Impact and trend of COVID-19 in the Brazilian prison system: an ecological study

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Abstract *Given the rapid spread of new coronavirus within the prison system, this study's objective was to identify spatial clusters for the occurrence of COVID-19 in the incarcerated population and analyze temporal trends of confirmed cases in the Brazilian prison system. This ecological study considered the five Brazilian macro-regions to be units of analysis, with its 26 states and the Federal District. The population was composed of all COVID-19 cases confirmed from April 14th to August 31st, 2020. The source used to collect data was the COVID-19 Monitoring Panel from the National Prison Department. Descriptive analysis, scan statistics, and time series were performed. A total of 18,767 COVID-19 cases were reported among the incarcerated population, 4,724 in São Paulo. The scan statistic analysis resulted in 14 spatial risk clusters for COVID-19 among persons deprived of liberty; the highest-risk cluster was in the Federal District. Although the country ends the series with a decreasing behavior, a growing trend was verified in most of the study period. The conclusion is that there is a need to implement mass testing among the incarcerated population while continually monitoring and recording COVID-19 cases.*

Key words *COVID-19, Prisoners, Prisons, Epidemiology*

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Introduction

In this century, society has been faced with a considerable health challenge after the emergence of coronavirus[1]. The disease called COVID-19 was initially reported in China at the end of 2019 and rapidly spread worldwide. The World Health Organization (WHO) declared the pandemic in March 2020[2,3].

Since the first case was officially reported in Brazil on February 26th[4], strategies have been implemented to contain its advancement. However, due to an unstable political context, little adherence to social isolation in certain regions, lack of national planning together with the states and cities, and existing social inequalities, the perspectives to control and prevent the disease are unfavorable[1].

An additional concern refers to the entry and dissemination of the coronavirus in Brazilian prisons, the conditions of which include: overcrowded and poorly ventilated cells, restricted access to water and basic sanitation, and a lack of health units, that is, healthcare is provided in areas scattered wherever space is available[5]. These characteristics cause these environments susceptible to the rapid dissemination of the disease, considering the well-documented history of the wide dissemination of influenza, tuberculosis, and other infectious and respiratory diseases[6,7].

Due to Brazil's incarceration conditions, it is estimated that a positive case contaminates up to 10 people[6], 80% of whom will remain asymptomatic or manifest mild symptoms. In contrast, 20% will develop the more severe forms of the disease, requiring hospitalization, while 6% of these will be hospitalized in Intensive Care Units[8].

The literature shows that in addition to the high risk imposed on persons deprived of liberty (PDL), a high incidence of COVID-19 in prisons may be a source of infection for the population in general[9]. The coronavirus may leave the prison system walls and reach local communities via prison officers, health workers, visitors, people who have served their time and are released, or those been transferred[10].

Countries like China, Brazil, India, Indonesia, and others have expressed generalized concern and have made an effort to control the COVID-19 dissemination within their prison systems[11]. The WHO recommends granting probation among prisoners in the risk group provided they do not pose a danger to society[8].

In Brazil, the measures proposed by the WHO were included in the Recommendation 62/2020 of the National Justice Council (CNJ)[12], which involved non-imprisonment and the release of risk groups such as the elderly, pregnant women, people with chronic, respiratory, or immunosuppressive conditions, in addition to sanitary measures such as restricted visitation and more frequent cleaning of cells and common areas, screening inmates, employees, and visitors, and isolating suspected or confirmed cases.

This pandemic context is alarming for Brazil and the world at a time when prisons are places presenting considerable challenges for the implementation of preventive and health promotion actions[5]; this study's objective was to identify spatial clusters susceptible to the occurrence of COVID-19 among PDL and analyze the trend of confirmed cases in Brazilian prisons over time.

Methods

An ecological study[13] was conducted in Brazil, a country with more than 773,000 incarcerated individuals and ranking 3rd with the largest population of PDL, only behind the United States of America and China[14,15].

The Brazilian five macro-regions were the units of analysis (Southeast, South, Northeast, North, and Midwest) with their 26 states and the Federal District (FD). The study population was composed of all COVID-19 cases confirmed in the country's prisons from April 14th to August 31st, 2020.

Data were collected from the COVID-19 Monitoring Panel of the prison system, National Prison Department (DEPEN), which monitors suspected and confirmed COVID-19 cases in Brazilian prisons and update information daily according to the self-report of the managers of prison units through a form available online[16]. The status of cases in each state is classified as either suspected, detected/confirmed, or death.

During collection, data were tabulated in spreadsheets using Microsoft Excel®, and information concerning the total number of COVID-19 cases detected in prisons per macro-regions and states was checked daily.

After the database was validated, a descriptive analysis was performed of the COVID-19 cases confirmed among PDL, calculating absolute and relative frequencies and incidence rate per state. The number of PDL per state was considered[16] to calculate the incidence rate, with the multiplication factor per 100,000 inhabitants.

To identify which states presented the highest risk of COVID-19 infection among PDL, the spa-

tial analysis technique, also called scan statistic, developed by Kulldorff and Nagarwalla[17], was used.

When using the scan statistic, the search for clusters is performed by placing a circle of a variable radius around each state's centroid and then calculating the number of observed and expected cases within each circle. A cluster is identified when the number within a circle is either greater or smaller than the expected[18].

The null hypothesis (H_0) refers to the non-existence of a high- or low-risk cluster, that is, all PDL have the same likelihood of contracting COVID-19, regardless of their location; while H_1 (alternative hypothesis) assumes the existence of clusters, i.e., areas in which PDL are more or less likely to contract the disease[17].

The Poisson model was used in this analysis. It is a probability distribution of a variable or event so that it satisfies the conditions in which the analysis calculates the number of times an event occurs in a given interval of time or region, while the likelihood of an event to occur is the same for each interval. The number of occurrences of an event in an interval is independent of the number of occurrences in another interval[18].

As for the formation of clusters, the option without geographical overlap was considered. The formation of circular clusters was selected with 999 replications using the Monte Carlo simulation. The test is not biased regardless of the number of replications, resulting in a correct level of significance[18].

The Gini coefficient was used to measure the spatial clusters' size, and 5% of the population was considered to be at risk. The number of cases is compared to the data of the population base, and the expected number of cases in each state is proportional to the size of the population at risk[19].

The relative risk (RR) and respective confidence interval (CI95%) of each cluster were calculated, enabling comparisons between information from distinct areas. Clusters with $p<0.05$ were considered statistically significant.

A cluster detection analysis was performed using SaTScan™ version 9.2, and the thematic map containing the RRs of the areas was developed using ArcGis® version 10.5. The R Studio® version 3.5.2 was used via the package forecast to make the time series analysis of the COVID-19 cases reported by the Brazilian prison system.

Time series was initially performed of the COVID-19 cases to analyze the temporal tendency of the cases detected in the Brazilian prison system. Time series is a set of observations concerning a variable ordered over time and recorded in regular periods; the objective is to identify patterns (growth, decrease, stability) of the variable of interest over time[20,21].

The COVID-19 daily incidence rates found from April 14th and August 31st, 2020, among PDL per Brazilian macro-region were considered in the time series.

Later, the Seasonal Decomposition of Time Series by Loess (STL) was used. This decomposition method (break) is based on a locally weighted regression (Loess), a method used to estimate non-linear relations, decomposing (breaking) a time series into three parts: trend, seasonality, and noise[21,22].

The trend refers to the general direction in which the time series variables develop over a time interval; that is, the time series trend is defined as a growth or decrease pattern of the variable in a given period. Seasonality refers to identical patterns that a time series seems to obey, regularly occurring over fixed periods. Finally, noise refers to fluctuations over a time series, with irregular and random movements, only noticeable when remaining components are removed[22].

For this study in which the daily time series does not show seasonality, the Multiple seasonal decomposition (MSTL), originated from the STL method and available in the package forecast, was used. It is indicated for non-seasonal time series, decomposing the time series into trend and noise.

The trend was selected from the time series components to characterize the behavior of the COVID-19 incidence over time. Graphics were developed for Brazil and its macro-regions using R Studio®.

This study was not registered or submitted to an Institutional Review Board, according to the CEP/CONEP system, because only aggregated publicly accessible data were used[23].

Results

Table 1 presents absolute and relative frequencies concerning COVID-19 cases detected among PDL and incidence rates per state and the Federal District.

A total of 18,767 COVID-19 cases were detected among PDL from April to August 2020; 4.724 (25.17%) of which occurred in São Paulo, followed by the Federal District (1,774 cases; 9.45%), which presented the highest incidence rate (10,695.77 per 100,000 inhabitants), and

Pernambuco with 1,357 cases (7.23%).Paraná presented the lowest detection rate, 161.67 per 100,000 inhabitants, with 48 (0.26%) cases confirmed among 29,690 PDL.

The scan statistic enabled identifying 14 spatial clusters at the risk of contracting COVID-19, which were classified into five groups according to their RR (Figure 1).

Hence, Group 1 was composed of seven clusters (p < 0.001), with a population of 124,307 PDL, 1,534 observed cases, and 3,121 expected cases, with a RR from 0.06 to 0.79 (CI95%: 0.04 – 0.83). This group is composed of the states in the macro-regions: Southeast (Espírito Santo); Hence, Group 1 was composed of seven clusters (p < 0.001), with a population of 124,307 PDL; 1,534 observed cases; and 3,121 expected cases, with a RR from 0.06 to 0.79 (CI95%: 0.04 – 0.83). This group is composed of the states in the macro-regions: Southeast (Espírito Santo); South (Paraná); Northeast (Alagoas, Ceará, Paraíba, and Sergipe); North (Amazonas).

Group 2 was composed of three clusters (p < 0.001), with a population of 71,852 PFD, 2,706 observed cases, and 1,804 expected cases, with RR from 1.42 to 1.65 (CI95%: 1.30 – 1.70), comprising two states in the Northeast (Pernambuco and Rio Grande do Norte) and three states in the North (Amapá, Pará, and Tocantins).

Group 3 was composed of two clusters (p < 0.001), with a population of 40,893 PDL, 2,068 observed cases, and 1,026 expected cases, with RR from 2.04 to 2.09 (CI95%: 1.86 – 2.17). This group comprises Santa Catarina (Sul), and Mato Grosso do Sul (Midwest).

Group 4 was also composed of two clusters (p < 0.001), with a population of 16,952 PDL, 1,488 observed cases and 425 expected cases, with RR from 3.58 to 3.71 (CI95%: 3.30 – 3.98), composed of Piauí (Northeast) and Mato Grosso (Midwest).

Finally, Group 5 was composed of one cluster (p < 0.001), with a population of 16,586 PDL, 1,774 observed cases and 416 expected cases, with RR equal to 4.59 (CI95%: 4.28 – 4.71). The Federal District, located in the Midwest, composes this group.

Figure 2 presents the temporal tendency of the COVID-19 incidence rate among PDL in Brazil and its five macro-regions. The incidence of the disease in the country mostly presented a growing behavior, reaching its highest around the 100th day, ending the series with a decreasing behavior and an incidence rate of 19,65 cases per 100,000 inhabitants.

Figure 2 shows that the Southeast and South ended the time series with a decreasing trend. The Southeast alternated between increasing and decreasing behavior, ending the time series with the lowest incidence rate (6.49 cases per 100,000 inhabitants). The South presented a growth behavior during most of the time series (reaching the highest incidence around the 100th day), ending with a decreasing behavior and an incidence rate of 10.59 cases per 100,000 inhabitants.

The Northeast and North ended the time series with a growing tendency. The Northeast presented the highest incidence around the 70th and 100th days, ending the period with a growing behavior and an incidence of 20.96 cases per 100,000 inhabitants. The North's time series presented a predominantly increasing behavior, ending the period with a growing tendency and with the highest rates among the macro-regions, with an incidence of 63.71 cases per 100,000 inhabitants (Figure 2).

Regarding the Midwest, the time series showed a predominantly increasing behavior, with the highest incidence around the 120th day, ending the period with a decreasing behavior. Despite a decrease at the end of the series, its incidence rate was 56.12 cases per 100,000 inhabitants.

Discussion

The results highlight issues that have been debated in the international literature regarding the incarceration conditions in different countries that are extremely susceptible to the rapid spread of the coronavirus.

Among all the world countries, 59% present occupation levels higher than the capacity officially reported[24], requiring alternative criminal sentences and decreasing the number of PDL exposed to the disease[25].

At a time in which Brazil is facing the pandemic of a virus of high transmissibility, prison overcrowding is an element that aggravates the situation of both PDL and workers. Brazil has a deficit of approximately 303,000 slots[14], which prevents minimum health conditions are ensured to inmates, demanding rapid answers, and the release of PDL to change this context[6].

The descriptive analysis shows that São Paulo presented the largest number of COVID-19 cases among PDL, followed by the FD, which presented the highest incidence rate, and Pernambuco. Note that in the study period, São Paulo had al-

Table 1. COVID-19 cases detected among persons deprived of liberty in the states and the Federal District, Brazil, from April to August, 2020.

| Macro-regions	States	Covid-19 cases	%	Population Deprived of Liberty	Rate (100.000 inhabitants)
Southeast	ES	393	2.09	23.427	1677.55
	MG	785	4.18	74.712	1050.70
	RJ	380	2.02	50.822	747.71
	SP	4,724	25.17	231.287	2042.48
South	PR	48	0.26	29.690	161.67
	RS	1,115	5.94	41.189	2707.03
	SC	1,196	6.37	23.470	5095.87
Northeast	AL	44	0.23	9.161	480.29
	BA	520	2.77	15.108	3441.88
	CE	632	3.37	31.569	2001.96
	MA	224	1.19	12.346	1814.35
	PB	259	1.38	13.326	1943.57
	PE	1,357	7.23	33.641	4033.77
	PI	407	2.17	4.433	9181.14
	RN	362	1.93	10.155	3564.74
	SE	14	0.07	6.244	224.21
North	AC	227	1.21	8.414	2697.88
	AM	144	0.77	10.890	1322.31
	AP	140	0.75	2.750	5090.90
	PA	639	3.40	20.825	3068.43
	RO	489	2.61	13.419	3644.09
	RR	100	0.53	3.688	2711.49
	TO	208	1.11	4.481	4641.82
Midwest	DF	1,774	9.45	16.586	10695.77
	GO	633	3.37	25.761	2457.20
	MS	872	4.65	17.423	5004.88
	MT	1,081	5.76	12.519	8634.87
Brazil		18,767	100.00	747.336	2511.19

most 14 times more cases than the FD and seven times more than Pernambuco[16], while there was a change in the counting of cases as the results of rapid tests were included, expanding the number of occurrences recorded[26].

These results corroborate the identification of spatial risk clusters for the occurrence of COVID-19 cases among PDL, being the highest risk cluster composed of the FD, followed by clusters composed of Piauí, Mato Grosso, Santa Catarina, and Mato Grosso do Sul.

The *Secretaria de Estado de Administração Penitenciária do Distrito Federal (SEAP-DF)* [State Secretariat of Prison Administration of the Federal District] recorded two inmates' deaths due to COVID-19 in five days and also reported

6,000 tests up to July 1st. According to DEPEN, it represents 50% of the total number of tests performed in the Brazilian prison system. Though, they do not report in detail how many tests were performed on PDL and correctional officers. The two blocks inaugurated by the Federal District to allocate confirmed cases of COVID-19 are already operating above capacity[27].

The contagion among PDL in Mato Grosso do Sul grew by 196%. According to the bulletin from the *Agência Estadual de Administração do Sistema Penitenciário (AGEPEN/MS)* [State Agency for the Administration of the Prison System], the state recorded 157 confirmed cases on July 31st while this number rose to 465 COVID-19 cases on August 14th. The contamination rate in
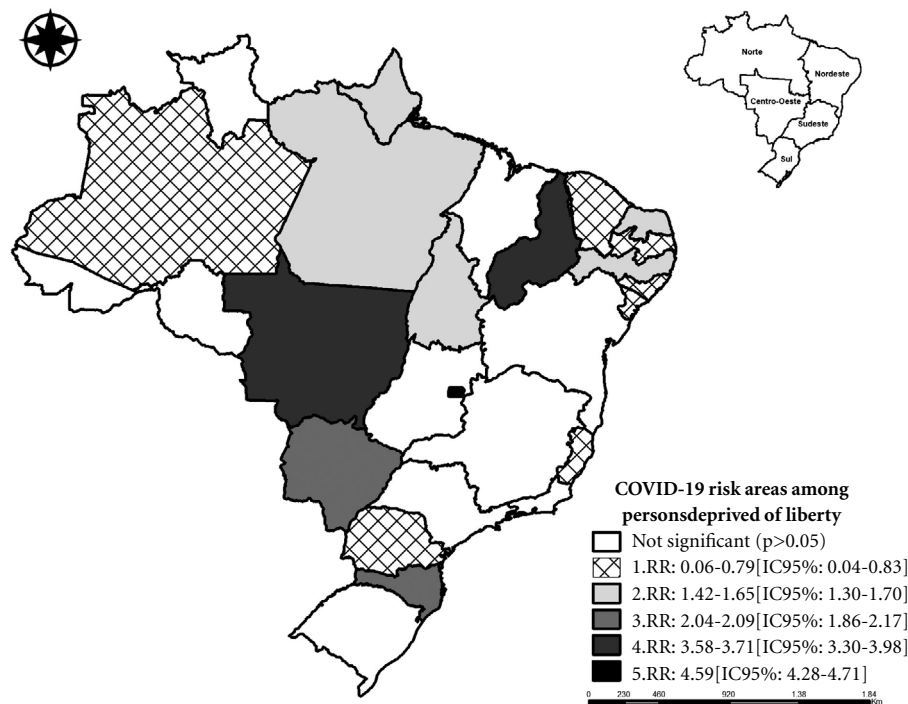
Figure 1. Risk areas for SARS-COV-2 infection among persons deprived of liberty and the states and Federal District, Brazil, from April to August, 2020.

the state prisons was 2.6%, and the likelihood of PDL to be contaminated was 94% greater than in the population in general[28].

The prison system in Mato Grosso is operating 70% above its capacity. In the bulletin from August 5th, the State Secretariat of Public Security (SESP) reported an increase by approximately 78% in the COVID-19 cases in two weeks. The State Central Prison in Cuiabá is the unit concentrating the highest number of COVID-19 cases among PDL, 347 cases[29].

According to the *Departamento de Monitoramento e Fiscalização do Sistema Carcerário e do Sistema de Execução de Medidas Socioeducativas do Conselho Nacional de Justiça (DMF/CNJ)*[30] [Prison System Monitoring and Surveillance Department and Socio-Educational Measures System from the National Justice Council] this information should be analyzed in light of the local contexts, paying special attention to the size of the incarcerated population and staff; the testing

policy adopted by each state and the FD; and the transparency and regularity in which information is disclosed, suggesting future investigations are needed.

The time series performed for the entire country and its macro-regions shows that, even though Brazil ended with a decreasing behavior, a growing tendency prevailed during the study's period.

The macro-regions present different behaviors over the time series, while the Northeast and North ended their series with a growing tendency, with the North presenting the highest incidence rate (63.71 cases per 100,000 inhabitants). The Midwest presented a growing trend during the series with a decreasing behavior at the end, however, with a high incidence rate of 56.12 cases per 100,000 inhabitants, the second highest in the country.

Data made available by the bulletin of the *Grupos de Monitoramento e Fiscalização do Siste-*
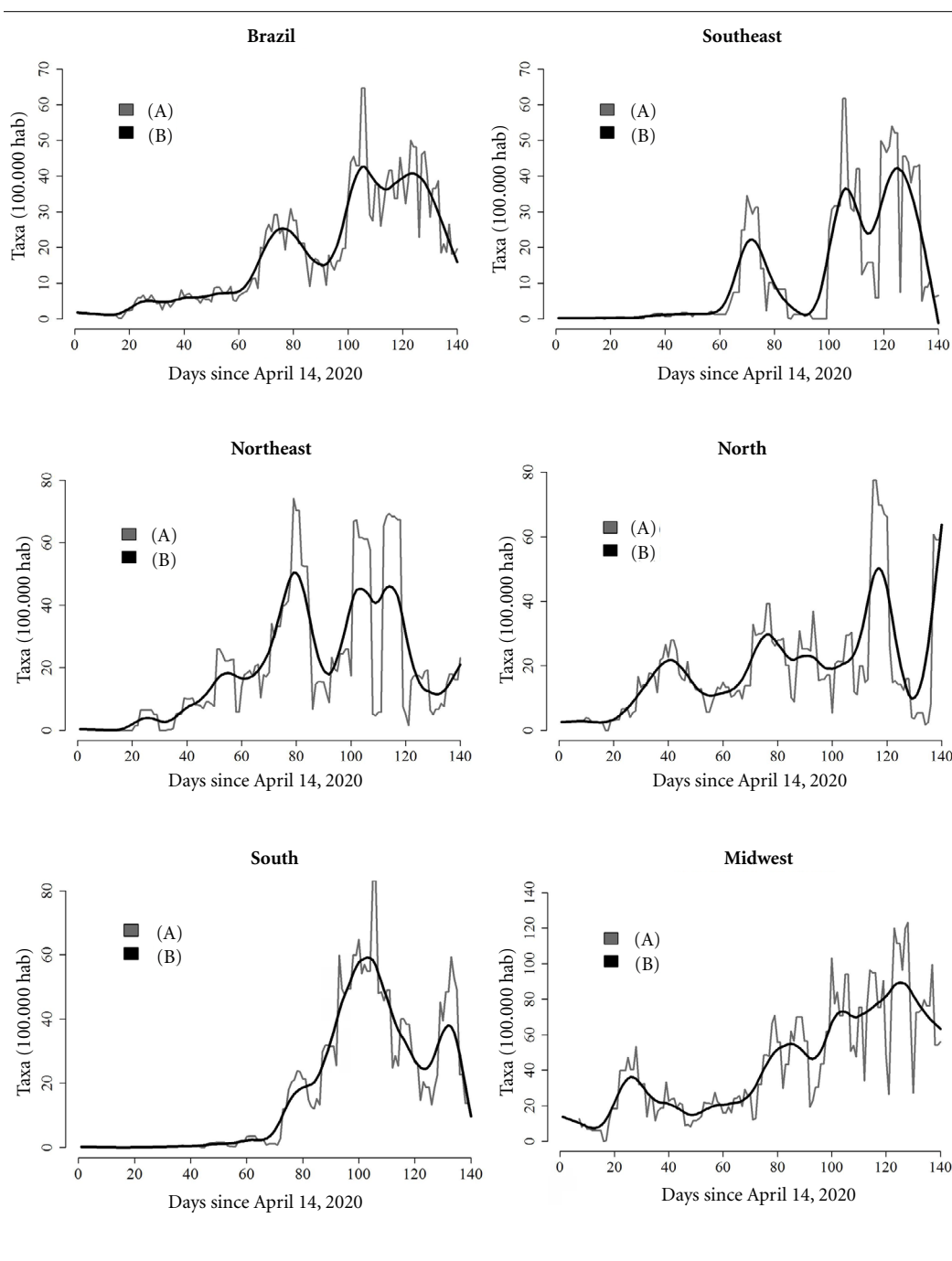
Figure 2. COVID-19 incidence trends among persons deprived of liberty in Brazil and per macro-regions, from April to August, 2020.

Legend: (A) Time series; (B) Trend.

ma Carcerário e do Sistema de Execução de Medidas Socioeducativas (GMF)[31] [Monitoring and Surveillance Groups of the Prison System and Socio-Educational Measures System] report that 51,221 tests were performed among PDL up to August 31st, 2020: 3,783 of these were performed

in the Northeast,4,239 in the North, and 12,511 in the Midwest while Ceará and Roraima did not report the total number of tests performed.

The total number of tests performed among PDL per state shows that the FD performed the highest number of tests (5,706), followed by Goiás (2,882), Mato Grosso (2,146), Pernambuco (2,030), Mato Grosso do Sul (1,777), and Pará (1,500)[31]. However, these prove insufficient when the population of incarcerated people, as reported by DEPEN in each state, is considered. These numbers correspond to approximately 34% in the FD, 17% in Mato Grosso, 11% in Goiás, 10% in Mato Grosso do Sul, 7% in Pará, and 6% in Pernambuco.

Another aspect refers to the growing tendency observed in the Southeast and South after 60 days. This behavior may be related to the entry and rapid dissemination of the coronavirus in the prisons with overcrowded cells or an increased number of tests performed among PDL in these regions starting in July.

According to the DMF/CNJ, on June 15th, 2020, the Southeast and South respectively accumulated 10.5% and 5.7% of the COVID-19 cases among PPL. This context, however, started changing at the end of July, with a significant increase in the report of cases in these regions, by 31.8% and 16.5%, respectively[30]. Note that these regions concentrate a significant portion of the country's incarcerated population, i.e., 50.6% (southeast) and 12.6% (South).

In one study conducted in 16 prisons in the United States, mass testing revealed an increase of 12.1 times the number of COVID-19 infections, on average, among PDL between April and May 2020, compared to the total number of cases confirmed by tests performed among inmates presenting symptoms[32].

This is alarming evidence considering the trends and high incidence rates reported in Brazil because there may be underreporting due to a lack of large-scale testing, while the viral load among the Brazilian PDL may be much larger.

Therefore, everyone presenting symptoms compatible with COVID-19 should be tested and isolated if testing positive, regardless of whether they are newcomers or not[6]. Cohort isolation[33] is recommended; that is, PDL with the same characteristics should be isolated according to groups in different prison cells.

Whenever parole is not granted to those in risk groups, research recommends that people are then allocated in independent prison units, with cells housing a small number of PDL, rein-forcing preventive measures to contain the transmission of SARS-COV-2 while providing regular medical assitance[6].

This context leads to a debate on the effective implementation of the *Lei de Execução Penal* [Penal Execution Law] 7.210/1984, which ensures fundamental rights to those under the state custody[34], including the right to health. With the *Política Nacional para Atenção Integral à Saúde da Pessoa Privada de Liberdade no Sistema Prisional (PNAISP)* [National Policy for Integral Healthcare Provided to Persons Deprived of Liberty within the Prison System], every prison will be accredited by the Brazilian Unified Health System (SUS) to be a unit of the Health Care Network, providing primary health care to PDL in the entire incarceration system[35]. However, even after the PNAISP publication, health managers do not usually consider prisons to be facilities where interventions are implemented and healthcare is provided[5].

These authors consider that the difficulties concerning physical and social structures allied with a lack or poor management of financial resources existing in the Brazilian prison system hinder access of PDL to the Health Care Network whenever advanced support is required due to COVID-19. There is a consensus that a lack of data concerning the incarcerated population impedes the adoption of effective measures, which only worsens with the pandemic[36].

Hence, there are inherent challenges imposed to the control of the pandemic in the Brazilian prison system, and this study presents important information regarding the dissemination of the coronavirus among PDL, indicating the need for further research considering the local contexts of risk areas and regions that present growth trends and high incidence rates, demanding continuous monitoring of cases to ensure that recommended measures are effectively implemented.

This study's limitation refers to the fact that only secondary data, with provisional and incomplete information, were used. For this reason, counting may be underestimated. Estimates should be interpreted together with other official databases such as the CNJ's monitoring bulletin.

In the short term, law markers, managers at the federal, state, and municipal levels, workers from the prison system, and society should understand that the pandemic continues to reshape the daily lives of people worldwide, and no one is safe until everyone is safe, including those currently encarcerated[9].

Collaborations

JA Crispim: conception, literature review, redaction, and final review, ACV Ramos, TZ Berra, MS Santos and FL Santos: Redaction, data analysis, and interpretation. LS Alves and FBP Costa: Critical review. RA Arcêncio: Redaction, critical review and final approval.

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