

## COVID-19 in Northeast Brazil: achievements and limitations in the responses of the state governments

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**Abstract** *The COVID-19 pandemic has been most severe in the poorest regions of Brazil, such as the states of the Northeast Region. The lack of national policies for pandemic control forced state and municipal authorities to implement public health measures. The aim of this study is to show the effect of these measures on the epidemic. The highest incidence of COVID-19 among the nine states in the Northeast was recorded in Sergipe, Paraíba and Ceará. Piauí, Paraíba and Ceará were the states that most tested. Factors associated with transmission included the high proportion of people in informal work. States with international airports played an important role in the entry of the virus and the initial spread, especially Ceará. All states applied social distancing measures, banned public events and closed schools. The response was a significant increase in social distancing, especially in Ceará and Pernambuco, a decline in the reproduction rate ( $R_t$ ), and a separation of the curve of observed cases versus expected cases if the non-pharmacological interventions had not been implemented in all states. Poverty, inequality, and the high rates of informal work provide clues to the intensity of COVID-19 in the region. On the other hand, the measures taken early by the governments mitigated the effects of the pandemic.*

**Key words** COVID-19, Northeast Brazil, Prevention and Control

## Introduction

Brazil reached the mark of 2,488,807 cases of COVID-19 on July 29, 2020<sup>1</sup>. Brazil is among the most unequal countries in the world, and the COVID-19 pandemic has deepened these inequalities, not only producing a greater impact on the number of cases and deaths in the poorest regions, such as the North and Northeast, but also increasing poverty<sup>2-5</sup>, racial and ethnic disparities<sup>6</sup> and strongly affecting women<sup>7,8</sup>.

The epidemic, while not sparing the wealthiest regions, has had a deeper impact on less favored states, such as those in the North and Northeast. The Northeast, one of the poorest regions of the country, constitutes 27% of the Brazilian population but has about a third (34%) of all cases and deaths (32%)<sup>1</sup>. A nationwide serological survey showed a remarkable variability in the prevalence of SARS coronavirus-2 antibodies in different Brazilian regions<sup>9</sup>, with extremely high rates in cities in the poorer regions. The new coronavirus pandemic has been a challenge for Brazil due to these deep internal inequalities, known to be associated with the pandemic both nationally and internationally.

In the absence of treatment and vaccines, the only effective strategy against COVID-19 is to reduce contact between susceptible and infected individuals through early identification of cases and reducing contact<sup>10</sup>, cleaning surfaces and potentially contaminated hands<sup>11</sup> and the use of masks<sup>12,13</sup>. The universally recommended strategy of testing cases and contacts and isolating the infected was practiced only timidly in Brazil. In the absence of national policies to control the pandemic, state and municipal authorities were responsible for implementing public health measures to reduce transmission for COVID-19, including declaring a state of emergency, closing retail and service companies, restricting transportation, and closing schools and universities<sup>14</sup>. The interventions varied substantially among states and municipalities, including both the measures that were adopted, and when they were instituted.

The objectives of this study are to explore the experience of the COVID-19 epidemic in the Northeast Region and to discuss the differences and similarities across the states of this region with respect to COVID-19, the social distance measures implemented, and how these differences can explain the epidemiological indicators of the epidemic in this region.

## Methodology

### Type and place of study

This is a mixed, descriptive and analytical study conducted in the Northeast Region of Brazil. This region is composed of nine states (Alagoas, Bahia, Ceará, Maranhão, Paraíba, Pernambuco, Piauí, Rio Grande do Norte and Sergipe) and 1,793 municipalities. It covers an area of approximately 1.5 million km<sup>2</sup> and has 53 million inhabitants.

### Data collection

The data used were extracted for each state from the following sources: 1) demographic and socioeconomic data from the Brazilian Institute of Geography and Statistics (IBGE)<sup>15</sup>; 2) federal and state decrees concerning specific control measures for COVID-19, with the effective date being considered the publication of the decree; 3) number of cases and deaths due to COVID-19 and for Serious Acute Respiratory Syndrome (SRAG) from the Ministry of Health and State Secretariats<sup>16,17</sup> and the Infogripe System<sup>18</sup>; 4) information on arrival and departure of national and international flights from the National Civil Aviation Agency (ANAC)<sup>19</sup>; and 5) mobility data from the *Google Mobility Report*<sup>20</sup> and the social isolation index developed by the Brazilian company Inloco<sup>21</sup>, using cellular phone data to help confront the pandemic.

Initiatives to develop measures of social mobility have been implemented by Google and the company In Loco, based on data captured by cell phones, with the objective of helping to face the COVID-19 pandemic. The social isolation index developed by Inloco shows the daily percentage of the population that are conforming to the social distancing guidelines in Brazilian states and municipalities since 02/01/2020<sup>21</sup>. The Google Community Mobility Report contains data on daily visits to the following locations: a) work, b) parks, beaches, squares and public gardens, c) supermarkets, drugstores and pharmacies, d) restaurants, shopping malls, museums, libraries and cinemas, e) subway stations, trains and buses, and f) residential areas. The movement of people (visits and length of stay) in different locations is calculated daily and compared to a baseline, which corresponds to the median movement during the period January 3 to February 6, 2020<sup>20</sup>. Mobility changes are presented as a percentage and are calculated daily until May 6,

2020 for the six categories. The Mobility Report covers 132 countries, including Brazil, and data are available from February 26th. For this study, the average movement in non-residential (areas a-e, above) and residential areas until June 13, 2020 was calculated. The Inloco social isolation index shows the daily percentage of the population that is meeting the recommendation for social distancing in Brazilian states and municipalities since 02/01/2020<sup>21</sup>.

The data on flights and passengers were collected from the Brazilian aviation authority ANAC and include the three state capitals with international airports (Fortaleza, Recife and Salvador). Data included: 1) number of landings (arriving or departing) of planes arriving from São Paulo, Rio de Janeiro or internationally per month, regardless of the airline; 2) number of passengers on these flights; and 3) ratio between flights and passengers per month between the routes mentioned above.

### Analysis

The data were summarized in the form of tables and graphs. Analysis of the data used the qualitative method of controlled comparison<sup>22,23</sup> to compare the differences and similarities among the Northeastern states.

The effective reproduction number over time ( $R_t$ ), the transmission parameter Beta and the observed and predicted curves for the number of cases were calculated using a compartmental model which divides the population among susceptible, exposed (individuals in incubation), asymptomatic infected, symptomatic infected and recovered<sup>24,25</sup>. The daily  $R_t$  value is defined as the average number of secondary cases infected by a case with onset of symptoms on day “t”, which in the present methodology also takes into account the secondary cases caused by asymptomatic infected individuals. The indicator can be interpreted as the higher the  $R_t$  value for a given location, the more uncontrolled the epidemic<sup>1</sup>.

### Results

Table 1 shows characteristics of the COVID-19 epidemic in the nine states of the region up to 7/21/2020. The state with the smallest difference between the first and the fiftieth and between the first and the hundredth case was Maranhão. The highest incidence of COVID-19 among the nine states was recorded in Sergipe (2049/100,000

pop.), followed by Paraíba (1713/100,000 pop.) and Ceará (1677/100,000 pop.). The region's first official death attributed to COVID-19 occurred in Pernambuco, on March 25. Until July 21, the ratio between the number of deaths and the number of confirmed COVID-19 cases notified was highest in Pernambuco (7.6%). The mortality rate for COVID-19 was highest in Ceará (80.1/100,000 pop.) followed by Pernambuco (64.4/100,000 pop.). In contrast, in Bahia, the ratio between the number of deaths and the number of confirmed COVID-19 cases was 2.2% and the mortality rate for COVID-19 was 20.1/100,000 inhabitants. The incidence of SRAG in Ceará reached 161.1/100,000, followed by 112.5/100,000 in Pernambuco and 97.8/100,000 in Piauí, indicating that there are a large number of cases of COVID-19 that are not being registered as such in these states, even considering the underreporting and delayed notification of SRAG cases<sup>26</sup>. The epidemic had already reached 100% of the municipalities in most states, with the exception of Bahia and Piauí.

Regarding testing for the identification of active cases, Piauí was the northeastern state that conducted the most tests (5122/100,000), followed by Paraíba (4954/100,000) and Ceará (4219/100,000). The relationship between the number of tests performed and the number of positive cases was higher in Piauí (4.0), Bahia (2.9) and Paraíba (2.9), and lower in Alagoas (2.0) and in Sergipe (1.7). These low numbers indicate that only people with a high probability of COVID-19 are being tested, i.e., the very symptomatic and the most severe cases (Table 1).

Table 2 presents some demographic indicators for the nine states. The population of each state ranges from 2.3 to 14.9 million inhabitants, from Sergipe to Bahia, respectively. Sergipe and Maranhão have the lowest percentages of elderly aged 60 and over. Demographic density also shows important differences, ranging from 12.4/km<sup>2</sup> in Piauí to 112.3/km<sup>2</sup> in Alagoas. Maranhão reports almost 10% excessive household occupancy by room, almost 2.5 times more than Bahia and Paraíba.

Using the method of controlled comparison<sup>22</sup>, the states were ranked by the main result variable: the aggregate number of notified cases of COVID-19 per 100,000 inhabitants of each state. Then, exploring other columns in the data, this ranking was compared with the ranking of other indicators that corresponded or approached correspondence with this main variable. Some of the indicators, such as the percentage of households

**Table 1.** Epidemiology of SRAG and COVID-19 in Northeastern States as of 7/21/2020.

State	Date of 1st case*	Days between 1st and 50th case*	Days between 1-100 cases*	Date of 1st death*	Number of Cases (Notified cases/100,000 pop.)**	Deaths (% of notified cases)**	Mortality (based on notified cases)/100,000 pop.	Incidence SRAG (based on notified cases)/100,000 pop.***	N (%) of municipalities with cases*	Tests*	Tests/100,000 pop.	Ratio of number of tests conducted and number of cases
Alagoas	08/mar	36	40	31/03	51680 (1549)	1443 (2,8)	43,2	97,6	102/102 (100)	105834	3171,2	2,0
Bahia	06/mar	16	20	29/03	133245 (896)	2988 (2,2)	20,1	41,2	413/417 (99,0)	386860	2601,1	2,9
Ceará	01/jan	33	47	24/03	153108 (1677)	7317 (4,8)	80,1	161,1	184/184 (100)	385250	4218,6	2,5
Maranhão	20/mar	11	16	29/03	108154 (1529)	2778 (2,6)	39,3	46,6	217/217 (100)	232291	3283,2	2,1
Paraíba	18/mar	21	24	31/03	68844 (1713)	1558 (2,3)	38,8	64,1	223/223 (100)	199058	4954,0	2,9
Pernambuco	12/mar	15	21	25/03	81382 (852)	6152 (7,6)	64,4	112,5	185/185 (100)	174680	1827,8	2,1
Piauí	19/mar	24	28	27/03	41815 (1278)	1158 (2,8)	35,4	97,8	218/224 (97,3)	167654	5122,0	4,0
Rio Grande do Norte	19/mar	16	21	28/03	45184 (1289)	1636 (3,6)	46,7	63,0	167/167 (100)	119141	3397,4	2,6
Sergipe	14/mar	33	38	02/04	47110 (2049)	1182 (2,5)	51,4	52,9	75/75 (100,0)	81223	3533,4	1,7

\*Source: <https://github.com/wcota/covid19br>; \*\*Source: <https://paineis.covid19br.org/> (Last updated: 21/07/2020); \*\*\*Source: <http://info.gripe.fiocruz.br/> (Last updated: 21/07/2020).

with excessive occupancy rates have a direct association with transmission and their selection is logical. Some of the other indicators such as proportion of people with formal jobs, do not have this direct association. These indicators represent a variety of different potential factors in transmission: not only issues of potential exposure, but also indirect and contextual factors, such as wealth distribution or a state history of supportive policies for workers' rights, including health. This pattern of classification of indicators is complemented by a review of all the indicators provided for each state. Maranhão, for example, is the state that reports the highest levels of values negatively associated with the health of the population. Ceará has an important percentage of the population below the poverty line and in extreme poverty, and has fewer households with piped water, indicators that are important in determining the distribution of infectious diseases. The highest incidence for COVID-19 was recorded in Ceará, followed by Maranhão and Pernambuco. The highest mortality rates were also observed in these three states.

Table 3 shows some well-known socioeconomic indicators for measuring the degree of poverty and inequality. There is an important similarity between the Human Development Index (HDI) of the Northeastern states, with Rio Grande do Norte, Ceará and Pernambuco standing out as those with slightly higher levels. The comparative analysis of income inequalities, measured through the Gini Index, also shows that they are shared at similar levels by all states, being slightly more accentuated in Sergipe, Alagoas, Bahia and Ceará (these last two states with very similar values), and especially in Maranhão. In fact, the state of Maranhão has the worst indicators, presenting the second worst HDI, the lowest per capita household monthly income, the highest percentages of the population below the poverty line and in extreme poverty and the highest proportion of people in informal work. Ceará has the best HDI, but has the fourth worst household income per capita, 42% of its population lives below the poverty line; almost of its population was employed in the reference week, and close to 30% had informal work. Pernambuco ranks third in HDI and per capita monthly household income. However, 41% of its population is below the poverty line, almost of its population was employed at the end of the fourth quarter of 2019, and almost 30% of the population aged 14 and over had informal work (Table 3).

**Table 2.** Demographic indicators in the Northeastern States.

State	Population <sup>a</sup>	% pop 60 years or greater <sup>b</sup>	Demographic Density <sup>c</sup>	% households with excess density <sup>d</sup>
Alagoas	3,337,357	14.7	112.3	5.8
Bahia	14,873,064	15.2	24.8	4.3
Ceará	9,132,078	15.2	56.8	6.3
Maranhão	7,075,181	12.5	19.8	9.9
Paraíba	4,018,27	14.8	66.7	4.3
Pernambuco	9,557,071	15.9	89.6	5.0
Piauí	3,273,227	15.6	12.4	4.6
Rio Grande do Norte	3,506,853	14.9	60.0	5.8
Sergipe	2,298,696	12.4	94.4	4.4

<sup>a</sup> IBGE: Estimated population 2019: <https://www.ibge.gov.br/cidades-e-estados>; <sup>b</sup> IBGE: Population projection for Brazil by sex and age 2010-2060; <sup>c</sup> IBGE: Demographic Density 2010: <https://www.ibge.gov.br/cidades-e-estados/al.html>; <sup>d</sup> IBGE: National Survey of Households 2018. Excess density is classified as 3 or more residents per bedroom.

Although all states in the region have many unfavorable socioeconomic indicators and share common social, political and cultural characteristics, they have differences that can contribute to understanding the epidemiology of COVID-19 in the region. This can be seen in Table 3, which brings together some well-known socioeconomic indicators of poverty and inequality. The Human Development Index (HDI), for example, is an indicator designed by the United Nations (UN) to measure the quality of life and economic development of a population, composed of education indicators (literacy and enrollment rate), life expectancy at birth, and income (GDP per capita). There are important similarities between the HDIs of the northeastern states, with Ceará, Rio Grande do Norte, and Pernambuco standing out as those with slightly higher levels. The comparative analysis of income inequalities, measured by the Gini Index, also allows us to see that they are shared at similar levels by all states, with the situation of inequality being slightly higher in Pernambuco, Sergipe, Alagoas, Bahia and Ceará (these last two states with very similar values). The state of Maranhão, in general, has the worst indicators, with the worst HDI, the lowest per capita monthly household income, the highest percentages of the population below the poverty line and in extreme poverty and the lowest proportion of people in informal work (Table 3).

The initial port of entry of cases in the country was in São Paulo, whose main airport (Guarulhos) has the largest number of international flights, with passengers arriving principally from Europe, and frequently embarking for other des-

tinations. Three state capitals in the Northeast region – Fortaleza, Recife and Salvador – have international airports. In January, about half of the 15,107 flights and 1,312,000 passengers that arrived in the Northeast region came directly from São Paulo and Rio de Janeiro, where the pandemic was already spreading, due to infected individuals arriving from abroad (Figure 1).

Other forms of COVID-19 entry were recorded in a non-systematic manner. For example, social events, such as a wedding that was widely reported in the media that took place at a seaside resort in the south of the state of Bahia<sup>27</sup>. There, people from different cities, including some with a history of recent trips to Europe, several of whom were infected with SARS-CoV-2, were responsible for infecting other participants and workers at the event. When they returned home they brought the virus with them.

The first cases of COVID-19 identified in the region were, in general, people who had arrived from trips abroad or from the Southeast of the country. Control measures started with the isolation of the first imported cases and the quarantine of contacts and were followed by the prohibition of public events and the closure of schools, adopted by all the state governments. The social distance rules adopted in the states of the Northeast were, for the most part, implemented on very similar dates, in mid-March<sup>14</sup>. In Paraíba, decrees implementing social distance were promulgated the day after notification of the first case of the disease (Chart 1). In Bahia, eleven days passed until the enactment of such actions at the state level. Three states – Maranhão, Rio Grande do

Table 3. Socioeconomic indicators of the Northeastern States.

State	HDI (2019) <sup>a</sup>	GINI (2019) <sup>b</sup>	Monthly household income per capita R\$ (2018) <sup>c</sup>	% Pop below the poverty line (2019) <sup>d</sup>	% Pop in extreme poverty (2019) <sup>e</sup>	% Households with piped water (2019) <sup>f</sup>	% of pop. 14 years or older unemployed PNAD (1 <sup>st</sup> trimester 2020) <sup>g</sup>	% pop. 14 years or older in formal jobs PNAD (1 <sup>st</sup> trimester 2020) <sup>g</sup>	Unemployment rate 4 <sup>o</sup> trimester of 2019 and 1 <sup>st</sup> trimester of 2020 <sup>g</sup>
Alagoas	0.683	0.550	731	40.0	17.2	80.2	16.5	51.4	13.6
Bahia	0.714	0.548	913	42.9	13.0	85.2	18.7	43.3	16.4
Ceará	0.735	0.548	942	42.0	12.0	79.1	12.1	42.6	10.1
Maranhão	0.639	0.526	636	53.0	19.2	70.3	16.1	35.1	12.1
Paraíba	0.722	0.547	929	40.0	11.2	76.3	13.8	43.3	12.1
Pernambuco	0.727	0.673	970	41.1	11.4	75.2	14.5	48.4	14.0
Piauí	0.697	0.526	827	41.9	14.2	85.1	13.7	37.6	13.0
Rio Grande do Norte	0.731	0.535	1057	38.0	10.3	87.0	15.4	48.2	12.6
Sergipe	0.702	0.575	980	44.1	13.9	85.0	15.5	47.1	14.8

<sup>a</sup>HDI - Human Development Index. UNDP - Radar MHDI: evolution of the MHDI and its component indexes in the period from 2012 to 2017; <sup>b</sup>IBGE: <https://www.ibge.gov.br/cidades-e-estados>; <sup>c</sup>IBGE: Monthly household income per capita. National Survey of Households 2018: <https://www.ibge.gov.br/cidades-e-estados>; <sup>d</sup>IBGE: People with per capita monthly income between R\$ 145 and R\$ 420. Synthesis of Social Indicators 2019; <sup>e</sup>IBGE: People with per capita monthly income below R\$ 145. Synthesis of Social Indicators 2019; <sup>f</sup>IBGE: National Household Sample Survey: <https://www.ibge.gov.br/cidades-e-estados>; <sup>g</sup>IBGE: Trimestral National Household Sample Survey (1<sup>st</sup> trimester 2020).

Norte and Piauí – implemented measures of social distance even before the confirmation of the first case. Maranhão was also the first state in the Northeast to decree total lockdown, for 13 days, from May 5, 2020, followed by the states of Ceará and Pernambuco.

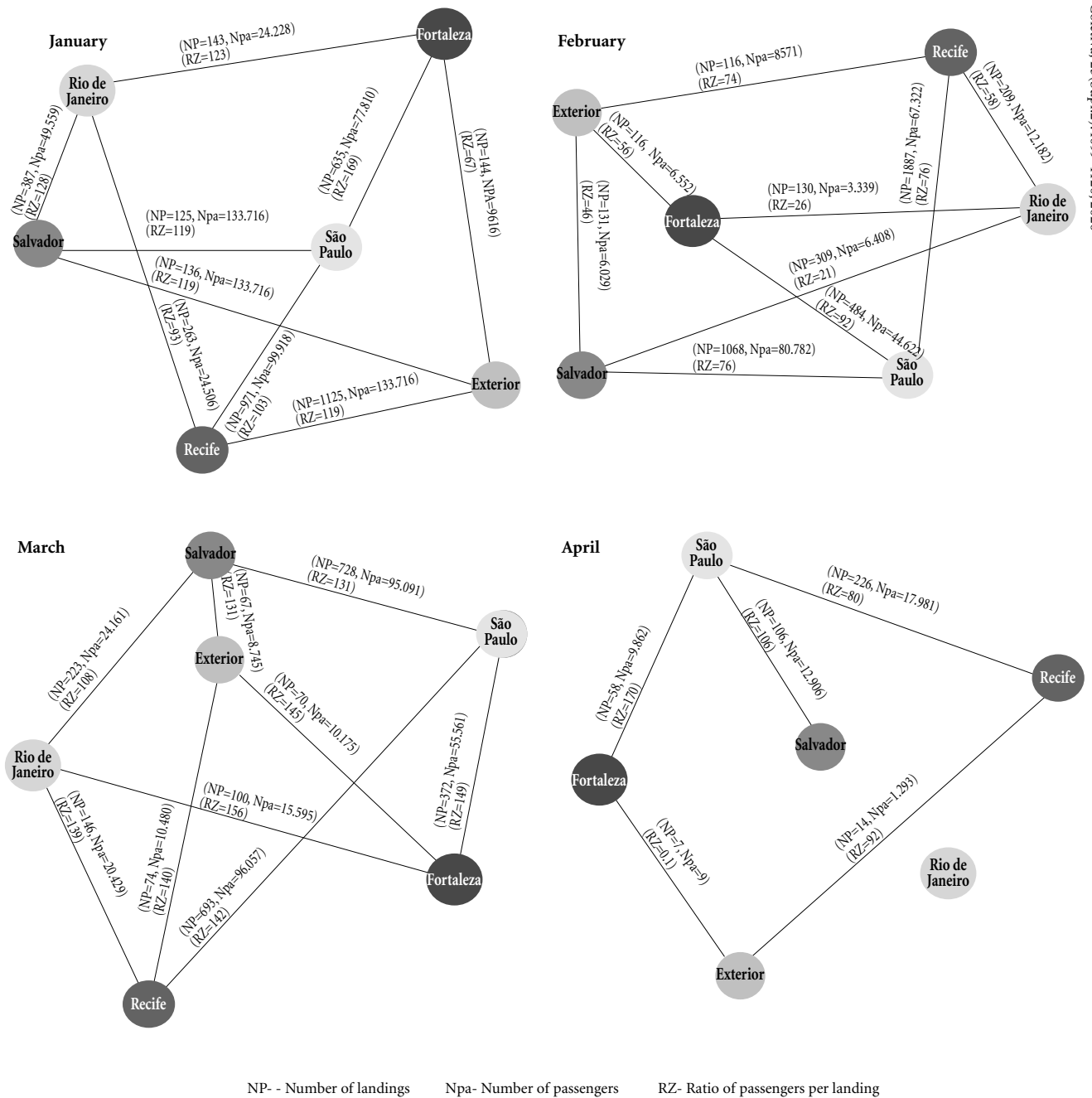
Most states adopted measures encompassing different spheres of social life, including downsizing or banning events, closing schools and universities, restrictions on the functioning of retail businesses, services and industry, closing and banning visits to parks, swimming pools and beaches, reduced transportation (municipal, intercity and interstate) and changes in the work schedules of public employees. The lack of specific legislation for social distancing at the state level for each measure considered is highlighted in gray in the Chart 1. However, it is important to note that in the state capitals and many municipalities, measures were also adopted in response to the epidemiology and political context of each location.

Figure 2 shows the evolution of the average mobility outside the home (column 1), the daily value of the number of effective reproduction over time – Rt (column 2) and the evolution curves of the accumulated number of cases observed and estimated using a SEIR model (column 3) for the nine states in the Northeast. All states show significant reductions in mobility outside the home as of the second half of March.

Most states maintained the social isolation index (Inloco) above 40%, but registered reductions by the 2nd week of May. Ceará, followed by Pernambuco, were the states that featured the highest levels of social distancing during the period of this study. Maranhão, which implemented the lockdown at the beginning of May, kept the social distancing rates at a level close to that of the beginning of the implementation, but showed a marked reduction after suspending the lockdown (Figure 2, column 1).

In all the states during the study there is great variability in the effective reproduction number (Rt) over time. However, the number remained above 1 most of the time, except for some rare moments when it was below 1 (Figure 2, column 2). However, since the beginning of June, the states of Alagoas, Maranhão and Pernambuco had a lower Rt. It is noteworthy that as of the date of submission of this article, in August 2020, Ceará still has an average Rt value above 1.

In Figure 2, column 3, the curve of the cumulative number of cases recorded and the curve of the numbers obtained from the model also



**Figure 1.** Number of landings, number of passengers, and passengers per landing in the international airports in the Northeast states arriving from the exterior and other Brazilian cities: São Paulo, Rio de Janeiro, destined for Salvador, Fortaleza and Recife from January to March 2020.

allows us to observe the effect of social distance measures on the curves. Thus, the state of Bahia started to distance themselves from the curve ex-

pected without interventions in the beginning of April, when the beta decreased from 1.40 to 0.87. Ceará also saw important impact from social

**Chart 1.** Measures of social distancing implemented in the Northeast states, date of the first case and days until social distancing until 13 May 2020.

State	1st case	Distanciamento social							Lockdown (the most restrictive limitations on personal mobility)	Isolation of cases	Days between 1st case and social distancing
		Events	Education	Parks, pools, beaches, etc.	Transport	Public Sector Services	Trade, services and industry				
Alagoas	08/mar	<ul style="list-style-type: none"> <li>- Prohibition of open events with more than 500 people and closed with more than 100 people (Decree 69501)</li> <li>- Prohibition of activities in public cultural facilities (Decree 69501) (16/03)</li> <li>- Total ban on events (Decree 69541) 03/20</li> </ul>	<ul style="list-style-type: none"> <li>- Closure of all schools (Decree 69501) 20/03</li> </ul>	<ul style="list-style-type: none"> <li>- Closure of parks and beaches (Decree 69502) 20/03</li> </ul>	<ul style="list-style-type: none"> <li>- Suspension of intercity and intracity bus service</li> </ul>	<ul style="list-style-type: none"> <li>- Teleworking for employees belonging to risk groups (Decree 69502) 16/03</li> <li>- Teleworking for all workers that can perform their activities remotely (Decree 69577) 30/03</li> </ul>	<ul style="list-style-type: none"> <li>- Suspension of trade, industry and non-essential services - except for deliveries (Decree 69502) 20/03</li> </ul>		<ul style="list-style-type: none"> <li>Self-isolation for anyone with flu symptoms (Decreto 69502) 17/03</li> </ul>	8	

it continues



**Chart 1.** Measures of social distancing implemented in the Northeast states, date of the first case and days until social distancing until 13 May 2020.

State	1st case	Distanciamento social							Isolation of cases	Days between 1st case and social distancing
		Events	Education	Parks, pools, beaches, etc.	Transport	Public Sector Services	Trade, services and industry	Lockdown (the most restrictive limitations on personal mobility)		
Bahia	06/mar	Prohibition of events with more than 50 people for municipalities with community transmission (Decree 19.529) 03/17 - Prohibition of events with more than 50 people for the whole State (Decree 19.586) 28/03	- Partial closing of schools (Decreto 19.529) 17/03 - Complete closing of schools (Decreto 19.586) 28/03		- Suspension of mooring of a large vessel (Decree 19.529) 17/03 - Suspension of the circulation of interstate buses (Decree 19.528) 19/03 - Suspension of intercity transport from where there is community transmission - except for professional activities (Decree 19,549) 19/03	- Teleworking for all workers that can perform their activities remotely (Decree 33.536) 17/03		Curfew: Itabuna and Ipiatú (Decree 19,688 - 12/5) and Jequié (Decree 19.691 - 14 // 5) Salvador - interdiction of places where movement increased most (Decree 32.389-9/5) and in neighborhoods / roads with the highest number of patients (Decree 32.399 - 13/5)	Self-isolation obligatory for persons with whatever disease symptoms (Decreto 19.529) 17/03	11

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**Chart 1.** Measures of social distancing implemented in the Northeast states, date of the first case and days until social distancing until 13 May 2020.

State	1st case	Distanciamento social							Lockdown (the most restrictive limitations on personal mobility)	Isolation of cases	Days between 1st case and social distancing
		Events	Education	Parks, pools, beaches, etc.	Transport	Public Sector Services	Trade, services and industry				
Ceará	01/jan	169/5000 - Suspension of license for events with more than 100 people (Decree 33.510) 16/03 Prohibition of collective activities in public facilities (Decree 33.510) 16/03	- Closing of all schools (Decree 33.510) 19/03	- 82/5000 Prohibition of frequenting beaches, rivers, lagoons and swimming pools (Decree 33.519) 19/03	-Suspension of intercity and metropolitan road transport and subway transport (Decree 33,519) - Suspension of interstate bus circulation (Decree 33,519) 19/03	- Teleworking for workers belonging to risk groups (Decree 19.528) 16/03 - Teleworking for all workers that can perform their activities remotely (Decree 33.536) 05/04	- Suspension of non-essential industrial activities and non-essential face-to-face commerce and services (Decree 33.519) 19/03	<b>Fortaleza</b> – restrictions on circulation of persons and vehicles (14.663 em 8/5)	Self-isolation for persons with symptoms (Decree 33.519) 19/03	33	
Maranhão	20/mar	- Suspension of license for events (Decree 35.660) 16/03 Prohibition of activities with agglomeration (Decree 35.677) 21/03	- Partial closing of all schools (Decree 35.662) 17/03		- Suspension of interstate transportation (Decree 35.672) 3/21 - Suspension of mooring of a large vessel from a country with circulation of the disease (Decree 35.677) 21/03		- Suspension of trade and non-essential services - except for deliveries (Decree 35.677) 3/21	<b>São Luís, São José de Ribamar, Paço do Lumiar and Raposa</b> – No road traffic allowed (Decree 35.784 - 05/05 por 10 dias)	Self-isolation for public sector workers with symptoms (Decree 35.660) 16/03	-4	

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**Chart 1.** Measures of social distancing implemented in the Northeast states, date of the first case and days until social distancing until 13 May 2020.

State	1st case	Distanciamento social							Lockdown (the most restrictive limitations on personal mobility)	Isolation of cases	Days between 1st case and social distancing
		Events	Education	Parks, pools, beaches, etc.	Transport	Public Sector Services	Trade, services and industry				
Paraíba	18/mar	- Suspension of State events (Decree 40.128) 19/03 - Prohibition of events in cities with cases of the disease (Decree 40.173) 04/04	- Partial closing of schools (Decreto 40.128) 19/03		- Suspension of disembarkation of cargo ship crews (Decree 40.135) 21/03 - Suspension of intercity transport in the largest municipalities (Decree 40.135) 21/03 - Reduction in the functioning of the main waterway crossings	- Relay for all servers and telework for those belonging to risk groups (Decree 40.128) 19/03 - Teleworking for all servers that can perform their activities remotely (Decree 40.136) 21/03	Suspension of trade and non-essential services - except for deliveries (Decree 40.135) 3/21			1	

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**Chart 1.** Measures of social distancing implemented in the Northeast states, date of the first case and days until social distancing until 13 May 2020.

State	1st case	Distanciamento social							Lockdown (the most restrictive limitations on personal mobility)	Isolation of cases	Days between 1st case and social distancing
		Events	Education	Parks, pools, beaches, etc.	Transport	Public Sector Services	Trade, services and industry				
Pernambuco	12/mar	<ul style="list-style-type: none"> <li>- Prohibition of events with more than 500 people (Decree 48,809) 14/03</li> <li>- Prohibition of events with more than 50 people (Decree 48,822) 18/03</li> <li>- Suspension of activities in cultural facilities and fitness centers (Decree 48,822) 18/03</li> <li>- Total ban on events (Decree 48,837) 24/03</li> </ul>	-Closing of all schools (Decreto 48.810) 28/03	<ul style="list-style-type: none"> <li>- Prohibition of use of parks and beaches (Decreto 48.881) 04/04</li> </ul>	<ul style="list-style-type: none"> <li>Suspension of mooring of large vessels (Decree 48,809) 14/03</li> <li>- Suspension of landing and tourism in an isolated community (Fernando de Noronha) (Decree 48.822) 18/03</li> <li>- Banning the disembarkation of cargo ship crew (Decree 48.830) 19/03</li> <li>- Suspension of any access to isolated community (Fernando de Noronha), except for essential activities (Decree 48.878) 03/04</li> </ul>	<ul style="list-style-type: none"> <li>- Telework for all workers belonging to a risk group (Decreto 48.810) 17/03</li> </ul>	<ul style="list-style-type: none"> <li>- Suspension of trade and non-essential services - except for deliveries (Decree 48.833) 3/21</li> </ul>	<b>Recife, Olinda, Camaragibe, São Lourenço da Mata and Jaboatão dos Guararapes</b> (Decree 49.017, de 16/5)	Self-isolation for persons coming for countries with cases of COVID-19 (Decreto 48.822) 18/03	2	

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**Chart 1.** Measures of social distancing implemented in the Northeast states, date of the first case and days until social distancing until 13 May 2020.

State	1st case	Distanciamento social							Lockdown (the most restrictive limitations on personal mobility)	Isolation of cases	Days between 1st case and social distancing
		Events	Education	Parks, pools, beaches, etc.	Transport	Public Sector Services	Trade, services and industry				
Piauí	19/mar	- Prohibition of open events with more than 100 people and closed with more than 50 people (Decree 18.884) 16/03	- Partial closure of schools (Decree 18,884) 16/03 - Total closure of schools (Decree 18,913) 30/03		- Suspension of intercity road transportation (Decree 18,924) 03/04			- Suspension of trade and non-essential services - except for deliveries (Decree 18,901) 3/21 - 50% reduction in the flow for essential activities (Decree 18,902) 23/03 - Reduction of working hours in industry (Decree 18,902) 23/03		-3	

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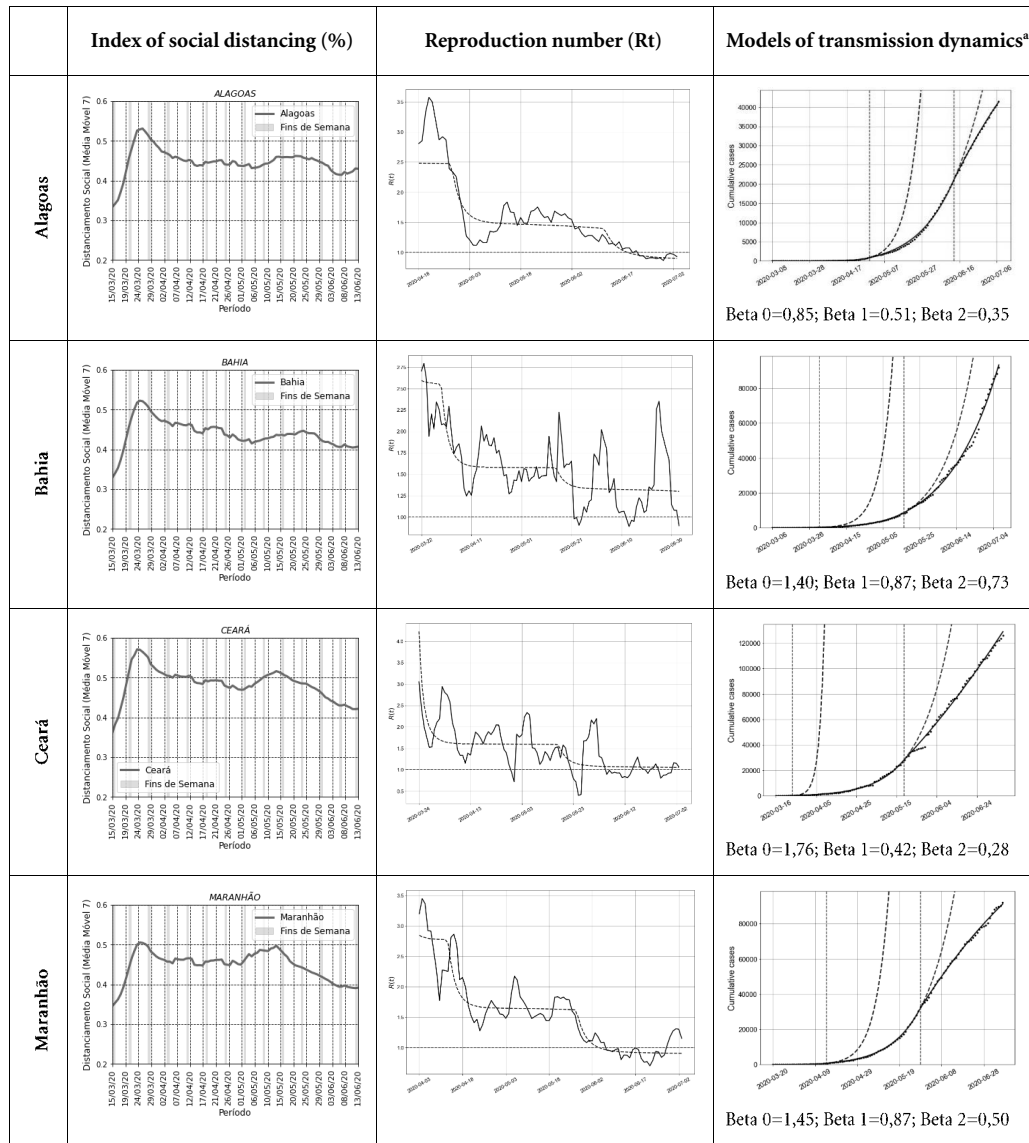
**Chart 1.** Measures of social distancing implemented in the Northeast states, date of the first case and days until social distancing until 13 May 2020.

State	1st case	Distanciamento social						Lockdown (the most restrictive limitations on personal mobility)	Isolation of cases	Days between 1st case and social distancing
		Events	Education	Parks, pools, beaches, etc.	Transport	Public Sector Services	Trade, services and industry			
Rio Grande do Norte	19/mar	<ul style="list-style-type: none"> <li>- Prohibition of events with more than 100 people (Decreto 29.524) 18/03</li> <li>- Prohibition of events with more than 50 people (Decreto 29.541) 21/03</li> <li>- Prohibition of events with more than 20 people (Decreto 29.583) 02/04</li> </ul>	<ul style="list-style-type: none"> <li>- Closing of all schools (Decreto 29.524) 18/03</li> </ul>			<ul style="list-style-type: none"> <li>- Telework for workers in any risk group (Decreto 29.512) 14/03</li> </ul>	<ul style="list-style-type: none"> <li>- Suspension of trade and non-essential services - except for deliveries and shopping centers with natural air circulation (Decreto 29.541) 3/21</li> <li>- Suspension of any establishment with artificial air circulation (Decreto 29.583) 02/04</li> </ul>		-5	

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**Chart 1.** Measures of social distancing implemented in the Northeast states, date of the first case and days until social distancing until 13 May 2020.

State	1st case	Distanciamento social						Lockdown (the most restrictive limitations on personal mobility)	Isolation of cases	Days between 1st case and social distancing
		Events	Education	Parks, pools, beaches, etc.	Transport	Public Sector Services	Trade, services and industry			
Sergipe	14/mar	<ul style="list-style-type: none"> <li>- Prohibition of open events with more than 100 people and closed events with more than 50 people (Decree 40.560) 17/03</li> <li>- Total ban on events (Decree 40,563) 20/03</li> <li>- Suspension of cinemas, theaters and the like (Decree 40.560) 17/03</li> </ul>	<ul style="list-style-type: none"> <li>- Closing of all schools (Decree 40.560) 17/03</li> </ul>		<ul style="list-style-type: none"> <li>-Suspension of mooring of a vessel coming from a region with virus circulation (Decree 40,563) 03/23</li> <li>- - Prohibition of the circulation of interstate buses from States with virus circulation (Decree 40,563) 23/03</li> </ul>	<ul style="list-style-type: none"> <li>- Teleworking for workers belonging to risk groups (Decree 40,560) 17/03</li> <li>- Relay and teleworking for all workers, as well as reduced working hours (Decree 40,563) 20/03</li> <li>- Teleworking for all workers that can perform their activities remotely (Decree 40.567) 25/03</li> </ul>	<ul style="list-style-type: none"> <li>- Revezamento de pessoal no comércio e na indústria (Decreto 40.563) 20/03</li> <li>- Suspensão ao comércio e serviços não essenciais – exceto para entregas (Decreto 40.563) 20/03</li> </ul>		3	



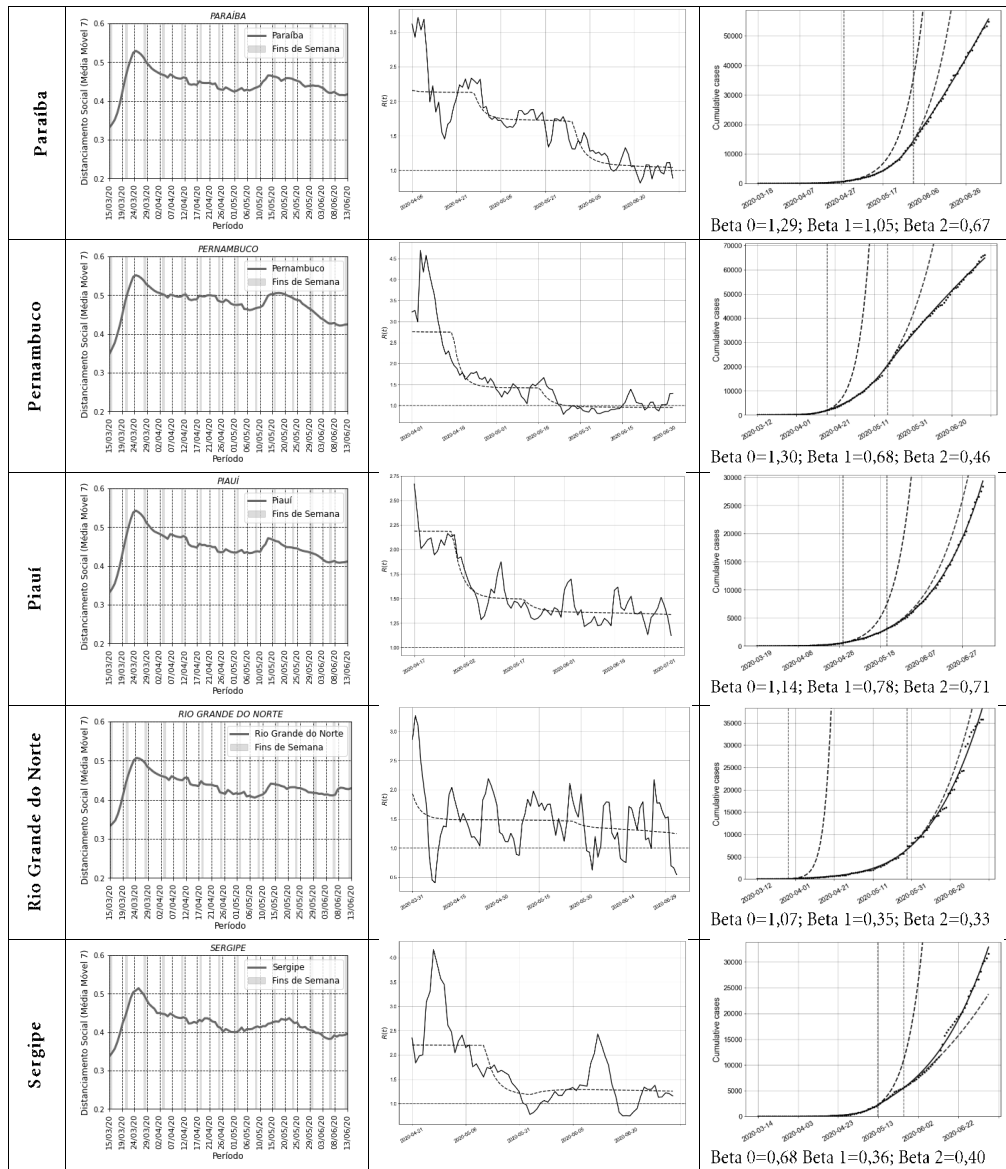
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**Figure 2.** Mobility Index, Reproduction Number (Rt), and effect of social distancing measures on transmission dynamics of COVID-19, from March to June 2020.

distancing measures, visible at the end of March 2020, with an increasing separation between the curves of expected and observed cases. At the same time the beta dropped from 1.76 to 0.71. Maranhão could only reduce the cases observed in relation to the expected number of cases in mid-April, about 15 days after implementing the lockdown (on 05/05/2020), when the beta moved

from 1.45 to 0.87. In a further sharp reduction, 15 days after the lockdown was declared, the beta fell from 0.87 to 0.50. Pernambuco separated from the expected curve without intervention around April 15, when the observed cases proved to be fewer than expected, and the beta fell from 1.30 to 0.68. In general, the SEIR models of all the states converged, showing a reduction in the





**Figure 2.** Mobility Index, Reproduction Number (Rt), and effect of social distancing measures on transmission dynamics of COVID-19, from March to June 2020.

slope of the epidemic curves due to the decrease in contact and transmission of COVID-19, in parallel to the social distancing strategies and mask use implemented in these states.

### Discussion

This study shows that COVID-19 has had a very severe impact on the Northeast region. The government's lack of leadership in formulating a consistent national response has led state governments and municipal administrations to take

decisions to respond to the epidemic and to mitigate it. This study focusing on the states of the Northeast region, one of the poorest regions of the country, but heterogeneous in some socioeconomic and demographic indicators, allows to verify the variations in the magnitude of the epidemic and explore the effectiveness of the social distance measures implemented in a socioeconomic and political context unfavorable.

The interaction between poverty, unemployment, education level, race, and gender and has been documented as determinants of COVID-19<sup>28,29</sup>. People with low incomes are more exposed to infectious diseases, including SARS-CoV-2, due to the lack of access to basic sanitation and treated water, the lack of access to education and health services, the use of public transport, subject to crowding and the difficulty of self-isolating, living in precarious housing and/or with an excessive number of residents, or also because they are more often unemployed or engaged in informal jobs. Brazil began the epidemic with 41% of workers listed as informal workers, that is, without social or labor rights, such as unemployment benefits, vacations, maternity leave or social security. It is not by chance that the nine states in the Northeast are among the 12 Brazilian states with the lowest reported income in the PNAD (National Household Survey) in May 2020<sup>30</sup>. This same survey showed that unemployment rates increased in 12 Brazilian states, half of which are in the Northeast Region, and four of these six are among the states with the highest unemployment rates in the country. In two of the states with increasing unemployment (Maranhão and Ceará), and in Pernambuco, which already reported an unemployment rate higher than Ceará, the highest case rates for COVID-19 were reported. High rates of unemployment or informal work, without government assistance for income support, lead to a daily search for an income and, consequently, to low adherence to social distance measures, and high rates of disease transmission<sup>14</sup>. Social distancing not only takes longer to reach the poorest peripheral areas and regions, but it is targeted at formal and salaried workers. In Medellín, the second largest city in Colombia, the emergency provision of minimum income for people in need, registered in advance via an app, enabled both timely mapping and delivery of income, ensuring the successful implementation of physical distancing and the mitigation of COVID-19<sup>31</sup>. In Brazil, the existence of the Single Registry (*Cadastro Único*) accelerated the delivery of the

emergency aid approved by Congress, which theoretically could arrive more quickly to needy segments of the population<sup>32</sup>. However, due to a series of operational failures, a large portion of this population had to expose themselves to large gatherings while waiting at banks and national lottery stations to receive the aid<sup>33</sup>.

The comparative analysis conducted among the states showed that several northeastern states share factors that could amplify the epidemic, such as high urban density, high levels of inequality, high rates of informal work, presence of an international airport and being internal domestic tourism destinations. Although these characteristics help to explain a part of the distribution pattern of COVID-19, it can not provide a more definitive explanation of the data provided. Possibly, one of the problems that aggravated COVID-19 in the Northeast was the early entry of the virus in the region, in this case, in the state of Ceará. Despite the fact that the authorities in Ceará launched a technically solid and effective set of preventive actions dated from the detection of the first official case, this state had the highest number of reported cases of COVID-19. However, retrospective investigation of cases of Severe Acute Respiratory Syndrome, conducted by the epidemiological surveillance service of the state and the Fortaleza Department of Health, showed that 50 cases of COVID-19 were confirmed in Fortaleza one day after Wuhan's notification to WHO in January<sup>34</sup>. Another study of the evolution and spread of the SARS-CoV-2 epidemic in the country showed that three different strains were circulating in Brazil, and that they were transmitted before the confirmation of the first official case<sup>35</sup>. One of the strains reached a higher prevalence in the Southeast Region, including São Paulo and Rio de Janeiro; the other two entered the country through the state of Ceará, probably from Europe and the United States<sup>35</sup>. The consequences of this process, unknown at the time, was the wide and silent spread of SARS-CoV-2 in the country, without mitigation measures being adopted<sup>36</sup>. When the governments of the states of the Northeast region took the first measures for social distancing in mid-March, when the first cases were officially notified, Ceará, for example, already had 1,160 confirmed COVID-19 cases, and about 1/3 of the cities in the interior of the state already had cases<sup>34</sup>. The situation in Ceará does not represent the failure of measures adopted for social distancing, as there is evidence that without these measures the situation would be even more serious, with more cases and

deaths. Rather, it may be related to weaknesses in the epidemiological surveillance system that did not have access to the first cases of COVID-19 that occurred in Fortaleza and in other parts of the State. It seems that the information about wealthy patients, entering the private health care system, wasn't promptly reported to the surveillance system<sup>24</sup>.

An important set of measures to restrict the movement of people and, consequently, reduce the spread of the epidemic, concerns measures to close businesses and non-essential services, close schools, as well as limit the movement of people within neighborhoods and between municipalities. We observed to a greater or lesser degree a reduction in social mobility and a slowdown in the progression of the epidemic in all states in the Northeast. However, as of the data of this submission, the reproductive number remained above 1 in all states, indicating that the epidemic is still growing.

At the same time that the epidemic entered, in most states, through its capitals and the more affluent population, and after community transmission was established in these cities, it headed for the interior of the states, much less well prepared than the capitals. The numbers of cases reported in all the capitals of the region, as of the date this paper was finished, are fewer than the total for the interior of the states. The  $R_t$  calculated for each state is now strongly influenced by the growth in the number of cases in the interior. The lack of tertiary care in these municipalities, especially with respect to ICU beds per capita, or the availability of health professionals with skills in the management of hospitalized patients in these units, combined with the difficulty of access of the population to these units constitutes greater fragility for those communities in the face of COVID-19 in the interior of the states. At the same time, in the absence of other measures to be carried out at this time, social distancing and social isolation measures, such as lockdown, may be the only way to actually reduce the transmission of COVID-19<sup>14</sup>.

The available data do not allow a more detailed breakdown of the social distancing measures in regions or neighborhoods of greater and lesser purchasing power, or of areas closer and farther from the capitals of the Northeast. How-

ever, a national serological study shows cities in the North Region with more than 20% prevalence, and the Northeast with about 15%, while most other developed regions have rates around 1%<sup>9</sup>. A survey carried out in the capital of Ceará, Fortaleza, demonstrates the great inequality experienced in large urban centers. While the poorest neighborhoods had almost a quarter of its population affected by COVID-19, the richest neighborhoods, producing the first cases, had six times less, staying in the 4% range<sup>37</sup>.

Poverty and striking inequality in the Northeast, associated with other socioeconomic and cultural conditions of the region, provide the clues for why COVID-19 is so intense and widespread. On the other hand, the fact that mitigation actions were taken early, as soon as the first cases were officially recognized, mitigated the effects of the pandemic. While the responses have been different by state – given the absence of centralized measures issued by the federal government – there was an important reduction in the number of deaths by COVID-19 in the region as a result of physical distancing measures and actions on health taken by the state governments.

The COVID-19 epidemic hit one of the most unequal countries in the world, aggravating an unprecedented political, economic and social crisis that preceded the outbreak of the epidemic. The recent picture of COVID-19 in Northeast Brazil demonstrates that various epidemics are occurring simultaneously. It is likely that there will be new waves both in the capitals and in the interior. This prognosis must remain until either a medical intervention, such as a vaccine, or the population reaches, after a few waves, levels of “herd immunity,” or more radical measures are implemented to support physical distancing, such as: income extended to vulnerable families, mass testing, isolation of confirmed cases with locations for isolation provided when it is not possible (hotels, schools, etc. ), and contact tracing; measures at this point in time have not been implemented at levels necessary to end or significantly reduce the disease. The COVID-19 epidemic in northeastern Brazil, which encompasses the region and the country in one of the most difficult periods of its political, economic and social history, will leave its marks forever in future generations.

## Collaborations

L Kerr, C Kendall, AAM Silva, EML Aquino, MY Ichihara and ML Barreto: conception, organization, data analysis, writing and editing. JM Pescarini: organization, data analysis, writing and editing. RLF Almeida, TVB Araújo and MFPM Albuquerque: data analysis and writing. JF Oliveira, C Teles, DCP Jorge, DB Miranda Filho, G Santana, L Gabrielli, R Souza and WV Souza: data analysis. N Almeida Filho and CMT Marteli: edition. NJ Silva and RAA Ximenes: data analysis and editing. SP Brandão Filho: organization and data analysis.

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