating in Wuhan, China: a modelling study. The Lancet. 2020; 395(10225):689-697.
15. Souza A, Abreu MC, Oliveira-Júnior FJ, Alves FW, Aristone F, Martins SD et al. Generalized models and the impacts of population density on COVID-19 transmission. J Health NPEPS. 2021; 6(2):1-23.
16. Pilecco FB, Coelho CG, Fernandes QHRF, Silveira IH, Pescarini JM, Ortelan Naiá et al. The effect of laboratory testing on COVID-19 monitoring indicators: an analysis of the 50 countries with the highest number of cases. Epidemiol. Serv. Saúde. 2021;30(2): e2020722
17. Fauci AS, Lane HC, Redfield RR. Covid-19 — Navigating the Uncharted. N Engl J Med. 2020; 382:1268-1269.
18. Gupta M, Wahl B, Adhikari B, Bar-Zeev N, Bhandari S, Coria A, et al. The need for COVID-19 research in low- and middle-income countries. Glob Health Res Pol. 2020; 5(33).
19. Patwary MM, Alam MA, Bardhan M, Disha AS, Haque MZ, Billah SM, et al. COVID-19 vaccine acceptance among low- and lower-middle-income countries: a rapid systematic review and meta-analysis. Vaccines. 2022;10(3):427.
20. Bates BR, Villegas-Botero A, Costales JA, Moncayo AL, Tami A, Carvajal A, Grijalva Mal. COVID-19 vaccine hesitancy in three latin american countries: reasons given

for not becoming vaccinated in Colombia, Ecuador, and Venezuela. Health Community. 2022; 37(12):1465–1475.

21. Urrunaga-Pastor D, Bendezu-Quispe G, Herrera-Añazco P, Uyen-Cateriano A, Toro-Huamanchumo CJ, Rodriguez-Morales AJ, et al. Cross-sectional analysis of COVID-19 vaccine intention, perceptions and hesitancy across Latin America and the Caribbean. Trav Med Infect dis. 2021; 41:102059.

22. Wang Q, Yang L, Jin H, Lin L. Vaccination against COVID-19: a systematic review and meta-analysis of acceptability and its predictors. Prev Med. 2021;150:106694.

23. Liu R, Zhang Y, Nicholas S, Leng A, Maitland E, Wang J. COVID-19 vaccination willingness among chinese adults under the free vaccination policy. Vaccines. 2021; 9(3):292.

24. Nascimento VF, Piber RS, Britis RF, Riegel F, Unicovsky MAR, Terças-Trettel ACP, et al. Opiniões de idosos acerca da vacina anticovid e sua possível recusa. Pers Bioet. 2023; 27(1):e2714.

25. Taschner NP. Vaccine hesitancy: old story, same mistakes. J Health NPEPS. 2021; 6(2):e5876.

Funding: The authors declare that there was no funding.

Conflict of interest: The authors declare no conflict interest.

Authors' participation:
- **Design:** Souza A, Souza DM, Abreu MC, Oliveira-Ju¤nior JF, Silva EB, Pobocikova I, Nunes RSC.
- **Development:** Souza A, Souza DM, Abreu MC, Oliveira-Ju¤nior JF, Silva EB, Pobocikova I, Nunes RSC.
- **Writing and proofreading:** Souza A, Souza DM, Abreu MC, Oliveira-Ju¤nior JF, Silva EB, Pobocikova I, Nunes RSC.

How to cite this article: Souza A, Souza DM, Abreu MC, Oliveira-Ju¤nior JF, Silva EB, Pobocikova I, et al. Demographic and socioeconomic factors in impacts of COVID-19 by regions in Brazil. J Health NPEPS. 2023; 8(1):e10825.

Submission: 26/01/2023
Accepted: 03/05/2023