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Regional Disparities in Excess Mortality Due to Covid-19 in Brazil: A Temporal Analysis from 2020 to 2022

Jose Drummond de Macedo Neto

jdmn1970@gmail.com

Federal University of Rio Grande, Rio Grande do Sul, Brazil https://orcid.org/0000-0002-0383-5383

Carolina Larrosa de Oliveira Claro

Federal Institute of Education, Science and Technology of Rio Grande do Sul, Rio Grande, Brazil https://orcid.org/0000-0002-8873-197X

Samuel de Carvalho Dumith

Federal University of Rio Grande, Rio Grande do Sul, Brazil https://orcid.org/0000-0002-5994-735X

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Abstract

Objective: To estimate excess mortality in Brazil between 2020 and 2022 and its association with socioeconomic indicators. As a secondary objective, we aimed to analyze the spatial autocorrelation in the distribution of excess mortality among Brazilian municipalities.

Methods: An ecological time-series study was performed, including all 5570 Brazilian municipalities. Expected deaths were estimated using Prais-Winsten regression.

Results: Between January 1, 2020, and December 31, 2022, an estimated 753,985 (95% CI 632,888; 875,081) excess deaths occurred in Brazil. This finding represented a percentage difference of 18.1% (95% CI 17.2%; 19.0%) compared to the expected deaths (Pscore). Official statistics reported 692,507 (95% CI 559,023; 825,990) deaths from COVID -19. Considering the years 2020 and 2021, the analysis showed that the mean Pscore of the capitals was higher than that of the municipalities in the countryside (p=0.01). The study also pointed out that in the first year of the pandemic (2020), the mean Pscore of municipalities with a higher GDP per capita (3rd tercile) was lower compared to municipalities with a lower GDP per capita (1st tercile) (p<0.001). In 2021, however, the results showed a reversal, and the mean Pscore of municipalities with a higher GDP per capita was higher compared to municipalities with a lower GDP per capita.

Conclusion: The results indicated excess mortality during the studies period. In 2020, the poorest municipalities were the most affected, while in 2021 it was the wealthiest.

INTRODUCTION

According to the World Health Organization (WHO), by May 2024, 7 million deaths from COVID-19 had been reported worldwide [1]. Brazil, with 702,000 deaths, was the second most affected country in absolute numbers, behind only the United States of America (USA), with 1.2 million deaths [1].

After the first notification of the disease in Brazil, the data showed a rapid growth of the pandemic in the country in the first year, although the confirmed cases present little statistical significance, since only 7% of the population were tested that year[2].

The lack of accessible, comparable testing strategies and accurate data on COVID-19 mortality has made it difficult to assess the impact on mortality in a timely manner. An alternative to overcome these limitations is to analyze overall mortality[3], which makes it possible to estimate excess mortality, defined as the number of deaths higher than expected in the absence of the pandemic[4].

In Brazil, some studies have estimated excess mortality during the COVID-19 pandemic[5–8], however, despite evidence of excess mortality in the country, the current work may be the first covering a three-year period. Furthermore, studies in Brazil linking excess mortality with socioeconomic indicators are scarce.

Thus, this study aimed to estimate the excess mortality that occurred in Brazil between 2020 and 2022 and its association with socioeconomic indicators. As a secondary objective, we analyzed the spatial autocorrelation in the distribution of excess mortality among municipalities. It is expected that the results will contribute to understanding the likely causes that led a region, state, or municipality to present higher estimates of excess mortality compared to other areas. This knowledge may contribute to preventive measures or to directing resources more efficiently.

METHODS

Study design and data source

The current work is an ecological time series study based on secondary data. The study included all 5,570 Brazilian municipalities. Using the tabulation tool (TABNET) of the Unified Health System (SUS), developed by the Department of Informatics of the SUS (DATASUS) and available at https://datasus.saude.gov.br/informacoes-de-saude-tabnet/, the total number of deaths per municipality of residence (overall mortality) between the years 2010 and 2022 was extracted. The officially reported COVID-19 deaths were obtained from the Ministry of Health's COVID-19 monitoring dashboard, available at https://covid.saude.gov.br/. The population data for the municipalities were obtained from the website of the Brazilian Institute of Geography and Statistics (IBGE), available at https://www.ibge.gov.br/estatisticas/sociais/populacao/9103-estimativas-de-populacao.html?edicao=25272. The GDP per capita of the municipalities was extracted from the IBGE website, available at https://www.ibge.gov.br/estatisticas/economicas/contas-nacionais/9088-produto-interno-bruto-dos-municipios.html?edicao=32575. The social vulnerability index (SVI) was extracted from the Institute for Applied Economic Research (IPEA), available at http://ivs.ipea.gov.br/index.php/pt/. All data were generated in Excel spreadsheets.

Variables

Excess mortality was characterized as the difference between observed deaths (overall mortality) and expected deaths (estimated). The percentage of excess mortality relative to expected deaths was termed the Pscore and obtained using the formula: Pscore = [(observed deaths – expected deaths) / expected deaths]*100. The excess mortality rate was calculated using the following formula: EMR = (excess mortality/population)*100,000. Underreporting of COVID-19 deaths was characterized when the estimated excess mortality was greater than the number of officially reported COVID-19 deaths, resulting in a ratio above 1.0. The SVI was classified by IPEA into three ranges: very low and low vulnerability (0.000/0.300); medium vulnerability (0.301/0.400); and high and very high vulnerability (0.401/1.000). The SVI is a synthetic indicator that expresses social fragilities, based on selected indicators that comprise three dimensions: urban infrastructure, human capital, and income and employment, ranging from 0 to 1. The closer the value is to 1, the greater the social vulnerability.

Statistical methods

To carry out the estimates and analyses, the municipalities were grouped into regions: North, Northeast, Southeast, Central-West, and South. The analyses also included the states and the Federal District. Another division was made in relation to the capitals and municipalities in the countryside, in addition to stratification by population size of the municipalities, divided into three categories: municipalities with a population of up to 50,000 inhabitants (small size), greater than 50,000 and up to 100,000 inhabitants (medium size), and greater than 100,000 inhabitants (large size), according to the classification adopted by the Brazilian Institute of Geography and Statistics (IBGE).

To calculate the expected deaths for the years 2020, 2021, and 2022, a ten-year time series of overall mortality by municipality of residence (2010 to 2019) was compiled. Seven municipalities presented incomplete mortality information between the years 2010 and 2013. Of these, two municipalities (Borá and Engenho Velho) had a time series from 2012 to 2019, four municipalities (Balneário Rincão, Pescaria Brava, Pinto Bandeira and Paraíso das Águas) had a time series from 2013 to 2019, and one municipality (Mojuí dos Campos) had a time series from 2014 to 2019. Other adjustments to the mortality time series were made to avoid potential biases. For municipalities where deaths recorded in 2019 were at least 50% higher or lower than in 2018, the mortality time series developed covered nine years (2010 to 2018). This adjustment was made for 258 municipalities. After the adjustments, the final mortality time series, created in an Excel spreadsheet, was imported into the statistical software Stata 14.0.

Based on this final series, it was possible to estimate the expected deaths for the years 2020, 2021, and 2022, using Prais-Winsten regression, which considers the serial autocorrelation between the years. The beta coefficient and 95% Confidence Intervals (95% CI) were extracted. From this information, the following variables were calculated for each municipality; the excess mortality, the mortality rate per 100,000 inhabitants (excess mortality in relation to the population), and the percentage of excess mortality in relation to expected deaths (Pscore). The ratio between excess mortality and deaths from COVID-19 was also calculated to identify possible underreporting of COVID-19 deaths during the pandemic period.

The t-test was used to compare the mean Pscore between capital municipalities and inland municipalities. ANOVA was used to compare the mean Pscore between regions of Brazil and between the division by population size of the municipalities. An association with a p-value < 0.05 was considered significant. The analyses that used means were performed with data from the years 2020 and 2021, as these years accounted for more than 90% of the excess mortality for the entire period. An adjustment was also made to these analyses, to include only municipalities with a Pscore between − 100% and 100%, to make the outcome symmetrical. This excluded 129 municipalities (2.3% of the total).

The spatial autocorrelation test was also performed with data from these two years. Using ArcMap software, the spatial autocorrelation test (Moran's I index) was applied to investigate whether the spatial variable influences the Pscore values in Brazilian municipalities. Subsequently, the local Moran's I index test was applied to identify clusters and outliers in the Pscore variable values. Based on the statistical value obtained in this test, it is possible to understand the spatial independence of the variable, namely:

- Null hypothesis - (spatial independence) I = 0

- Values between 0 and +1 - direct correlation

- Values between 0 and -1 - inverse correlation

RESULTS

Between 2020 and 2022, Brazil recorded 753,985 (95% CI: 632,888; 875,081) excess deaths. This finding represented a Pscore of 18.1% (95% CI: 17.2%; 19.0%), indicating 359 (95% CI: 348.3; 369) excess deaths per 100,000 inhabitants. In absolute numbers, the Southeast region, with 42.2% of the Brazilian population, recorded an excess mortality of 338,794 (95% CI: 236,044; 441,544) deaths, concentrating 45.0% of the excess deaths estimated for Brazil. The states of São Paulo, Minas Gerais, Paraná, and Rio de Janeiro accounted for half of the country's excess mortality (Table 1).

Table 1
Covid-19 deaths, excess mortality, ratio between excess mortality and Covid-19 deaths, excess mortality per 100,000 inhabitants and Pscore, according to the Federative Units, Brazil, accumulated 2020/2022

Region/FU	Covid-19 deaths	Excess mortality	Ratio between excess mortality and Covid-19 deaths	Excess mortality per 100,000 inhabitants	Pscore (%)
Brazil	**692,507 (95%CI:559,023;825,990)**	**753,985 (95%CI:632,888;875,081)**	**1.09 (95%CI:1.03;1.15)**	**359 (95%CI:348;369)**	**18.1 (95%CI:17.2;19.0)**
North	**51,340 (95%CI:27,756;74,924)**	**57,023 (95%CI:31,697;82,350)**	**1.11 (95%CI:1.04;1.18)**	**309 (95%CI:258;360)**	**21.2 (95%CI:18.1;24.2)**
RO	7,399 (95%CI:1,889;12,909)	8,819 (95%CI:1,640;15,998)	1.19 (95%CI:1.08;1.31)	496 (95%CI:380;612)	34.3 (95%CI:23.6;44.9)
AC	2,040 (95%CI:-278;4,358)	1,515 (95%CI:-973;4,004)	0.74 (95%CI:0.32;1.17)	172 (95%CI:30;313)	11.7 (95%CI:2.4;21.0)
AM	14,418 (95%CI:-4900;33,736)	16,216 (95%CI:-4,559;36,992)	1.12 (95%CI:1.03;1.22)	391 (95%CI:286;496)	28.1 (95%CI:25.1;31.1)
RR	2,157 (95%CI:-989;5,303)	1,725 (95%CI:-419;3,869)	0.80 (95%CI:0.58;1.02)	285 (95%CI:245;325)	18.3 (95%CI:15.6;21.1)
PA	18,953 (95%CI:7,831;30,075)	21,304 (95%CI:9,655;32,952)	1.12 (95%CI:1.00;1.25)	248 (95%CI:197;299)	16.7 (95%CI:14.6;18.7)
AP	2,165 (95%CI:-956;5,286)	2,048 (95%CI:-535;4,631)	0.95 (95%CI:0.75;.1.14)	242 (95%CI:204;280)	18.3 (95%CI:16.0;20.7)
TO	4,208 (95%CI:2,168;6,248)	5,396 (95%CI:3,330;7,461)	1.28 (95%CI:0.99;1.57)	343 (95%CI:274;412)	21.8 (95%CI:17.3;26.3)
Northeast	**133,469 (95%CI:97,576;169,362)**	**166,799 (95%CI:122,830;210,768)**	**1.25 (95%CI:1.17;1.33)**	**292 (95%CI:261;323)**	**15.2 (95%CI:13.5;17.0)**
MA	11,034 (95%CI:5,190;16,878)	18,805 (95%CI:7,996;29,615)	1.70 (95%CI:1.49;1.91)	266 (95%CI:195;336)	17.3 (95%CI:12.5;22.1)
PI	8,027 (95%CI:2,280;13,774)	10,571 (95%CI:4,912;16,231)	1.32 (95%CI:1.03;1.60)	323 (95%CI:290;356)	16,7 (95%CI:14,8;18,5)
CE	28,067 (95%CI:4,705;51,429)	30,589 (95%CI:5,179;55,999)	1.09 (95%CI:1.02;1.16)	335 (95%CI:247;423)	17,3 (95%CI:11,9;22,6)
RN	8,689 (95%CI2,436;14,942)	7,184 (95%CI:3,316;11,051)	0.83 (95%CI:0.56;1.09)	205 (95%CI:159;250)	10,5 (95%CI:7,9;13,1)
PB	10,525 (95%CI:3,562;17,488)	14,143 (95%CI:6,360;21,925)	1.34 (95%CI:1.10;1.59)	352 (95%CI:293;411)	16,8 (95%CI:13,5;20,2)
PE	22,579 (95%CI:8,805;36,353)	30,594 (95%CI:9,914;51,275)	1.35 (95%CI:1.20;1.51)	320 (95%CI:215;425)	15,5 (95%CI:10,6;20,3)
AL	7,196 (95%CI:874;13,518)	10,384 (95%CI:1,626;19,142)	1.44 (95%CI1.25;1.64)	311 (95%CI:227;395)	16,8 (95%CI:11,8;21,7)
SE	6,482 (95%CI:1,278;11,686)	5,382 (95%CI:1,553;9,212)	0.83 (95%CI:0.67;0.99)	234 (95%CI:187;281)	12,9 (95%CI:10,0;15,7)
BH	30,870 (95%CI:12,763;48,977)	39,147 (95%CI:15,902;62,392)	1.27 (95%CI:1.18;1.36)	263 (95%CI:207;320)	13,5 (95%CI:10,1;16,8)
Southeast	**332,613 (95%CI:212,898;452,329)**	**338,794 (95%CI:236,044;441,544)**	**1.02 (95%CI:0.91;1.12)**	**383 (95%CI:368;399)**	**17,8 (95%CI:16,5;19,2)**
MG	64,015 (43,908;84,122)	70,661 (95%CI:51,109;90,213)	1.10 (95%CI:1.04;1.17)	334 (95%CI:316;351)	16,3 (95%CI:15,3;17,3)
ES	14,679 (95%CI:8,007;21,351)	13,879 (95%CI:7,318;20,441)	0.95 (95%CI:0.85;1.04)	345 (95%CI:315;376)	18,3 (95%CI:16,0;20,7)
RJ	76,508 (95%CI:1,879;151,137)	64,856 (95%CI:21,252;108,459)	0.85 (95%CI:0.55;1.15)	376 (95%CI:323;428)	14,6 (95%CI:11,9;17,3)

95% CI: Confidence Interval

Region/FU	Covid-19 deaths	Excess mortality	Ratio between excess mortality and Covid-19 deaths	Excess mortality per 100,000 inhabitants	Pscore (%)
Brazil	**692,507 (95%CI:559,023;825,990)**	**753,985 (95%CI:632,888;875,081)**	**1.09 (95%CI:1.03;1.15)**	**359 (95%CI:348;369)**	**18.1 (95%CI:17.2;19.0)**
North	**51,340 (95%CI:27,756;74,924)**	**57,023 (95%CI:31,697;82,350)**	**1.11 (95%CI:1.04;1.18)**	**309 (95%CI:258;360)**	**21.2 (95%CI:18.1;24.2)**
SP	177,411 (95%CI:87,007;267,815)	189,398 (95%CI:99,387;279,408)	1.07 (95%CI:1.02;1.11)	412 (95%CI:382;442)	20,1 (95%CI:19,0;21,1)
South	**109,563 (95%CI:84,374;134,752)**	**122,576 (95%CI:96,274;148,879)**	**1.12 (95%CI:1.06;1.18)**	**409 (95%CI:386;432)**	**19,3 (95%CI:17,7;21,0)**
PR	45,472 (95%CI:26,525;64,419)	56,731 (95%CI:34,470;78,992)	1.25 (95%CI:1.18;1.31)	496 (95%CI:474;519)	24,9 (95%CI:22,9;26,9)
SC	22,583 (95%CI:15,900;29,266)	26,152 (95%CI:19,334;32,970)	1.15 (95%CI:1.06;1.25)	365 (95%CI:336;394)	19,9 (95%CI:18,1;21,7)
RS	41,508 (95%CI:26,321;56,695)	39,693 (95%CI:27,557;51,830)	0.96 (95%CI:0.86;1.05)	349 (95%CI:326;372)	14,4 (95%CI:13,3;15,6)
Central west	**65,522 (95%CI:34,566;96,478)**	**68,792 (95%CI:40,479;97,106)**	**1.05 (95%CI:0.97;1.13)**	**422 (95%CI:381;463)**	**25,0 (95%CI:23,5;26,5)**
MS	10,903 (95%CI:1,745;20,061)	12,318 (95%CI:2,847;21,790)	1.13 (95%CI:1.01;1.25)	443 (95%CI:380;507)	23,6 (95%CI:20,2;27,0)
MT	15,015 (95%CI:6,842;23,188)	16,694 (95%CI:7,846;25,542)	1.11 (95%CI:1.04;1.18)	479 (95%CI:409;549)	29,3 (95%CI:25,4;33,1)
GO	27,766 (95%CI:11,003;44,529)	29,540 (95%CI:13,985;45,094)	1.06 (95%CI:0.95;1.17)	421 (95%CI:385;456)	23,3 (95%CI:21,3;25,4)
DF	11,838	10,240	0.87	340	25.9
95% CI: Confidence Interval					

Regarding the percentage of excess mortality in relation to expected deaths (Pscore), the Central-West region presented the highest Pscore, with 25.0% (95% CI: 23.5%; 26.5%), and the Northeast region the lowest Pscore with 15.2% (95% CI: 13.5%; 17.0%). Among the states, Rondônia presented the highest Pscore, with 34.3% (95% CI: 23.6%; 44.9%), and the state of Rio Grande do Norte the lowest, with 10.5% (95% CI: 7.9%; 13.1%) (Table 1).

The Central-West region recorded the highest excess mortality rate, with 422 (95% CI: 381; 463) deaths per 100,000 inhabitants, while the Northeast region had the lowest, with 292 (95% CI: 261; 323) excess deaths per 100,000 inhabitants. Considering the estimated excess mortality rate for Brazil, nine states presented values above this parameter (Table 1).

During the studied period, Brazil officially registered 692,507 (95% CI: 559,023; 825,990) deaths from COVID-19. Considering this result, the ratio between excess mortality and deaths from COVID-19 in Brazil was 1.09 (95% CI: 1.03; 1.15). The Northeast region presented the highest ratio and the Southeast region the lowest, with values of 1.25 (95% CI: 1.17; 1.33) and 1.02 (95% CI: 0.91; 1.12), respectively. The state of Maranhão presented a ratio of 1.70 (95% CI: 1.49; 1.91) and the state of Acre a ratio of 0.74 (95% CI: 0.31; 1.17), evidencing significant underreporting of the number of deaths from COVID-19 in Maranhão and a possible decrease in deaths from other causes in Acre (Table 1).

Regarding the capital municipalities, an estimated 196,234 excess deaths occurred during the period, indicating 391 excess deaths per 100,000 inhabitants. The excess mortality rate ranged from 188 per 100,000 inhabitants in Natal to 679 per 100,000 in Porto Velho. The estimated Pscore was 20.0%, ranging from 9.5% in Natal to 53.4% in Porto Velho. The ratio between excess mortality and COVID-19 deaths in the capital municipalities was 0.96, ranging from 0.54 in Natal to 1.91 in São Luís, indicating a probable decrease in deaths from other causes in Natal and significant underreporting of COVID-19 deaths in São Luís. The capital municipalities, representing 23.9% of the Brazilian population, accounted for 26.0% of excess deaths in Brazil (Table 2).

The study also showed that 2021 had the highest excess mortality rate of the period, with 439,000 (95% CI: 369; 509) excess deaths. This represents a Pscore of 31.6% (95% CI: 30.3%; 32.9%) for that year. Considering both 2020 and 2021, Brazil accumulated 626,000 (95% CI: 516; 736) excess deaths, resulting in a Pscore of 22.7% (95% CI: 21.8%; 23.6%). Thus, 90.5% of the excess mortality for the entire period occurred in these two years. In 2020, there were 187,000 (95% CI: 146; 228) excess deaths, with a Pscore of 13.7% (95% CI: 12.6; 14.8%). In 2022, however, there was a significant reduction in excess mortality compared to 2021, of 312,000 deaths (95% CI: 372; 252), reaching 71.8% (95% CI: 76.4%; 67.1%). The Pscore for the year 2022 was 9.0% (95% CI: 7.7; 10.45). The largest reductions occurred in the northern region (86.4%), in the state of Rio de Janeiro (98.4%), in the capitals (82.3%), and in municipalities with more than 100,000 inhabitants (77.6%).

The analyses presented in Tables 3 and 4 were carried out considering that the years 2020 and 2021 accounted for more than 90% of the excess mortality during the period. The Central-West region was the most affected, with a mean Pscore of 29.8%. The differences found in the mean Pscores between the regions were only not significant between the Central-West region and North region, the second most affected region, and between the Southeast and South

regions. The mean Pscore for capital municipalities was 10.7 p.p. higher compared to inland municipalities (p-value = 0.01). The mean Pscore for municipalities with more than 100,000 inhabitants was 5.4 p.p. higher compared to municipalities with up to 50,000 inhabitants (p < 0.001) (Table 3).

In the first year of the pandemic (2020), the poorest municipalities, in the 1st tercile of GDP per capita, showed a mean Pscore 3.3 p.p. higher compared to the richest municipalities, in the 3rd tercile (p = 0.0001), and the municipalities with high social vulnerability showed a mean Pscore 4.9 p.p. higher compared to the municipalities with low social vulnerability (p < 0.001). In 2021, however, the wealthiest municipalities, in the 3rd tercile of GDP per capita, and municipalities with low social vulnerability showed higher mean Pscores compared to the poorest municipalities in the 1st tercile of GDP per capita and compared to municipalities with high social vulnerability, respectively (Table 4).

Figure 1 presents the results of applying the spatial autocorrelation test to the Pscore in Brazilian municipalities, using the Moran's I index. The test indicated that the data showed spatial correlation, meaning that the space variable influenced the Pscore value for Brazilian municipalities, and that the Pscore values are grouped in neighboring regions, in the form of clusters.

The highest occurrence of clusters of municipalities with high Pscore values and neighboring municipalities also with high Pscore values was found in the North and Central-West regions. Few Brazilian municipalities formed this type of cluster, with the majority concentrated in the Southeast and Northeast regions.

The municipalities highlighted in light blue represent "Low Low" type clusters; formed by municipalities with a low Pscore value and neighboring municipalities also with a low value, that is, in both types of clusters formed, municipalities with similar characteristics are identified. The municipalities represented in red indicate "High Low" type outliers, which signal places where the Pscore is high, but with neighboring municipalities that have low values. The municipalities classified in this outlier are few and mostly located in the Southeast and Northeast of Brazil.

The municipalities represented in dark blue represent "Low High" outliers. Municipalities with this classification have low Pscores, while neighboring municipalities have higher values. These clusters are concentrated mainly in the Central-West region of the country.

DISCUSSION

The current study aimed to estimate excess mortality in Brazil between 2020 and 2022 and its association with socioeconomic indicators. The results showed excess mortality during this period and indicated that 90% of the excess mortality occurred between 2020 and 2021, with 2021 being the worst period of the pandemic. The results also showed that the mean Pscore of municipalities with a higher GDP per capita and lower social vulnerability was lower in 2020, with a reversal of this situation in 2021. The study also found 10% underreporting of deaths from COVID-19 in Brazil.

Estimates of the Pscore among Brazilian states showed heterogeneous values, ranging from 10.5% in the state of Rio Grande do Norte to 34.3% in the state of Rondônia. The same occurred with the capital municipalities, where the Pscore varied from 9.5% in Natal to 53.4% in Porto Velho. Other studies in Brazil have also reported heterogeneous values in their results. In Brazil, in 2020, the estimated Pscore was 13.7%, ranging from 2% in the state of Rio Grande do Sul to 74% in the state of Amazonas[9], and in the same year, half of the Brazilian states presented an excess mortality rate above 25%, and some states had mortality rates close to 50% [10]. Another study identified significant heterogeneity among the federative units in the year 2020[5].

These variations in the Pscore between states and capitals may be related to differences in the sanitary measures adopted, the capacity of the health system to absorb patient demand, especially severe cases, and the financial condition of each state and capital. China is an example of how strict mitigation measures kept excess mortality from COVID-19 low in the early years of the pandemic[11]. In countries like Australia and New Zealand, the mortality rate during the pandemic remained below usual levels, possibly due to social distancing measures that reduced deaths from infectious diseases unrelated to COVID-19 [12] and to the rapid sanitary measures that were adopted by the government in New Zealand, which included border control measures, control of community transmission, and case-based control [13]. In Brazil, regional, demographic, socioeconomic, and racial differences expose individuals to the risk of death from COVID-19 or other causes in distinct ways[9], where black and mixed-race individuals less frequently utilize hospital resources and have a higher hospital mortality rate compared to white individuals[14].

The mean Pscore for capital municipalities was higher than the mean Pscore for municipalities inland (p = 0.01). This finding is consistent with another study, although the authors used a shorter analysis period[15]. Municipalities with more than 100,000 inhabitants showed a higher mean Pscore compared to municipalities with up to 50,000 inhabitants (p = 0.0001). It should be considered that capital municipalities have a population exceeding 290,000 inhabitants, which may have contributed to this finding.

The results of the current study indicated that in 18 states and 15 capital municipalities, the ratio between excess mortality and reported COVID-19 deaths was greater than 1, meaning that the number of COVID-19 deaths was lower than the estimated excess mortality. This finding is consistent with other studies[16,17]. There were also states and capitals where this ratio was less than 1, indicating a higher number of COVID-19 deaths than the estimated excess mortality, a finding verified in other studies[18]. The ability to test and monitor the pandemic through more effective surveillance may be a likely explanation for the differences found in the ratio between excess mortality and deaths from COVID-19. On the other hand, the social distancing measures adopted may have reduced other causes of death.

Regarding the socioeconomic aspects related to the Pscore, the study findings showed a controversial result. In the first year of the pandemic, the mean Pscore was higher in municipalities with greater social vulnerability and lower GDP per capita, while in the second year, municipalities with higher GDP per capita and lower social vulnerability showed a higher mean Pscore. However, it should be noted that in most countries, the disease first affected urban

centers integrated into international circuits and the middle and upper classes of the population, later spreading to peripheral regions and to the poorer and more socially vulnerable groups[19].

Considering the spatial analysis, it was possible to identify that the space variable influenced the Pscore value, meaning the distribution was not random. The specialization of Pscore values and the presentation of clusters and outliers allow the identification of clusters with common characteristics, which can facilitate the work of researchers studying the behavior of this variable in the territory. It can also be useful for making more informed decisions regarding prevention measures or even the allocation of resources, considering the similarities and differences found in that region.

Several important limitations should be considered in this study. The first concerns the estimates of excess mortality for a three-year period, which greatly increases the uncertainty in the projections of expected deaths based on pre-pandemic deaths. The second limitation concerns differences in the choice of statistical method for projecting expected deaths. These issues may lead to possible underestimation or overestimation in the estimates of excess mortality and the consequent Pscore result, making it difficult to compare studies. Finally, there is the inherent limitation of ecological studies, which lack information at the individual level, as they use population data.

The strengths of this study include the inclusion of all Brazilian municipalities in the analyses. Furthermore, the excess mortality estimates covered a three-year period, which, despite the abovementioned limitations, showed a decrease in excess mortality rates, providing a more up-to-date picture for evaluating the pandemic in Brazil. The study also used socioeconomic and spatial correlation indicators, offering an alternative analysis that is not often portrayed in studies, and which may be essential for understanding the distribution of excess mortality in a country of continental dimensions like Brazil.

The results of the current study, demonstrating regional disparities in excess mortality and providing evidence that this distribution was not random, highlight for public policy managers, the need for pandemic response actions that take regional characteristics into account.

It is recommended that future studies with diverse approaches be conducted to further explore the controversial finding that the pandemic initially affected the poorest municipalities and in the second year affected the wealthiest municipalities.

References

1. World Health Organization. WHO Coronavirus (COVID-19) Dashboard. Situation by region, country, territory & área, 2024
2. Marinho PRD, Cordeiro GM, Coelho HFC, Brandão SCS. Covid-19 in Brazil: A sad scenario. *Cytokine Growth Factor Rev*. 2021;58:51-54.doi:10.1016/j.cytogfr.2020.10.010
3. Aburto JM. The Need for All-Cause Mortality Data to Aid Our Understanding of the COVID-19 Pandemic in Latin America. *Am J Public Health*. 2021;111(10):1721-1722. doi:10.2105/AJPH.2021.306478.
4. Mathieu E, Ritchie H, Rodés-Guirao L, et al. Coronavirus Pandemic (COVID-19). *Our World in Data*. Published online 2020.
5. Guimarães RM, Oliveira MPRPB de, Dutra VGP. Excess mortality according to group of causes in the first year of the COVID-19 pandemic in Brazil. *Revista Brasileira de Epidemiologia*. 2022;25. doi:10.1590/1980-549720220029
6. Saraceni V, Cruz OG, Cavalcante JR, et al. Excesso de mortalidade por todas as causas na pandemia de COVID-19 no município do Rio de Janeiro (RJ). *Revista Brasileira de Epidemiologia*. 2023;26. doi:10.1590/1980-549720230013.2
7. Orellana JDY, Cunha GM da, Marrero L, Moreira RI, Leite I da C, Horta BL. Excesso de mortes durante a pandemia de COVID-19: subnotificação e desigualdades regionais no Brasil. *Cad Saude Publica*. 2021;37(1). doi:10.1590/0102-311x00259120
8. Silva GA e, Jardim BC, Santos CVB dos. Excesso de mortalidade no Brasil em tempos de COVID-19. *Cien Saude Colet*. 2020;25(9):3345-3354. doi:10.1590/1413-81232020259.23642020
9. Santos AM dos, Souza BF de, Carvalho CA de, et al. Excess deaths from all causes and by COVID-19 in Brazil in 2020. *Rev Saude Publica*. 2021;55:71. doi:10.11606/s1518-8787.2021055004137
10. Lima EEC, Vilela EA, Peralta A, et al. Investigating regional excess mortality during 2020 COVID-19 pandemic in selected Latin American countries. *Genus*. 2021;77(1):30. doi:10.1186/s41118-021-00139-1
11. Xiao H, Wang Z, Liu F, Unger JM. Excess All-Cause Mortality in China After Ending the Zero COVID Policy. *JAMA Netw Open*. 2023;6(8):e2330877-e2330877. doi:10.1001/jamanetworkopen.2023.30877
12. Karlinsky A, Kobak D. Tracking excess mortality across countries during the COVID-19 pandemic with the World Mortality Dataset. *Elife*. 2021;10. doi:10.7554/eLife.69336
13. Baker MG, Wilson N, Anglemyer A. Successful Elimination of Covid-19 Transmission in New Zealand. *New England Journal of Medicine*. 2020;383(8). doi:10.1056/NEJMc2025203
14. Peres IT, Bastos LSL, Gelli JGM, et al. Sociodemographic factors associated with COVID-19 in-hospital mortality in Brazil. *Public Health*. 2021;192:15-20. doi:10.1016/j.puhe.2021.01.005
15. Marinho F, Torrens A, Teixeira R, et al. *Aumento Das Mortes No Brasil, Regiões, Estados e Capitais Em Tempo de COVID-19: Excesso de Óbitos Por Causas Naturais Que Não Deveria Ter Acontecido* .; 2020.
16. Ramírez-Soto MC, Ortega-Cáceres G. Analysis of Excess All-Cause Mortality and COVID-19 Mortality in Peru: Observational Study. *Trop Med Infect Dis*. 2022;7(3):44. doi:10.3390/tropicalmed7030044
17. Islam N, Shkolnikov VM, Acosta RJ, et al. Excess deaths associated with covid-19 pandemic in 2020: age and sex disaggregated time series analysis in 29 high income countries. *BMJ*. Published online May 19, 2021:n1137. doi:10.1136/bmj.n1137

18. Kelly G, Petti S, Noah N. Covid-19, non-Covid-19 and excess mortality rates not comparable across countries. *Epidemiol Infect*. 2021;149:e176. doi:10.1017/S0950268821001850
19. Machado CV et. al. *Políticas e Sistemas de Saúde Em Tempos de Pandemia: Nove Países, Muitas Lições*. (Machado CV, Pereira AMM, Freitas AMM, eds.). Série Informação para ação na Covid-19 | Fiocruz; 2022. doi:10.7476/9786557081594

Tables

Table 1. Covid-19 deaths, excess mortality, ratio between excess mortality and Covid-19 deaths, excess mortality per 100,000 inhabitants and Pscore, according to the Federative Units, Brazil, accumulated 2020/2022

Region/FU	Covid-19 deaths	Excess mortality	Ratio between excess mortality and Covid-19 deaths	Excess mortality per 100,000 inhabitants	Pscore (%)
Brazil	**692,507 (95%CI:559,023;825,990)**	**753,985 (95%CI:632,888;875,081)**	**1.09 (95%CI:1.03;1.15)**	**359 (95%CI:348;369)**	**18.1 (95%CI:17.2;19.0)**
North	**51,340 (95%CI:27,756;74,924)**	**57,023 (95%CI:31,697;82,350)**	**1.11 (95%CI:1.04;1.18)**	**309 (95%CI:258;360)**	**21.2 (95%CI:18.1;24.2)**
RO	7,399 (95%CI:1,889;12,909)	8,819 (95%CI:1,640;15,998)	1.19 (95%CI:1.08;1.31)	496 (95%CI:380;612)	34.3 (95%CI:23.6;44.9)
AC	2,040 (95%CI:-278;4,358)	1,515 (95%CI:-973;4,004)	0.74 (95%CI:0.32;1.17)	172 (95%CI:30;313)	11.7 (95%CI:2.4;21.0)
AM	14,418 (95%CI:-4900;33,736)	16,216 (95%CI:-4,559;36,992)	1.12 (95%CI:1.03;1.22)	391 (95%CI:286;496)	28.1 (95%CI:25.1;31.1)
RR	2,157 (95%CI:-989;5,303)	1,725 (95%CI:-419;3,869)	0.80 (95%CI:0.58;1.02)	285 (95%CI:245;325)	18.3 (95%CI:15.6;21.1)
PA	18,953 (95%CI:7,831;30,075)	21,304 (95%CI:9,655;32,952)	1.12 (95%CI:1.00;1.25)	248 (95%CI:197;299)	16.7 (95%CI:14.6;18.7)
AP	2,165 (95%CI:-956;5,286)	2,048 (95%CI:-535;4,631)	0.95 (95%CI:0.75;.1.14)	242 (95%CI:204;280)	18.3 (95%CI:16.0;20.7)
TO	4,208 (95%CI:2,168;6,248)	5,396 (95%CI:3,330;7,461)	1.28 (95%CI:0.99;1.57)	343 (95%CI:274;412)	21.8 (95%CI:17.3;26.3)
Northeast	**133,469 (95%CI:97,576;169,362)**	**166,799 (95%CI:122,830;210,768)**	**1.25 (95%CI:1.17;1.33)**	**292 (95%CI:261;323)**	**15.2 (95%CI:13.5;17.0)**
MA	11,034 (95%CI:5,190;16,878)	18,805 (95%CI:7,996;29,615)	1.70 (95%CI:1.49;1.91)	266 (95%CI:195;336)	17.3 (95%CI:12.5;22.1)
PI	8,027 (95%CI:2,280;13,774)	10,571 (95%CI:4,912;16,231)	1.32 (95%CI:1.03;1.60)	323 (95%CI:290;356)	16,7 (95%CI:14,8;18,5)
CE	28,067 (95%CI:4,705;51,429)	30,589 (95%CI:5,179;55,999)	1.09 (95%CI:1.02;1.16)	335 (95%CI:247;423)	17,3 (95%CI:11,9;22,6)
RN	8,689 (95%CI2,436;14,942)	7,184 (95%CI:3,316;11,051)	0.83 (95%CI:0.56;1.09)	205 (95%CI:159;250)	10,5 (95%CI:7,9;13,1)
PB	10,525 (95%CI:3,562;17,488)	14,143 (95%CI:6,360;21,925)	1.34 (95%CI:1.10;1.59)	352 (95%CI:293;411)	16,8 (95%CI:13,5;20,2)
PE	22,579 (95%CI:8,805;36,353)	30,594 (95%CI:9,914;51,275)	1.35 (95%CI:1.20;1.51)	320 (95%CI:215;425)	15,5 (95%CI:10,6;20,3)
AL	7,196 (95%CI:874;13,518)	10,384 (95%CI:1,626;19,142)	1.44 (95%CI1.25;1.64)	311 (95%CI:227;395)	16,8 (95%CI:11,8;21,7)
SE	6,482 (95%CI:1,278;11,686)	5,382 (95%CI:1,553;9,212)	0.83 (95%CI:0.67;0.99)	234 (95%CI:187;281)	12,9 (95%CI:10,0;15,7)
BH	30,870 (95%CI:12,763;48,977)	39,147 (95%CI:15,902;62,392)	1.27 (95%CI:1.18;1.36)	263 (95%CI:207;320)	13,5 (95%CI:10,1;16,8)
Southeast	**332,613 (95%CI:212,898;452,329)**	**338,794 (95%CI:236,044;441,544)**	**1.02 (95%CI:0.91;1.12)**	**383 (95%CI:368;399)**	**17,8 (95%CI:16,5;19,2)**
MG	64,015 (43,908;84,122)	70,661 (95%CI:51,109;90,213)	1.10 (95%CI:1.04;1.17)	334 (95%CI:316;351)	16,3 (95%CI:15,3;17,3)
ES	14,679 (95%CI:8,007;21,351)	13,879 (95%CI:7,318;20,441)	0.95 (95%CI:0.85;1.04)	345 (95%CI:315;376)	18,3 (95%CI:16,0;20,7)
RJ	76,508 (95%CI:1,879;151,137)	64,856 (95%CI:21,252;108,459)	0.85 (95%CI:0.55;1.15)	376 (95%CI:323;428)	14,6 (95%CI:11,9;17,3)

SP	177,411 (95%CI:87,007;267,815)	189,398 (95%CI:99,387;279,408)	1.07 (95%CI:1.02;1.11)	412 (95%CI:382;442)	20,1 (95%CI:19,0;21,1)
South	**109,563 (95%CI:84,374;134,752)**	**122,576 (95%CI:96,274;148,879)**	**1.12 (95%CI:1.06;1.18)**	**409 (95%CI:386;432)**	**19,3 (95%CI:17,7;21,0)**
PR	45,472 (95%CI:26,525;64,419)	56,731 (95%CI:34,470;78,992)	1.25 (95%CI:1.18;1.31)	496 (95%CI:474;519)	24,9 (95%CI:22,9;26,9)
SC	22,583 (95%CI:15,900;29,266)	26,152 (95%CI:19,334;32,970)	1.15 (95%CI:1.06;1.25)	365 (95%CI:336;394)	19,9 (95%CI:18,1;21,7)
RS	41,508 (95%CI:26,321;56,695)	39,693 (95%CI:27,557;51,830)	0.96 (95%CI:0.86;1.05)	349 (95%CI:326;372)	14,4 (95%CI:13,3;15,6)
Central west	**65,522 (95%CI:34,566;96,478)**	**68,792 (95%CI:40,479;97,106)**	**1.05 (95%CI:0.97;1.13)**	**422 (95%CI:381;463)**	**25,0 (95%CI:23,5;26,5)**
MS	10,903 (95%CI:1,745;20,061)	12,318 (95%CI:2,847;21,790)	1.13 (95%CI:1.01;1.25)	443 (95%CI:380;507)	23,6 (95%CI:20,2;27,0)
MT	15,015 (95%CI:6,842;23,188)	16,694 (95%CI:7,846;25,542)	1.11 (95%CI:1.04;1.18)	479 (95%CI:409;549)	29,3 (95%CI:25,4;33,1)
GO	27,766 (95%CI:11,003;44,529)	29,540 (95%CI:13,985;45,094)	1.06 (95%CI:0.95;1.17)	421 (95%CI:385;456)	23,3 (95%CI:21,3;25,4)
DF	11,838	10,240	0.87	340	25.9

95% CI: Confidence Interval

Table 2. Covid-19 deaths, excess mortality, excess mortality per 100,000 inhabitants, ratio between excess mortality and Covid-19 deaths and Pscore, by capital municipalities, Brazil, accumulated 2020/2022

Capital municipalities	Covid-19 deaths	Excess mortality	Excess mortality per 100,000 inhabitants	Ratio between excess mortality and Covid-19 deaths	Pscore %
Porto Velho	2,738	3,597	679	1.31	53.4
Rio Branco	1,208	1,269	312	1.05	20.4
Manaus	9,906	10,642	488	1.07	29.8
Boa Vista	1,640	1,125	282	0.69	17.6
Belém	5,429	5,608	376	1.03	19.3
Macapá	1,613	1,341	266	0.83	17.9
Palmas	735	808	270	1.10	22.7
São Luís	2,747	5,244	476	1.91	32.5
Teresina	2,875	2,742	317	0.95	16.9
Fortaleza	11,864	12,899	483	1.09	27.1
Natal	3,060	1,664	188	0.54	9.5
João Pessoa	3,292	3,595	444	1.09	22.4
Recife	6,607	10,235	622	1.55	28.9
Maceió	3,196	4,458	438	1.39	24.2
Aracaju	2,606	1,879	286	0.72	16.3
Salvador	9,021	11,578	403	1.28	22.6
Belo Horizonte	8,265	7,995	318	0.97	15.9
Vitória	1,450	1,379	381	0.95	21.0
Rio de Janeiro	37,905	21,168	315	0.56	11.5
São Paulo	44,346	44,140	360	1.00	18.3
Curitiba	8,544	10,186	527	1.19	30.3
Florianópolis	1,331	1,640	327	1.23	20.7
Porto Alegre	6,586	4,918	331	0.75	13.3
Campo Grande	4,619	4,726	527	1.02	27.7
Cuiabá	3,729	3,915	639	1.05	36.6
Goiânia	7,976	7,239	478	0.91	26.4
Brasília	11,838	10,240	340	0.87	25.9
TOTAL	**205,126**	**196,234**	**391**	**0.96**	**20.0**

Table 3. Mean Pscore (%) according to municipalities in the capital and the inland, division by population size of the municipalities and regions of Brazil, B

Municipalities in the capital and the inland/ division by population size of the municipalities/regions of Brazil	Municipalities (n)	M
Brazil*		
Inland municipalities	5,414	2
Capital municipalities	27	3
Municipalities with up to 50,000 inhabitants	4,768	2
Municipalities >50,000 and with up to 100.000 inhabitants	349	2
Municipalities >100,000 inhabitants	324	2
Region*		
North	434	2
Northeast	1,769	1
Southeast	1,637	2
South	1,163	2
Central-West	438	2
* Municipalities with a Pscore between -100% e 100%		
** Test t		
*** Anova		
The differences found in the mean Pscores between the regions were only not significant between the Central-West region and North region and between th		
The differences found in the mean Pscores were significant between the municipalities with up to 50,000 inhabitants and the municipalities with more than		

Table 4. Mean Pscore (%) according to GDP per capita and Social Vulnerability, municipalities of Brazil**,** 2020,2021

Variável	2020		2021
	Mean (DP)	Value P (Anova)	Mean (DP)
GDP per capita*		0.0001	
1 st tercile	12.4(23.4)		19.4(25.0)
2 nd tercile	11.1(23.7)		30.1(25.8)
3 rd tercile	9.1(21.7)		35.0(25.0)
Social vulnerability **		<0.001	
Very low and low	8.3 (22.0)		33.7 (24.9)
Medium	12.2 (23.3)		29.8 (26.6)
High and very high	13.2 (23.6)		20.2 (25.2)
*year:2019			
**year:2010			
Municipalities with Pscore between (-100% e 100%)			
In 2020, the association was only not significant between the 1st and 2nd terciles of GDP per capita and between municipalities with medium, high, and very			
In 2021, the association was significant across all terciles of GDP per capita and across all social vulnerability indices.			

Figures

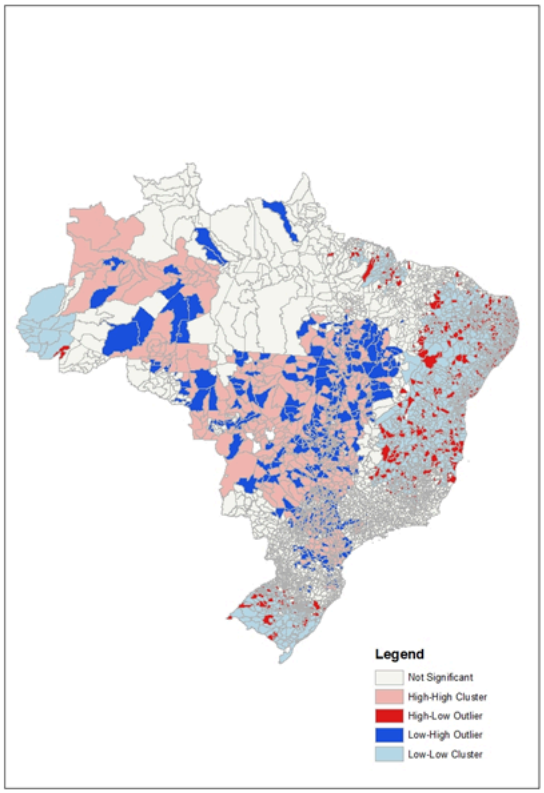


Figure 1

Spatial autocorrelation test for the Pscore in Brazilian municipalities, accumulated 2020/2021