


Social distancing in São Paulo State: demonstrating the reduction in cases using time series analysis of deaths due to COVID-19

Distanciamento social no estado de São Paulo: uso de série temporal dos óbitos por causa da COVID-19 para demonstrar a redução de casos

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ABSTRACT: *Introduction:* Demonstrating the results of Social Distancing Strategies (SDS) became a relevant factor to obtain support by the population in São Paulo State and in Brazil. The delay in the processing of PCR tests and the small number of tests available limits the ability of sanitary authorities to make meaningful data available as to the number of cases or the number of deaths due to COVID-19. *Methodology:* We use a time series analysis of deaths due to COVID-19 referenced to the date of deaths (as opposed to the date in which the test results were obtained). *Results:* We demonstrate that the SDS adopted in São Paulo City and State clearly brought meaningful results to delay the growth of COVID-19 cases. We also show that by using this type of time series it is possible to identify different trends for regions, allowing for targeted approaches. Additionally, by using a time series which is death-oriented makes it possible to identify, for São Paulo City, the effects of the SDS with the Social Isolation Index (SII) adopted in the state and to make a gross estimate for the SII, which prevents the growth of the disease. *Conclusion:* The use of a time series of deaths due to COVID-19 referenced to the date of the event allows a better understanding of the effects of the SDS on the progression of the COVID-19 epidemic in São Paulo State, Brazil.

Keywords: Covid-19. Time series. Epidemic.

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Conflict of interests: nothing to declare – **Financial support:** none.

RESUMO: *Introdução:* Demonstrar os resultados das estratégias de distanciamento social (EDS) tornou-se um fator relevante para obter apoio da população do estado de São Paulo e do Brasil. A demora no processamento dos testes do tipo RCP e o pequeno número de testes disponíveis limita a capacidade das autoridades sanitárias de disponibilizar dados significativos sobre o número de casos ou o número de óbitos por causa da Covid-19. *Metodologia:* Usamos uma série temporal de óbitos pela Covid-19 referenciada à data dos óbitos (diferentemente da data em que os resultados dos exames foram obtidos). *Resultados:* Demonstramos que é visível que as EDS adotadas no município e no estado de São Paulo trouxeram resultados significativos que atrasam o crescimento dos casos de Covid-19. Também mostramos que utilizando esse tipo de série temporal é possível identificar diferentes tendências para as regiões, permitindo abordagens direcionadas. Além disso, utilizando-se uma série temporal orientada ao óbito, é possível identificar, para o município de São Paulo, os efeitos das EDS com o Índice de Isolamento Social (IIS) adotado no estado e fazer uma estimativa bruta para o IIS, que quebra o crescimento da doença. *Conclusão:* O uso de uma série temporal dos óbitos devidos à Covid-19, referenciada diretamente à data do óbito, permite compreender os efeitos do distanciamento social na evolução da epidemia de COVID-19 no estado de São Paulo, Brasil.

Palavras-chave: Covid-19. Série temporal. Epidemia.

INTRODUCTION

Social Distancing Strategies (SDS) are known tools used for controlling the spread of pandemics and are being used for the current COVID-19 pandemic¹. China², Italy³, Spain, and several European countries⁴, New York State⁵ and others have been using SDS successfully. In this article, we analyze indicators that demonstrate that the SDS adopted in São Paulo State, Brazil, since March 16th has provided clear results that saved lives and protected the health system of the state from being overloaded due to the progression of the epidemic. Data from the end of April, however, shows that the number of cases tends to increase as the adherence to SDS by the population decreases.

The main difficulty in assessing the effectiveness of the SDS adopted in São Paulo stems from the fact that the amount of tests performed in the state is small, with 91,552 PCR test kits supplied to the state by the Brazilian Ministry of Health until May 1st, 2020⁶. Instituto Butantan, the organization responsible for coordinating the testing in the state, informed that 35,600 PCR tests were performed on April 22nd⁷. Considering the 42-million people in the state, this translates into 85 tests per 100 thousand people; considering the whole country, Brazil occupies the 133rd position among the countries that test for COVID-19⁸. In addition, there was a delay of several weeks between collecting the samples and obtaining the results in the initial phase of the epidemic. Finally, Brazilian authorities, in their daily briefings and bulletins, inform the number of cases and deaths due to COVID-19, using the date in which test results were obtained, not the date of the initial symptoms or the date of death.

In this communication, we use a time-series analysis of deaths attributed to COVID-19, in which each death is referenced to the date of death, and not to the date in which a COVID-19 test had its results concluded. The series is obtained from the Civil Registry in Brazil, and its analysis demonstrates that SDS had a significant impact on reducing the number of deaths in São Paulo State. We also estimate the reduction in the number of deaths obtained with the SDS and the intensity of social distancing needed to halt the spread of disease.

METHODOLOGY

In order to assess the effects of SDS in São Paulo City and State on the evolution of deaths due to COVID-19 on a daily basis, we used the public data from the National Association of the Registrars for Natural Persons (Associação dos Registradores de Pessoas Naturais — ARPEN), an organization that congregates all Public Notaries in Brazil. Their website presents the number of deaths attributed to COVID-19 referenced to the date in which they happened⁹. In Brazil, a public notary is an organization legally responsible for issuing and keeping registry of births, deaths, marriages, and other legal events. A death certificate is an official document containing a field in which a certified physician informs the cause of death. ARPEN's website also contains data informing the number of COVID-19-suspected deaths, attributed by a certified physician. The term "Confirmed COVID-19 deaths" is used for cases in which there was a PCR test with positive result for COVID-19. The term "Suspected COVID-19 deaths" is used for cases in which COVID-19 was described as a cause of death with clinical diagnosis.

Some uncertainty arises from the fact that, being a new disease for which biochemical tests are not widely available, it is possible that the cause of death may be attributed to other factors but COVID-19 in some cases. Following the guidelines by the Brazilian Ministry of Health, we chose to include the deaths attributed directly to COVID (suspected and confirmed) plus the excess deaths attributed by the ARPEN data to Severe Acute Respiratory Syndrome (SARS) in 2020 with respect to 2019 (deaths in 2020 minus the deaths in 2019, which we consider a baseline) in the count discussed in this article.

For avoiding fluctuations and facilitating visual observations, each data point represents the average of five days: two days before, the data shown, and two days after the date shown.

RESULTS

Figure 1 shows the number of deaths per day in São Paulo State, Brazil, attributed to COVID-19 (suspected and confirmed cases) plus the deaths per day attributed to SARS.

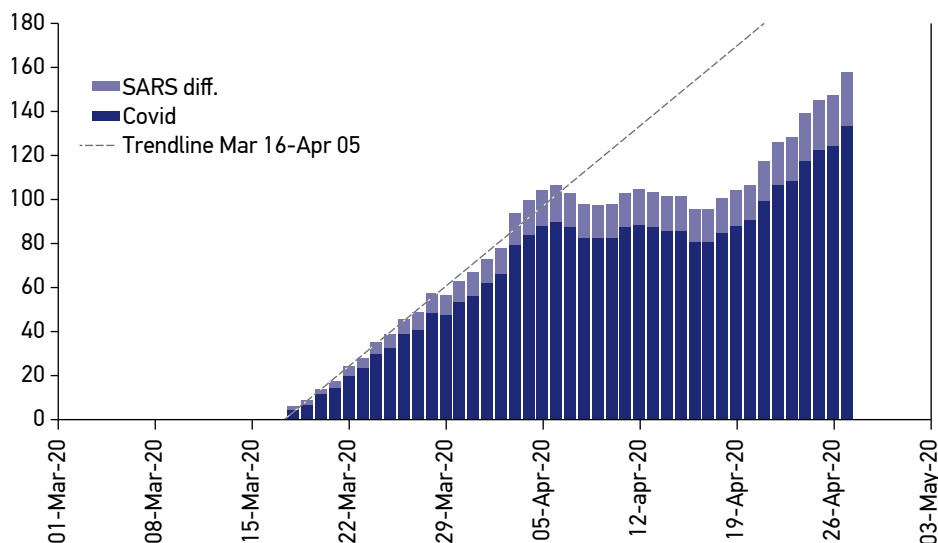
Three sequential trends in the data relating the number of deaths per day attributed to COVID-19 can be identified in Figure 1. There is a steep rise in the recorded events

from March 17th to April 5th, at a rate of about 5.2 deaths per day. After that, a flattening was seen until April 19th, followed by a second rise. We limit the period to April 27th because there is a (potential) 14-day delay between the death and the consolidation of information on the website, and more recent data is not consolidated at the date we finished the present article.

We hypothesize that the abrupt change in the rising trend observed around April 5th can be attributed to the Social Distancing measures adopted by São Paulo State between March 16th and March 22nd. In this period, state decrees were issued, establishing a system of work-from-home and the mandatory closure of non-emergency businesses and educational institutions throughout the state. The time delay, of around 17 days, is consistent with observations of the delay between the onset of symptoms and death as an outcome, found to be 17.8 days on average¹⁰.

It is striking how the evolution shown in Figure 1 differs from the evolution obtained by plotting (Figure 2) the daily data informed by the Ministry of Health and by the State Secretary of Health, which, as aforementioned before, is referenced to the date of test results and not to the date of death. It is of utmost importance to remember that the shape of the plot shown in Figure 2 is affected by:

- the number of deaths at a given date;
- the number of tests performed;



Source: Associação dos Registradores de Pessoas Naturais do Estado de São Paulo (ARPEN)⁹.

Figure 1. Number of deaths per day (data is averaged for 5 days) in São Paulo State, Brazil, attributed to confirmed or suspected cases of COVID- and to SARS (SARS diff. denotes the additional cases attributed to SARS [severe acute respiratory syndrome] in 2020 with respect to the cases in 2019). The dashed trendline fits the period until April 5th and rises at a rate of 5.2 deaths per day.

- the delay between testing and obtaining results.

Not only the time evolution in Figure 1 is different from that in Figure 2: the total number of deaths displayed for Figure 2 is 1,825, whereas in Figure 1 (based on death certificates) it stands for 3,293.

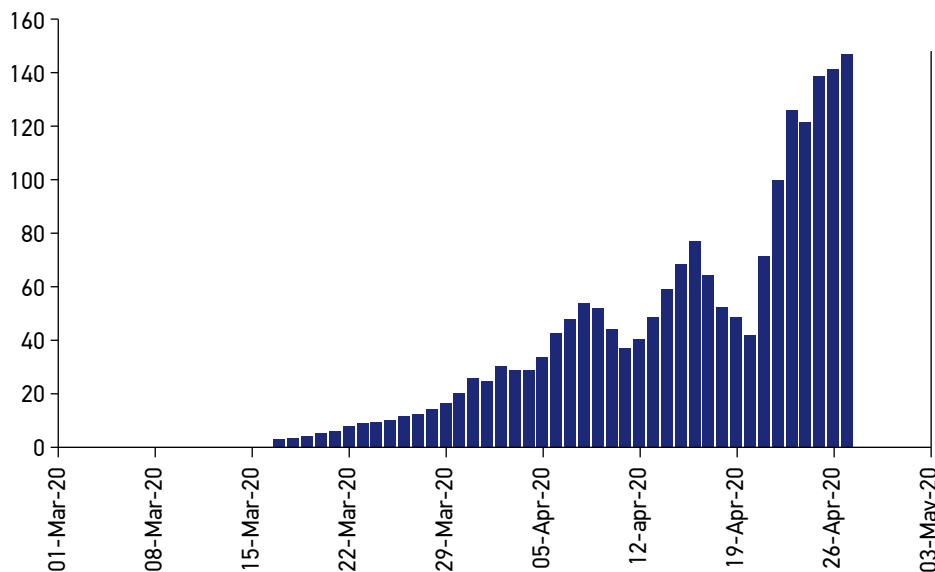
DIFFERENT BEHAVIORS IN SÃO PAULO CITY, IN THE REST OF THE STATE, AND IN BRAZIL

Additional insight on the evolution of the disease can be obtained by disaggregating the data.

Figure 3 shows the evolution of the number of deaths per day for São Paulo City. The steep rise until April 5th climbs at a rate of 3.1 deaths per day. Like what was seen regarding the behavior for the state's population, there is a flattening of cases after April 5th. However, the increase in the number of cases after April 19th is not as visible in this case.

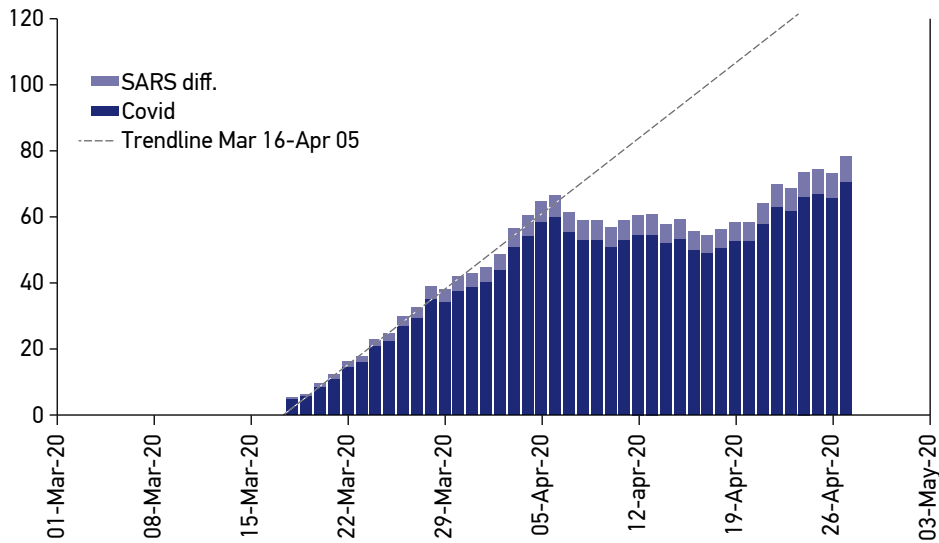
As to the case of São Paulo State, excluding São Paulo City, the evolution is shown in Figure 4. Once more, there is a steep rise in the figures until April 5th, at a rate of 2.1 deaths per day (two thirds of the value observed for São Paulo City). Then, there is a flattening, until April 18th, followed by a new rising stage.

The evolution in the number of deaths per day for Brazil displays a quite different behavior, shown in Figure 5. The flattening, which is very evident for São Paulo State (Figure 1)



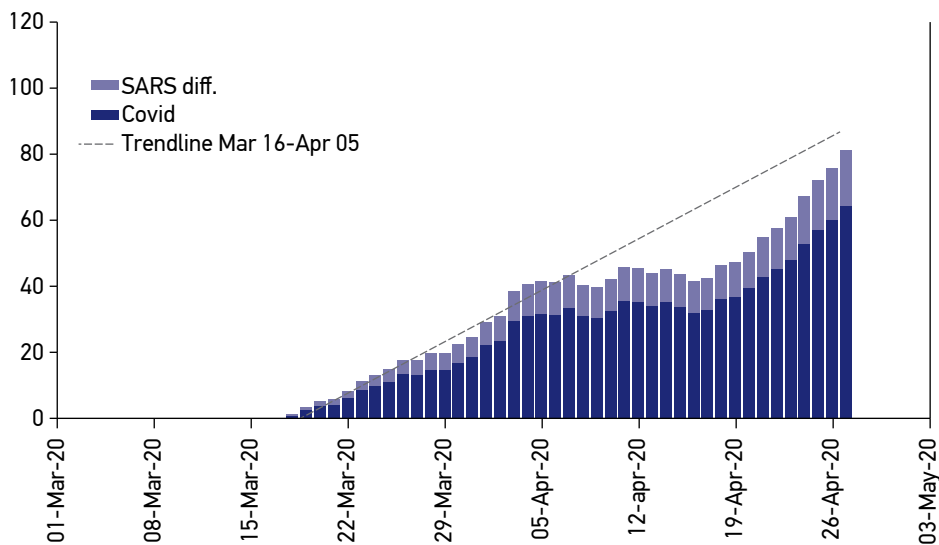
Source: Brazil⁶.

Figure 2. Number of deaths per day (data is averaged for 5 days) in São Paulo State, Brazil, attributed to confirmed cases of COVID-19, referenced to the date in which the PCR test was informed.



Source: Associação dos Registradores de Pessoas Naturais do Estado de São Paulo (ARPEN)⁹.

Figure 3. Number of deaths per day (data is averaged for 5 days) in São Paulo City, Brazil, attributed to confirmed or suspected cases of COVID-19 and to SARS (SARS diff. denotes the additional cases attributed to SARS [severe acute respiratory syndrome] in 2020 with respect to the cases in 2019).



Source: Associação dos Registradores de Pessoas Naturais do Estado de São Paulo (ARPEN)⁹.

Figure 4. Number of deaths per day (data is averaged for 5 days) in São Paulo State, Brazil, excluding São Paulo City, attributed to confirmed or suspected cases of COVID-19 and to SARS (SARS diff. denotes the additional cases attributed to SARS [severe acute respiratory syndrome] in 2020 with respect to the cases in 2019).

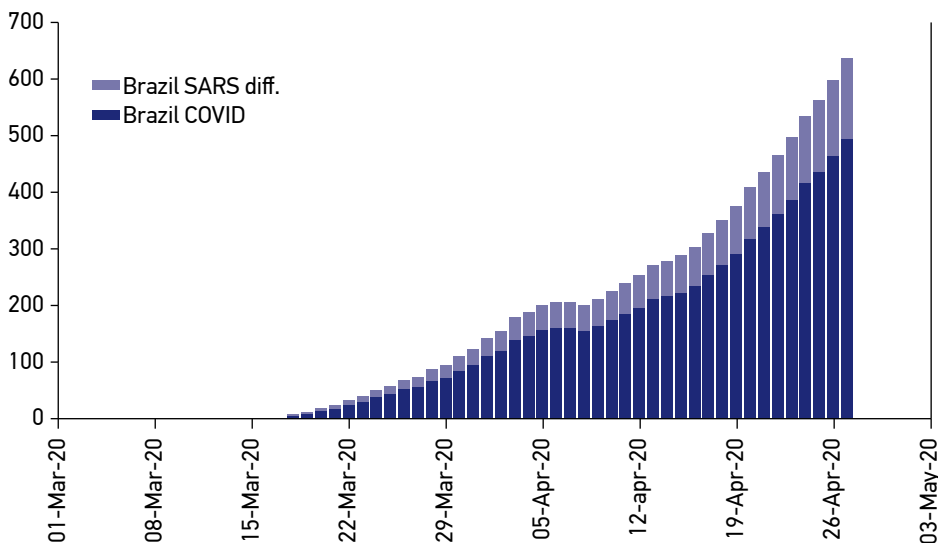
and for São Paulo City (Figure 3), is much shorter for the case of Brazil, lasting only for three or four days, before the curve starts to grow again (Figure 5).

DISCUSSION

The data shown above demonstrate that SDS can change the course of the spread of disease. Additionally, data show the relevance of measuring the events referenced to the date they happened and data also show that, not surprisingly, but relevant to the way Brazilian authorities have been treating and forecasting the data, considering the events at the time they occur is essential to understand the features of the time evolution, informing about the spread of the disease, as opposed to the speed of testing or its announcement.

Consider, for example, the different behaviors shown in Figures 3, 4 and 5, highlighting the importance of localized information to design strategies to cope with the pandemic. Whereas the SDS in São Paulo City seems to produce results in controlling the spread of disease, the results for São Paulo State seem less effective in this respect, and the data for Brazil indicates a much worse situation.

In São Paulo City, the SDS made the evolution in the number of deaths to stabilize (or even slightly decrease) between April 7th and April 20th. It must be noted that the number of deaths slightly increased after April 21st (Figure 3).



Source: Associação dos Registradores de Pessoas Naturais do Estado de São Paulo (ARPEN)⁹.

Figure 5. Number of deaths per day (data is averaged for 5 days) in Brazil, attributed to confirmed or suspected cases of COVID-19 and to SARS (SARS diff. denotes the additional cases attributed to SARS [severe acute respiratory syndrome] in 2020 with respect to the cases in 2019).

The ability to track the spread of the disease in time, even with some delay, allows for a better understanding of how to analyze, develop, and implement strategies to confront the epidemic. For São Paulo City, Table 1 shows a measurement of its spread in terms of additional deaths per day, and the corresponding social distancing index measured 15 days before. From such data, it is possible to make a gross estimation for the SDI value, which will slow down the spread of the disease. It appears that at a SDI between 52 and 56%, makes the progression of the disease to cross the break-even point: an SDI of 56% causes decrease deaths 0.40 per day, whereas an SDI of 52% increase deaths to 0.82 per day. For the normal-life period (before March 16th) the disease progressed at a rate of 3.18 deaths per day. The values obtained from this gross estimate should be analyzed with care, because the spread of the disease is affected by other factors beyond the SDI and it is not known how the SDI relates specifically to the transmission rate of the virus, so that similar values of SDI might result in different transmission rates for different environments, for example when temperature, humidity, population density, and use of masks¹¹ changes.

For the rest of São Paulo State, the situation in terms of control over the spread of the disease seems worse, as shown in Figure 4. Except for São Paulo City, the summary for the state is shown in Table 2. In this case, we do not present a value for the SDI, given that it does not seem to make sense to consider an index averaged over the 645 different municipalities, which have a wide range of different populations and social characteristics. It is worth mentioning that from April 6th to April 19th, the number of municipalities in which there was at least one death attributed to COVID-19 grew from 33 to 91. This factor implies that the dynamics for the spread must have involved bringing the

Table 1. São Paulo City: growth rate of daily deaths and social distancing index (SDI)* measured 15 days before the period for which the deaths growth rate was measured.

Period for growth rate	Growth rate (additional deaths per day)	Social Distancing Index, SDI (15 days before the period for growth rate)
Mar16-Apr05	3.18	31%
Apr06-Apr20	-0.40	56%
Apr21-Apr27	0.82	52%

*The SDI was obtained from: <https://www.saopaulo.sp.gov.br/coronavirus/isolamento/>.

Table 2. São Paulo State, excluding São Paulo City: growth rate of daily deaths for the three periods shown in Figure 4.

Period for growth rate	Growth rate (additional deaths per day)
Mar16-Apr05	2.12
Apr06-Apr19	0.30
Apr20-Apr27	3.00

disease from other cities or regions in many cases (there was no lockdown policy enacted in Brazil until May 11th), which confirms the smaller relevance of local SDS (measured by an SDI) for this period.

Finally, we mention that to obtain support from the population to the measures needed for SDS, it is helpful to demonstrate that the strategy is working. The data referenced to the date of the death, as shown in Figure 1 or Figure 3 is thus more effective to demonstrate success than the data referenced to the date of the test result (Figure 3).

CONCLUSION

Using a time series analysis referenced to the date of death, and not to the date of testing for COVID-19, we demonstrated that the Social Distancing Strategy adopted in São Paulo State brought substantial results in terms of reducing the number of infections. The results were evident for São Paulo City, where the rate of the spread of COVID-19 was substantially reduced, especially between April 5th and April 20th.

A gross estimate, using the data for São Paulo City, indicated that a Social Distancing Index (as defined and informed by the State Government) higher than 55% may be needed to reduce the number of deaths.

Additionally, when comparing the data for São Paulo City to that from the other regions of the state, we observed different trends in the spread of the disease, implying that it is essential to have localized data to define local targets for the SDI.

A limitation in our approach, if it is to be used for fast response decisions, is the delay which exists between the death and the emission of the Death Certificate and its filing in the Civil Registry database, which can be as long as 15 days. We used the available time series, which had the data as to the number of deaths referenced to the date of the death, to demonstrate that referencing to the date of the death was relevant. We believe the authorities might be able to use primary data informing the *causa mortis* and referencing the death to the date of death, as opposed to the date in which the result of a PCR test was made available. The point of our argument is not that the ARPEN data should be used for policy—we used ARPEN data to demonstrate that by referencing the deaths to the date of the death more can be learned about the evolution of the disease and the measures taken to control it. It seems to us that by reporting information about the deaths caused by COVID-19 referenced to the test results date is distorting, and unnecessarily hindering the advance of the understanding about the spread of the disease in Brazil.

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Received on: 05/12/2020

Accepted on: 05/14/2020

Author's contribution: the author conceived the idea, obtained the data, and wrote and revised the manuscript.

