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Determinants of physical distancing during the covid-19 epidemic in Brazil: effects from mandatory rules, numbers of cases and duration of rules

Determinantes do distanciamento físico durante a epidemia de covid-19 no Brasil: efeitos de medidas mandatórias, números de casos e duração das normas restritivas

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Abstract *During the covid-19 pandemic, physical distancing is being promoted to reduce the disease transmission and pressure on health systems. Yet, what determines physical distancing? Through a panel data analysis, this article identifies some of its determinants. Using a specifically built index that measures the strictness of physical distancing rules in the 27 Brazilian states, this paper isolates the effect of mandatory physical distancing rules from other potential determinants of physical distancing. The article concludes that physical distancing is influenced by at least three variables: the strictness of mandatory physical distancing rules, the number of confirmed cases of covid-19, and the duration of rules. Evidence also indicates that the effect of physical distancing measures is relatively stronger than that of the number of cases –physical distancing is determined proportionally more by mandatory policies than people's awareness about the severity of the epidemic. These results have at least two policy implications. First, governments should adopt mandatory measures in order to increase physical distancing – rather than expect people to adopt them on their own. Second, the timing of adopting them is important, since people are unlikely to comply with them for long periods of time.*

Key words *Covid-19, Brazil, NPIs, Physical distancing*

Resumo *Durante a pandemia de covid-19, o distanciamento físico está sendo promovido para reduzir a transmissão da doença e a pressão sobre os sistemas de saúde. No entanto, o que determina o distanciamento físico? Através de uma análise de dados em painel, este artigo identifica alguns de seus determinantes. Usando um índice que mede o rigor das regras de distanciamento nas 27 unidades da federação brasileiras, isolou-se o efeito de regras obrigatórias de distanciamento de outros potenciais determinantes. O artigo conclui que o distanciamento é influenciado por ao menos três variáveis: rigor das regras obrigatórias, número de casos confirmados e duração das regras. Os resultados também indicam que o efeito das medidas de distanciamento é relativamente mais forte do que o do número de casos – o distanciamento físico é determinado proporcionalmente mais por políticas obrigatórias do que pelo grau de conscientização acerca da gravidade da epidemia. Os resultados têm ao menos duas implicações em termos de políticas. Primeiro, governos devem adotar medidas obrigatórias para aumentar o distanciamento físico – ao invés de esperar que as pessoas as adotem por conta própria. Segundo, o momento de adotá-las é importante, pois é improvável que se mantenham níveis altos de distanciamento fisico por longos períodos de tempo.*

Palavras-chave *Covid-19, Brasil, NPIs, Distanciamento físico*

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Introduction

What determines physical distancing? In the context of an epidemic in which there are no better alternatives to reduce the transmission of a disease and no effective treatment, the answer to this question might determine government policies to contain an epidemic. If people practice physical distancing voluntarily, based on the severity of the epidemic or out of a sense of social responsibility, strict physical distancing measures would be largely unnecessary. However, if people respond mainly to mandatory restrictions (closing non-essential shops, suspending classes, suspending mass gatherings, etc), governments should adopt these non-pharmaceutical interventions (NPIs) in order to contain an epidemic.

Maloney and Taskin[1] argued that the covid-19 pandemic *per se* led to voluntary demobilization and that this effect is stronger than that of NPIs, what was observed in all but the poorest countries. This finding was reinforced by case studies on the US and Sweden, where evidence indicates that physical distancing increased *before* mandatory measures were adopted. The causal mechanism could be not only the fear of getting infected but also empathy for those most vulnerable to the virus[2] or people's belief in science[3]. If this is true, lifting restrictive measures during the epidemic would not have a great impact, as people would practice physical distancing anyway. From a different angle, Engle et al.[4], Brzezinski et al.[5], Painter and Qiu[6] and Anderson et al.[7] demonstrated that mandatory physical distancing measures in the United States significantly increased the probability of someone staying at home.

In addition, physical distancing levels may depend on the length of restrictions on people's mobility: the longer they last the higher the costs for people to stay at home, reducing their probability of complying with physical distancing rules. Frequent extensions may also create confusion and frustration, leading people to reduce levels of compliance, something that was observed in Italy[8].

Through a panel data analysis, this paper seeks to answer the question of what influences physical distancing during the covid-19 pandemic. It looks at the effects of mandatory physical distancing rules, numbers of covid-19 cases, and the duration of mandatory rules on the levels of physical distancing in Brazil. As physical distancing policies in Brazil were implemented mainly by states (27 in total, including the Federal District), comparing their policies and respective outcomes might indicate the extent to what mandatory policies are necessary to increase physical distancing in the context of an epidemic. Evidence presented in this article suggests that levels of physical distancing are positively correlated with the strictness of mandatory restrictions and the severity of the epidemic, as well as negatively correlated with the number of days since the first mandatory measures were adopted.

Method and data

In order to identify some of the potential determinants of physical distancing levels during the covid-19 pandemic in Brazil I conducted a panel data analysis (using a balanced panel) covering the period 22 Mar – 24 May 2020. I created a daily series for all variables starting from 22 Mar, when all Brazilian states had reported at least one case of covid-19. The model has the following variables and uses the following data sources.

Dependent variable: physical distancing

The Brazilian geolocation company In Loco generates data on daily levels of physical distancing discriminated by state, using data collected through apps in over 60 million smartphones in Brazil. The company monitors movement trends, producing data that is similar to those of Google Mobility Reports. In Loco uses various apps, including those of the main telecommunication companies, retailer stores, banks, etc. in Brazil[9]. Data is aggregated into the 'social distancing index', which is used here as a proxy for physical distancing, a method used in previous research[10,11]. The index has values expressed in percentages (in a scale of 0% to 100%), in which 100% is a hypothetical situation in which the whole population stays at home for a whole day. In the model, I use rolling averages (7 days) to minimize the effect of short-term variations.

Independent variables

Strictness of mandatory physical distancing rules

I created an index that measures the strictness of physical distancing rules, which I have called the *physical distancing rules index* (PDI). This index is composed of six variables, measuring: whether mass gatherings, as well as cultural, sport or religious activities are suspended; whether bars, pubs, restaurants and similar places are closed; whether non-essential shops are closed; whether non-essential indus-

Ciência & Saúde Coletiva, 25(9):3393-3400, 2020

tries are closed; whether classes are suspended; and whether there are restrictions on passenger transportation. Each of these variables represents a type of agglomeration of people that may be restricted by NPIs: if these activities were all suspended, the aggregate effect should be a broad reduction in the number of agglomerations. For each of these variables, values of 2, 1 or 0 were assigned depending on whether suspension or restriction was full, partial or non-existent (details are in Table 1 and Chart 1). As the sum of the values would vary between 0 and 12 (there are six variables), the index's values were adjusted to be between 0 and 10 (a more intuitive scale), in which 10 is the greatest level of restriction.

This index has at least one caveat: its values are a non-weighted sum of the variables, regardless of how much the activities they measure produce in terms of agglomerations. This could be corrected by an index with weighted variables, but this would require data about how much different activities produce agglomerations of people (not available) or arbitrary assumptions.

Number of cases of covid-19

A high number of cases should make people more aware of the epidemic or more afraid of getting infected, which is likely to influence their behaviour. In the model, I use rolling averages (7 days) to compensate for random factors affecting the number of reported cases in a given day. For example, cases during weekends and bank holidays take longer to be reported to the Ministry of Health (which consolidates data from all Brazilian states).

Underreporting is of course a problem, but the high correlation between the number of cases and the number of deaths (0.80) indicates that underreporting rates did not vary substantially over time. Number of deaths were not used in the model due to a high number of observations with a value of zero: in a log scale these observations would either be discarded or have arbitrary values, which is likely to bias results. Data for this variable come from Brazil's Ministry of Health.

Duration of physical distancing rules

Levels of physical distancing should be negatively correlated with the number of days since mandatory physical distancing rules were introduced. The longer the rules last the less likely people are to comply with them (holding everything else constant), which should occur for a few reasons: their savings (in case they have them) were all spent; people are looking for jobs or need to increase their income; social isolation produces stress; or people may seek to escape from domestic abuse. In the model, this variable is measured by the number of days since the first mandatory physical distancing rule was introduced in a given state.

Levels of development

In poorer places people should be less likely to practice physical distancing as they are less likely to have savings and more likely to have informal jobs, reducing incentives for them to stay at home. This variable is measured through GDP per capita, which has a substantial variation in Brazil: between R$ 12,800 a year in the poorest state (Maranhão) and R$ 80,500 in the richest one (Distrito Federal). The interpretation of results for this variable should be cautious though as it is likely to capture the effect of others: lower levels of GDP per capita are associated with a lower number of ICU beds, a lower percentage of people living in urban areas, a lower population density, less access to reliable information and a lower educational level, which might all influence levels of physical distancing. Data for this variable come from the Brazilian Institute of Geography and Statistics (IBGE).

Table 1. Variables of the index.

# of the variable	Description of the variable	Values
1	Mass gatherings and cultural, sport or religious activities	2 = Full suspension 1 = Partial suspension or restriction 0 = No suspension or restriction
2	Bars, pubs, restaurants and similar places	
3	Non-essential shops	
4	Non-essential industries	
5	Classes	
6	Public transportation	

- Information used to code the values of these variables come from open sources, especially legal documents from state governments, complemented by news from local media. Details are in the Chart 1 and in Moraes[12,13]. The original dataset is in Moraes[14].

Chart 1. Variables and values of the physical distancing rules index (PDI).

Variable 1 (mass gatherings and cultural, sport or religious activities)
Full (2): The following activities or places are suspended or closed: gatherings with more than 20 people, gyms, religious temples, concert halls, cinemas, theatres, cultural centres, etc. Partial (1): At least one of the abovementioned activities or places is suspended or closed (even if only in part of the territory). No suspension (0): None of the abovementioned activities or places is suspended or closed.
Variable 2 (bars, pubs, restaurants, etc.)
Full (2): The following places must remain closed: bars, pubs, restaurants, cafés, etc. (except for takeaway or delivery) Partial (1): At least one of the abovementioned places' activities is suspended or there are strict rules for those that remain open (even if only in part of the territory), including the use of no more than 50% of their capacity. No suspension (0): None of the abovementioned places has to suspend or reduce activities.
Variable 3 (non-essential shops)
Full (2): Only essential shops and services can remain open Partial (1): Some non-essential shops or services can remain open (for example: electronic stores, clothing shops or beauty salons) or they can remain open but limited to up to 50% of their capacity (even if only in part of the territory). No suspension (0): None of the abovementioned places has to suspend or reduce activities.
Variable 4 (non-essential industry)
Full (2): Only essential industries can remain open. Partial (1): Some non-essential industries can remain open or they can operate at a maximum of 50% of their capacity (even if only in part of the territory). No suspension (0): There are no restrictions.
Variable 5 (classes)
Full (2): All classes are suspended. Partial (1): Some classes are authorized,or schools can open with a maximum of 50% of their capacity (even if only in part of the territory). No suspension (0): There are no restrictions.
Variable 6 (public transportation)
Full (2): Both intermunicipal and interstate public transportation are suspended. Partial (1): Only intermunicipal or interstate public transportation is suspended, or they can operate with a maximum of 50% of their capacity (even if only in part of the territory). No suspension (0): There are no restrictions.

Health infrastructure

In places with limited health infrastructure, people should have more incentives to practice physical distancing as they would be less likely to have healthcare available. In the model, this is measured by the number of ICU beds per 100,000 people. Data for this variable come from Brazil's Ministry of Health (DATASUS).

Political party or coalition in power

The ideology of a government in power might indicate people's willingness to practice physical distancing. A stronger sense of social responsibility might be more common among left-wing people, so that voters who elected left-wing candidates would be more likely to practice physical distancing. In contrast, people who elected

Ciência & Saúde Coletiva, 25(9):3393-3400, 2020

right-wing candidates might put more emphasis on their freedom of going and coming, making them less likely to practice physical distancing. In the model there are three values for this variable: 0 for a left-wing party or coalition; 1 for a centrist party or coalition; or 2 for a right-wing party or coalition.

Population density

People living in places with a high population density have a greater risk of getting infected and infecting others, creating more incentives for people to stay at home. In the model, this is measured by the log of the population density. Data for this variable come from the Brazilian Institute of Geography and Statistics (IBGE).

Results and discussion

As observed in Figure 1, values of the PDI are highly and positively correlated with values of the social distancing index, suggesting that these two phenomena are associated.

Yet, there is substantial variation across states, suggesting that other variables also determine levels of physical distancing. Moreover, physical distancing's decrease over time was on average higher than the decrease in the strictness of mandatory physical distancing rules. This is puzzling because it coincided with rising numbers of cases and deaths due to covid-19, which should make people comply more – rather than less – with physical distancing rules. This indicates that the length of legal rules of physical distancing may be negatively correlated with levels of physical distancing.

Results from a panel data analysis indicate that levels of physical distancing depend on the strictness of mandatory physical distancing rules, on the number of confirmed cases of covid-19 and on the number of days since the first mandatory measures were introduced. As observed in Table 2, the coefficients of these three variables were similar across different models. An increase of one additional unit in the PDI (which has a scale of 0 to 10) is expected to increase physical distancing by about 0.8 percentage point. The effect of an increase in the number of cases is also significant: one additional unit increases physical distancing by about 0.9 percentage point. Yet, it is important to consider that one unit in the log scale represents an increase of about 3 times in the number of cases per 100,000 people. Consequently, an increase of 3 times in the number of cases have an effect only slightly stronger than the effect of increasing one additional unit in the strictness of mandatory physical distancing rules.

The duration of mandatory physical distancing measures is also statistically significant: holding everything else constant, an additional day of physical distancing mandatory rules decreases physical distancing by about 0.2 percentage point. This implies that keeping physical distancing levels constant over time requires an increase in the strictness of physical distancing rules or other measures that increase physical distancing (Table 2).

Data indicates that GDP per capita might have an influence but it does not add predictive power to the model. Due to a high or medium correlation of GDP per capita with the number of ICUs per 100,000 people (correl = 0.82), the ideology of the political party/coalition in power (correl = -0.50), and population density (correl = 0.34), separate models with each of these variables were built. The number of ICU beds and population density were significant but did not increase the predictive power of the models, and the political party (or coalition) in power was not statistically significant. The R^2 values for models with state dummies should be interpreted with caution as they are inflated by the use of these dummies. The R^2 of 0.54 in model 2 indicates a good predictive power of the model, suggesting that more than 50% of the variation in physical distancing levels is caused by the strictness of physical distancing rules, the number of confirmed covid-19 cases, and the length of mandatory physical distancing measures.

There are at least three limitations in these models. First, the physical distancing rules index captures only the suspension or restriction of activities, not including measures that are also essential to contain an epidemic, such as awareness campaigns, mandatory use of PPE, cash transfers (which encourages people to stay at home), or the enforcement of legal rules. Second, the models do not capture overall social norms, which may lead people to stay at home more in certain states than in others. Third, there is variation over time for the independent variables of interest (strictness of physical distancing rules, number of covid-19 cases, and number of days since mandatory measures were introduced), but not for the other covariates, either because there was no daily data available or because they only change substantially over larger periods of time. Therefore, the results for population density, GDP per capita, ideology and ICU beds should be interpreted with caution.

These findings do not imply that similar results should be found in other countries, as there might be specific determinants in Brazil not cap-

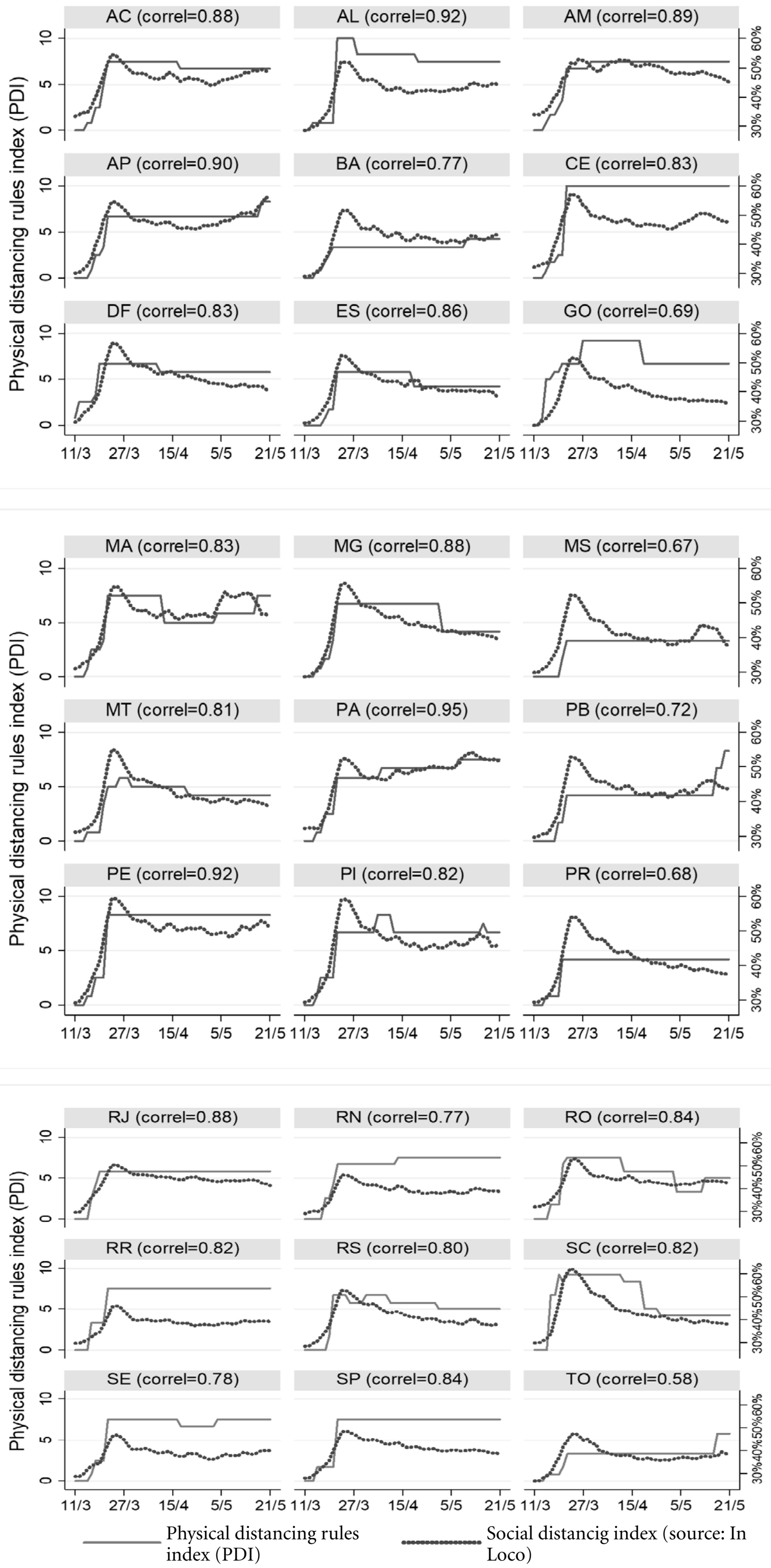

Figure 1. Physical distancing rules index (PDI) and social distancing index, 11 Mar-21-May (only business days).

- Centred-moving averages (3 days) for values of the social distancing index.
- AC: Acre, AL: Alagoas, AM: Amazonas, AP: Amapá, BA: Bahia, CE: Ceará, DF: Distrito Federal, ES: Espírito Santo, GO: Goiás, MA: Maranhão, MG: Minas Gerais, MS: Mato Grosso do Sul, MT: Mato Grosso, PA: Pará, PB: Paraíba, PE: Pernambuco, PI: Piauí, PR: Paraná, RJ: Rio de Janeiro, RN: Rio Grande do Norte, RO: Rondônia, RR: Roraima, RS: Rio Grande do Sul, SC: Santa Catarina, SE: Sergipe, SP: São Paulo, TO: Tocantins.

Ciência & Saúde Coletiva, 25(9):3393-3400, 2020

Table 2. Determinants of physical distancing in Brazil (22 March – 24 May 2020).

Social distancing index (0-100%)	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Physical distancing rules index (PDI)	0.799***	0.788***	0.799***	0.799***	0.799***	0.799***
	(0.055)	(0.054)	(0.055)	(0.055)	(0.055)	(0.055)
Number of days	-0.194***	-0.195***	-0.194***	-0.194***	-0.194***	-0.194***
	(0.007)	(0.006)	(0.007)	(0.007)	(0.007)	(0.007)
Log cases	0.926***	0.945***	0.926***	0.926***	0.926***	0.926***
	(0.075)	(0.074)	(0.075)	(0.075)	(0.075)	(0.075)
Log GDP per capita			1.008**			
			(0.298)			
ICU beds				0.048**		
				(0.014)		
Ideology					0.048	
					(0.445)	
Log population density						0.287**
						(0.085)
Constant	49.287***	49.166***	39.118***	48.362***	49.287***	49.370***
	(0.533)	(0.600)	(3.239)	(0.682)	(0.533)	(0.524)
State dummies	Yes	No	Yes	Yes	Yes	Yes
# of observations	1.725	1.725	1.725	1.725	1.725	1.725
R^2	0.772	0.544	0.772	0.772	0.772	0.772

*** p< 0.001, ** p< 0.01, *< 0.05.
- The numbers of the models are indicated at the top row.
- Physical distancing rules index (PDI): strictness of mandatory physical distancing rules; number of days: days since the first mandatory physical distancing rules was adopted; log cases: log of the number of new confirmed cases; Log GDP per capita: log of the GDP per capita; ICU beds: number of ICU beds per 100,000 people; ideology: ideology of the political party or coalition in power (left-wing, centre or right-wing); log population density: log of the population density.

tured in this model. Among others, the federal government encouraged people not to respect physical distancing and sought to undermine states' policies of physical distancing, which is likely to have influenced people's behaviour[15].

Conclusions

This paper was an attempt to estimate the determinants of physical distancing levels. Results show that mandatory physical distancing rules and the number of confirmed covid-19 cases are positively correlated with physical distancing levels, while the duration of rules are negatively correlated with them. It also shows that the effect of physical distancing mandatory rules is relatively stronger than the effect of the number of cases, suggesting that people respond more to mandatory rules of physical distancing than to the severity of the epidemic.

These findings have at least two policy implications. First, increasing physical distancing to high levels requires governments to adopt mandatory measures, especially when numbers of cases and deaths are not high. For a variety of reasons, a substantial part of the population seems to have a risk-taking behaviour, which might result from economic needs, cultural or psychological traits, or influence from pandemic-negationists.

Second, evidence indicates that mandatory physical distancing rules have an 'expiry date': for a variety of reasons people's compliance with mandatory rules decrease over time, even if the number of cases and deaths from covid-19 increases. This implies that the 'timing' for adopting mandatory measures is important, as compliance with rules might decrease when it is most needed. This also implies that keeping levels of physical distancing constant over time are likely to require additional mandatory restrictions, a greater enforcement or non-mandatory measures (awareness campaigns or cash transfers to people, for example). This problem might be minimized by an on-off lockdown policy, as suggested by Scherbina[16], which may not be the best solution from an epidemiological point of view, but necessary in some cases for practical reasons.

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