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Area-level inequalities in Covid-19 outcomes in Brazil in 2020 and 2021: An analysis of 1,894,165 severe Covid-19 cases

Antonio Fernando Boing[a,*], Alexandra Crispim Boing[a], Maria Amélia Veras[b], Josimari Telino de Lacerda[a], Rafael Lopes Paixão da Silva[c], Paulo Roberto Barbato[d], Caroline Fabrin[a], S.V. Subramanian[e]

[a] *Programa de Pós-graduação em Saúde Coletiva, Universidade Federal de Santa Catarina, SC, Brazil*
[b] *Faculdade de Ciências Médicas da Santa Casa de São Paulo, SP, Brazil*
[c] *Instituto de Física Teórica, Universidade do Estado de São Paulo, SP, Brazil*
[d] *Universidade Federal da Fronteira Sul, Campus Chapecó, SC, Brazil*
[e] *Harvard Center for Population & Development Studies, Harvard University, USA*

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ABSTRACT

The study aims to analyze inequalities in Covid-19 outcomes in Brazil in 2020/2021 according to the per capita Gross Domestic Product (pcGDP) of municipalities. All cases of Severe Acute Respiratory Syndrome (SARS) who were hospitalized or died, regardless of hospitalization, registered in Brazil in 2020 and 2021 were analyzed (n = 2,902,742), including those with a confirmed diagnosis of Covid-19 (n = 1,894,165). We calculated lethality due to Covid-19, the performance of diagnostic tests among patients with SARS, and the hospital care received by those with Covid-19 according to the pcGDP of the patients' municipalities of residence. Data were analyzed for each epidemiological week and the risk of each outcome was estimated using Poisson regression. Municipalities in the lowest pcGDP decile had (i) 30% (95%CI 28%–32%) higher lethality from Covid-19, (ii) three times higher proportion of patients with SARS without the collection of biological material for the diagnosis of Covid-19, (iii) 16% (95%CI 15%–16%) higher proportion of SARS patients testing in a period longer than two days from the onset of symptoms, (iv) 140% (95%CI 134%–145%) higher absence of CT scan use. There is deep socioeconomic inequality among Brazilian municipalities regarding the occurrence of Covid-19 negative outcomes.

1. Introduction

The Covid-19 pandemic is a major threat to global health and has resulted in serious negative impacts on human life. As of March 12, 2022, just over two years after the first diagnosed case, 456.8 million cases and 6.04 million deaths have been reported worldwide (Our World in Data, 2022). Furthermore, the pandemic has had significant repercussions on health services (World Health Organization, 2022), education (Organization for Economic Co-operation and Development, 2022), and the economy (World Bank, 2022a).

Initial studies have found that the impact of Covid-19 is unevenly distributed between countries and among individuals according to socioeconomic characteristics. In 2020, when analyzing the spread of the disease in populations, Horton (Horton, 2020) characterized Covid-19 as a syndemic, that is, being the product of the interaction between pre-existing clinical conditions and social, economic, and political factors. Studies conducted in Latin America (Cifuentes et al., 2021), North America (Karmakar et al., 2021), Europe (Magalhães et al., 2021), Asia (Yoshikawa and Kawachi, 2021), and Africa (Shaw et al., 2021) have confirmed the existence of strong inequality, with worse outcomes from Covid-19 being described among populations with worse socioeconomic indicators, whether individual or contextual.

Brazil is among the countries with the highest cumulative number of cases and deaths from Covid-19 (Our World in Data, 2022). Furthermore, Brazil has the ninth highest income inequality - measured by the GINI coefficient - in the world and has shown increasing levels of poverty and unemployment in recent years (World Bank, 2022b). Its history is marked by socioeconomic inequalities among regions and disparities that are reproduced in the distribution of disease burden and access to health services. Moreover, the country is notorious for having one of the worst responses to the pandemic, with a lack of national coordination and a flawed approach to controlling the disease (Castro

* Corresponding author.
E-mail address: antonio.boing@ufsc.br (A.F. Boing).

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et al., 2021).

Consequently, studies restricted to some Brazilian municipalities have shown that the most underprivileged social groups have a higher prevalence of SARS-CoV-2 (Correia et al., 2022), higher mortality rates (Li et al., 2021), and higher lethality (Bernardo et al., 2021). Analyses of national data showed a higher incidence of Covid-19 in municipalities with greater inequality (Raymundo et al., 2021), higher in-hospital mortality rates among brown and black patients (Peres et al., 2021), and the existence of regional clusters in the distribution of infections and deaths (Lima et al., 2021). However, these analyses focused only on the first year of the pandemic and did not explore all cases of Severe Acute Respiratory Syndrome (SARS) due to Covid-19 registered in the country until the end of 2021. To the best of our knowledge, no studies have explored inequalities in the country regarding the performance of tests for the diagnosis of Covid-19 and that have analyzed the lethality of severe cases of Covid-19 by epidemiological week in different waves of the epidemic and in moments before and after the start of vaccination. Analyzing the area-level inequalities of a syndemic event in one of the most unequal countries in the world is vital for an improved understanding of Covid-19 and for the formulation of equitable public policies.

The objective of the present study was to analyze inequalities in (i) the performance of diagnostic tests among patients with SARS, (ii) in-hospital care received by patients with Covid-19, and (iii) lethality of severe cases due to Covid-19, according to the per capita Gross Domestic Product (GDP) of the Brazilian municipalities in 2020 and 2021.

2. Methods

All cases of SARS registered in Brazil in 2020 and 2021 were analyzed. Data were obtained from the Ministry of Health according to the official record of the Influenza Epidemiological Surveillance Information System (SIVEP-Gripe). All cases of SARS diagnosed in Brazilian territory must be registered in this system, and its completion is mandatory for public and private health services. All hospitalized SARS cases or deaths from SARS, regardless of hospitalization, including those diagnosed with Covid-19, are included in the system. SIVEP-Gripe is managed by the Ministry of Health and includes SARS cases in the country since the Influenza A(H1N1)pdm09 pandemic of 2009. Health services should test cases of SARS to diagnose the viral agent causing the disease.

In the present study, cases of any age and whose symptoms started between epidemiological week 12 of 2020 (started on March 15) and week 52 of 2021 (started on December 26) were included according to the database updated on March 03, 2022. The selected outcomes were as follows: (1) Covid-19 lethality, calculated by dividing the deaths caused by the disease by the total number of patients diagnosed with Covid-19 registered in SIVEP-Gripe; the proportion of Covid-19 patients who (2) were admitted to an ICU bed; (3) received ventilatory support (invasive or non-invasive); (4) had no X-ray examination performed; and (5) had no computed tomography performed (CT). We also analyzed the proportion of: (6) SARS patients who had no biological sample collected for diagnosis of the infectious agent that was causing SARS, and (7) tested people who performed the test three or more days after the onset of symptoms. Outcomes 6 and 7 were estimated for all SARS patients, regardless of the infectious agent, as they are important procedures to identify cases of Covid-19 among SARS patients, which would allow more appropriate clinical management. The other outcomes were calculated for patients whose final diagnostic outcome was SARS due to Covid-19. In the SIVEP-Gripe database, a case of covid-19 can be confirmed through laboratory test, clinical evaluation and/or imaging. 88.6% of the covid-19 cases analyzed in the present study were confirmed through laboratory test.

The independent variable was municipal per capita GDP. Brazil is divided into 27 federative units and 5570 municipalities. For each of them, the Brazilian Institute of Geography and Statistics (IBGE) calculated the GDP and resident population for 2018 in partnership with the State Statistical Bodies, State Secretariats of Government, and Superintendence of the Manaus Free Trade Zone. The values, estimated in reais (R$), were divided into deciles according to their distribution. SIVEP-Gripe records the patients' municipalities of residence using the same codes standardized by IBGE for the entire national territory, allowing the linkage of the databases.

In the data analysis, the values of all outcomes and their respective confidence intervals (95%CI) were initially calculated according to each per capita GDP decile. Then, a heat map was constructed with the distribution of outcomes 1, 4, and 5 along the epidemiological weeks, analyzed according to per capita GDP. Finally, using Poisson regression, crude and age-adjusted models were calculated to estimate the relative risk and the 95%CI of each of the seven outcomes according to the contextual socioeconomic variable. Since less Covid-19 testing is done in poorer areas there might be a detection bias that artificially reduces the number of Covid-19 cases in poorer areas. Furthermore, 33.3% of the national SRAG cases did not have the information of the etiological agent. So, as sensitivity analysis we calculated outcomes 1–5 including all SRAG cases. All analyses were performed using Stata 15.1. The analyzed data were public and anonymized (available at https://opendatasus.saude.gov.br/), which does not require submission to a research ethics committee. This study followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guideline.

3. Results

Data from 2,902,742 cases of SARS and 1,894,165 cases with a final diagnostic classification of Covid-19 were analyzed. The mean age of people with Covid-19 was 57.5 years (standard deviation: 18.1 years); 55.6% were men, and approximately five out of six people reported five or more symptoms of the disease. The lethality of patients with severe Covid-19 was 34.3%, while 37.7% of them were admitted to ICU beds and eight out of ten used ventilatory support (Table 1). It was observed that in 4.1% of SARS cases, no sample was collected to identify the infectious agent, and when there was collection, it took place three or more days after the onset of symptoms in 71.8% of cases (Table 2).

The lethality of severe Covid-19 fluctuated significantly between the deciles of municipal per capita GDP. The figure reached 42.6% among confirmed cases residing in the poorest municipalities, whereas among the cases from richer municipalities, the proportion was 31.8%. The ICU hospitalization rate and use of ventilatory support did not vary significantly among the deciles of municipal per capita GDP (Table 1). When analyzing data from patients with SARS, it was found that in 8.8% of the cases from the poorest municipalities, there was no biological sample collection for the diagnosis of the infectious agent. In the richest municipalities, this value was 2.9%. Additionally, in municipalities with lower per capita GDP, there was a higher proportion of patients in whom the collection of biological material was performed only three or more days after the onset of symptoms (78.2% vs. 67.9% in the extreme deciles). Among the municipalities with the highest per capita GDP, a greater number of CT scans were performed.

The temporal analysis of the lethality analyzed showed higher values of the indicator in the first epidemiological weeks of 2020, at the end of the same year, and in the first four months of 2021 (Fig. 1). At all times, municipalities with the lowest per capita GDP had the highest values, and among such municipalities, the peaks of higher lethality extended for a longer period of time. When analyzing Fig. 1, there is a similarity between the periods of greater lethality and those of less testing, and with a greater proportion of testing only three or more days after the onset of symptoms. In all the indicators analyzed in Fig. 1, the municipalities with the lowest income had the worst values in the historical series, which includes the weeks before and after the start of vaccination in the country (dated January 17, 2021).

Table 3 presents the results of crude and age-adjusted regression models. While no significant differences were identified among the

Table 1
Distribution of cases, lethality of severe cases, proportion of ICU admissions and proportion of use of ventilatory support (with respective 95% CI) among patients with severe Covid-19 according to deciles of the per capita Gross Domestic Product of Brazilian municipalities. Brazil, 2020–2021.

	Patients with severe acute respiratory syndrome n (%)	Patients with Covid-19 diagnosis confirmed n (%)	Lethality due to severe Covid-19* % ($CI_{95\%}$)	ICU admission * % ($CI_{95\%}$)	Use of ventilatory support * % ($CI_{95\%}$)
Decile 10 (richest)	1,066,814 (36.7)	704,697 (37.2)	31.8 (31.7–31.9)	38.6 (38.5–38.7)	79.8 (79.7–79.9)
Decile 9	553,047 (19.1)	370,568 (19.6)	31.4 (31.2–31.5)	34.4 (34.2–34.6)	79.7 (79.5–79.8)
Decile 8	309,330 (10.7)	205,010 (10.8)	35.6 (35.4–35.9)	37.4 (37.2–37.6)	79.6 (79.4–79.8)
Decile 7	332,352 (11.4)	220,160 (11.6)	35.8 (35.6–36.0)	39.4 (39.2–39.7)	78.9 (78.7–79.0)
Decile 6	199,884 (6.9)	126,146 (6.7)	39.6 (39.4–39.9)	38.4 (38.1–38.7)	79.2 (79.0–79.5)
Decile 5	167,212 (5.8)	103,194 (5.4)	40.5 (40.2–40.8)	38.3 (38.0–38.6)	80.7 (80.4–81.0)
Decile 4	105,192 (3.6)	61,520 (3.2)	39.0 (38.6–39.4)	38.1 (37.7–38.5)	79.0 (78.6–79.4)
Decile 3	66,711 (2.3)	39,619 (2.1)	41.9 (41.4–42.4)	39.7 (39.2–40.2)	80.7 (80.3–81.1)
Decile 2	59,011 (2.0)	37,341 (2.0)	40.3 (39.8–40.8)	37.7 (37.2–38.2)	79.2 (78.8–79.7)
Decile 1 (poorest)	43,189 (1.5)	25,910 (1.4)	42.6 (41.9–43.2)	40.6 (39.9–41.2)	78.4 (77.8–78.9)
All	2,902,742 (100.0)	1,894,165 (100.0)	34.3 (34.2–34.3)	37.7 (37.6–37.8)	79.6 (79.6–79.7)

$CI_{95\%}$: 95% Confidence Interval.
* Among patients with confirmed Covid-19 diagnosis registered in the Brazilian Influenza Epidemiological Surveillance Information System (SIVEP-Gripe).

Table 2
Proportion of patients who had no biological sample collected for the diagnosis of Covid-19, who had sample collected 3+ days after symptom onset, who did not undergo an x-ray and computed tomography exam (with respective 95% CI) according to deciles of the per capita Gross Domestic Product of Brazilian municipalities. Brazil, 2020–2021.

	No biological sample collected for the diagnosis of Covid-19* % ($C_{I95\%}$)	Sample collected 3+ days after symptom onset ‡ * % ($C_{I95\%}$)	No x-ray** % ($C_{I95\%}$)	No computed tomography ** % ($C_{I95\%}$)
Decile 10 (richest)	2.9 (2.9–2.9)	67.9 (67.8–68.0)	52.6 (52.5–52.7)	18.1 (18.0–18.3)
Decile 9	3.6 (3.5–3.6)	73.0 (72.9–73.1)	56.6 (56.4–56.8)	22.6 (22.4–22.8)
Decile 8	4.0 (3.9–4.0)	72.9 (72.7–73.0)	57.0 (56.7–57.3)	27.1 (26.8–27.3)
Decile 7	4.8 (4.7–4.9)	73.8 (73.6–74.0)	57.5 (57.2–57.8)	26.9 (26.6–27.1)
Decile 6	5.3 (5.2–5.4)	75.3 (75.1–75.5)	50.1 (49.7–50.5)	30.6 (30.2–31.0)
Decile 5	5.9 (5.8–6.1)	75.2 (75.0–75.2)	51.7 (51.2–52.1)	31.9 (31.5–32.3)
Decile 4	6.3 (6.2–6.5)	76.0 (75.8–76.3)	49.3 (48.8–49.9)	41.7 (41.1–42.3)
Decile 3	6.6 (6.4–6.8)	76.5 (76.1–76.8)	53.7 (53.0–54.4)	45.8 (45.1–46.6)
Decile 2	7.6 (7.4–7.9)	78.8 (78.4–79.2)	50.0 (49.3–50.8)	44.7 (43.9–45.5)
Decile 1 (poorest)	8.8 (8.6–9.1)	78.2 (77.8–78.6)	49.6 (48.7–50.6)	45.0 (44.0–46.0)
All	4.1 (4.0–4.1)	71.8 (71.7–71.8)	54.0 (54.0–54.1)	24.2 (24.1–24.2)

*Among patients with Severe Acute Respiratory Syndrome; **: among patients with confirmed Covid-19 diagnosis registered in the Brazilian Influenza Epidemiological Surveillance Information System (SIVEP-Gripe); ‡: among patients with biological sample collected.

deciles of municipal per capita GDP for the performance of X-ray examinations, hospitalizations in ICU beds, and the use of ventilatory support, there were marked differences in the other outcomes. The analyzed lethality was 30% higher (CI95% 28%–32%) among cases residing in municipalities with the lowest per capita GDP. Moreover, the non-collection of diagnostic samples was 3.07 (CI95% 2.96–3.17) times higher in these places; the performance of a biological exam within a period of three or more days after the onset of symptoms was 16.0% (CI95% 15%–16%) higher, always with a clear gradient of worse values as the per capita GDP decile decreased. The same phenomenon was observed in the absence of CT scans, which was 140% (CI95% 134%–145%) more common among residents of the poorest municipalities. Sensitivity analysis exploring all SARS cases showed similar results in the Poisson analysis. Only the absence of x-ray examinations (higher in the poorest decile) was different compared to the analysis including only confirmed covid-19 cases (Supplementary Tables 1, 2 and 3).

4. Discussion

The present study identified inequalities among Brazilian municipalities in lethality due to severe Covid-19, in the performance of diagnostic tests, and in hospital care. Most importantly, we found that municipalities with the lowest per capita GDP had higher lethality rates from severe Covid-19, a lower collection rate of diagnostic tests for Covid-19 among patients with SARS, a lower performance of tests within two days after the onset of symptoms, and a lower performance of CT scans.

In the Municipality of São Paulo, Brazil, in 2020, the risk of death from Covid-19 was clearly related to socioeconomic indicators, being higher among residents with lower education and income, living in crowded houses, and living in neighborhoods with greater concentrations of favelas (Ribeiro et al., 2021). The higher lethality of severe cases of Covid-19 in municipalities with lower per capita GDP has also been observed in other countries (Yoshikawa and Kawachi, 2021; Martín-Sánchez et al., 2021; Gutierrez and Bertozzi, 2020) and may be the result of the accumulation of multiple factors that negatively affect the lives of residents in these regions. Synergistically, poor living and working conditions, less access to health services, and a higher prevalence of pre-existing chronic diseases increase the probability of the greater spread of the virus, while decreasing the chance of pre- and post-exposure protection, early diagnosis, and access to medical care. In Brazil, locations with a majority of African American residents and lower levels of education and income have less access to adequate urban and residential structures (Boing et al., 2021). Furthermore, in more disadvantaged populations, there is a greater proportion of crowded households and intergenerational co-habitation (Instituto Brasileiro de Geografia e Estatística, 2021), which are important factors that can contribute to the spread of the virus to people at greater risk of death from Covid-19.

In more disadvantaged regions, there may also be an over-representation of the essential workforce and economic sectors in

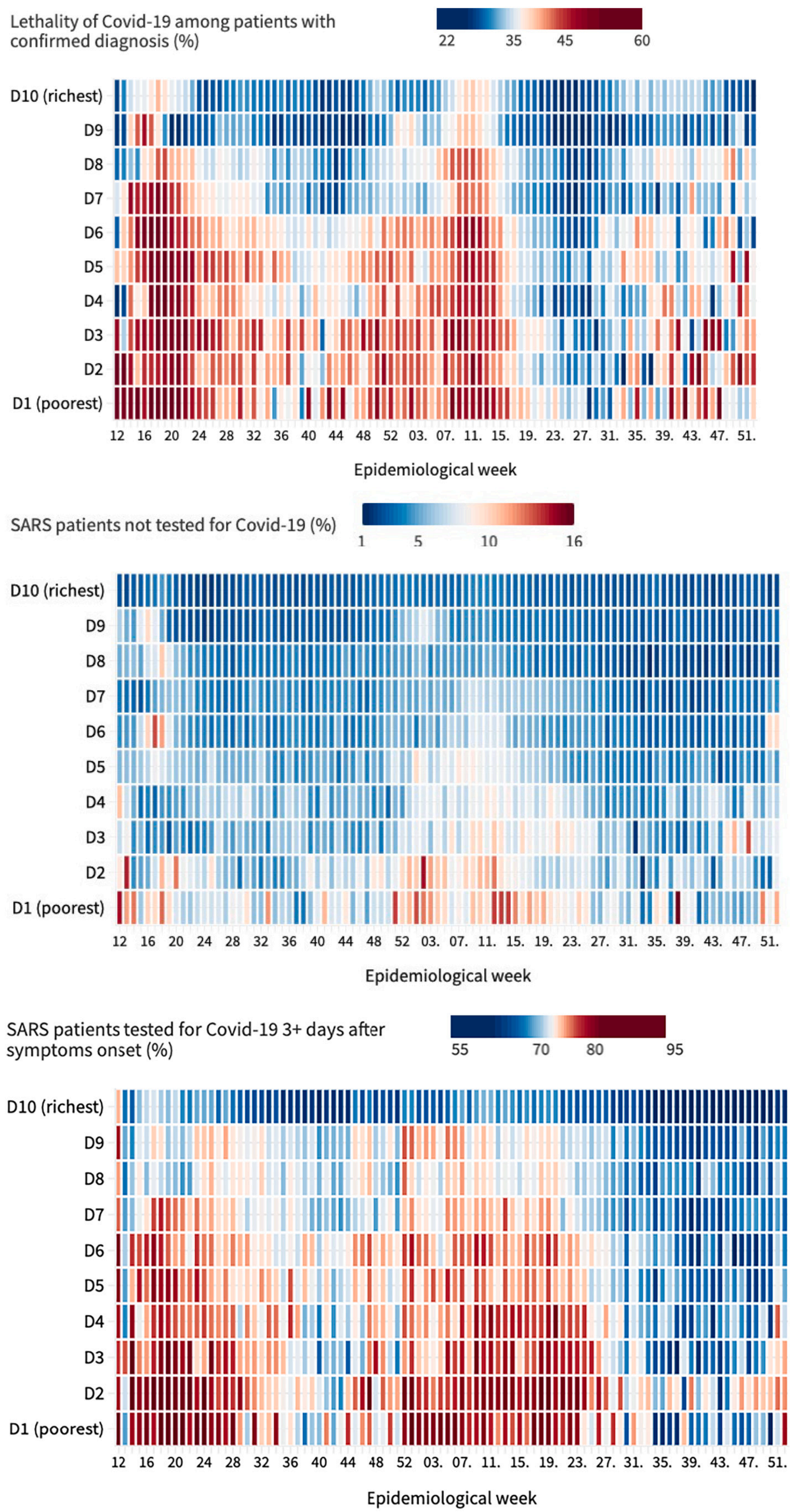

Fig. 1. Heat map of (1) lethality due to severe Covid-19 among SARS cases registered in the Brazilian Influenza Epidemiological Surveillance Information System (SIVEP-Gripe), (2) proportion of SARS patients without sample collection for testing for Covid-19 and (3) proportion of SARS patients testing for Covid-19 three days or more after onset of symptoms according to decile of Gross Domestic Product per capita of Brazilian cities and epidemiological week of symptom onset. Brazil, 2020–2021.

Table 3
Relative risk of lethality due to severe Covid-19, ICU admission, use of ventilatory support, failure to collect a diagnostic sample for Covid-19, sample collected 3+ days after symptom onset, failure to perform x-ray and computed tomography according to deciles of per capita Gross Domestic Product of Brazilian municipalities. Brazil, 2020–2021.

	Lethality due to severe Covid-19** RR ($IC_{I95\%}$)	ICU admission ** RR ($IC_{I95\%}$)	Use of ventilatory support ** RR ($IC_{I95\%}$)	No sample collection * RR ($C_{I95\%}$)	Sample collected 3+ days after symptom onset ‡ * RR ($C_{I95\%}$)	No x-ray** RR ($C_{I95\%}$)	No computed tomography ** RR ($C_{I95\%}$)
Crude analysis							
Decile 10 (richest)	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Decile 9	0.99 (0.98–0.99)	0.89 (0.89–0.90)	1.00 (1.00–1.00)	1.23 (1.21–1.25)	1.08 (1.07–1.08)	1.08 (1.07–1.08)	1.25 (1.23–1.26)
Decile 8	1.12 (1.11–1.13)	0.97 (0.96–0.98)	1.00 (1.00–1.00)	1.37 (1.34–1.40)	1.07 (1.07–1.08)	1.09 (1.08–1.09)	1.49 (1.47–1.51)
Decile 7	1.14 (1.13–1.14)	1.02 (1.02–1.03)	0.99 (0.99–0.99)	1.66 (1.63–1.69)	1.09 (1.08–1.09)	1.09 (1.09–1.10)	1.48 (1.46–1.50)
Decile 6	1.25 (1.24–1.26)	1.00 (0.99–1.00)	0.99 (0.99–1.00)	1.82 (1.78–1.86)	1.11 (1.11–1.11)	0.95 (0.94–0.96)	1.69 (1.66–1.71)
Decile 5	1.27 (1.26–1.28)	0.99 (0.98–1.00)	1.01 (1.01–1.02)	2.05 (2.00–2.10)	1.11 (1.10–1.11)	0.98 (0.97–0.99)	1.76 (1.73–1.78)
Decile 4	1.23 (1.21–1.24)	0.99 (0.98–1.00)	0.99 (0.99–1.00)	2.18 (2.12–2.24)	1.12 (1.12–1.12)	0.94 (0.93–0.95)	2.30 (2.26–2.34)
Decile 3	1.32 (1.30–1.33)	1.03 (1.02–1.04)	1.01 (1.00–1.02)	2.28 (2.21–2.36)	1.13 (1.12–1.13)	1.02 (1.01–1.02)	2.53 (2.48–2.57)
Decile 2	1.27 (1.25–1.28)	0.98 (0.96–0.99)	0.99 (0.99–1.00)	2.64 (2.55–2.72)	1.16 (1.16–1.17)	0.95 (0.94–0.96)	2.46 (2.42–2.51)
Decile 1 (poorest)	1.34 (1.32–1.36)	1.05 (1.03–1.07)	0.98 (0.98–0.99)	3.05 (2.95–3.16)	1.15 (1.14–1.16)	0.94 (0.92–0.96)	2.48 (2.42–2.54)
Adjusted analysis***							
Decile 10 (richest)	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Decile 9	1.00 (1.00–1.01)	0.90 (0.89–0.90)	1.00 (1.00–1.00)	1.22 (1.20–1.25)	1.07 (1.07–1.08)	1.07 (1.07–1.08)	1.25 (1.24–1.26)
Decile 8	1.12 (1.12–1.13)	0.97 (0.96–0.98)	1.00 (1.00–1.00)	1.37 (1.34–1.40)	1.07 (1.07–1.07)	1.08 (1.08–1.09)	1.49 (1.47–1.51)
Decile 7	1.12 (1.11–1.13)	1.02 (1.02–1.03)	0.99 (0.99–0.99)	1.66 (1.63–1.69)	1.09 (1.08–1.09)	1.09 (1.09–1.10)	1.48 (1.46–1.49)
Decile 6	1.23 (1.22–1.24)	0.99 (0.98–1.00)	0.99 (0.99–1.00)	1.82 (1.76–1.86)	1.11 (1.11–1.11)	0.95 (0.95–0.96)	1.68 (1.66–1.70)
Decile 5	1.26 (1.26–1.28)	0.99 (0.98–1.00)	1.02 (1.01–1.02)	2.05 (2.00–2.10)	1.11 (1.10–1.11)	0.98 (0.98–0.99)	1.74 (1.71–1.76)
Decile 4	1.21 (1.20–1.22)	0.98 (0.97–1.00)	0.99 (0.99–1.00)	2.18 (2.12–2.24)	1.12 (1.12–1.13)	0.94 (0.93–0.95)	2.27 (2.26–2.30)
Decile 3	1.28 (1.26–1.29)	1.02 (1.01–1.04)	1.01 (1.01–1.02)	2.29 (2.22–2.37)	1.13 (1.12–1.13)	1.03 (1.01–1.04)	2.47 (2.42–2.51)
Decile 2	1.25 (1.24–1.27)	0.97 (0.96–0.99)	1.00 (0.99–1.00)	2.64 (2.56–2.73)	1.16 (1.16–1.17)	0.96 (0.94–0.97)	2.39 (2.35–2.44)
Decile 1 (poorest)	1.30 (1.28–1.32)	1.04 (1.03–1.06)	0.99 (0.98–0.99)	3.07 (2.96–3.17)	1.16 (1.15–1.16)	0.95 (0.93–0.97)	2.40 (2.34–2.45)

*: Among patients with Severe Acute Respiratory Syndrome; **: among patients with confirmed Covid-19 diagnosis registered in the Brazilian Influenza Epidemiological Surveillance Information System (SIVEP-Gripe); ***: age adjusted; ‡: among patients with biological sample collected.

which remote work is less feasible, including that for the most vulnerable residents. Previous studies conducted during the pandemic have shown that in municipalities with lower per capita income, there was a lower proportion of people who performed physical distancing (Kavanagh et al., 2021). Such living and working conditions can increase the exposure to SARS-CoV-2, making it difficult to manage active cases.

Pre-existing medical conditions have been associated with worse outcomes from Covid-19. For example, a higher risk of death from Covid-19 has been reported in individuals with pre-existing cancer, hypertension, diabetes, heart disease, and chronic kidney disease (Ssentongo et al., 2020). Since a greater burden of chronic diseases has been found in municipalities with lower socioeconomic status (Song et al., 2020), the increased risk of severe symptoms and death from Covid-19 in more underprivileged regions can be partially attributed to the spatial distribution of pre-existing clinical conditions.

For decades, access to health services has varied substantially in Brazil depending on where people live. In less favored regions, there is less access to multiple health services, whether outpatient or in-hospital (Szwarcwald et al., 2021). Moreover, there is an unequal distribution of the health workforce at the subnational level in the country, especially among doctors and nurses (Sousa et al., 2012); in the poorest areas, there are a greater number of unskilled health professionals. Analysis of hospital lethality from Covid-19 by Brazilian states clearly indicates the important impact that the lack of doctors, especially intensivists, has on these rates (Portella et al., 2021). Additionally, even though new ICU beds have been made available, the teams' experience in case management makes a difference. In a study conducted in São Paulo comparing two ICUs in the same hospital, the one operated by newly formed teams had higher lethality than the ICU that was already functioning before COVID with a very experienced team (Sztajnbok et al., 2021).

It is also noteworthy that our study found that the Brazilian municipalities that constitute the poorest strata had less testing to identify the infectious agent in cases of SARS, a result also observed in other contexts (Lieberman-Cribbin et al., 2020). The analysis of global data indicates a negative association between the number of tests performed and lethality, but with a low impact as the number of cases increases (Hasan et al., 2021). In Brazil, a national testing plan for the identification of Covid-19 was developed late, with heterogeneous implementation in the national territory and an insufficient number of tests. Poorer municipalities may have had greater budgetary difficulties in the acquisition of additional tests and less laboratory infrastructure to process the samples. The timely identification of Covid-19 cases among SARS patients allows for more planned and controlled clinical actions. Moreover, with the diagnosis confirmed, coordinated actions between epidemiological surveillance and patients allow for the isolation of the patient cases and the tracing of their contacts, reducing the spread of the virus and the overload and collapse of the healthcare network (Pilecco et al., 2021).

The probability of using ventilatory support was slightly negatively associated with municipal per capita GDP. However, the magnitude of the difference between the deciles was small. This result was similar to that observed in Mexico (Gutierrez and Bertozzi, 2020). The same direction of association and reduced magnitude of difference were found for the use of X-ray examinations among Covid-19 cases, whereas the use of CT scans was significantly higher in the deciles with the highest per capita GDP. The use of CT scans is not recommended for the diagnosis of Covid-19 when RT-PCR tests are available, but chest imaging is suggested to guide the clinical management of moderate-to-severe cases (World Health Organization, 2021). The observed differences may be associated with different conducts of adherence to clinical protocols, variations in the physical structure and availability of professionals and equipment in hospital units according to the wealth of municipalities.

This study has limitations. There is a possibility of underreporting cases of SARS. Poor data recording in municipalities with a lower structure of health services can lead to differences in the magnitude of the observed associations. However, the registration of SARS cases in SIVEP-Gripe is mandatory for all public and private health services, and is an important and reliable source available in the country for monitoring the epidemic. The last census was conducted in Brazil in 2010, and municipal per capita GDP is one of the only updated socioeconomic measures available for all municipalities in the country since then. The lack of socioeconomic data for a period closer to the occurrence of the outcomes has prevented the exploration of other indicators in the analysis of inequalities. Given the lack of testing, especially in poorer areas, it might be possible that test was reserved to the most severe cases, which could produce a selection bias. Nonetheless, the sensitivity analysis including all SARS cases showed similar results to when only Covid-19 cases were included. We cannot compare the values observed in the present study with studies that included in their analysis mild cases or even asymptomatic patients. We did not analyze mild cases of covid-19 as they are not included in SIVEP-Gripe and are poorly registered in the country.

4.1. Public health implications

The syndemic characteristic of Covid-19 requires effective action by the government, given that its most negative outcomes are modulated by pre-existing inequalities, and considering that its repercussions on societies also amplify social injustices. Tackling the social inequalities caused and amplified by Covid-19, a phenomenon observed in both high- and low-income countries, must be on the global agenda and coordinated multilaterally. We observed that in one of the most unequal countries in the world, the locations with the lowest per capita GDP had the highest lethality and worst health care during a public health emergency. In Brazil, there needs to be national coordination and cooperation between federated entities so that equitable and effective policies can be developed and heavily financed. Moreover, continuous monitoring of Covid-19-related inequalities should be encouraged, including expanding the linkage of national and regional databases and disaggregating data to smaller geographic units.

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The authors declare no conflicts of interest and no funding specifically for this study.

CRediT authorship contribution statement

Antonio Fernando Boing: Conceptualization, Methodology, Writing – original draft, Visualization. **Alexandra Crispim Boing:** Conceptualization, Writing – review & editing. **Maria Amélia Veras:** Writing – review & editing. **Josimari Telino de Lacerda:** Writing – review & editing. **Rafael Lopes Paixão da Silva:** Writing – review & editing. **Paulo Roberto Barbato:** Writing – original draft, Writing – review & editing. **Caroline Fabrin:** Writing – review & editing. **S.V. Subramanian:** Writing – review & editing.

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ypmed.2022.107298.

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