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Social isolation relaxation and the effective reproduction number (R_t) of COVID-19 in twelve Brazilian cities

O relaxamento do isolamento social e o número efetivo de reprodução (R_t) do COVID-19 em doze municípios brasileiros

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Abstract *We analyzed the social isolation relaxation strategies adopted by the twelve biggest Brazilian cities in 2020, in relation to the number of cases, number of deaths and the effective reproduction number (R_t), which are internationally considered the fundamental epidemiological criteria for allowing wider population mobility in public spaces. The Brazilian central government has not set unique guidelines neither for closure nor for opening, and states and cities have taken the lead in strategy definition. Until July 31 2020, in Belém do Pará, Fortaleza, Manaus, Recife and Rio de Janeiro, where the epidemic peak had already been surpassed, and in Salvador and São Paulo, in which the peak seemed to be already reached, the R_t curve followed a decreasing path after the openings. Porto Alegre, a city in which the epidemic curve was flattened, had an increase in R_t after the start of relaxation. In Belo Horizonte, Brasília, Curitiba and Goiânia, where the curve was also flattened, the R_t remained stable after the opening. The decision on how to operationalize the relaxation of social isolation and the speed with which it happened was heterogeneous among the cities studied. Also, broad population testing strategies were not done in any of the cities.*
Key words *COVID-19, Social Isolation, Health Policies, Cities*

Resumo *Este trabalho analisou as estratégias de relaxamento do isolamento social adotadas pelas doze maiores cidades brasileiras em 2020, em relação ao número de casos, número de óbitos e ao número efetivo de reprodução (R_t), considerados internacionalmente os critérios epidemiológicos fundamentais para permitir uma maior mobilidade da população nos espaços públicos. O governo federal não estabeleceu diretrizes únicas nem para o fechamento nem para a abertura, e os estados e municípios assumiram o protagonismo na definição da estratégia. Até 31 de julho, em Belém do Pará, Fortaleza, Manaus, Recife e Rio de Janeiro, onde o pico epidêmico já havia sido ultrapassado, e em Salvador e São Paulo, em que o pico parecia já ter sido atingido, o R_t seguiu uma curva decrescente após as aberturas. Em Porto Alegre, aonde a curva epidêmica foi achatada, houve aumento do R_t após o início do relaxamento. Em Belo Horizonte, Brasília, Curitiba e Goiânia, nos quais a curva também foi achatada, o R_t manteve-se estável após a abertura. A decisão de como operacionalizar o relaxamento do isolamento social e a velocidade com que isso aconteceu foi heterogênea entre as cidades estudadas. Além disso, amplas estratégias de testagem populacional não foram realizadas em nenhuma das cidades.*
Palavras-chave *COVID-19, Isolamento Social, Políticas de Saúde, Cidades*

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Introduction

The COVID-19 pandemic is presently the biggest sanitary and humanitarian emergency in the world. In Brazil, on August 18, 2020, the number of cases exceeded 3,2 million and the number of deaths reached more than 105 thousand. However, studies performed in the country points to an important under reporting of cases, indicating that the dimension of the pandemic is much bigger than the official statistics[1-3].

Although COVID-19 cases and deaths are still growing in Brazil, several states and cities have already started their mobility restriction relaxation. The drivers of this process seem to be: i) fatigue related to the long isolation process; ii) productive activity reduction that affected formal and informal jobs; iii) revenue frustration of the three government levels; iv) activism against isolation measures.

According to Brazilian federalism, the city administration is responsible for deciding the population mobility level. Such autonomy was supported by a Federal Supreme Court decision, which recognized the concurrent jurisdiction of States, Federal District and cities to legislate on public health, trusting to these entities the prerogatives of isolation, quarantine and locomotion and circulation banning, as well as the provision of public services and the definition of essential activities[4].

Since the beginning, Brazil stood out in the national and international scenario by the lack of coordination of the federal government in the preparation of guidelines, both for containment and mitigation phases and also for restriction relaxation phases[5]. In summary, restriction relaxation consists in the progressive reopening of public places, public transportation and non-essential business.

The Economic Commission for the Latin America and Caribbean[6] estimated that, in the face of an economic contraction of 5.3% in Latin America countries, over 30 million of inhabitants will became poor, and according to the Organization for Economic Co-operation and Development, the unemployment rate will increase from 9.4% (scenario without a second outbreak) to 10.2% (scenario with a second outbreak and new confinements)[7].

The economic activity reduction resulting from social isolation measures lead to revenue reduction in the three government levels[8]. Especially the State and city governments, which were already facing serious budgetary crises, started to fear to be uncapable of meeting their financial commitments. This scenario was made worse by insufficient implementation of social protection measures[9]. This has weakened the support of many public authorities to the broad social isolation measures.

Although a consensus exists in associating mobility restriction measures with the pandemic control[10,11], many political leaders insisted to fight against them, which seemed to interfere with this practice adoption by the population[12]. Their justification was the potential impacts of the economic contraction over employment and income, and also over poverty and morbimortality indicators. However, studies indicate that economic contraction will happen, regardless of the isolation measures adopted[10].

According to the recommendations of the World Health Organization[13], the epidemiological situation in a given area should be assessed using the criteria of reduction of cases, reduction of deaths, combined with the criteria of R_t lower than 1.

This work analyzed the social isolation relaxation strategies adopted by the twelve biggest Brazilian cities in relation to the number of cases, number of deaths and to the Effective Reproduction Number (R_t), in 2020.

Methodology

Our analysis was made in two blocks, the epidemiological situation and the exit plans. Regarding the epidemiological situation, we identified the epidemic evolution, demarcating dates of the first case, the first 100 cases and the 500 first cases notified, as well as the epidemic dynamics on July 31, 2020, the Effective Reproduction Number (R_t) and the number of daily cases at the same date. We used the number of new cases and new deaths by date of notification, provided by the Ministry of Health[14], and for the analysis of R_t, we used *Farol Covid* website[15]. We chose the final period of the analysis in July to include all the dates of relaxation measures identified in the study plus 21 days (average time from infection to death for COVID-19 cases[16]), plus 14 days (digitation opportunity of COVID-19 death cases[17]).

We chose to use *Farol Covid* because it provides the R_t estimates disaggregated by city over time, a key information to the analysis. The platform provides the estimated values according to Systrom[18], based on Bayesian methodology. Therefore, the estimated R_t on a given day is a

function of the likelihood of the observed data and of a priori distribution of the R_t. The data likelihood was specified according to a distribution of Poisson for the R_t, and the a priori distribution of the R_t, given the R_t of the previous day (R_{t-1}), was set as a normal distribution centered in R_{t-1}.

We analyzed the exit plans through protocols published in official pages and other documents available on the Internet, to mark the first relaxation measure date and the R_t on this date. The criteria adopted for the start of the relaxation measures, the sequential relaxation strategy and the return criteria to more restrictive measures were also observed.

We analyzed the twelve biggest Brazilian cities in population numbers. Ordered by decreasing population size, our sample included São Paulo, Rio de Janeiro, Brasília (Federal District), Salvador, Fortaleza, Belo Horizonte, Manaus, Curitiba, Recife, Goiânia, Belém do Pará and Porto Alegre. The option for big cities was due to the nonexistence of a national unified protocol and to the need of the cities to adopt different strategies, even under a single State guidance.

Results

In Brazil, the first confirmed cases occurred in the end of February 2020, in São Paulo. In other cities, the first cases were registered in March 2020. Except for Goiânia, Recife and Belém do Pará, the 100 first cases were reached still in March. Only Rio de Janeiro and São Paulo reached 500 cases still in March.

In relation to the epidemiological situation, on July 31, all twelve cities remained in stage of community transmission. On this date, the relaxation measures had been already started in all cities.

As to the exit plans, they had no complete conceptualization available for consultation, being the data found fragmented in decrees, public presentations and press reports. Even when in the form of a decree, the information focused on very practical aspects, such as delimitation of which services could resume their activities on a given date and those that would be allowed to do it later. The main documents and legal regulations consulted can be found in Chart 1.

In Porto Alegre, the government authorized the reopening of several activities by phases, with rules for people presence in closed spaces. In Curitiba, the government defined the public services and essential private activities that should be kept opened, and established operational rules for other services.

In São Paulo, the government established different opening hours for industrial, commercial and services activities during the pandemic, also in phases. In Rio de Janeiro, the government implemented a plan in six steps, with the minimal expected progression interval of 15 days, if the curve of cases and deaths remained stable. Belo Horizonte has not joined formally the State program, called "*Minas Consciente*"[19]. It established its own plan, with start and progression of the opening based on three indicators: the *effective reproduction number* (R_t), the occupation rate of ICU beds dedicated to COVID-19 and the occupation rate of clinical hospital beds dedicated to COVID-19, with possible reversion of the openings, depending on the indicators' result.

In Goiânia, the government established rules for public transport services operation and recommended opening hours for industrial, commercial and services activities. In Brasília, the Federal District government established, after judicial intervention, the scaling of reopening of several sectors, with hours restriction and minimum spacing of 15 days between phases.

Salvador adopted, along with the Bahia government, a protocol for resumption of the activities based on the rate of occupation of ICU beds exclusive for COVID-19. It was divided in three phases, namely: between 70 and 75% of occupation, between 65 and 70% and below 65%, with at least five days of stability for phase changing.

Recife, soon after a metropolitan region two-week closure established by the Pernambuco government, started a relaxation process in five phases and based on three indicators: occupation of ICU beds, number of daily confirmed cases and number of deaths, with interval of seven days for phase changing.

Fortaleza has joined the Ceará program, in which four phases were projected with interval of 14 days. The criteria adopted were the declining demand trend in the community health clinics (*Unidades de Pronto Atendimento*) and other urgency sites, the ICU bed occupation rate, the COVID-19 hospital admissions number, the COVID-19 related deaths and a specific territorial analysis for each city region.

The Belém opening plan was accompanied by an Economic Resumption Plan. The plan did not provide cut-off lines or indicators that would allow the evolution of the expected phases, but mentioned that it was based on the following

Chart 1. Legal documents regulating the post-closure opening due to the coronavirus pandemic, Brazilian cities selected, 2020.

City	Regulation	Date	Description
Porto Alegre	"New measures update decree of public calamity - be aware of what is authorized to operate"[30]	Downloaded on 5/20/2020	Consolidates all the city degrees related to the return of operation of several activities
Curitiba	City Decree 470	3/26/2020	Established complementary measures to face the Emergency in Public Health due to the new coronavirus and defined the public services and essential activities that must be safeguarded by the government and the private sector
	Resolution Number 1	4/16/2020	
São Paulo	City Decree 59,349	4/14/2020	Recommends opening hours for the industrial, commercial and services activities during the state of public calamity to face coronavirus pandemic
Rio de Janeiro	City Decree 47,488	6/2/2020	Institutes the Strategic Committee for development, improvement and monitoring of the Resumption Plan due to the impacts of COVID-19 pandemic, and other provisions
Belo Horizonte	City Decree 17,361	5/22/2020	Provides for the gradual and safe reopening of the sectors that had their activities suspended due to the measures for facing and preventing the epidemic caused by the new coronavirus
Goiânia	City Decree 951	4/28/2020	Provides for complementary measures for facing the crisis provoked by the pandemic caused by the new coronavirus in the collective public transport and recommends opening hours of industrial, commercial and services establishments within the city of Goiânia
Brasília	Decree 40,817 of the Federal District Government	5/22/2020	Provides for the measures for facing the public health emergency of international importance due to the new coronavirus and other provisions
Salvador	City Decree 32,580	7/15/2020	Provides for the criteria of reopening of the sectors that had the activities suspended due to the measures for facing and preventing the pandemic caused by the new coronavirus as indicated and other provisions
Recife	Decree 49,055 of the Pernambuco State Government	5/31/2020	Systematizes the resumption of economic activities
Fortaleza	City Decree 14,699	6/7/2020	Adhesion to the state plan: Plan of Responsible Resumption of Economic and Behavioral Activities of the State
Belém	City Decree 96,378	6/1/2020	Includes publication of the Plan of Economic Resumption
Manaus	Decree 42,330 of the Amazonas State Government	5/28/2020	Provides for the schedule of gradual resumption of the economic activities in Manaus from June 1st, 2020

Source: Elaborated by the authors, based on the researches developed for the article.

criteria: health risk; capacity of care; essentiality of the service; accumulated losses with risks to survival of the companies and consequences for the maintenance of work positions and income.

Manaus followed the measures adopted by the Amazonas State and did not established distancing rules or economic activity restriction, legislating only on the public administration functioning and on use of individual protection measures, such as masks. Four phases were planned, as well as the possibility of reviewing the reopening based on the following indicators: availability of ICU and clinical hospital beds, transmission rate and number of new cases.

All plans proposed gradual openings, established previous criteria to be met and foresaw a possible setback if the epidemiological situation deteriorated significantly. The models always considered, to some extent, in addition to the epidemiological situation, the health system capacities, the preventive measures in scale and the preparation of the society to the "new normal".

Concerning the health system capacities, all cities implemented case testing, although in several of them the results showed significant delay and there was no availability for testing all the contacts. None of the cities implemented populational testing in large scale or adopted, after the start of community transmission, robust sanitary surveillance strategies that could enable to track and isolate contacts effectively.

The economic sectors opening order varied among cities, being the essential sectors opening the first step, although the definition of what was essential carried some differences among cities. Presential school return had not been started in any of the cities up to the cut-off date of this study (July 31). According to the plans, broad measures of population guidance and communication in relation to transmission prevention measures were taken by all cities.

The temporal distribution of new cases and new deaths can be seen in the Figures 1 and 2, respectively. Since the daily data has a great variability, we used the numbers softened by the 14-day moving average.

The graphs show that the pandemic first wave peak seemed to have already happened in five cities where the pandemic was very impacting: Manaus, Fortaleza, Belém, Recife and Rio de Janeiro. The epidemic seemed to have already reached the peak in São Paulo and Salvador, up to the cut-off date of this study (July 31). In Salvador, the correction for underreporting confirmed this impression (data not shown). In Goiânia, Belo Horizonte, Porto Alegre and Curitiba, the cases occurred in much lower rates and the epidemic curve seems to have been flattened by the social isolation measures, thus becoming longer in time (Figure 1). In Brasília, there was a different behavior in relation to the new cases (Figure 1) and new deaths (Figure 2), with a very high populational case rate and a relatively low death rate. This discrepancy disappeared when the cases were corrected for the under notification (data not shown).

Curitiba and Goiânia started to relax social isolation in April and Porto Alegre and Belo Horizonte in May. These are exactly the cities in which the pandemic had less impact, considering populational rates. The Federal District also started the relaxation in May.

Manaus, Fortaleza, Belém, Recife, Rio de Janeiro and São Paulo started the relaxation in June. The first five presented signs that the epidemic peak had already been gone. Salvador started the relaxation on June 15.

Only Porto Alegre showed R_t lower than 1.0 at relaxation start, according to criteria recommended by the World Health Organization[13]. The other cities had the R_t varying from 1.11 to 1.69 at the relaxation start (Figure 3).

On our study cut-off date, Belém, Rio de Janeiro and Fortaleza had the R_t lower than one. For the other cities, the R_t varied from 1.04 to 1.30 (Figure 3).

Curitiba, Goiânia and Belo Horizonte remained with a high disease spread risk rate (R_t higher than 1.2) since the relaxation start until July, despite a downward trend on the indicator, less pronounced in Belo Horizonte. Porto Alegre, which was at the low disease spread risk rate (R_t lower than 1.0) almost achieve the high-risk rate.

Rio de Janeiro, Recife and Manaus were at the high-risk rate previously, had a downward trend at the relaxation start and remained at the low-risk rate after the opening. Belém and Fortaleza were at the high-risk rate, showed a downward trend before the relaxation start and remained with R_t near 1.0 after the opening. São Paulo reached a R_t lower than one in the beginning of July but presented a value near the high-risk limit in the cut-off date of the study. Salvador was at the high-risk rate before the relaxation and reached an R_t near 1.0 in July. Brasília was at the high-risk rate (R_t higher than 1.2) at the relaxation start, showing a slight downward trend after that (Figure 3).

Discussion and conclusion

In Brazil, the new coronavirus epidemic is ongoing since the ending of February 2020, even after months of restrictive rules and other measures. The Brazilian federative model, already marked by a strong municipalism, plus the federal omission in this crisis management, has favored the role of cities in the plan preparation for the pandemic, signaling important changes in the federative relationship[20].

The present study analyzed how the twelve biggest Brazilian municipalities faced the COVID-19 epidemic in 2020, emphasizing the

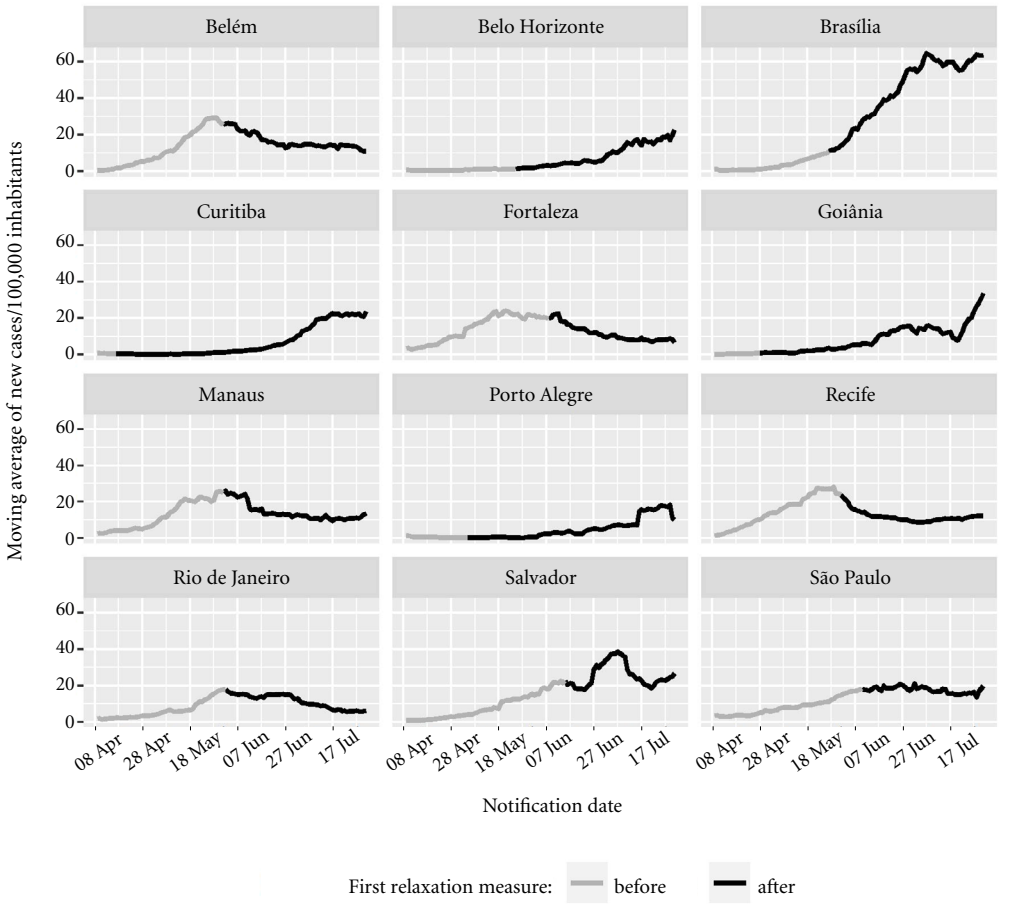

Figure 1. Moving average of new cases per 100,000 inhabitants in the last 14 days, according to the notification date, for twelve municipalities, 2020.

Source: Elaborated by the authors with data from Brazilian Ministry of Health.

opening strategies after the initial social isolation measures. Despite the fact that common elements are observed in the plans, the decision on how to operationalize the relaxation of social isolation and the speed with which it happened, was heterogeneous among them. It was not possible to identify an ideal plan on when or how to reopen business, public spaces and other places that were closed due to the pandemic.

Epidemiological data, like the incidence, mortality, transmission rates, number of cases and number of deaths are at the same time decisive indicators to guide the relaxation of the isolation measures, and indicators that allow the assessment of public measures adopted to mitigate the pandemic. Some of these measures were present in some plans. However, in none of the municipalities studied, large-scale population tests that could access the ongoing case incidence rates were carried out.

The ability to monitor the epidemic, including testing for identification and isolation of cases, as well as quarantine guidance for contacts, is one of the criteria that, according to the European Commission, must be observed for the relaxation of social distance measures[21]. Mass testing, as adopted in Germany and South Korea, is a strategy of great importance for controlling COVID-19, since the incubation period is longer compared to other viruses, causing the high transmissibility of the disease by asymptomatic patients[22].

We used the officially case definition adopted by Brazilian Ministry of Health and the official data available for the study period. These data have been used in several studies and are the best information available on the pandemic in Brazil, since data from serological surveys are scarce and there was no mass testing of the population. Data is recorded by the date of notification, the safest option to avoid registration errors. To minimize

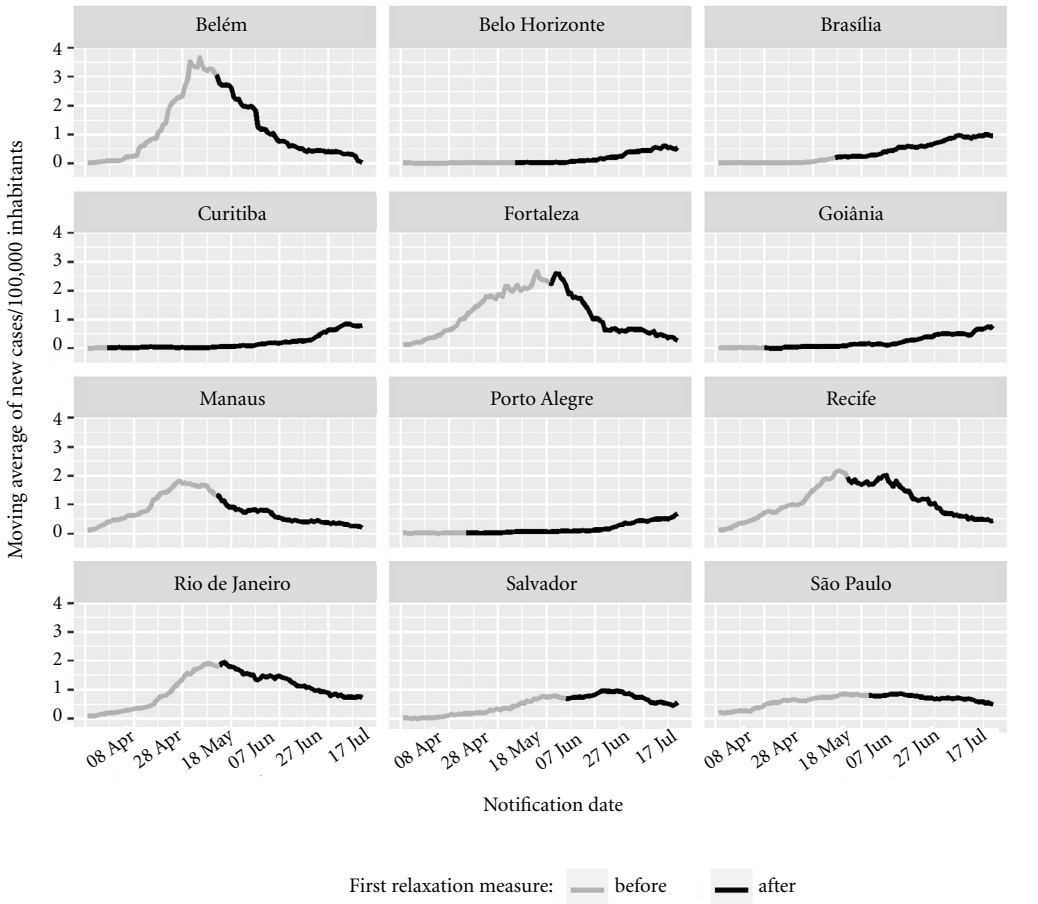

Figure 2. Moving average of new deaths per 100,000 thousand inhabitants in the last 14 days, according to the notification date, for twelve municipalities, 2020.

Source: Elaborated by the authors with data from Brazilian Ministry of Health.

the problems associated with the notification dates, we used the moving average of the indicators in last 14 days. Its smooth the curve of the indicators, especially on weekends, when the notification rate is lower, and is compatible with the mean notification delay of COVID-19 deaths in Brazil, equal to 14 days[17].

We are aware that underreporting of cases may have occurred for COVID-19 in Brazil in 2020, since tests were not widely available and mass testing was not done. For the analysis of the epidemic curve of each municipality, over time, the most relevant information was the shape of the curve and the stage of the curve in which the municipality was at the time of easing social isolation. We analyzed the cases epidemic curves corrected for under notification (data not shown) and, except for Brasilia and Salvador, both situations mentioned at the results section, the shape of the curves was similar for corrected and uncorrected data. For this reason, we maintained the original data of cases and deaths available at the Ministry of Health database.

The R_t is the official measure of the COVID-19 transmission rate and is widely used in every country. The R_t we used, produced by the *Farol Covid* team, uses the number of cases per notification date, in the same way that it is done by the Ministry of Health and other researchers. In order to minimize the problems related to the notification delay and delay in the release of results, *Farol Covid* does not disclose R_t of the 10 days prior to the consultation date on the website. In this work, R_t used refers to a period prior to more than six months from the date of data collection, also decreasing the potential problems of notification delay.

Farol Covid uses Bayesian methodology to estimate R_t, which can generate final results sensitive to *a priori* distribution chosen. The use of

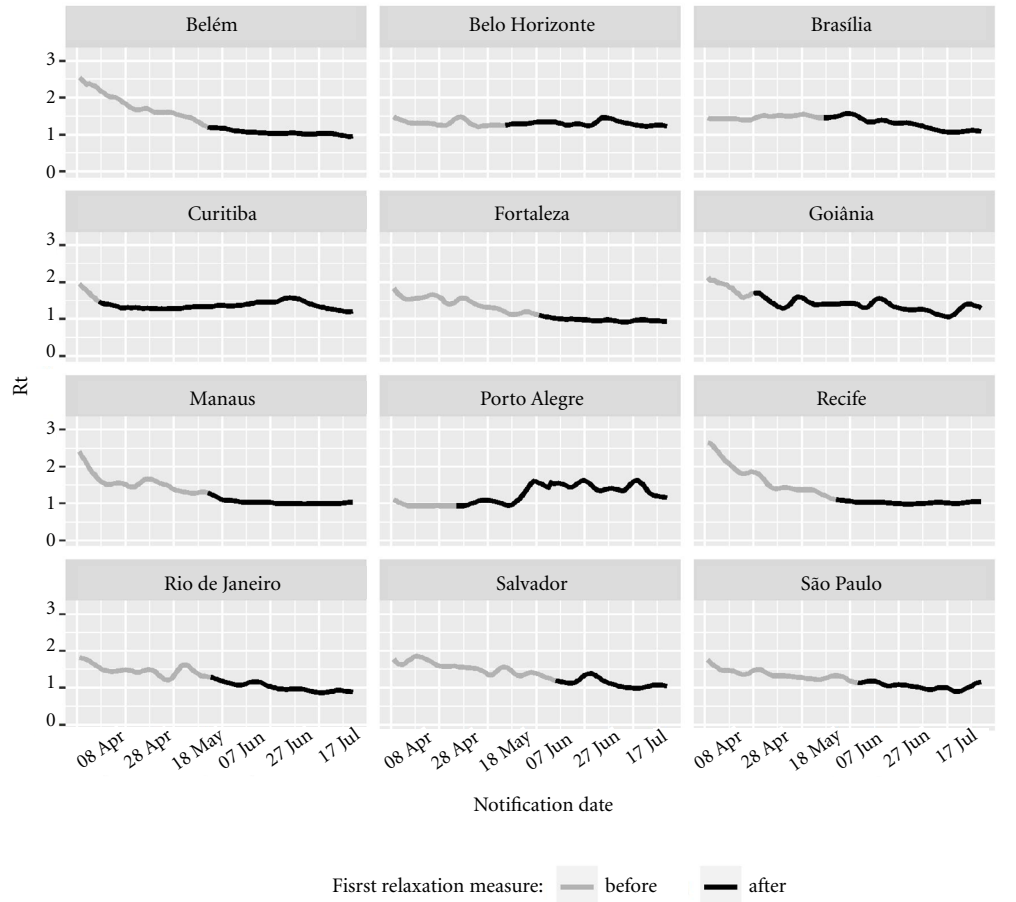

Figure 3. Effective Reproduction Number (Rt) according to the notification date, for twelve municipalities, 2020.

Source: Elaborated by the authors with data from *Farol Covid*.

the Bayesian update for *a priori* distributions ensures that confidence in a given value of R_t will be recalibrated as new data is incorporated into the analysis, improving the *a priori* distribution used.

This study pointed to a worrying situation, which later materialized in the last months of 2020 and in 2021. The pandemic spread across the territory in a heterogeneous way. Seroprevalence research based on probabilistic household samples from 133 large sentinel cities in the country showed a remarkable variability in the prevalence of SARS-CoV-2 antibodies in Brazilian regions, with extremely high rates in cities in the poorest regions[23]. For Kerr et al.[24], despite not sparing the wealthiest regions, the pandemic has been worst in the poorest regions, especially in the North and Northeast states.

The inequalities in the spread of the disease may be reflecting the existing social inequalities, a marked feature of Brazil. The impacts of the pandemic may have been influenced by the disadvantages of vulnerable groups in poorer regions. In Brazil, the COVID-19 pandemic aggravated an unprecedented political, economic and social crisis that preceded the epidemic's entry[24].

The sustainability and effectiveness of measures to restrict mobility depend on the implementation of social protection and support policies for vulnerable populations, allowing the survival of individuals and families as long as the restrictions for the development of economic activities and its effects are in place[25].

In Brazil, in addition to social isolation, the expansion of the capacity to provide health services and forms of economic support to individuals, families and companies, are part of the strategies to face the pandemic. However, as with isolation measures, the other strategies have also been implemented through uncoordinated actions and plans, by different levels of government,

without an evident effort of articulation and coordination at the national level to face the crisis[26].

The difficulty of mass testing made the municipalities choose to establish their resumption indicators in structural care issues, such as the number and occupation of intensive care beds and/or clinical beds and the frequency of visits to the emergency units, at the expense of transmission indicators. Pressures from specific economic sectors in each region and/or municipality also led to a definition of essential activities, which should be part of the resumption, which is quite heterogeneous.

Conflicts with the economic sector were evidenced by Figueiredo et al.[27], who investigated processes sent to the Supreme Federal Court addressing the COVID-19 issue and found that most (81.4%) of the cases requested decisions on relaxation (permission, closing or limitations on the functioning of trade and transportation), with 54.3% dealing with requests for opening and 45.7% were requests for closing establishments and limitations on the circulation of people.

Conflicts and intergovernmental mismatch were two elements that reduced strongly the effectiveness of actions against COVID-19[5], indicating that the country is facing a sanitary and federative crisis at the same time[28].

Even with the heterogeneous relaxation strategies, the social mobility restriction measures adopted by the cities studied contributed for the epidemic curve flattening over time, certainly preserving thousands of lives. Undoubtedly, they could have done better if there had been an effective coordination among the levels of government and if the debate of the strategies were more based on scientific evidence than on political motivation.

The reflection proposed by this article is important, in light of scientific evidence that points to a worrying future scenario that will still demand many interventions to reduce the transmission of COVID-19 in Brazil[10,29].

Collaborations

MSM Castro participated in the design of the study, writing of the text, analysis and interpretation of data and in the final approval of the work. AB Tavares contributed to the conception and writing of the text and analysis of the results. ALJ Martins, GDM Silva, WD Miranda and FP Santos participated in the interpretation of the data and review of the manuscript. R Paes-Sousa coordinated the work and contributed to the design of the study, writing of the manuscript, data analysis and final approval of the work. All authors agree with the final version of the article and are responsible for all aspects of the work.

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