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COVID-19 Pandemic in Brazil: History, Characteristics, and Evolution

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Abstract

This chapter describes the eruption and spread of the SARS-COV-2 virus throughout Brazil. We also describe the governmental measures used to combat the virus, the regional influences impacting viral spreading, and the prevalence of the disease in different Brazilian subpopulations. It is hoped that such information will contribute to the control of the virus and help to prepare the region for future pandemics.

Keywords

COVID-19 · SARS-CoV-2 · Pandemic Brazil · Governmental measures · Regional characteristics

1 Brief Historical Facts of the COVID-19 Pandemic in Brazil

The coronavirus disease 2019 (COVID-19) is an infectious respiratory disease from a novel coronavirus named SARS-CoV-2 (severe acute respiratory syndrome-coronavirus-2). The first case of COVID-19 was reported on December 31, 2019, in Wuhan, China [1]. After a few weeks, the disease reached other countries in Asia, Europe, and North America. In South America, the disease

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P. C. Guest (ed.), *Identification of Biomarkers, New Treatments, and Vaccines for COVID-19*, Advances in Experimental Medicine and Biology 1327, https://doi.org/10.1007/978-3-030-71697-4_3

was reported late. The first case occurred in Sao Paulo city, Brazil [2]. The World Health Organization (WHO) declared the outbreak a Public Health Emergency of International Concern (PHEIC) on January 30, 2020, and 2 months later, on March 11, 2020, it was declared a pandemic [1–3]. Two hundred fourteen countries worldwide have been affected by COVID-19, with more than 118 million confirmed cases and 2.6 million deaths as of March 11, 2021 [4]. In Brazil, one year into the COVID-19 epidemic, more than 11 million confirmed cases and 270 thousand deaths have been reported [5]. Brazil currently holds the record of the second highest COVID-19 cases and second highest number of deaths in the world. Since May 2020, the country has been considered the epicenter of the disease pandemic in Latin America [6]. The United States (US) occupies the first place in the total number of COVID-19 cases and deaths [4].

The first case reported in Sao Paulo city, Brazil, occurred on February 26, 2020, when a 61-year-old man who arrived from Turin, Italy, presented with symptoms compatible with severe acute respiratory illness, such as fever, dry cough, sore throat, and runny nose [7, 8]. Brazil has 26 states and one Federative Unit located in five regions: North, Northeast, Midwest, Southeast, and South. Each Brazilian state displays specific characteristics, such as social, economic, and climatic features.

A couple of days later, 16 Brazilian states displayed around 182 suspected cases. In the Southeast region, the most populous one, Sao Paulo and Rio de Janeiro, Brazil's largest cities, were the most affected. After a few weeks, the pandemic rapidly spread into the rest of the country, reaching all Brazilian states. On March 9, 2020, the Brazilian Ministry of Health tested all patients in private and public hospitals with severe acute respiratory illness for COVID-19. A couple of months later, several states collapsed due to the Public Health System being overloaded after the first case. In April 2020, Sao Paulo, Rio de Janeiro, Pernambuco, Ceara, and Amazonas displayed the peak of deaths related to the COVID-19 [7].

Candido et al. reported that most of these infected people arrived from Italy, followed by China, France, Switzerland, South Korea, and Spain, between February and March [9]. This resulted in rapid virus dissemination around the country, differently to China and other countries [9]. The route from Italy to Sao Paulo was the main one for importing COVID-19 to Brazil, followed by Rio de Janeiro, Belo Horizonte, and other states. Sao Paulo becomes an epicenter of Brazil's disease, which would be associated with the destination for many people flying from Italy.

On March fifth, the Brazilian Ministry of Health reported the COVID-19 local transmission, with one person being infected by a man who arrived from Italy in Sao Paulo city [10]. Also, local transmission occurred in Rio de Janeiro and Bahia states. Two weeks later, it was declared the COVID-19 community transmission in the national territory by the Brazilian Ministry of Health, where health organizations could not identify the origin of the first patient infected. Several Brazilian institutes of research examined samples from patients who tested positive for COVID-19, evaluating the genetic sequencing. At the beginning of the pandemic, there were six different lineages of SARS-CoV-2. One specific lineage rapidly spread in the Brazilian territory, which would be associated with the COVID-19 community transmission. The virus lineage characterization might geographically elucidate the virus lineage circulation, identify the lineage in each state inside the country and outside, and understand the virus dissemination. After the community transmission, the contagion rapidly disseminated, making it hard to control the virus spread in Brazil, due to the difficulty of tracking the virus propagation.

Afterward, all Brazilian states followed the National Contingency Plan (NCP) to take action against COVID-19. The NCP measures follow scientific-based evidence and recommendations published by the WHO. By the end of March 2020, Brazilian authorities recommended physical distancing, although the lockdown was implemented only in some states, such as Amapa, Ceara, Maranhao, MatoGrosso, Para, Pernambuco, Parana, Piaui, and Tocantins. On July 29, Brazil reached 69,074 COVID-19 new cases in one day, peaking in daily new case numbers [11].

Classical drugs already used as an antiviral treatment, such as chloroquine, hydroxychloroquine, azithromycin, remdesivir, liponavir-ritonavir, and interferon-β-1b have been proposed as therapeutic strategies to treat the patients. However, several clinical research institutes have failed to show the drugs' efficacy and safety to treat COVID-19 patients. For example, Geleris et al. studied the hydroxychloroquine effect in severe patients with COVID-19 at a large medical center in New York City [12]. The authors did not find a significant effect on the risk of death in severe patients with COVID-19.

On June 11, the Butantan Institute in Sao Paulo signed an agreement to develop and produce a vaccine against SARS-CoV-2 (CoronaVAC), initially developed by the Chinese biopharmaceutical company, SinoVac Biotech. This vaccine already showed positive results in phase 1 and 2 preclinical studies. The phase 3 clinical test is in progress to certify the vaccine safety and efficacy [13]. Other vaccines also are in clinical tests in Brazil, including the Astra Zeneca/Oxford University and Johnson & Johnson vaccines. The most optimistic estimate for the conclusion of the COVID-19 vaccine studies is by early 2021 for global distribution [14].

2 Governmental Measures to Combat the Pandemic

The COVID-19 pandemic in Brazil started in February 2020, after it reached several countries in Asia, Europe, and North America [15]. Despite the scientific-based evidence and recommendations from the World Health Organization [16], the Federal Brazilian government has made conflicting and mismatching decisions that somehow influenced the disease epidemic in Brazil [17, 18]. The turbulence observed mainly in the first months of the pandemic directly impacted the disease dissemination in the country. Figure 3.1 highlights some important decisions and events related to the Federal Brazilian government during the COVID-19 pandemic progression in the country. An association has been between the decision-making of the Brazilian government and the subsequent disease-spread dynamics. The factors involved in this turbulence are complex involving several spheres and Brazilian authorities. The detailed description and discussion of each decision/event lie outside the scope of this chapter. The discordance between the Federal government and state/municipal governments and the discrepancy of the decision-

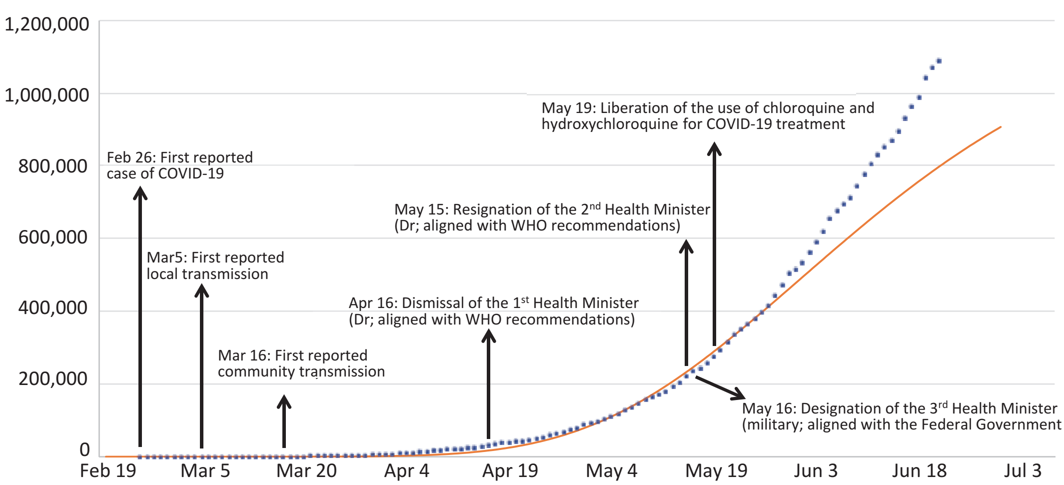

Fig. 3.1 Total number of COVID-19 cases in Brazil and Federal Brazilian government events related to the disease pandemic. Reported number was obtained from the Brazilian Ministry of Health (blue line) and the predicted number was calculated according to the mathematical model proposed by Tang et al. [6] (red line)

making among Brazilian states and municipalities also help to explain the specific response to the COVID-19 epidemic in each Brazilian state/city.

Apart the Federal Brazilian government decisions, distinct COVID-19 epidemic dynamics occurred among the Brazilian states and cities, probably due to particular characteristics and governmental measures to combat the spread of disease. Several interventional measures against COVID-19 dissemination were implemented, including quarantine, lockdown, and facemask use. These measures and implementations varied throughout the country due to intrinsic factors related to each Brazilian state and city with respect to specific, regional characteristics and extrinsic factors associated with safety. This included local and state government decisions concerning the disease management and the awareness of the population.

Using a simple mathematical model as previously proposed by our group [19, 20], we predicted the development of the COVID-19 epidemic in Brazil and in the five Brazilian states with the highest number of COVID-19 cases in each region: Para (North); Bahia (Northeast); Sao Paulo (Southeast); Minas Gerais (Midwest); and Santa Catarina (South). The total number of cases, daily new cases, and growth rate are shown in Figs. 3.2, 3.3, and 3.4, respectively.

Until June, the predicted number of total cases was close to the reported number according to this model in the whole country. However, after July, the reported number started to grow up in comparison with the predicted number, suggesting that interfering factors probably impaired the control of the disease pandemic (Fig. 3.2a). At the end of October, the reported number was about four times higher than the predicted number (Fig. 3.2a). Sao Paulo presented a similar response to the whole country with a reported number around two times higher than the predicted number (Fig. 3.2d). Bahia, Minas Gerais, and Para presented a less pronounced elevation in the reported number in comparison to the predicted number (Fig. 3.2b, c, e), and Santa Catarina had the best response (Fig. 3.2f). The daily new cases and the growth rate followed the results of the total number of cases (Figs. 3.3 and 3.4, respectively).

The interfering and interventional measures, including social distancing/isolating (quarantine and lockdown), the mandatory use of facemasks, and government decisions about the lives of the people and economic activities (reopening, flexibilization, and school returning) usually presented a direct correlation with the epidemic curve dynamics. The reported number of cumulative cases was expected to be higher than the predicted number in the Brazilian states, where these extrinsic factors are not completely efficacious to avoid the SARS-CoV-2 spread. On the other hand, when local authorities successfully implemented measures to combat the disease epidemic, the reported cumulative number of cases was expected to be similar or even lower than the predicted number [20].

The Sao Paulo state is the most populous in Brazil, with more than 46 million people (IBGE, 2019). Its capital is Sao Paulo city, with more than 12 million people. Sao Paulo state has been considered the epicenter of the COVID-19 pandemic in Brazil and Latin America since May 2020 [20]. The Sao Paulo state government established various preventive and protective measures and public health policies [21]. The government decreed a quarantine on March 24, and facemask use has been obligatory since May 7, 2020. On July 1, 2020, most of the Sao Paulo state reopened some trading sections, including shopping, commerce, and services (with restriction to 20% of the maximum capacity and 4 h per day), with more flexibility and reopening on August 7 (40% of the maximum capacity and 8 h per day). Another contributing factor for the increasing number of COVID-19 cases in the Sao Paulo state is the amount of testing for the disease. For example, in July 2020, the state performed around 54% more tests for COVID-19 than in June 2020. As shown in Fig. 3.1, the impact of reopening and flexibility procedures seemed to impair the COVID-19 epidemic curve. Similar effects, but less pronounced, were observed in the Bahia, Minas Gerais, and Para states, sug-

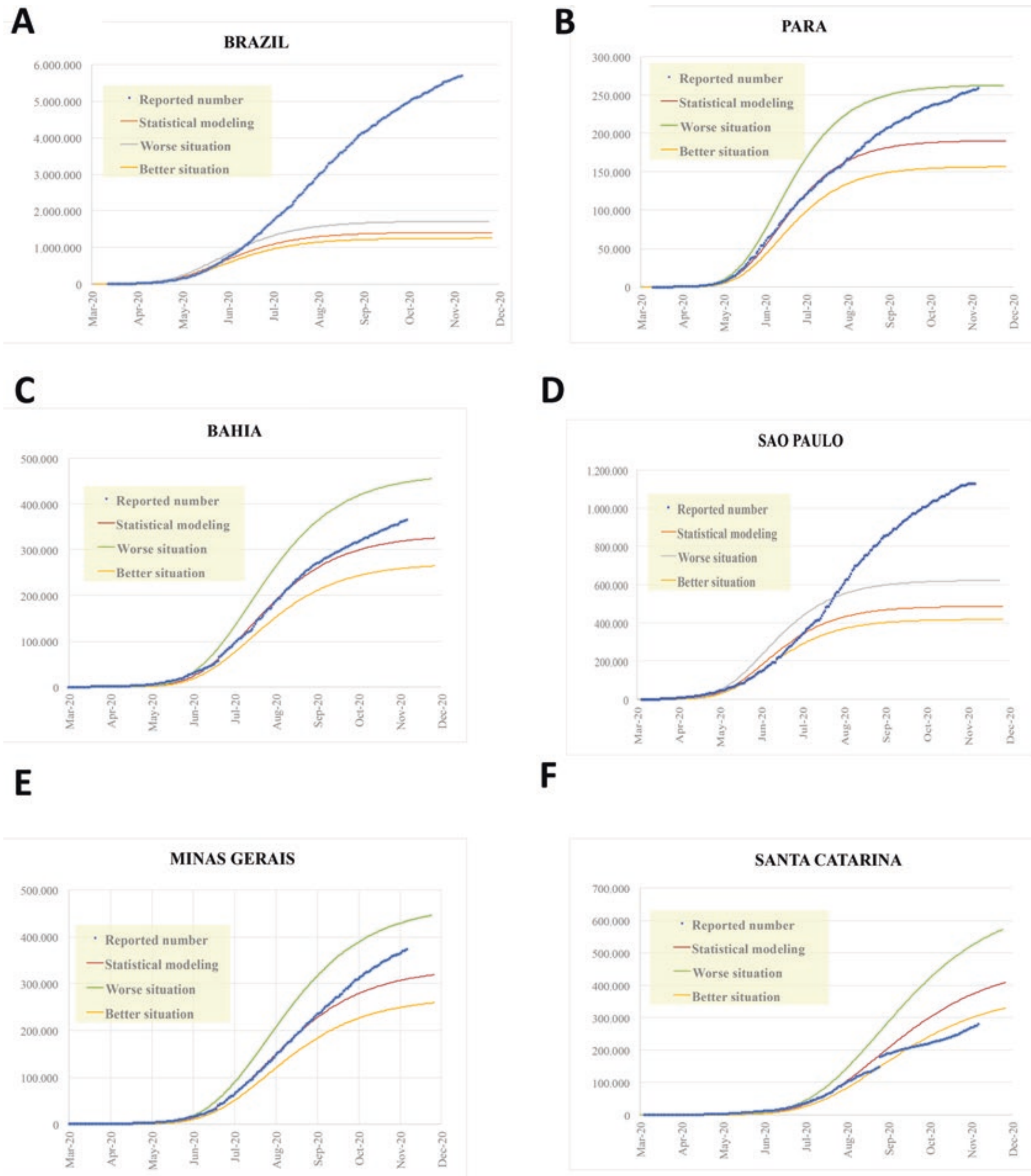

Fig. 3.2 Total number of COVID-19 cases in Brazil (**a**), Para (**b**), Bahia (**c**), Sao Paulo (**d**), Minas Gerais (**e**), and Santa Catarina (**f**)

gesting that the same factors may have contributed to the SARS-CoV-2 spread, including the reopening and increased flexibility. Santa Catarina state, on the other hand, presented the best response, indicating that appropriate measures were implemented there to combat the disease pandemic.

3 Regional Characteristics Influencing the COVID-19 Dissemination

Brazil is a vast country with continental dimensions. The total area consists of more than 8.5 million km^2, and the total population is almost

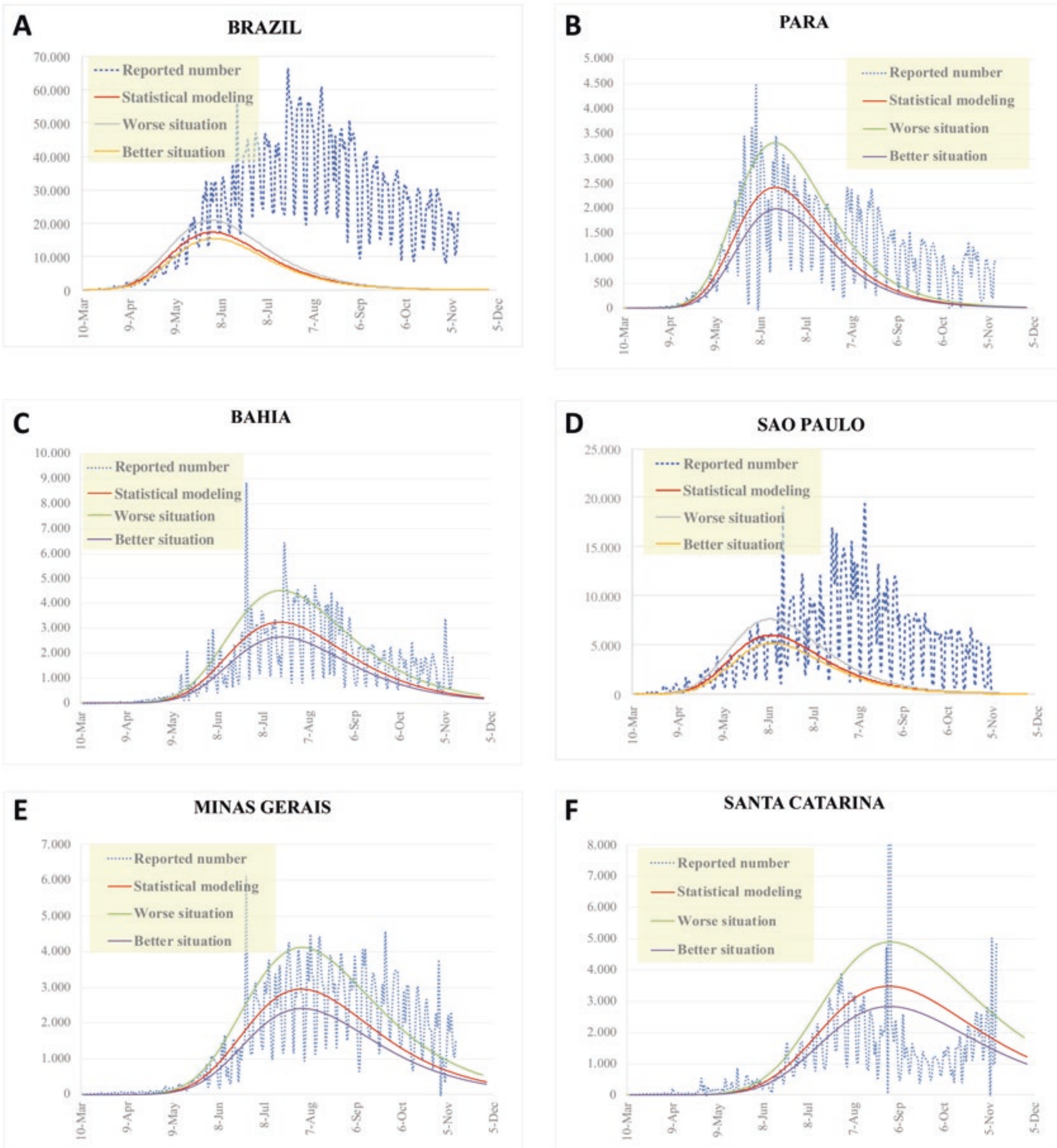

Fig. 3.3 Daily new cases of COVID-19 in Brazil (**a**), Para (**b**), Bahia (**c**), Sao Paulo (**d**), Minas Gerais (**e**), and Santa Catarina (**f**)

212 million people. The country is divided into five geographic regions, with a total of 26 Brazilian states and one Federative unit: North (7 states), Northeast (9 states), Midwest (3 states and one Federative unit), Southeast (4 states), and South (3 states). The high heterogeneity and complexity of the characteristics among the Brazilian regions and states and discrepancies among governmental authorities have directly influenced the dynamics of the COVID-19 pandemic within the country, resulting in specific and local disease epidemic curves. Mathematical modeling of the COVID-19 pandemic is affected by several interfering factors that have to be considered, including governmental decisions concerning social distancing and isolation (e.g., quarantine and lockdown), protective and preventive measures (e.g., mandatory use of face

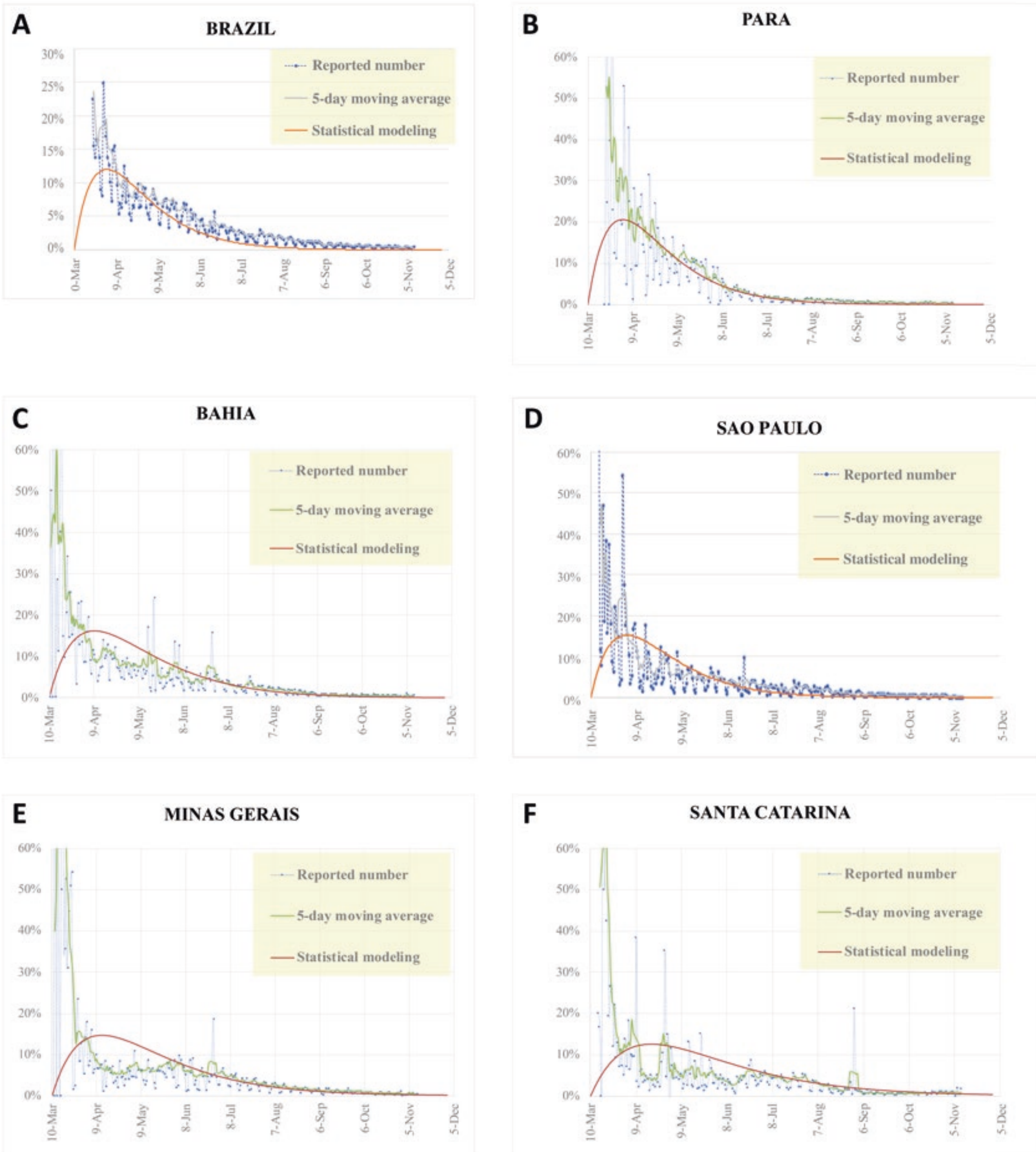

Fig. 3.4 Growth rate (%) of COVID-19 in Brazil (**a**), Para (**b**), Bahia (**c**), Sao Paulo (**d**), Minas Gerais (**e**), and Santa Catarina (**f**)

masks and frequent sanitation of the hands), and restriction of economic activities (e.g., closing/reopening of commercial trades and schools, measures of flexibility) [20, 22].

COVID-19 dissemination dynamics vary mainly due to two factors: a) intrinsic factors linked to the specific and regional/local characteristics, and b) extrinsic factors related to several external decisions to combat the pandemic growth. These latter include preventive measures, governmental decisions, and population awareness in combating the COVID-19 pandemic. The previous section discussed these factors. The intrinsic factors are associated with specific and local characteristics, including geographic localization, total area, population, demographic density, per capita income, and public health system.

Brazil is a developing country with high social differences. Fifty percent of Brazilian families earn about R$ 820 per month (~$200) and only 10% of the population take in 43.1% of the total income in Brazil (IBGE, 2019). The unemployment index was 11.2% in January 2020 (before the pandemic). The disease pandemic exacerbated this situation as millions of people lost their jobs, and the peak of the unemployment index in July 2020 was 13.8% (13.1 million people). Previous findings suggest that the most vulnerable people to the COVID-19 pandemic are those in low social classes, who are potentially more exposed to the virus.

Other important intrinsic factors account for the spatial occupation of each region or locality, presence of isolated communities (e.g., indigenous communities), accessibility to public health systems (e.g., disposal of intensive care units, doctors, and respirators per 100.000 people), and regional susceptibility to the disease (Table 3.1). Some studies suggest that previous immunization for other viruses, including MMR viral triplice vaccine (measles, mumps, and rubella), dengue vaccine, and poliovirus vaccine, could provide some immunity against SARS-CoV-2 [23]. However, additional studies are necessary to evaluate the real protective capacity of previous vaccines against SARS-CoV-2 infection.

4 Prevalence of the Disease in Different Subpopulations

About 80% of patients with COVID-19 infection have a mild form of the disease and are asymptomatic. Overall, among individuals with COVID-19, approximately 14% of the patients require hospital care because they present difficulty breathing, of which approximately 5% may need respiratory assistance in an intensive care unit [24]. This situation is exacerbated in the elderly and people with underlying comorbidities who are more likely to become seriously infected [25].

Patients with chronic diseases, such as diabetes, obesity, hypertension, asthma, chronic obstructive pulmonary disease, smokers, and pregnant women, are considered to be at risk of a worse COVID-19 outcome. Also noteworthy are hematological diseases, including sickle cell anemia and thalassemia, advanced chronic kidney disease (grades 3, 4, and 5), and chromosomal diseases, resulting from impaired immune function, as well as immunosuppression caused by treatment of autoimmune diseases such as lupus and cancer [26–30].

In Brazil, deaths associated with COVID-19 are strongly related to socioeconomic factors, demographics, and comorbidities. Wollenstein-Betech et al. evaluated data of 113,214 Brazilian patients with 50,387 deceased and reported that variables associated with the high prediction of mortality include the geographic location of the hospital, renal and liver chronic disease, immunosuppression, obesity, neurological, cardiovascular, and hematologic diseases, diabetes, chronic pneumopathy, immunosuppression, respiratory symptoms and hospitalization in a public hospital. The authors observed that patients with a low level of education showed a significant association with higher mortality and that mortality was inversely proportional to self-reported education level, suggesting that this may have also significantly impacted the COVID-19 scenario.

De Souza et al. analyzed data from Brazilian COVID-19 patients registered on the Influenza Epidemiological Surveillance Information System (SIVEP-Gripe) database, which includes suspected and confirmed COVID-19 cases as reported by public health and private services [31]. The authors reported that the most prevalent comorbidities were cardiovascular disease [23,085 out of 34,693 cases (66.5%)] and diabetes [17,271 out of 31,672 patients (54.5%)].

Diabetic patients have a dysfunction of the immune system and exhibit low-grade chronic inflammation [32, 33]. In diabetic patients, there is an elevation of pro-inflammatory cytokines such as interleukin-6 and tumor necrosis factor alpha [34–36]. This condition may favor cytokine storming in the late stage of the coronavirus infections through unknown mechanisms [37], leading to an increased risk of complications due to virus infection [38]. Patients with COVID-19 have raised blood total leukocytes and neutrophils, reduced lymphocyte number, and an

Table 3.1 Characteristics of the Brazilian states related to the COVID-19 pandemic

State/ Federative Unit	Total population	Population density (inhab./km^2)	Human development Index	Per capita income	Number of ICU per 100,000 inhab.	Number of doctors per 100,000 inhab.	Number of respirators per 100,000 inhab.	Total number of COVID-19 cases	Total of deaths related to COVID-19	Cases per 100,000 inhab.	Deaths per 100,000 inhab.	Mortality rate (%)
Acre	894470	5.4	0.719	890	5	108	16	30951	693	3917	77.5	2.24
Alagoas	3351543	120.4	0.683	731	9	132	15	91142	2254	2744	67.3	2.47
Amapá	861773	6.0	0.74	880	5	95	10	52832	751	7035	87.1	1.42
Amazonas	4207714	2.7	0.733	842	7	111	20	163399	4588	4218	109.0	2.81
Bahia	14930634	26.4	0.714	913	10	135	20	355753	7711	2352	51.6	2.17
Ceará	9187103	61.7	0.735	942	9	126	21	275671	9370	3118	102.0	3.40
Distrito Federal	3055149	530.3	0.85	2686	30	338	63	214655	3719	8352	121.7	1.73
Espírito Santo	4064052	88.2	0.772	1477	20	223	35	158768	3884	4087	95.6	2.45
Goiás	7113540	20.9	0.769	1306	15	169	24	258241	5797	3959	81.5	2.24
Maranhão	7114598	21.6	0.687	636	8	81	14	186572	4091	2723	57.5	2.19
Mato Grosso	3526220	3.9	0.774	1403	17	148	38	144258	3828	4474	108.6	2.65
Mato Grosso do Sul	2809394	7.9	0.766	1514	14	195	31	83439	1622	3185	57.7	1.94
Minas Gerais	21292666	36.3	0.787	1358	15	221	28	362340	9069	1736	42.6	2.50
Pará	8690745	7.0	0.698	807	8	85	16	254384	6767	3151	77.9	2.66
Paraíba	4039277	71.5	0.722	929	12	155	21	133958	3130	3397	77.5	2.34
Paraná	11516840	57.8	0.792	1621	18	209	31	216266	5269	1952	45.8	2.44
Pernambuco	9616621	98.1	0.727	970	16	157	29	163642	8667	1764	90.1	5.30
Piauí	3281480	13.0	0.697	827	7	126	14	114530	2441	3585	74.4	2.13
Rio de Janeiro	17366189	396.9	0.796	1882	25	248	42	313089	20759	1902	119.5	6.63
Rio Grande do Norte	3534165	66.9	0.731	1057	12	152	21	81876	2588	2402	73.2	3.16
Rio Grande do Sul	11422973	40.5	0.787	1843	14	244	28	253272	5903	2244	51.7	2.33
Rondônia	1796460	7.6	0.725	1136	13	142	25	72295	1464	4135	81.5	2.03
Roraima	631181	2.8	0.752	1044	4	136	17	57789	693	11629	109.8	1.20

(continued)

Table 3.1 (continued)

State/ Federative Unit	Total population	Population density (inhab./km^2)	Human development Index	Per capita income	Number of ICU per 100,000 inhab.	Number of doctors per 100,000 inhab.	Number of respirators per 100,000 inhab.	Total number of COVID-19 cases	Total of deaths related to COVID-19	Cases per 100,000 inhab.	Deaths per 100,000 inhab.	Mortality rate (%)
Santa Catarina	7252502	75.8	0.808	1769	12	221	28	266637	3163	3722	43.6	1.19
São Paulo	46289333	186.5	0.826	1946	19	260	39	1123299	39549	2551	85.4	3.52
Sergipe	2318822	105.8	0.702	980	10	162	21	84709	2228	3817	96.1	2.63
Tocantins	1590248	5.7	0.743	1056	8	146	19	75991	1105	5077	69.5	1.45

Data of the characteristics were obtained from IBGE (2019) and data of COVID-19 were obtained from the Brazilian Ministry of Health on November 4th, 2020. *Inhab* inhabitants, *ICU* intensive care units increased neutrophil/lymphocyte ratio (NLR) [39–41]. These latter alterations positively correlate with the inflammatory state and COVID-19 severity [42–44].

In an analysis of 67,180 confirmed COVID-19 cases reported on the SIVEP-Gripe system, de Souza et al. observed that 65% (44,027 out of 67,180) of COVID-19 infections in individuals above 50 years of age and a lower proportion of 2.2% (1454 out of 67,180) in people less than 20 years old [31]. The authors reported 85% COVID-19 deaths in individuals above 50 years of age. In this same study, 16 newborns, 381 infants (1–12 months old), 518 children (1–12 years old), and 258 adolescents (12–17 years of age) were diagnosed with COVID-19.

Pachiega et al. extracted data from the bulletin about the epidemiological situation of COVID-19 available on the official website from the 26 Brazilian States and the Federal District [44]. They observed a high prevalence of comorbidities (83%) among patients who died from COVID-19 in Brazil, with 35% of these comorbidities being chronic heart diseases. The authors found that the group that presented chronic heart diseases was composed mainly of men aged over 60 years. This fact may indicate that this comorbidity may be predictive of a worse prognosis for COVID-19.

According to the Pan American Health Organization (PAHO), other groups also require the Public Health System's high attention due to their vulnerability. These groups include the indigenous population, prisoners, and employees of long-term institutions for the elderly, such as nursing homes.

The first COVID-19 case in Brazil's indigenous population was from the Amazonas and confirmed on April 1st [45]. This first case had previous contact with an infected doctor who had access to an Indigenous group. This infected woman spread the virus to her ethnic group. The first COVID-19-caused death was a 15-year-old Indigenous Yanomami teenager from Roraima State who did not have comorbidities. In data available by the Health Ministry on November 9th, 2020, 33,011 COVID-19 cases and 479 deaths among Indigenous individuals were reported. Brazil has 34 Indigenous Sanitary Districts (DSEIs), and the highest number of cases and deaths was reported in the Mato Grosso do Sul DSEI.

The overcrowding phenomenon in Brazilian prisons associated with structural aspects of these places, such as inadequate ventilation and poor health services, makes the occupants of these facilities more susceptible to COVID-19. On May 11, 2020, 531 confirmed cases and 22 deaths resulted from COVID-19 in the Brazilian prison system [46]. We evaluated actual data (November 9) that showed 36,132 cases and 121 deaths with the highest numbers in São Paulo State. As described before, the most affected people are those above 60 years of age and with comorbidities such as heart diseases and diabetes. However, the scientific data about this regarding the Brazilian prisoner population are still scarce.

5 Concluding Remarks

Because of the complexity of several interfering factors involved in Brazil's COVID-19 dissemination dynamics, the determining epidemiological features are not entirely understood yet. This work highlights intrinsic and extrinsic interfering factors on the COVID-19 epidemic in different Brazilian states and cities. Intrinsic factors include high heterogeneity and complexity of the regional/local characteristics. These include: total population and population density; the percentage of the elderly population; high-risk population, children, indigenous population, in jail population, and other vulnerable people; availability of public health systems; per capita income; and Human Development Index (HDI). Extrinsic factors also vary enormously among Brazilian states and cities and include governmental decisions to combat the COVID-19 epidemic and people's awareness. The governmental decisions involve social distancing/isolation (e.g., public distancing among people, quarantine, and lockdown), facemask use, frequent hand sanitation, and restriction of economic activities such as closing/reopening of commercial trades and schools, and measures of flexibility. Mathematical models for predicting the COVID-19 pandemic for the understanding of the disease spread are still under investigation and validation.

Further studies are necessary to address several aspects of the COVID-19 pandemic in Brazil, especially in states and cities with persistent duration and those with risk of secondary waves of the epidemic, as well as to measure the effectiveness of the governmental measures and people awareness of the disease spread dynamics, helping to understand and to take other decisions against the disease dissemination.

Acknowledgements The authors of this study receive research financial support and scholarships from FAPESP, CAPES, CNPq, and PRPGP/Cruzeiro do Sul.

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