

RESEARCH ARTICLE

Analysis of the impact of coronavirus disease 19 on hospitalization rates for chronic non-communicable diseases in Brazil

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Abstract

Background

The coronavirus disease (COVID-19) pandemic has impacted health services and health-care systems worldwide. Studies have shown that hospital admissions for causes related to chronic non-communicable diseases (NCDs) have decreased significantly during peak pandemic periods. An analysis of the impact of the COVID-19 pandemic on hospital admissions for NCDs is essential to implement disability and mortality mitigation strategies for these groups. Therefore, this study aimed to analyze the impact of the COVID-19 pandemic on hospital admissions for NCDs in Brazil according to the type of NCD, sex, age group, and region of Brazil.

Methods

This is an ecological study conducted in Brazil. Data on hospital admissions from January 1, 2017 to May 31, 2021 were extracted from the Unified Health System's Hospital Admissions Information System. The hospital admission rates per 100,000 thousand inhabitants were calculated monthly according to the type of NCD, sex, age group, and region of Brazil. Poisson regression models were used to analyze the impact of the COVID-19 pandemic on the number of hospital admissions. In this study, the pre-pandemic period was set from January 1, 2017 to February 29, 2020 and the during-pandemic from March 1, 2020 to May 31, 2021.

Results

There was a 27.0% (95.0%CI: -29.0; -25.0%) decrease in hospital admissions for NCDs after the onset of the pandemic compared to that during the pre-pandemic period.

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Decreases were found for all types of NCDs—cancer (-23.0%; 95.0%CI: -26.0; -21.0%), diabetes mellitus (-24.0%; 95.0%CI: -25.0%; -22.0%), cardiovascular diseases (-30.0%; 95.0%CI: -31.0%; -28.0%), and chronic respiratory diseases (-29.0%; 95.0%CI: -30.0%; -27.0%). In addition, there was a decrease in the number of admissions, regardless of the age group, sex, and region of Brazil. The Northern and Southern regions demonstrated the largest decrease in the percentage of hospital admissions during the pandemic period.

Conclusions

There was a decrease in the hospitalization rate for NCDs in Brazil during the COVID-19 pandemic in a scenario of social distancing measures and overload of health services.

Introduction

Brazil is the third leading country heavily impacted by the coronavirus disease (COVID-19) pandemic with respect to the number of cases, only after the United States and India. In Brazil, COVID-19 has caused high morbimortality and high costs for society in general that are leading to unprecedented social and economic impacts, aggravating socioeconomic disparities. In country, the first case and death due to COVID-19 were reported on February 26 and March 17, 2020, respectively [1]. Since then, 25,620,209 cases and 628,067 deaths due to COVID-19 have been confirmed in Brazil [1]. The high volume of COVID-19 cases across the country can be primarily attributed to the low incidence of testing, lack of adherence to isolation and social distancing measures at the federal level, and delay in the national COVID-19 vaccination campaign [2]. Moreover, novel variants of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), such as P.1. (gamma) emerging from the Brazilian Amazon and Omicron of the South Africa, have contributed to the disease's high transmissibility in the country [3, 4].

Over the course of the pandemic, most countries have adopted strategies to limit virus mobility (e.g., lockdowns) and have suspended non-essential economic activities, resulting in school and university closures. Large-scale events have been banned, and restrictions have been implemented to limit the movement of people at specific times to reduce the transmission of SARS-CoV-2 and the consequential strain on healthcare services [5–8]. Studies have shown that lockdown and social distancing measures are effective strategies for reducing the prevalence of COVID-19 and the rates of hospitalizations and mortality due to COVID-19, especially in conjunction with other preventive measures [5, 7, 9].

In Brazil, a national lockdown was not instituted by the federal government. However, measures to restrict the movement of people and suspend non-essential activities were gradually and distinctly enacted by governors and mayors of different Brazilian states and the Federal District [5, 8]. The Federal District was the first region in the country to promote social distancing immediately after the onset of the COVID-19 pandemic was declared on March 11, 2020 by suspending massive events and educational activities [5, 8]. Some municipalities implemented the blocking measures before the pandemic was declared in early March to contain the increase in cases [5, 8]. Subsequently, all Brazilian states implemented social distancing measures until the end of March 2020, including suspension of in-person events and classes, quarantine for the groups most vulnerable to serious COVID-19 outcomes, a full or partial economic standstill, transportation restrictions, or quarantine of the population [5, 8]. Most Brazilian states adopted these strategies for a period of 1–10 days after notification of the first COVID-19 case. Some areas, mainly states in the Northern and Northeastern regions, adopted these measures early

on, even before notification of the first local case. Seven states suspended all economic activities during the first 13 days after notification of the first case in these areas [5].

The literature has thoroughly evidenced that individuals with chronic non-communicable diseases (NCDs), such as cancer, diabetes mellitus, cardiovascular diseases (CVDs), and chronic respiratory diseases (CRDs), are at high risk for negative outcomes related to COVID-19, including need for hospitalization and ventilatory support and death [10, 11]. Studies have shown that the excess number of deaths among individuals with NCDs during the pandemic cannot be solely attributed to the lethality of COVID-19; adoption of social distancing strategies has also contributed to mortality in this population. Social distancing strategies have affected patient management in health services, resulting in a lower demand for access to health services, reduced number of appointments, and suspension of care activities, elective primary care, and highly complex health procedures. Additionally, overwhelming of health services by patients suspected of having COVID-19 have compromised the care and treatment of patients with NCDs, especially in low- and middle-income countries [12–17].

Studies conducted in developed and developing countries have reported a decrease in hospital admissions for causes related to NCDs, such as cancer, diabetes mellitus, CVD, and CRD during the COVID-19 pandemic [13, 16–20]. The Brazilian healthcare system, mainly the public system (Unified Health System [SUS]), was substantially affected by the COVID-19 pandemic [20]. This event occurred heterogeneously across the states and regions of the country. As observed in other countries, there was a downward trend in NCD-related hospital admissions in Brazil during the pandemic [16, 17, 20], which explains the decline in access to health services and less-than-ideal care for people with NCD-related health problems. In patients with NCDs, limited access to health services can result in increased rates of complications, disabilities, and a higher mortality, aggravating the syndemic between COVID-19 and NCDs [21–23].

Brazil is still one of the major centers of the COVID-19 pandemic, although cases have fallen significantly after vaccinations began in January 2021. Although studies have indicated that COVID-19 has resulted in reduced hospital admissions for NCDs, few national investigations have analyzed the effect of this reduction, especially according to type of the NCD, sex, age group, and region of Brazil. Additionally, few studies have compared the number of admissions during the period prior to the pandemic with that during the pandemic using models adjusted for important covariates, such as sex, age group, and potential seasonality in hospital admissions for NCDs. Thus, this study was designed to help better understand the impact of the COVID-19 pandemic on hospital admissions for NCDs in Brazil by verifying the potential effect of social distancing strategies on these individuals' access to health care. These findings may support the implementation of public policies and decision making for better management of NCDs during pandemics. This study aimed to analyze the impact of the COVID-19 pandemic on hospital admissions for NCDs in Brazil, with additional analysis according to the type of NCD, sex, age group, and region of the country to determine whether the COVID-19 pandemic had different impacts on these subgroups.

Materials and methods

Study design

This is an ecological of the impact of the COVID-19 pandemic on NCD-related hospital admissions in the Brazilian public health system (SUS).

Setting

The study was conducted in the Federal District and in the 26 states of the Brazilian federation, which are grouped into five major regions—North (seven states), Northeast (nine states), Midwest (three states and the Federal District), Southeast (three states), and South (three states).

Population

The study population included adults aged ≥ 20 years who had been hospitalized for NCD-related causes in the SUS from January 1, 2017 to May 31, 2021. NCDs were classified according to the International Statistical Classification of Diseases and Related Health Problems, Tenth Revision (CID-10), using the following codes: cancer (C00–C97), diabetes mellitus (E10–E14), CVD (I00–I99), and CRD (J30–J98). NCDs were grouped according to the recommendations of the World Health Organization and previous studies [24, 25].

The unit of analysis was the number of hospital admissions for NCD-related causes in adults, which were aggregated by month and year, sex, age group, and region of Brazil. Cases of hospital admissions with unknown data on sex and age group were excluded.

Data source

Data was retrieved from the Hospital Admissions Information System (SIH) of the SUS on August 16, 2021. This information system was used to process the production relative to hospital admissions in the SUS, and the Hospital Admission Authorization was the source document. The SIH data contain records of all admissions funded by the SUS, thus allowing us to analyze the overall utilization of health services and impact of interventions on morbimortality indicators for all causes. The SIH-SUS is one of the largest national health information systems, recording data from approximately 11.5 million hospitalizations per year [26]. We also used population data obtained from the Brazilian Institute of Geography and Statistics to extract information on resident populations [27] and project the population according to sex, age group, and region of Brazil using arithmetic interpolation.

Variables

The following indicators were calculated: (i) hospital admission rate for all types of NCDs, (ii) hospital admission rate related to cancer, (iii) hospital admission rate related to diabetes mellitus, (iv) hospital admission rate related to CVD, and (v) hospital admission rate related to CRD. These rates were estimated monthly. Admission rates for each condition were defined as the number of hospital admissions for the respective condition divided by the resident population. To calculate the number of cases per 100,000 residents, these rates were multiplied by 100,000.

The monthly number of hospital admissions for each type of NCD was the dependent variable. The following were the independent variables: (i) sex (male or female), age group (20–39 years, 30–39 years, 40–49 years, 50–59 years, 60–69 years, 70–79 years, or ≥ 80 years), (iii) region of Brazil (North, Northeast, South, Southeast, or Midwest), and a “dummy” variable of “0” for the pre-pandemic period (January 1, 2017 to February 29, 2020) and “1” for the pandemic period (March 1, 2020 to May 31, 2021). Although the first case in Brazil was reported on February 26, 2020, because of a small number of confirmed cases during the last 4 days of February 2020, we considered the onset of the pandemic period as March 1, 2020. The month of hospital admission was also used as an independent variable to control for possible seasonal variations in hospital admissions over time.

Data analysis

We used STATA, version 16.0, to analyze the data. Hospital admissions are presented as absolute numbers and rates for the total period. Rates were also provided for each month and stratified by the type of NCD, sex, age group, and region of Brazil. Furthermore, we have presented the absolute number, average number of cases, and average rate of hospital admissions per

100,000 inhabitants during the pre-pandemic (January 1, 2017 to February 29, 2020) and pandemic (March 1, 2020 to May 31, 2021) periods.

Initially, we compared the pre-pandemic and pandemic periods using Student's t-test for independent samples. Next, Poisson regression models with robust variance were applied to analyze the impact of the COVID-19 pandemic on hospitalizations for NCDs. The dependent variable included in the models was the monthly number of hospitalizations for NCDs. Each model was adjusted for sex, age group, region of Brazil, the dummy variable representing the impact of the COVID-19 pandemic ("0," pre-pandemic period; "1," pandemic period), and the month of hospitalization to control for possible seasonal variations in outcomes. The monthly population was used as the exposure variable. We also created stratified models to verify the impact of the pandemic on subgroups according to sex, age group, and region of Brazil. The results of the models are presented as incidence rate ratio (IRR), 95.0% confidence interval (95.0% CI), and regression coefficient. P-values <0.05 were considered statistically significant.

In our study, we used a Poisson regression model with robust variance as used in other studies that evaluated the impact of the COVID-19 pandemic on hospital admissions [28–31]. As mentioned, this model allowed including gender, age group, region of Brazil, the dummy variable representing the impact of the COVID-19 pandemic ("0," pre-pandemic period; "1," pandemic period) and the month of admission to control for possible seasonal variations as dependent variables. Studies show that the Poisson regression model is more suitable for time series count data when compared to the classical interrupted time series (ITS) model [32]. In addition, comparative analysis showed similar results between this model and the ITS in the analysis of interventions [18]. This model was also used instead of the negative binomial model since the data for all outcomes are not overdispersed. All assumptions of the Poisson model were met: (i) dependent variable—count per unit of time and/or space; (ii) observations independent of each other; (iii) the distribution of counts follows a Poisson distribution; (iii) model mean and variance are similar, without overdispersion. Overdispersion was analyzed for all dependent variables by Person Chi-Square for dispersion (p-values of the models ranged from 0.99 to 1.04, indicating the absence of overdispersion) [33].

Ethical considerations

The data used in this study are available in anonymized secondary and public databases, preventing identification of participants and other sensitive variables. Thus, the requirement for ethical approval and informed consent was waived for this study, in compliance with Resolution 510/16 of the National Health Council of the Ministry of Health.

Results

From January 1, 2017 to May 31, 2021, there were 9,504,213 hospital admissions for NCD-related causes in Brazil—4,650,367 (48.9%) were related to CVD, 3,261,659 (34.3%) were related to cancer, 1,068,633 (11.2%) were related to CRD, and 523,554 (5.5%) were related to diabetes mellitus. The monthly average number of admissions for NCD-related causes for the total period was 179,324.8. The means for each specific NCD were as follows: 87,742.8 for CVD, 61,540.7 for cancer, 20,162.9 for CRD, and 9,878.4 for diabetes mellitus.

There was a decrease in the mean hospitalization rate for NCDs after the onset of the pandemic in March 2020 (Fig 1 and Table 1). There was a 27.8% decrease in the average hospital admission rate for all NCDs, which decreased from 261.8 (pre-pandemic period) to 189.1 cases per 100,000 inhabitants (pandemic period). In addition, the mean hospital admission rates for all the types of NCD decreased—cancer (72.0 vs. 55.6 cases per 100,000 inhabitants; 22.0% decrease), diabetes mellitus (14.0 vs. 10.0 cases per 100,000 inhabitants; 28.6% decrease),

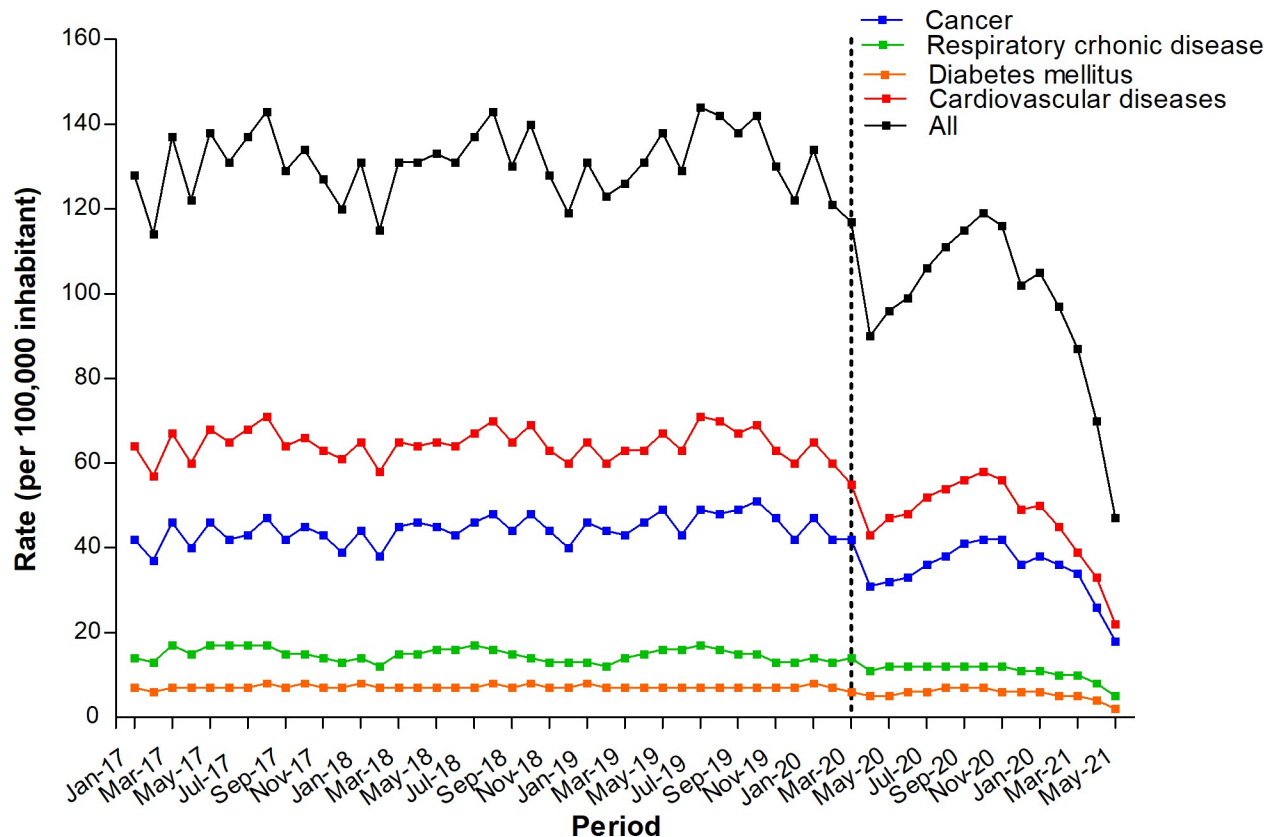


Fig 1. Hospital admission rate for chronic non-communicable diseases (NCDs) in Brazil according to the type of NCD. Pre-pandemic period: January 1, 2017 to February 29, 2020; Pandemic period: March 1, 2020 to May 31, 2021.

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CVD (141.6 vs. 100.0 cases per 100,000 inhabitants; 29.4% decrease), and CRD (34.2 vs. 23.2 cases per 100,000 inhabitants; 32.2% decrease) (Table 1).

Furthermore, stratified analysis revealed a decrease in the mean hospital admission rate for NCDs during the pandemic period, regardless of sex (Fig 2 and Table 2). There was a 26.0% decrease in the mean hospital admission rate for male patients for all NCDs, which decreased from 291.0 (pre-pandemic period) to 215.3 cases per 100,000 inhabitants (pandemic period). There was a 30.0% decrease in the mean hospital admission rate for female patients for all NCDs (pre-pandemic period vs. pandemic period: 235.8 vs. 162.8 cases per 100,000 inhabitants). We also verified a significant decline in hospital admission rates for cancer, diabetes mellitus, CVD, and CRD, regardless of sex, during the pandemic period (Table 2).

There was a decrease in the average hospital admission rate for all types of NCD during the pandemic period from the pre-pandemic period, regardless of age group (Fig 3 and Table 3)—20–39 years (from 31.7 to 22.9 cases per 100,000 inhabitants; 27.8% decrease), 40–49 years (from 90.6 to 64.2 cases per 100,000 inhabitants; 29.0% decrease), 50–59 years (from 167.1 to 125.5 cases per 100,000 inhabitants; 24.9% decrease), 60–69 years (from 308.7 to 230.0 cases per 100,000 inhabitants; 25.4% decrease), 70–79 years (from 478.3 to 342.9 cases per 100,000 inhabitants; 28.2% decrease), and ≥ 80 years (from 724.4 to 515.0 cases per 100,000 inhabitants; 28.7% decrease) (Table 3).

In addition, there was a decrease in the average hospital admission rate for all types of NCD during the pandemic period from the pre-pandemic period, regardless of region of Brazil (Fig 4 and Table 4)—North (from 233.2 to 149.1 cases per 100,000 inhabitants; 36.1% decrease),

Table 1. Hospital admissions for chronic non-communicable diseases (NCDs) in Brazil before and after the onset of the coronavirus disease pandemic according to the type of NCD.

Variables	Pre-pandemic		Pandemic		Δ - % (95.0%CI)	p-value*
	Mean	95.0% CI	Mean	95.0% CI		
Cancer						
All cases, sum	2,471,199		790,460			
Cases	4,645	4,407–4,883	3,764	3,445–4,083	-19.0(-21.8;-16.4)	<0.001
Rate (per 100,000)	72.0	67.4–76.6	55.6	49.6–61.5	-22.0(-26.4;-19.7)	<0.001
Diabetes mellitus						
All cases, sum	396,927		126,627			
Cases	746	711–781	603	554–652	-19.2(-22.1;-16.5)	<0.001
Rate (per 100,000)	14.0	12.9–15.0	10.0	8.9–11.4	-28.6(-31.0;-24.0)	<0.001
Cardiovascular diseases						
All cases, sum	3,587,156		1,063,211			
Cases	6,742	6,414–7,070	5,062	4,615–5,510	-24.9(-28.0;-22.1)	<0.001
Rate (per 100,000)	141.6	129.0–154.2	100.0	85.3–115.1	-29.4(-33.9;-25.4)	<0.001
Chronic respiratory disease						
All cases, sum	823,239		245,394			
Cases	1547	1,498–1,596	1,168	1,103–1,233	-24.5(-26.4;-22.7)	<0.001
Rate (per 100,000)	34.2	30.7–37.6	23.2	19.5–26.9	-32.2(-36.5;-28.5)	<0.001
All types						
All cases, sum	7,278,521		2,225,692			
Cases	13,681	13,096–14,266	10,598	9,785–11,411	-22.5(-25.3;-20.0)	<0.001
Rate (per 100,000)	261.8	240.6–283.0	189.1	164.9–214.2	-27.8(-31.5;-24.3)	<0.001

Note: The mean number and rate of hospital admissions were compared between the pre-pandemic (January 1, 2017 to February 29, 2020) and pandemic (March 1, 2020 to May 31, 2021) periods.

95.0% CI = 95.0% confidence interval; *Student’s t-test for independent samples.

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Midwest (from 259.6 to 118.7 cases per 100,000 inhabitants; 27.1% decrease), Northeast (from 254.34 to 178.0 cases per 100,000 inhabitants; 30.0% decrease), South (from 360.3 to 251.7

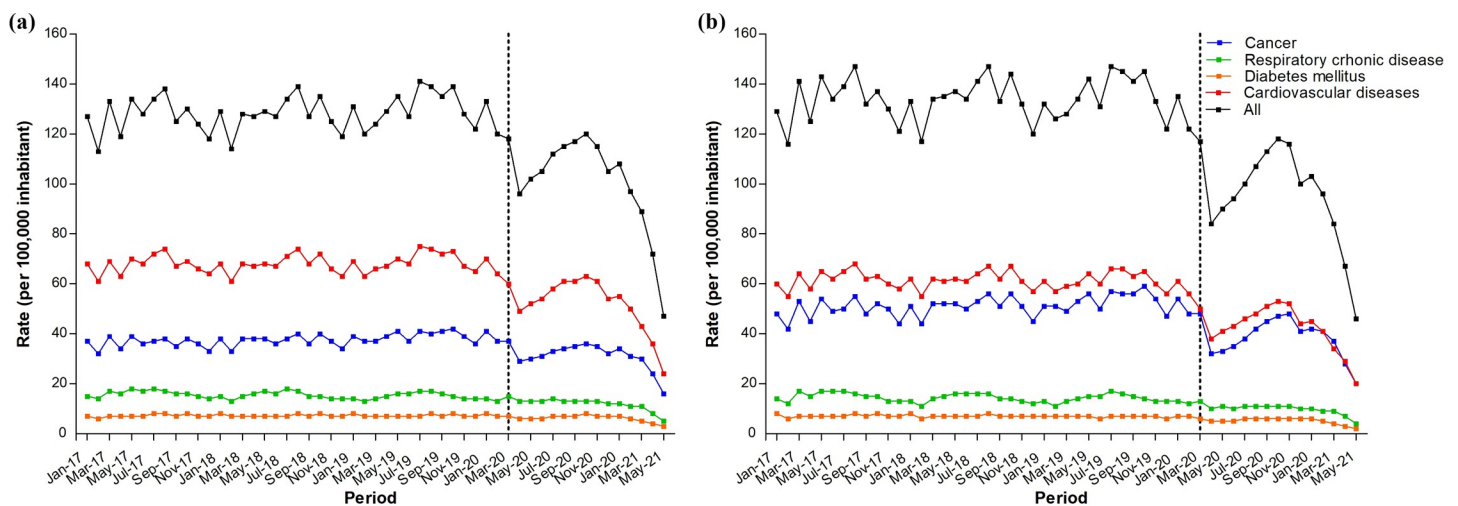


Fig 2. Hospital admission rate for chronic non-communicable diseases (NCDs) in Brazil according to the type of NCD and sex: (a) male and (b) female. Pre-pandemic period: January 1, 2017 to February 29, 2020; Pandemic period: March 1, 2020 to May 31, 2021.

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Table 2. Hospital admissions for chronic non-communicable diseases (NCDs) in Brazil before and after the onset of the coronavirus disease pandemic according to the type of NCD and sex.

Variables	Male						Female					
	Pre-pandemic		Pandemic		Δ - % (95.0% CI)	p-value*	Pre-pandemic		Pandemic		Δ - % (95.0% CI)	p-value*
	Mean	95.0% CI	Mean	95.0% CI			Mean	95.0% CI	Mean	95.0% CI		
Cancer												
All cases, sum	1,014,437		342,700				1,456,762		447,760			
Cases	3,814	3,519–4,108	3,263	2,834–3,692	-14.4 (-19.5; -10.3)	0.046	5,476	5,129–5,823	4,264	3,806–4,722	-22.1(-25.8; -18.9)	<0.001
Rate (per 100,000)	76.7	68.5–85.0	60.5	49.9–71.0	-21.1 (-27.2; -16.5)	0.029	67.3	62.2–71.4	50.7	45.1–56.2	-24.7(-27.5; -21.3)	<0.001
Diabetes mellitus												
All cases, sum	197,751		67,607				199,176		59,020			
Cases	743	689–797	644	561–726	-13.3 (-18.7; -8.9)	0.051	748	703–793	562	506–617	-24.9(-28.0; -22.2)	<0.001
Rate (per 100,000)	14.8	13.2–16.4	11.4	9.5–13.4	-23.0 (-28.0; -18.3)	0.018	13.1	11.7–14.6	8.8	7.2–10.3	-32.8(-38.5; -29.4)	<0.001
Cardiovascular diseases												
All cases, sum	1,838,911		572,657				1,748,245		490,554			
Cases	6,913	6,383–7,443	5,454	4,723–6,184	-21.1(-26.0; -16.9)	0.003	6,472	6,183–6,961	4,671	4,153–5,190	-27.8(-32.8; -25.5)	<0.001
Rate (per 100,000)	160.2	140.3–180.0	116.0	92.4–139.6	-27.6(-34.1; -22.5)	0.012	123.0	107.9–138.2	84.4	66.4–102.3	-31.8(-38.5; -25.9)	0.005
Chronic respiratory diseases												
All cases, sum	416,916		131,032				406,323		114,362			
Cases	1,567	1,491–1,639	1,247	1,149–1,346	-20.4(-22.9; -17.9)	<0.001	1,527	1,461–1,593	1,089	1,003–1,174	-28.7(-31.4; -26.3)	<0.001
Rate (per 100,000)	39.4	33.7–45.1	27.3	21.1–33.5	-30.7(-37.4; -25.7)	<0.001	29.0	25.1–32.8	19.1	15.0–23.1	-34.1(-40.2; -29.6)	0.003
All types												
All cases, sum	3,468,015		1,113,996				3,810,506		1,111,696			
Cases	13,037	12,102–13,972	10,609	9,285–11,933	-18.6(-23.3; -14.6)	0.005	14,325	13,625–15,024	10,587	9,619–11,555	-26.1(-29.4; -23.1)	<0.001
Rate (per 100,000)	291.0	256.2–326.0	215.3	173.5–257.0	-26.0(-32.3; -21.2)	0.016	232.5	208.6–256.3	162.8	134.7–190.2	-30.0(-35.4; -25.8)	<0.001

Note: The mean number and rate of hospital admissions were compared between the pre-pandemic (January 1, 2017 to February 29, 2020) and pandemic (March 1, 2020 to May 31, 2021) periods. 95.0% CI = 95.0% confidence interval; *Student’s t-test for independent samples.

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cases per 100,000 inhabitants; 30.1% decrease), and Southeast (from 253.6 to 177.6 cases per 100,000 inhabitants; 24.6% decrease) (Table 4).

Table 5 presents results of the Poisson multiple regression models adjusted for sex, age group, region of Brazil, month, and the dummy variable indicating the impact of the pandemic. Compared to the pre-pandemic period, there were significant decreases in admissions related to cancer (-23.0%; 95.0%CI: -26.0; -21.0%), diabetes mellitus (-24.0%; 95.0%CI: -25.0%; -22.0%), cardiovascular diseases (-30.0%; 95.0%CI: -31.0%; -28.0%), and chronic respiratory diseases (-29.0%; 95.0%CI: -30.0%; -27.0%). Considering all types of NCDs, there was a 27.0% decline (95.0% CI = -29.0%; -25.0%) in NCD-related hospital admissions after the onset of the COVID-19 pandemic. There was a greater decrease in CRD-related hospital admissions than in cancer-related (29.0% vs. 23.0%) and diabetes mellitus-related (29.0% vs. 24.0%) hospital admissions during the pandemic period from the pre-pandemic period. There was an even

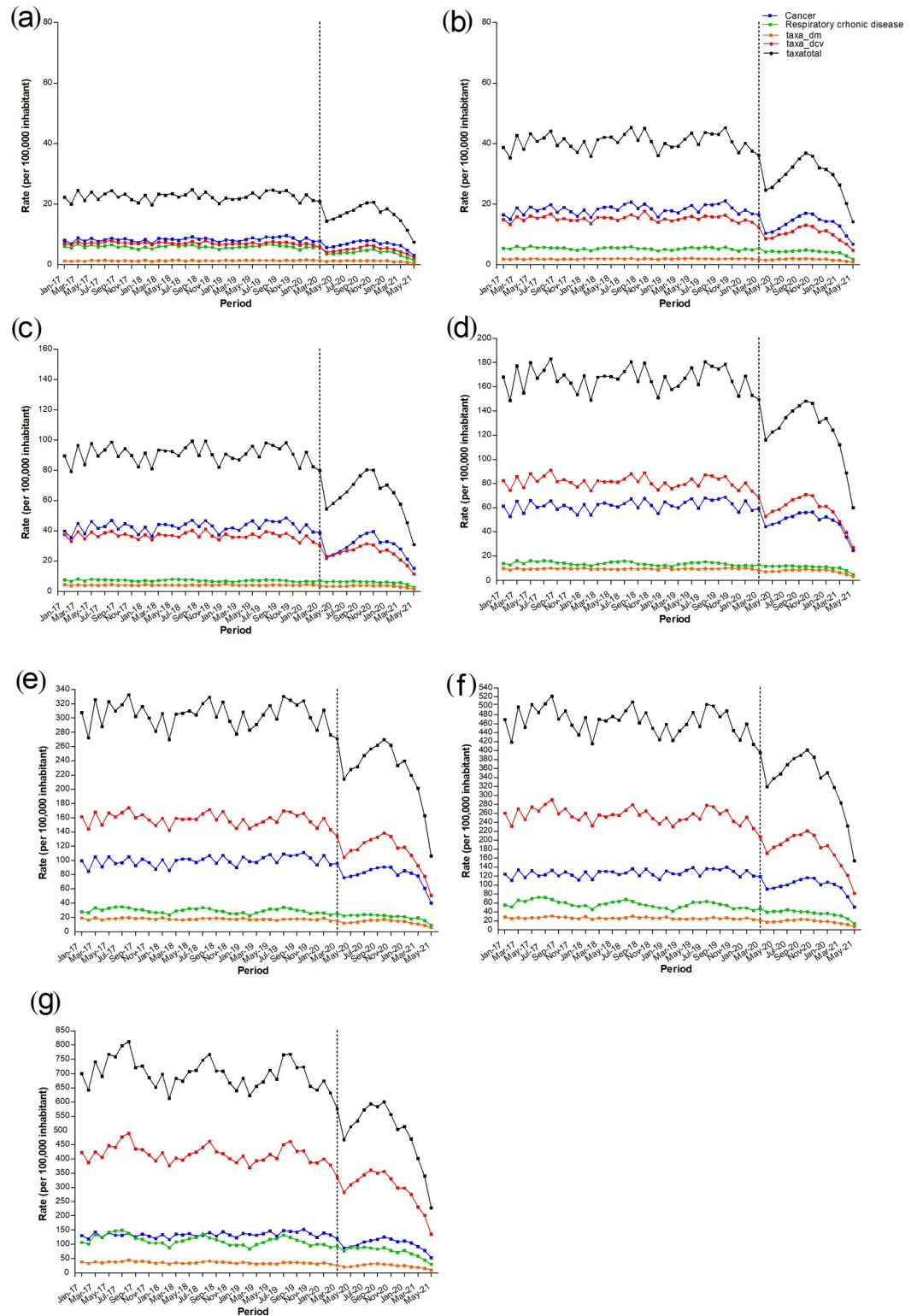


Fig 3. Hospital admission rate for chronic non-communicable diseases (NCDs) in Brazil according to the type of NCD and age group: (a) 20–29 years, (b) 30–39 years, (c) 40–49 years, (d) 50–59 years, (e) 60–69 years and (f) 70–79 years and (g) ≥ 80 years. Pre-pandemic period: January 1, 2017 to February 29, 2020; Pandemic period: March 1, 2020 to May 31, 2021.

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Table 3. Hospital admissions for chronic non-communicable diseases (NCDs) in Brazil before and after the onset of the coronavirus disease pandemic according to the type of NCD and age group.

Variables	20–39 years					40–49 years					50–59 years					
	Pre-pandemic		Pandemic		P-value*	Pre-pandemic		Pandemic		P-value*	Pre-pandemic		Pandemic		P-value*	Δ - % (95.0% CI)
	Mean	95.0% CI	Mean	95.0% CI		Mean	95.0% CI	Mean	95.0% CI		Mean	95.0% CI	Mean	95.0% CI		
Cancer																
All cases, sum	345,809	102,803				459,399	132,799				541,058	174,058				
Cases	2,275	2,035–2,514	1,713	1,434–1,999	0.009	6,044	5,256–6,833	4,426	3,484–5,368	0.021	7,119	6,788–7,449	5,801	5,272–6,330	-18.5 (-22.3; -15.0)	<0.001
Rate (per 100,000)	13.3	11.9–14.7	10.0	8.4–11.6	0.008	42.5	37.0–47.9	29.8	23.5–36.0	0.009	61.7	59.3–64.0	48.4	44.4–52.5	-21.6 (-25.1; -17.9)	<0.001
Diabetes mellitus																
All cases, sum	41,955	14,490				44,496	15,027				83,697	27,205				
Cases	276	265–286	242	222–260	<0.001	585	571–599	500	458–543	<0.001	1,101	1,070–1,132	906	811–1,002	-17.7 (-24.2; -11.5)	<0.001
Rate (per 100,000)	1.6	1.6–1.7	1.4	1.3–1.5	<0.001	4.2	4.0–4.3	3.4	3.0–3.7	<0.001	9.6	9.3–10.0	7.7	6.8–8.5	-19.8 (-26.9; -15.0)	<0.001
Cardiovascular diseases																
All cases, sum	290,884	76,870				110,879					710,289	207,358				
Cases	1,913	1,788–2,039	1,281	1,137–1,425	<0.001	5,193	5,085–5,301	3,695	3,397–3,994	<0.001	9,345	9,121–9,570	6,911	6,213–7,610	-26.1 (-31.9; -20.5)	<0.001
Rate (per 100,000)	11.2	10.5–11.9	7.5	6.4–8.3	<0.001	36.8	36.1–37.4	25.1	23.0–27.1	<0.001	81.8	79.2–84.4	58.4	52.0–64.9	-28.6 (-34.4; -23.1)	<0.001
Chronic respiratory diseases																
All cases, sum	146,322	41,541				26,192					121,697	38,810				
Cases	962	948–977	692	646–738	<0.001	1013	995–1,030	873	805–940	<0.001	1601	1,565–1,637	1293	1,196–1,391	-19.2 (-23.6; -15.0)	<0.001
Rate (per 100,000)	5.6	5.5–5.7	4.0	3.8–4.3	<0.001	7.2	7.1–7.3	5.9	5.4–6.4	<0.001	14.1	13.6–14.3	10.9	10.0–11.8	-22.7 (-26.5; -17.5)	<0.001
All types																
All cases, sum	824,970	235,704				975,607	284,897				1,456,741	447,431				
Cases	5,327	5,070–5,783	3,928	3,498–4,357	<0.001	12,836	11,962–13,710	9,496	8,416–10,576	<0.001	19,167	18,888–19,446	14,914	13,839–15,988	-22.2 (-26.7; -17.8)	<0.001
Rate (per 100,000)	31.7	29.6–33.8	22.9	20.4–25.4	<0.001	90.6	84.7–96.4	64.2	57.1–71.2	<0.001	167.1	164.8–169.4	125.5	115.9–135.0	-24.9 (-29.7; -20.3)	<0.001

(Continued)

Table 3. (Continued)

Variables	60–69 years				70–79 years				≥80 years					
	Pre-pandemic		Pandemic		P-value*	Pre-pandemic		Pandemic		P-value*	Pre-pandemic		Pandemic	
	Mean	95.0% CI	Mean	95.0% CI		Mean	95.0% CI	Mean	95.0% CI		Mean	95.0% CI	Mean	95.0% CI
Cancer														
All cases, sum	584,197		199,633			380,666		128,898			160,070		52,269	
Cases	7,686	7,525–7,848	6,654	6,226–7,082	<0.001	5,008	4,859–5,158	4,296	3,967–4,626	<0.001	2,106	2,061–2,150	1,742	1,621–1,863
Rate (per 100,000)	100.6	97.7–103.5	80.5	74.3–86.7	<0.001	130.5	123.4–137.6	101.8	90.3–113.2	<0.001	142.5	133.8–151.2	108.4	95.1–121.7
diabetes mellitus														
All cases, sum	104,519		33,587			79,643		23,971			42,617		12,347	
Cases	1,375	1,348–1,401	1,119	1,008–1,230	<0.001	1,047	1,023–1,072	799	729–868	<0.001	560	531–590	411	365–457
Rate (per 100,000)	18.0	17.5–18.6	13.6	12.0–15.2	<0.001	26.7	26.1–27.3	18.7	16.0–20.7	<0.001	35.9	35.1–36.8	24.5	22.1–26.9
Cardiovascular diseases														
All cases, sum	925,606		281,820			768,922		234,726			496,750		151,558	
Cases	12,179	11,786–12,571	9,394	8,440–10,347	<0.001	10,117	9,929–10,305	7,824	7,187–8,460	<0.001	6,536	6,327–6,744	5,051	4,603–5,500
Rate (per 100,000)	160.5	153.0–168.0	114.7	100.8–128.6	<0.001	262.3	250.7–273.9	184.5	164.1–205.1	<0.001	427.4	414.9–439.9	303.6	276.2–331.1
Chronic respiratory diseases														
All cases, sum	171,419		52,414			171,717		48,079			135,077		38,358	
Cases	2,255	2,194–2,316	1,747	1,606–1,887	<0.001	2,259	2,190–2,328	1,602	1,463–1,741	<0.001	1,777	1,720–1,834	1,278	1,167–1,389
Rate (per 100,000)	29.6	28.5–30.7	21.2	19.1–23.3	<0.001	58.7	55.6–61.8	37.8	33.4–42.2	<0.001	118.5	112.1–124.9	78.4	69.1–87.7
All types														
All cases, sum	1,785,741		567,454			1,400,948		435,674			834,514		254,532	
Cases	23,496	22,920–24,072	18,915	17,334–20,496	<0.001	18,433	18,068–18,798	14,522	13,384–15,660	<0.001	10,980	10,705–11,255	8,484	7,806–9,162
Rate (per 100,000)	308.7	297.1–320.4	230.0	206.6–253.5	<0.001	478.3	456.5–500.1	342.9	305.2–380.6	<0.001	724.4	697.6–751.3	515.0	464.7–565.3

Note: The mean number and rate of hospital admissions were compared between the pre-pandemic (January 1, 2017 to February 29, 2020) and pandemic (March 1, 2020 to May 31, 2021) periods. 95.0% CI = 95.0% confidence interval; * Student's t-test for independent samples.

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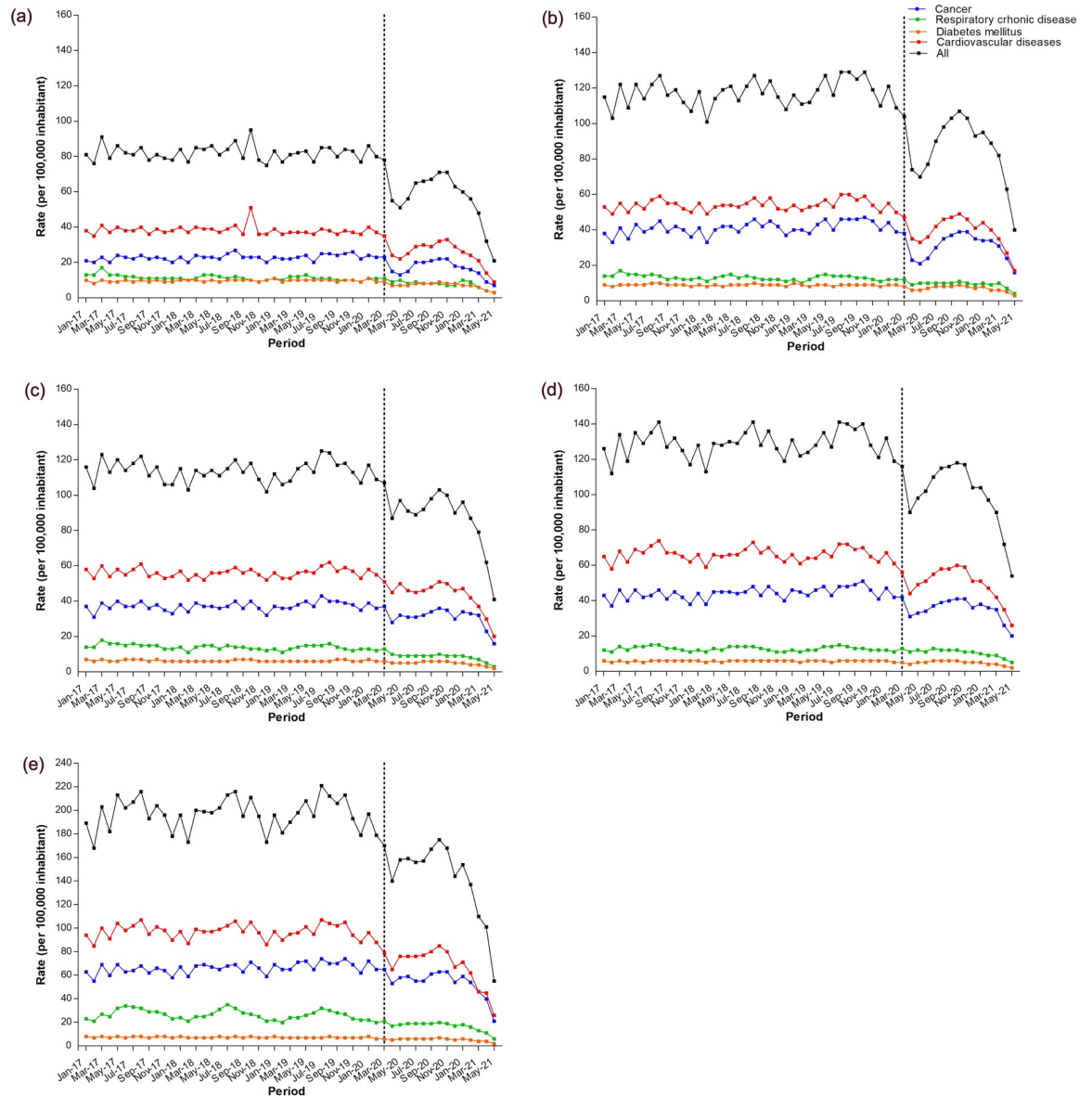


Fig 4. Hospital admission rate for chronic non-communicable diseases (NCDs) in Brazil according to the type of NCD and region of Brazil: (a) North, (b) Northeast, (c) Midwest, (d) Southeast, and (e) South. Pre-pandemic period: January 1, 2017 to February 29, 2020; Pandemic period: March 1, 2020 to May 31, 2021.

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greater decline in CVD-related hospital admissions than in cancer-related (30.0% vs. 23.0%) and diabetes mellitus-related (30.0% vs. 24.0%) hospital admissions during the pandemic period from the pre-pandemic period.

Table 6 presents the results of analyses stratified by sex, age group, and region of Brazil for hospital admissions. There was a decline in the number of hospital admissions, regardless of age group, sex, and region of Brazil (Table 6). Similar results were verified for causes related to cancer (Table 7), diabetes mellitus (Table 8), CVD (Table 9), and CRD (Table 10). In addition, there was a greater decrease for most of causes related to NCDs in the Northern and Southern regions of the country than in other regions (Tables 6–10).

Table 4. Hospital admissions for chronic non-communicable diseases (NCDs) in Brazil before and after the onset of the coronavirus disease pandemic according to the type of NCD and region of Brazil.

Variables	North						Midwest											
	Pre-pandemic		Pandemic		Δ - % (95.0%CI)	p-value*	Pre-pandemic		Pandemic		Δ - % (95.0%CI)	p-value*						
	Mean	95.0% CI	Mean	95.0% CI			Mean	95.0% CI										
Cancer																		
All cases, sum	98,620		29,741				159,107		54,498									
Cases	185	172-197	141	125-157	-23.8(-27.3; -20.3)	<0.001	1,130	1,065-1,196	867	786-948	-23.4(-26.2; -20.7)	<0.001						
Rate (per 100,000)	40.8	38.2-43.3	28.9	25.8-32.1	-29.2(-32.5; -25.9)	<0.001	65.3	61.3-69.2	48.3	43.4-53.3	-26.0(-29.2; -22.9)	<0.001						
Diabetes mellitus																		
All cases, sum	41,296		12,630				26,867		8,307									
Cases	77	73-81	60	54-65	-22.1(-26.0; -19.7)	<0.001	242	230-254	190	175-206	-21.5(-23.9; -18.9)	<0.001						
Rate (per 100,000)	26.8	24.5-29.0	18.1	15.6-20.5	-32.5(-36.3; -29.3)	<0.001	20.7	18.9-22.5	14.5	12.5-16.6	-30.0(-33.9; -26.2)	<0.001						
Cardiovascular diseases																		
All cases, sum	163,891		45,477				239,092		76,571									
Cases	308	294-321	216	198-235	-29.8(-32.6; -26.8)	<0.001	1,484	1,418-1,550	1,101	1,011-1,190	-25.8(-28.7; -23.3)	<0.001						
Rate (per 100,000)	128.9	115.4-142.4	79.3	65.8-92.9	-38.5(-42.9; -34.8)	<0.001	135.7	122.6-148.7	93.0	78.4-107.5	-31.5(-30.0; -27.7)	<0.001						
Chronic respiratory diseases																		
All cases, sum	48,626		14,043				59,518		15,151									
Cases	91	89-93	66	63-70	-27.5(-29.2; -24.7)	<0.001	358	349-367	270	258-282	-24.6(-26.1; -23.2)	<0.001						
Rate (per 100,000)	36.8	32.6-41.0	22.7	18.6-27.0	-38.2(-42.9; -34.1)	<0.001	32.8	29.3-36.2	22.2	18.5-25.9	-32.3(-36.9; -28.4)	<0.001						
All types																		
All cases, sum	352,433		101,891				484,384		154,527									
Cases	662	638-685	485	451-519	-26.7(-29.3; -24.2)	<0.001	910	873-947	735	682-788	-19.2(-21.9; -16.8)	<0.001						
Rate (per 100,000)	233.2	211.4-255.1	149.1	126.6-171.6	-36.1(-40.1; -32.7)	<0.001	259.6	237.5-281.6	188.7	162.4-215.0	-27.1(-31.6; -23.6)	<0.001						
Variables	Northeast						South						Southeast					
	Pre-pandemic		Pandemic		Δ - % (95.0% CI)	p-value*	Pre-pandemic		Pandemic		Δ - % (95.0% CI)	p-value*	Pre-pandemic		Pandemic		Δ - % (95.0% CI)	p-value*
	Mean	95.0% CI	Mean	95.0% CI			Mean	95.0% CI	Mean	95.0% CI			Mean	95.0% CI	Mean	95.0% CI		
Cancer																		
All cases, sum	601,667		182,129				545,857		179,695				1,065,948		344,397			
Cases	1,130	1,065-1,196	867	786-948	-23.3(-26.2; -20.8)	<0.001	1026	973-1,079	855	779-932	-16.7(-19.9; -13.6)	<0.001	2003	1,899-2,107	1,639	1,498-1,780	-18.2(-21.1; -15.5)	<0.001
Rate (per 100,000)	65.3	61.3-69.2	48.3	43.4-53.3	-26.0(-29.2; -22.9)	<0.001	101.7	95.2-108.4	80.4	71.6-89.2	-20.9(-24.8; -17.7)	<0.001	69.5	64.9-74.0	53.9	48.0-59.7	-22.4(-26.0; -19.3)	<0.001
Diabetes mellitus																		
All cases, sum	129,187		40,093				60,540		18,113				139,037		47,484			
Cases	242	230-254	190	175-206	-21.5(-23.9; -18.9)	<0.001	113	108-119	86	79-93	-23.9(-26.8; -21.8)	<0.001	261	248-273	226	206-245	-13.4(-16.9; -10.2)	0.003
Rate (per 100,000)	20.7	18.9-22.5	14.5	12.5-16.6	-30.0(-33.9; -22.2)	<0.001	12.8	11.8-13.7	8.7	7.7-9.8	-32.0(-34.7; -28.5)	<0.001	9.7	9.1-10.4	7.7	6.7-8.6	-20.6(-26.4; -17.3)	0.001

(Continued)

Table 4. (Continued)

Cardiovascular diseases													
All cases, sum	789,764	231,271											
Cases	1,484 1,418– 1,550	1,101 1,011– 1,190											
Rate (per 100,000)	135.7 122.6– 148.7	93.0 78.4– 107.5											
Chronic respiratory diseases													
All cases, sum	190,591	56,790											
Cases	358 349– 367	270 258– 282											
Rate (per 100,000)	32.8 29.3– 36.2	22.2 18.5– 25.9											
All types													
All cases, sum	1,711,209	510,283											
Cases	3,216 3,097– 3,335	2,429 2,264– 2,595											
Rate (per 100,000)	254.4 232.8– 276.0	178.0 153.6– 202.6											

Note: The mean number and rate of hospital admissions were compared between the pre-pandemic (January 1, 2017 to February 29, 2020) and pandemic (March 1, 2020 to May 31, 2021) periods. 95.0% CI = 95.0% confidence interval; * Student's t-test for independent samples.

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Table 5. Poisson multiple regression models of the impact of the coronavirus disease pandemic on hospital admissions for chronic non-communicable diseases (NCDs) in Brazil according to the type of NCDs.

Type of NCDs	IRR	95.0% CI	β	p-value*
Cancer				
Pre-pandemic	Reference			
Pandemic	0.77	0.74–0.79	-0.265	<0.001
Chronic respiratory diseases				
Pre-pandemic	Reference			
Pandemic	0.71	0.70–0.73	-0.342	<0.001
Diabetes mellitus				
Pre-pandemic	Reference			
Pandemic	0.76	0.74–0.78	-0.276	<0.001
Cardiovascular diseases				
Pre-pandemic	Reference			
Pandemic	0.70	0.69–0.72	-0.341	<0.001
All types of NCD				
Pre-pandemic	Reference			
Pandemic	0.73	0.71–0.75	-0.316	<0.001

Note: Each Poisson multiple regression model was adjusted for sex, age group, region of Brazil, month, and the dummy variable indicating the impact of the pandemic. The resident population was included as an exposure variable. Pre-pandemic period: January 1, 2017 to February 29, 2020; Pandemic period: March 1, 2020 to May 31, 2021. IRR = incidence rate ratio; 95.0% CI = 95.0% confidence interval; β = regression coefficient; *Wald statistic.

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Discussion

This study analyzed the impact of the COVID-19 pandemic on the hospitalization rate for NCDs in Brazil, stratified according to the type of NCDs, sex, age group, and region of Brazil. We found a significant decrease in the number of hospital admissions for all types of NCD after the onset of the COVID-19 pandemic, regardless of sex, age group, and region of Brazil. We also observed the largest declines in NCD-related hospital admissions in the North and South after the onset of the pandemic.

Similar studies conducted in both developing and developed countries have also reported a decrease in the number of hospitalizations for chronic conditions after the onset of the COVID-19 pandemic [13, 17–20, 34, 35]. An investigation conducted in four hospitals in New York, an epicenter of the COVID-19 pandemic in the United States, showed that weekly hospitalizations increased by 144.0% at the peak of the pandemic, while a decrease was observed in hospitalizations for exacerbations of chronic conditions such as heart failure and chronic obstructive pulmonary disease (COPD) [34]. Another study conducted in the United States that included data from 201 hospitals in 36 states found a decline in hospital admissions for diabetes (35.8% decrease), congestive heart failure (43.8% decrease), COPD or asthma (61.6% decrease), and other chronic conditions during the pandemic period (April 2020) compared to those during the pre-pandemic period [13]. In Alberta, Canada, an investigation showed a decrease in emergency admissions related to chronic conditions during the pandemic period—diabetes mellitus (21.0% decrease), COPD (25.0% decrease), and arterial hypertension (29.0% decrease) [18]. A study in Hong Kong, China, estimated a 44.0% decrease in the number of hospital admissions related to COPD [19].

Other studies in Brazil have also reported similar results [16, 17, 20, 35, 36]. In a national survey using SIH-SUS data, hospital admission rates for clinical cancer decreased from 13.9 to

Table 6. Poisson multiple regression models of the impact of the coronavirus disease pandemic on the hospitalization rate for all types of chronic non-communicable diseases in Brazil according to subgroups by age group, sex, and region of Brazil.

Variables	IRR	95.0% CI	β	p-value*
Age group (years)				
20–39	0.72	0.68–0.77	-0.322	<0.001
40–49	0.70	0.68–0.74	-0.344	<0.001
50–59	0.75	0.72–0.78	-0.286	<0.001
60–69	0.74	0.72–0.77	-0.296	<0.001
70–79	0.71	0.69–0.74	-0.336	<0.001
≥80	0.70	0.68–0.74	-0.346	<0.001
Sex				
Female	0.76	0.74–0.78	-0.272	<0.001
Male	0.70	0.68–0.72	-0.359	<0.001
Region of Brazil				
North	0.68	0.64–0.71	-0.390	<0.001
Midwest	0.75	0.72–0.78	-0.293	<0.001
Northeast	0.71	0.68–0.75	-0.338	<0.001
Southeast	0.75	0.72–0.78	-0.280	<0.001
South	0.70	0.68–0.84	-0.349	<0.001

Note: The adjusted variables for the models of each subgroup were sex, age group, region of Brazil, month, and the dummy variable indicating the impact of the pandemic. All these variables were included in each subgroup model, except the dummy variable of each subgroup in the respective model. The resident population was included as an exposure variable. Pre-pandemic period: January 1, 2017 to February 29, 2020; Pandemic period: March 1, 2020 to May 31, 2021. IRR = incidence rate ratio; 95.0% CI = 95.0% confidence interval; β = regression coefficient; *Wald statistic.

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10.2 cases per 100,000 inhabitants (26.6% decrease), while the admission rates for surgical cancer decreased from 20.2 to 14.5 cases per 100,000 inhabitants (28.2% decrease) after the onset of the pandemic between March and June 2020 compared to those during the same period prior to the pandemic [17]. Similarly, another study found a 21.0% decrease in the number of cancer-related hospitalizations compared to those in the period in 2020 [20]. An additional study identified a significant decrease in the number of hospital admissions for NCDs, including cancer; CVD; and endocrine, nutritional, and metabolic diseases, between January and June 2020 in Brazil [16]. An investigation showed a 15.0% decline in the hospitalization rate for CVD in Brazil between March and May 2020 compared to that in the same period in 2019, regardless of the age group [35]. Using SIH-SUS data, a study also detected a 6.6% decline in the number of admissions related to diabetes mellitus throughout Brazil in 2020 compared to that in 2019 [36].

The causes for the decline in hospital admissions during the period after the onset of the COVID-19 pandemic are multifactorial. Demand for health services is negatively impacted by fears of becoming infected with SARS-CoV-2 by other patients, mobility restriction policies, social isolation, and reduced access to healthcare during the pandemic, including postponement of appointments and elective care procedures as healthcare resources were redirected to care for patients with COVID-19 [13, 17, 34, 35, 37]. In particular, prevention, early detection and continuous monitoring of patients with NCDs that are carried out mainly in primary health care have suffered a significant reduction, impacting access to health services and hospitalizations [38]. Brazil, due to the scarcity of health resources and the pressure under the

Table 7. Poisson multiple regression models of the impact of the coronavirus disease pandemic on the hospitalization rate for cancer in Brazil according to subgroups by age group, sex, and region of Brazil.

Variables	IRR	95.0% CI	β	p-value*
Age group (years)				
20–39	0.75	0.70–0.82	-0.282	<0.001
40–49	0.70	0.66–0.74	-0.254	<0.001
50–59	0.79	0.75–0.82	-0.239	<0.001
60–69	0.80	0.77–0.83	-0.223	<0.001
70–79	0.78	0.75–0.80	-0.253	<0.001
≥80	0.76	0.73–0.79	-0.275	<0.001
Sex				
Male	0.80	0.78–0.82	-0.220	<0.001
Female	0.74	0.72–0.76	-0.299	<0.001
Region of Brazil				
Midwest	0.80	0.76–0.86	-0.214	<0.001
Northeast	0.73	0.67–0.79	-0.317	<0.001
North	0.71	0.64–0.79	-0.337	<0.001
Southeast	0.77	0.74–0.82	-0.255	<0.001
South	0.79	0.75–0.83	-0.236	<0.001

Note: The adjusted variables for the models of each subgroup were sex, age group, region of Brazil, month, and the dummy variable indicating the impact of the pandemic. All these variables were included in each subgroup model, except for the dummy variable of each subgroup in the respective model. The resident population was included as an exposure variable. Pre-pandemic period: January 1, 2017 to February 29, 2020; Pandemic period: March 1, 2020 to May 31, 2021. IRR = incidence rate ratio; 95.0% CI = 95.0% confidence interval; β = regression coefficient; *Wald statistic.

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system, shifted the beds for the care of patients with NCDs to patients with COVID-19, impacting on the reduction of hospitalizations of patients [38]. In addition, healthcare professionals have been disproportionately affected by the COVID-19 pandemic with high infection rates, leading to reduced capacity to care for patients with NCDs [39, 40].

This study also demonstrated a larger decrease in hospital admissions for most types of NCDs in the North and South of Brazil. The Northern region was the first to experience an increase in the number of cases and a collapse of the healthcare system. The exponential increase in COVID-19 cases led authorities to adopt more proactive, rigorous social distancing measures, which significantly affected the population's access to health services, which may explain the larger decline in hospital admissions for NCDs in the North than in other regions [5, 20]. The Southern region also had a higher incidence of COVID-19 cases per 100,000 inhabitants than all other regions, except the Midwest, and subsequently adopted stricter measures for social distancing and access to health services. Additionally, the Northern region is one of the least developed regions in Brazil and has the least amount of economic resources. Even before the COVID-19 pandemic, individuals from the North had less access to health services compared to other regions [17]. Therefore, our results indicated that individuals with NCDs had unequal access to health services during the COVID-19 pandemic, pointing to the need for strategies to promote greater equity in health access in all regions, especially those with larger gaps in health services.

This study has some limitations. First, the study only included hospitalizations of individuals reported in the SUS and did not include hospitalizations in the private system. Although the SIH-SUS covers 70.0% of Brazilian hospitalizations [41], the non-inclusion of

Table 8. Poisson multiple regression models of the impact of the coronavirus disease pandemic on the hospitalization rate for diabetes mellitus in Brazil according to subgroups by age group, sex, and region of Brazil.

Variables	IRR	95.0% CI	β	p-value*
Age group (years)				
20–39	0.87	0.84–0.91	-0.133	<0.001
40–49	0.82	0.78–0.85	-0.204	<0.001
50–59	0.79	0.75–0.83	-0.235	<0.001
60–69	0.75	0.71–0.79	-0.285	<0.001
70–79	0.70	0.66–0.73	-0.364	<0.001
≥80	0.67	0.64–0.71	-0.395	<0.001
Sex				
Male	0.81	0.79–0.84	-0.207	<0.001
Female	0.70	0.68–0.73	-0.350	<0.001
Region of Brazil				
Midwest	0.72	0.69–0.77	-0.322	<0.001
Northeast	0.74	0.70–0.77	-0.302	<0.001
North	0.71	0.68–0.75	-0.339	<0.001
Southeast	0.82	0.77–0.87	-0.200	<0.001
South	0.71	0.67–0.75	-0.337	<0.001

Note: The adjusted variables for the models of each subgroup were sex, age group, region of Brazil, month, and the dummy variable indicating the impact of the pandemic. All these variables were included in each subgroup model, except the dummy variable of each subgroup in the respective model. The resident population was included as an exposure variable. Pre-pandemic period: January 1, 2017 to February 29, 2020; Pandemic period: March 1, 2020 to May 31, 2021. IRR = incidence rate ratio; 95.0% CI = 95.0% confidence interval; β = regression coefficient; *Wald statistic.

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hospitalizations in the private system may have led to underestimation of hospitalization rates. As these data were not included in our analysis of the impact of the pandemic on the hospitalization rate for NCDs, the results of this study may be under- or overestimated. Second, individuals in the private system may present different characteristics from those hospitalized in the public system (e.g., distribution by age, race and sex). The private sector in Brazil has a higher proportion of female, older, white and more educated users, therefore with a higher socioeconomic level when compared to the public sector (Unified Health System) [42]. The private sector encompasses a vast diversification of hospital services and an even greater concentration of revenue compared to the public sector. Therefore, it would be impossible to generalize the results of the study for the entire Brazilian population and these differences, if analyzed, may impact the estimates. Third, there was a high proportion of missing data for many variables in dataset, such as race, and education level, which made it impossible to use these variables in the present study to analyze the impact according with these variables. Thus, it was impossible to analyze the sensitivity of the pandemic's impact according to these variables. Fourth, this study did not analyze the specific CID-10 in each NCD subgroup. The pandemic's impact may differ for specific groups of diseases and chronic conditions (e.g., hypertension, specific cancers, and COPD). Five, important confounders were not included in the analysis, such as the number of hospital beds, number of healthcare workers per inhabitants, degree of social distancing measures in the regions, including specific restrictions and prevalence of NCDs in the regions, for example. Sixth, we do not have data on the prevalence and characteristics of patients with NCDs before and during the COVID-19 pandemic, according to a large group of causes, which makes it difficult to analyze that the results of this

Table 9. Poisson multiple regression models of the impact of the coronavirus disease pandemic on the hospitalization rate for cardiovascular disease in Brazil according to subgroups by age group, sex, and region of Brazil.

Variables	IRR	95.0% CI	β	p-value*
Age group (years)				
20–39	0.67	0.63–0.72	-0.400	<0.001
40–49	0.68	0.65–0.71	-0.382	<0.001
50–59	0.71	0.69–0.75	-0.336	<0.001
60–69	0.71	0.68–0.74	-0.339	<0.001
70–79	0.70	0.67–0.73	-0.354	<0.001
≥80	0.70	0.68–0.74	-0.343	<0.001
Sex				
Male	0.74	0.72–0.75	-0.304	<0.001
Female	0.67	0.65–0.69	-0.404	<0.001
Region of Brazil				
Midwest	0.75	0.71–0.78	-0.294	<0.001
Northeast	0.70	0.66–0.73	-0.361	<0.001
North	0.65	0.61–0.68	-0.435	<0.001
Southeast	0.73	0.69–0.76	-0.323	<0.001
South	0.67	0.63–0.70	-0.400	<0.001

Note: The adjusted variables for the models of each subgroup were sex, age group, region of Brazil, month, and the dummy variable indicating the impact of the pandemic. All these variables were included in each subgroup model, except the dummy variable of each subgroup in the respective model. The resident population was included as an exposure variable. Pre-pandemic period: January 1, 2017 to February 29, 2020; Pandemic period: March 1, 2020 to May 31, 2021. IRR = incidence rate ratio; 95.0% CI = 95.0% confidence interval; β = regression coefficient; *Wald statistic.

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study are due only to social distancing measures. Finally, this study only included hospital admissions and not admissions to other levels of care (eg, Primary Health Care).

However, our study also has several strengths. First, our study analyzed the impact of COVID-19 on hospital admissions for all major types of NCDs, including cancer, diabetes mellitus, CVD, and CRD, and was not limited to one group of diseases. We also assessed the impact of the pandemic on subgroups by sex, age, and region of Brazil. We utilized data from Brazil's largest database of hospital admissions throughout all regions of Brazil to help us understand how the COVID-19 pandemic has affected hospital admissions for NCDs in the country. Thus, this study provides important results regarding the changing trends in the use of health services in Brazil, which can support interventions and public policies to mitigate the effects of the pandemic on the care of people with NCDs. Moreover, we considered seasonal variations in the regression models to control for the influence of seasonality on the outcomes.

In conclusion, there was a decrease in the hospitalization rate for NCDs in Brazil during the COVID-19 pandemic in a scenario of social distancing measures and overload of health services. These results are alarming as this decline can result in increased incidence of disability and mortality and may reduce the quality of life of people with NCDs, thus having an immense impact on public health. Multiple NCDs-related conditions require immediate assistance to prevent harm to patients; consequently, fewer hospitalizations can lead to irreversible disabilities. Despite the pandemic, it is important for individuals with NCDs to receive proper care in the hospital system. System managers and government agencies must implement strategies that increase access to hospital services in Brazil during the pandemic period, regardless of the region of Brazil. Actions such as increasing the number of elective procedures, periodic

Table 10. Poisson multiple regression models of the impact of the coronavirus disease pandemic on the hospitalization rate for chronic respiratory diseases in Brazil according to subgroups by age group, sex, and region of Brazil.

Variables	IRR	95.0% CI	β	p-value*
Age group (years)				
20–39	0.72	0.69–0.74	-0.330	<0.001
40–49	0.82	0.79–0.86	-0.193	<0.001
50–59	0.78	0.74–0.82	-0.249	<0.001
60–69	0.71	0.68–0.75	-0.335	<0.001
70–79	0.64	0.61–0.68	-0.441	<0.001
≥80	0.66	0.63–0.70	-0.416	<0.001
Sex				
Male	0.75	0.73–0.77	-0.290	<0.001
Female	0.67	0.65–0.69	-0.398	<0.001
Region of Brazil				
Midwest	0.59	0.56–0.63	-0.521	<0.001
Northeast	0.71	0.69–0.74	-0.338	<0.001
North	0.68	0.64–0.71	-0.391	<0.001
Southeast	0.80	0.77–0.84	-0.219	<0.001
South	0.62	0.59–0.65	-0.479	<0.001

Note: The adjusted variables for the models of each subgroup were sex, age group, region of Brazil, month, and the dummy variable indicating the impact of the pandemic. All these variables were included in each subgroup model, except the dummy variable of each subgroup in the respective model. The resident population was included as an exposure variable. Pre-pandemic period: January 1, 2017 to February 29, 2020; Pandemic period: March 1, 2020 to May 31, 2021. IRR = incidence rate ratio; 95.0% CI = 95.0% confidence interval; β = regression coefficient; *Wald statistic.

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examinations, consultations with specialists and in primary health care, and using telemedicine as an alternative to in-person visits can reduce the risk of hospitalizations for NCDs. Therefore, the findings of this study can contribute to the development, implementation, and effectiveness of public policies and protocols for decision making regarding the management of patients with NCDs in Brazil.

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References

1. Ministério da Saúde, Secretaria de Vigilância em Saúde. COVID-19-Painel Coronavírus. 2021 [cited 25 Apr 2020] p. 2. Available: <https://covid.saude.gov.br/>
2. Cardoso CR de B, Fernandes APM, Santos IKF de M. What happens in brazil? A pandemic of misinformation that culminates in an endless disease burden. *Rev Soc Bras Med Trop.* 2021; 54: 1–2. <https://doi.org/10.1590/0037-8682-0713-2020> PMID: 33338115
3. Plante JA, Mitchell BM, Plante KS, Debbink K, Weaver SC, Menachery VD. The variant gambit: COVID-19's next move. *Cell Host Microbe.* 2021; 29: 508–515. <https://doi.org/10.1016/j.chom.2021.02.020> PMID: 33789086
4. Karim SSA, Karim QA. Omicron SARS-CoV-2 variant: a new chapter in the COVID-19 pandemic. *Lancet.* 2021; 398: 2126–2128. [https://doi.org/10.1016/S0140-6736\(21\)02758-6](https://doi.org/10.1016/S0140-6736(21)02758-6) PMID: 34871545
5. Silva LLS da, Lima AFR, Polli DA, Razia PFS, Pavão LFA, Hollanda Cavalcanti MAF de, et al. Social distancing measures in the fight against covid-19 in brazil: Description and epidemiological analysis by state. *Cad Saude Publica.* 2020; 36: 1–15. <https://doi.org/10.1590/0102-311X00185020> PMID: 32965378
6. Loewenthal G, Abadi S, Avram O, Halabi K, Ecker N, Nagar N, et al. COVID-19 pandemic-related lockdown: response time is more important than its strictness. *EMBO Mol Med.* 2020; 12: 1–8. <https://doi.org/10.15252/emmm.202013171> PMID: 33073919
7. Caristia S, Ferranti M, Skrami E, Raffetti E, Pierannunzio D, Palladino R, et al. Effect of national and local lockdowns on the control of COVID-19 pandemic: A rapid review. *Epidemiol Prev.* 2020; 44: 60–68. <https://doi.org/10.19191/EP20.5-6.S2.104> PMID: 33412795
8. Aquino EML, Silveira IH, Pescarini JM, Aquino R, de Souza-Filho JA. Social distancing measures to control the COVID-19 pandemic: Potential impacts and challenges in Brazil. *Cien Saude Colet.* 2020; 25: 2423–2446. <https://doi.org/10.1590/1413-81232020256.1.10502020> PMID: 32520287
9. Alfano V, Ercolano S. The efficacy of lockdown against COVID-19: a cross-country panel analysis. *Appl Health Econ Health Policy.* 2020; 18: 509–517. <https://doi.org/10.1007/s40258-020-00596-3> PMID: 32495067
10. Dorjee K, Kim H, Bonomo E, Dolma R. Prevalence and predictors of death and severe disease in patients hospitalized due to COVID-19: A comprehensive systematic review and meta-analysis of 77 studies and 38,000 patients. *PLoS One.* 2020; 15: 1–27. <https://doi.org/10.1371/journal.pone.0243191> PMID: 33284825
11. Du P, Li D, Wang A, Shen S, Ma Z, Li X. A Systematic Review and Meta-Analysis of Risk Factors Associated with Severity and Death in COVID-19 Patients. *Can J Infect Dis Med Microbiol.* 2021;2021. <https://doi.org/10.1155/2021/6660930> PMID: 33936349
12. Fernandes GA, Junior APN, Azevedo E Silva G, Feriani D, França E Silva ILA, Caruso P, et al. Excess mortality by specific causes of deaths in the city of São Paulo, Brazil, during the COVID-19 pandemic. *PLoS One.* 2021; 16: 1–8. <https://doi.org/10.1371/journal.pone.0252238> PMID: 34097694
13. Birkmeyer JD, Barnato A, Birkmeyer N, Bessler R, Skinner J. The Impact Of The COVID-19 Pandemic On Hospital Admissions In The United States. *Health Aff.* 2020; 39: 2010–2017. <https://doi.org/10.1377/hlthaff.2020.00980> PMID: 32970495
14. Conti S, Ferrara P, Mazzaglia G, D'Orso MI, Ciampichini R, Fornari C, et al. Magnitude and time-course of excess mortality during COVID-19 outbreak: population-based empirical evidence from highly impacted provinces in northern Italy. *ERJ Open Res.* 2020; 6: 00458–02020. <https://doi.org/10.1183/23120541.00458-2020> PMID: 33015145

15. Nogueirai PJ, De Araújo Nobre M, Nicola PJ, Furtado C, Vaz Carneiro A. Excess mortality estimation during the COVID-19 pandemic: Preliminary data from Portugal. *Acta Med Port.* 2020; 33: 376–383. <https://doi.org/10.20344/amp.13928> PMID: 32343650
16. Maselli-Schoueri JH, De Carvalho LEW, Rezende LFM, Fonseca FLA, Ferrari G, Adami F. Hospital admissions associated with noncommunicable diseases during the COVID-19 outbreak in Brazil. *JAMA Netw Open.* 2021; 4: 8–11. <https://doi.org/10.1001/jamanetworkopen.2021.0799> PMID: 33683330
17. Mafra da Costa A, Ribeiro AL, Ribeiro AG, Gini A, Cabasag C, Reis RM, et al. Impact of COVID-19 Pandemic on Cancer-Related Hospitalizations in Brazil. *Cancer Control.* 2021; 28: 1–7. <https://doi.org/10.1177/10732748211038736> PMID: 34406894
18. Rennert-May E, Leal J, Thanh NX, Lang E, Dowling S, Manns B, et al. The impact of COVID-19 on hospital admissions and emergency department visits: A population-based study. *PLoS One.* 2021; 16: 1–11. <https://doi.org/10.1371/journal.pone.0252441> PMID: 34061888
19. Chan KPF, Ma TF, Kwork WC, Leung JKC, Chiang KY, Ho JCM, et al. Significant reduction in hospital admissions for acute exacerbation of chronic obstructive pulmonary disease in Hong Kong during coronavirus disease 2019 pandemic. *Respir Med.* 2020; 171: 106085. <https://doi.org/10.1016/j.rmed.2020.106085> PMID: 32917356
20. Fonseca GA, Normando PG, Loureiro LVM, Rodrigues REF, Oliveira VA, Melo MDT, et al. Reduction in the number of procedures and hospitalizations and increase in cancer mortality during the COVID-19 pandemic in Brazil. *J Glob Oncol.* 2021; 7: 4–9. <https://doi.org/10.1200/GO.20.00471> PMID: 33405961
21. Leite JS, Feter N, Caputo EL, Doring IR, Cassuriaga J, Reichert FF, et al. Managing noncommunicable diseases during the covid-19 pandemic in brazil: Findings from the pampa cohort. *Cienc e Saude Coletiva.* 2021; 26: 987–1000. <https://doi.org/10.1590/1413-81232021263.39232020> PMID: 33729353
22. Horton R. Offline: COVID-19 is not a pandemic. *Lancet.* 2020; 396: 874. [https://doi.org/10.1016/S0140-6736\(20\)32000-6](https://doi.org/10.1016/S0140-6736(20)32000-6) PMID: 32979964
23. Basu S. Non-communicable disease management in vulnerable patients during Covid-19. *Indian J Med Ethics.* 2020; V: 103–105. <https://doi.org/10.20529/IJME.2020.041> PMID: 32393447
24. WHO—World Health Organization. ICD-10 International Statistical Classification of Diseases and Related Health Problems. 10th ed. Geneva: WHO; 2011. Available: http://www.who.int/classifications/icd/ICD10Volume2_en_2010.pdf
25. Malta DC, Andrade SSCA, Oliveira TP, Moura L, Prado RR, Souza MFM. Probability of premature death for chronic non-communicable diseases, Brazil and Regions, projections to 2025. *Rev Bras Epidemiol.* 2019;22. <https://doi.org/10.1590/1980-549720190030> PMID: 30942336
26. Akemi Iwakura Tomimatsu MF, de Andrade SM, Soares DA, de Freitas Mathias TA, da Penha Marques Sapata M, de Paula Soares DFP, et al. Quality of external-cause data in the Hospitalization Information System. *Rev Saude Publica.* 2009; 43: 413–420. <https://doi.org/10.1590/s0034-89102009000300004> PMID: 19347175
27. Instituto Brasileiro de Geografia e Estatística. Sistema IBGE de Recuperação Automática (SIDRA). 2021.
28. Libruder C, Ram A, Hershkovitz Y, Tanne D, Bornstein NM, Leker RR, et al. Reduction in Acute Stroke Admissions during the COVID-19 Pandemic: Data from a National Stroke Registry. *Neuroepidemiology.* 2021; 55: 354–360. <https://doi.org/10.1159/000516753> PMID: 34237727
29. Filippo O De, D'Ascenzo F, Angelini F, Bocchino PP, Conrotto F, Saglietto A, et al. Reduced rate of hospital admissions for ACS during Covid-19 outbreak in Northern Italy. *N Engl J Med.* 2020; 383: 85–88. <https://doi.org/10.1056/NEJMc2009567> PMID: 32348641
30. Hasibul Hasan ATM, Das SC, Islam MS, Mansur M, Shajedur Rahman Shawon M, Hassan R, et al. Impact of COVID-19 on hospital admission of acute stroke patients in Bangladesh. *PLoS One.* 2021; 16: 1–9. <https://doi.org/10.1371/journal.pone.0240385> PMID: 33439890
31. Wambua S, Malla L, Mbevi G, Nwosu A-P, Tuti T, Paton C, et al. The indirect impact of COVID-19 pandemic on inpatient admissions in 204 Kenyan hospitals: An interrupted time series analysis. *PLOS Glob Public Heal.* 2021; 1: e0000029. <https://doi.org/10.1371/journal.pgph.0000029>
32. Bernal JL, Cummins S, Gasparrini A. Interrupted time series regression for the evaluation of public health interventions: a tutorial. *Int J Epidemiol.* 2017; 46: 348–355. <https://doi.org/10.1093/ije/dyw098> PMID: 27283160
33. Gardner W, Mulvey EP, Shaw EC. Regression analyses of counts and rates: Poisson, overdispersed Poisson, and negative binomial models. *Psychol Bull.* 1995; 118: 392–404. <https://doi.org/10.1037/0033-2909.118.3.392> PMID: 7501743
34. Blecker S, Jones SA, Petrilli CM, Admon AJ, Weerahandi H, Francois F, et al. Hospitalizations for Chronic Disease and Acute Conditions in the Time of COVID-19. *JAMA Intern Med.* 2021; 181: 269–271. <https://doi.org/10.1001/jamainternmed.2020.3978> PMID: 33104158

35. Normando PG, Araujo-Filho J de A, Fonseca G de A, Rodrigues REF, Oliveira VA, Hajjar LA, et al. Reduction in hospitalization and increase in mortality due to cardiovascular diseases during the COVID-19 pandemic in Brazil. *Arq Bras Cardiol.* 2021; 116: 371–380. <https://doi.org/10.36660/abc.20200821> PMID: 33566937
36. De Negreiros RV, Da Fonseca ENR, De Abreu RA, Freire EE, Gaudêncio E de O, Safra G, et al. Hospitalization for diabetes mellitus in Brazil between 2016 and 2020. *Brazilian J Dev.* 2021; 7: 77218–77232. <https://doi.org/10.34117/bjdv7n8-100>
37. Fonseca EM da, Shadlen KC, Bastos FI. The politics of COVID-19 vaccination in middle-income countries: Lessons from Brazil. *Soc Sci Med.* 2021; 281: 114093. <https://doi.org/10.1016/j.socscimed.2021.114093> PMID: 34144480
38. Wright A, Salazar A, Mirica M, Volk LA, Schiff GD. The Invisible Epidemic: Neglected Chronic Disease Management During COVID-19. *J Gen Intern Med.* 2020; 35: 2816–2817. <https://doi.org/10.1007/s11606-020-06025-4> PMID: 32666485
39. Buonafine CP, Paiatto BNM, Leal FB, de Matos SF, de Moraes CO, Guerra GG, et al. High prevalence of SARS-CoV-2 infection among symptomatic healthcare workers in a large university tertiary hospital in São Paulo, Brazil. *BMC Infect Dis.* 2020; 20: 1–8. <https://doi.org/10.1186/s12879-020-05662-8> PMID: 33267836
40. Danhieux K, Buffel V, Pairen A, Benkheil A, Remmen R, Wouters E, et al. The impact of COVID-19 on chronic care according to providers: a qualitative study among primary care practices in Belgium. *BMC Fam Pract.* 2020; 21: 1–6. <https://doi.org/10.1186/s12875-019-1070-0> PMID: 31901226
41. Drumond E de F, França EB, Machado CJ. SIH-SUS e SINASC: utilização do método probabilístico para relacionamento de dados. *Cad saúde colet, (Rio J).* 2006; 251–264.
42. Belon AP, da Silveira NYJ, Barros MB de A, Baldo C, da Silva MMA. Atendimentos de emergência a vítimas de violências e acidentes: Diferenças no perfil epidemiológico entre o setor público e o privado. *VIVA—Campinas/SP, 2009. Cienc e Saude Coletiva.* 2012; 17: 2279–2290. <https://doi.org/10.1590/S1413-81232012000900010> PMID: 22996880