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ORIGINAL ARTICLE

Social distancing measures could have reduced estimated deaths related to COVID-19 in Brazil

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Abstract

Social distancing was planned as a preventive measure to control the extensive spread of COVID-19. COVID-19-related deaths in Brazil were analyzed during the period of social distancing measures. Mortality data for COVID-19 was obtained from the Worldometer website (www.worldometer.info). Deaths were estimated up to the 31st day after the occurrence of the 5th COVID-19-related death in Brazil. Social distance was measured using Google's community mobility reports (https://www.google.com/covid19/mobility/). The Brazilian epidemic curves were interconnected, and mathematical models were evaluated to fit the mortality estimation curves. The optimistic model was defined in the opening period of social distancing and, therefore, in the lower mobility (40-60%). The realistic model was calculated according to relaxed social distance measures (<40%) and the pessimistic model was calculated based on the transmission rate between 2-3. Thus, the equations of the mathematical models provided the outcomes for the date of June 9, 2020, as follows: realistic model with 40,623 deaths, pessimistic model with 64,310 deaths and the optimistic model with a projection of 31,384 deaths. As a result of these analyzes, on May 24, 2020, there were a total of 22,965 deaths related to COVID-19, and those deaths included within the proposed mathematical models were 17,452 for the optimistic model, 22,623 for the realistic model and 32,825 for the pessimistic model. Thus, it is concluded that social distancing measures promoted by the Brazilian public managers contributes to the reduction in approximately ten thousand deaths related to COVID-19 in the current pandemic scenario.

Keywords: Beta-coronavirus; Centers for Disease Control and Prevention (U.S.A.); Coronavirus; Coronavirus Infections; Death; SARS Virus.

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Authors summary

Why was this study done?
Social distancing measures are widely used as non-pharmacological measures with better performance in flattening the COVID-19 epidemic curve. Non-pharmacological interventions are public health measures with individual, environmental and community scope, covering the isolation of cases, quarantine applied to contacts, and the voluntary practice of not frequenting places with crowds of people. The mathematical model collaborates for intervention measures in the field of public health and should be widely used in the daily lives of public health managers in Brazil and worldwide. Thus, this research analyzed whether social distance had an influence on the outcome of expected deaths related to COVID-19.

What did the researchers do and find?
A mathematical projection was made on the number of outcomes with death related to COVID-19. The mathematical projections of the proposed model projected an estimate of 17,452 deaths for the optimistic hypothesis, with 22,623 deaths for the realistic model and 32,825 deaths for the pessimistic model. As of May 24, 2020, 22,965 COVID-19-related deaths have been confirmed.

What do these findings mean?
The non-pharmacological intervention of social distance is effective as a public health measure with individual, environmental and community reach, promoting the isolation of cases, reduction of contact between individuals and reduction in the number of deaths related to COVID-19.

INTRODUCTION

Coronavirus Disease 2019 (COVID-19) has caused a global recession in the economic and health systems[1-3]. It is characterized as a pandemic in Brazil and worldwide.

In reports released by The Imperial College (England)[4] emphasized the importance of non-pharmacological interventions to control the current pandemic. In addition, findings by Dehning et al5 (in Germany) and Garcia and Duarte[6] (in Brazil) corroborate the hypothesis that social isolation is fundamental for disease control, being a non-pharmacological and effective measure for reducing the hypothetical epidemic curve for COVID-19.

Such measures have important impacts on daily activities, both on people's lives and on society in general, as reported by Garcia and Duarte[6]. There are several effects of this measure of social isolation, such as the increase in domestic violence for women and children, as these populations are more vulnerable in their homes and there are economic losses for people, families, companies and countries[6].

It is noteworthy that Brazil adopted the pandemic control scenario using social distance as one of the sanitary measures. Thus, studies with mathematical models are important to assist public managers in making decisions. Therefore, the objective of this study is to analyze the outcomes of deaths by COVID-19.

METHODS

This is a study of mathematical projection and secondary data. COVID-19 mortality data, which occurred in Brazil, were obtained from the Worldometer website (www.worldometer.info)[7].

Worldometer[7] is managed by an international team of developers, researchers, and volunteers, who provide global statistical health data, available in a timely manner to a global audience. It is published by a digital media company based in the United States of America, being recognized as independent from state influence and other agents of global society, having no political, governmental or corporate affiliations.

Deaths were estimated from the 5th death until the 31st day after the 5th death record. This data collection occurred between March 9th and April 17th.

Social distancing was defined as a reduction in the mobility of people and was assessed via COVID-19 Community Mobility Reports – Google (https://www.google.com/covid19/mobility/), which makes available Community mobility reports founded on charts with trends and inclinations over time by region and in different categories of locations.

Initially, a link was achieved for Brazilian COVID-19 mortality. Temporal adjustments were finalized, enabling the comparison of data on the Cartesian x-axis, and the adjustment of number of deaths per each 10,000,000 inhabitants, that permitted the procurement of data on the Cartesian y-axis.

Historically, there have been some regressions to determine the best mathematical model that would permit the representation of the mortality estimation curve for Brazilian COVID-19. Whilst searching for the correct mathematical model that best fits the mortality estimation curves, the subsequent models were evaluated: Linear, Logarithmic, Inverse, Quadratic, Cubic, Composite, S, Growth, Exponential and Logistic (Figure 1).

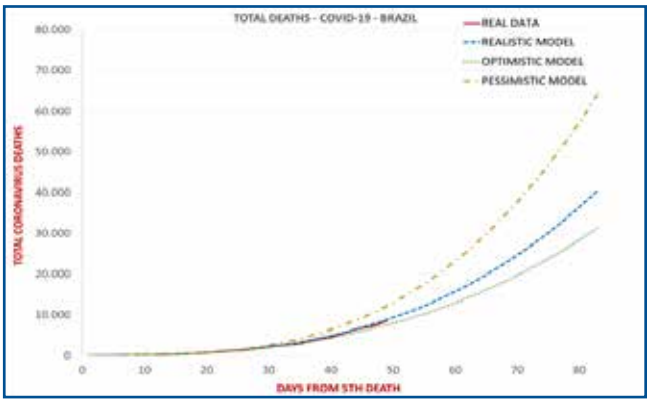

Figure 1: Optimistic, realistic, pessimistic projections and real data concerning deaths related to COVID-19 in Brazil. Edited by Menezes et al. https://doi.org/10.1101/2020.04.28.20083675

The key model, from all available points, was termed a realistic model. Two other models were computed using parts of the data. One that has a greater vertical tendency (Pessimistic model) and another that was further compressed or flattened (Optimistic model).

The realistic model was computed according to extra relaxed social distancing measures (<40%) and the pessimistic model was calculated founded on a R0 ≈ 2-3. For this estimate, a significance of alpha, (α) less than 0.01 ($p < 0.01$, <1%) and $R2 > 0.95$ was implemented.

The datasets were manipulated using Microsoft Excel version 16.36, for MacOS Catalina version 10.15.4. Statistical calculations were computed via IBM SPSS Statistic Subscription application 1.0.0.1347 64-Bits for MacOS. These values were considered statistically significant for ($p<0.05$, <5%) and the recognized beta, (β) value was 0.1.

Finally, data from the continuous PNAD10 was used, which promotes data collection for the Brazilian territory, by large regions, Federation units and Metropolitan regions containing Municipalities of Capitals, Integrated Development Region (RIDE) of Greater Teresina and Municipalities of Capitals for the collection of mobile data by cell phone[10].

RESULTS

It was found that the mathematical models that came closest were the cubic and quadratic models. However, the cubic model was better adjusted $R2 = 0.998$ (table 1).

In figure 2 there are optimistic, realistic and pessimistic models compared to the real data. It was observed that the cubic model approached the mortality growth curve, and algebraically approached as follows:

$$x(t)=11{,}422+0{,}269*t+0{,}265*t^2+0{,}069*t^3$$

t is the number of days after the fifth COVID-19 related death.

Table 1: Summary and parameter estimates.

Dependent variable: Deaths									
Equation	Model summary					Parameter estimates			
	R2	Z	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.859	170.682	1	28	.000	-450.108	67.532		
Logarithmic	.545	33.587	1	28	.000	-789.488	556.986		
Invers	.188	6.495	1	28	.017	788.676	-1442.125		
Quadratic	.995	2654.798	2	27	.000	124.413	-40.191	3.475	
Cubic	**.998**	**4350.630**	**3**	**26**	**.000**	**11.422**	**.269**	**.265**	**.069**
Composed	.963	732.622	1	28	.000	13.567	1.204		
Potency	.947	497.163	1	28	.000	2.110	1.902		
S	.565	36.326	1	28	.000	6.343	-6.475		
Growth	.963	732.622	1	28	.000	2.608	.185		
Exponenctial	.963	732.622	1	28	.000	13.567	.185		
Logistic	.963	732.622	1	28	.000	.074	.831		

The independent variable is Days from the 5th Death.

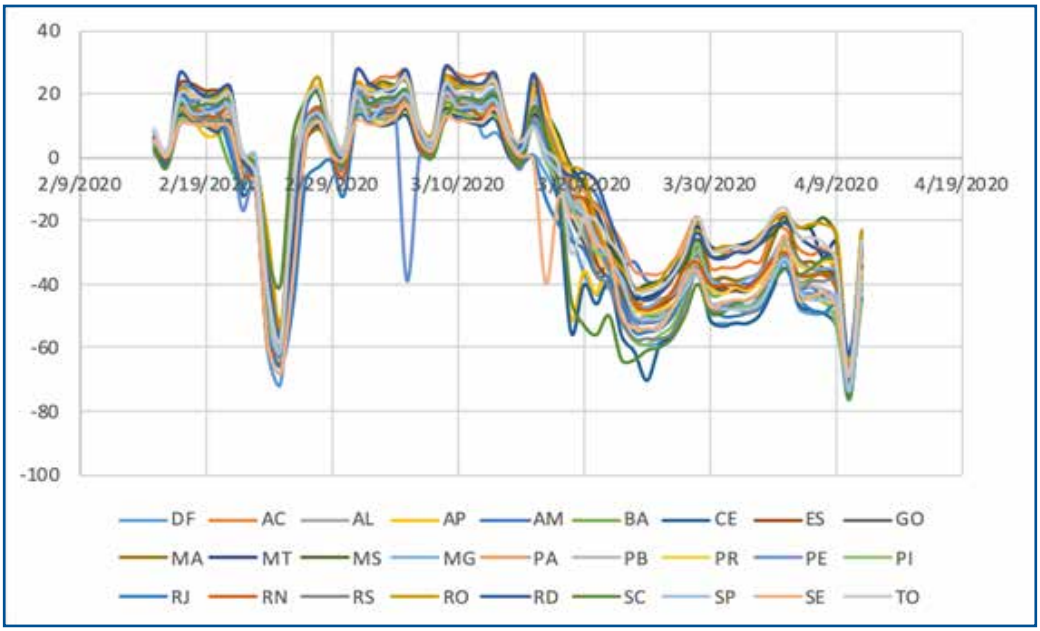

Figure 2: Comparison between total deaths related to COVID-19 in Brazil and projected via mathematical model.

For this situation, the mathematical model predicted 40,623 deaths on June 9, 202011. The maximum pessimistic model predicts 64,310 deaths and the maximum optimistic model predicts 31,384 deaths. In this date (May 24, 2020), 22,965 deaths have been reported, while our model projected 17,45211 for the optimistic model, 22,623 for the realistic model and 32,82511 for the pessimistic model (table 2).

Figure 3 illustrates data from community mobility reports in Brazilian states. There is a mathematical indication of a reduction in social mobility from the end of March 2020.

Table 2: Estimates of accumulated deaths related to COVID-19 in Brazil.

Day	Optimistic	Realistic	Pessimitic
May/20	14.760	18.091	27.028
May/21	15.405	18.944	28.407
May/22	16.069	19.823	29.832
May/23	16.751	20.729	31.305
May/24	17.452	21.662	32.825
May/25	18.172	22.623	34.394
May/26	18.910	23.612	36.013
May/27	19.668	24.630	37.682
May/28	20.446	25.676	39.402
May/29	21.243	26.751	41.174
May/30	22.060	27.856	42.999
May/31	22.897	28.991	44.877
Jun/1	23.755	30.156	46.809
Jun/2	24.634	31.353	48.796
Jun/3	25.533	32.580	50.839
Jun/4	26.454	33.839	52.938
Jun/5	27.396	35.130	55.095
Jun/6	28.360	36.453	57.309
Jun/7	29.346	37.810	59.583
Jun/8	30.354	39.199	61.916
Jun/9	31.384	40.623	64.310

Figure 3: Community Mobility Reports in all Brazilian States. DF: Federal District; AC: Acre; AL: Alagoas; AP: Amapa; AM: Amazonas; BA: Bahia; CE: Ceara; ES: Espirito Santo; GO: Goias; MA: Maranhao; MT: Mato Grosso; MS: Mato Grosso do Sul; MG: Minas Gerais; PA: Para; PB: Paraiba; PR: Parana; PE: Pernambuco; PI: Piaui; RJ: Rio de Janeiro; RN: Rio Grande do Norte; RS: Rio Grande do Sul; RO: Roraima; RD: Rondonia; SC: Santa Catarina; SP: Sao Paulo; SE: Sergipe; TO: Tocantins.

DISCUSSION

This study was initiated to assess deaths related to COVID-19 in Brazil between March 9, 2020 to April 17, 2020. Thus, it was possible to design possible scenarios based on the non-pharmacological measure of mobility in the Brazilian community. It was found that the real data are closer to the realistic model. However, it is worth noting that the mathematical model presented was adequate, however, if the growth of deaths by COVID-19 continues to increase. In stabilizing the pandemic epidemiological curve or decreasing it, it will be necessary to revise the mathematical model.

In the mathematical model, considering the non-implementation of the non-pharmacological intervention mechanism of social detachment, it was predicted that on May 24, 2020 there would be a total number of deaths related to COVID-19 of 32,825. The findings in tables 1 and 2 and figures 1, 2 and 3 confirm the mathematical projections made. However, the number of actual deaths were 22,965.

In view of the initial mathematical projection, published in pre-print[10], in a specific projection for the date of June 9, 2020, it is estimated that there were approximately ten thousand lives saved by the exclusive action of Brazilian social distance.

However, in some research scenarios, such as the State of São Paulo, only a small number of cases of COVID-19 were reported (the State of São Paulo only communicates critical cases of COVID-19 and reports that it is a measure of full orientation Ministry of Health of Brazil). This situation promotes the event of underreporting of the disease. Thus, the regression model between total deaths and social mobility was not performed, since the number of COVID-19 cases increases exponentially. The dependent variable was social mobility, and this variable was registered via mobile cellular telephony.

Also, Garcia and Duarte[6] reported that the actions of the Unified Health System (SUS) and other areas of the social protection system are essential in an articulated way, in order to favor people's adherence to non-pharmacological interventions and minimize the impacts harmful effects of Community measures. The protection of public health should guide the decisions to be taken by managers. It is essential that these decisions are based on the best available evidence and communicated in a transparent manner, in order to promote the population's trust and that the guidelines of the authorities and people's adherence to the INF will be decisive for the course of the COVID-19 epidemic in Brazil[6].

It is salutary to highlight that mathematical estimates have limitations. One of them refers to the point of analysis of the variable social mobility, which was collected from mobile telephony. According to PNAD 2018[10], about a quarter of the Brazilian population does not have access to mobile telephony, therefore this population was excluded from the analysis of the raw data of this research, as the model does not include those Brazilians who do not have or do not use mobile cellular telephony[10].

Finally, it is concluded that the mathematical model demonstrated that the reduced mobility of the community, in the form of social distance, was able to decrease the total number of deaths expected and related to COVID-19 in Brazil, in approximately ten thousand lives.

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Author contributions

Pedro de Lemos Menezes draft the manuscript, wrote introduction and discussion section gave final approval for the version submitted for publication.

Gustavo Nakamura Alves Vieira draft the manuscript, reviewed interpretation analysis and gave final approval of the manuscript.

David M. Garner draft the manuscript, performed statistical analysis and improved interpretation analysis, reviewed English Grammar and Spelling.

Vitor E. Valenti draft the manuscript, wrote introduction and discussion section and gave final approval for the version submitted for publication.

Competing interests

The authors declare absence of financial and non-financial interests.

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Resumo

Introdução: O distanciamento social foi planejado como uma medida preventiva para controlar a disseminação extensiva da COVID-19. Nós analisamos as mortes relacionadas à COVID-19 no Brasil durante o período de medidas de distanciamento social. Os dados de mortalidade do COVID-19 foram obtidos no site da Worldometer (www.worldometer.info). As mortes foram estimadas até o 31º dia após a 5ª morte. O distanciamento social foi medido por meio dos relatórios de mobilidade comunitária COVID-19; Google (https://www.google.com/covid19/mobility/). As curvas epidêmicas brasileiras foram interligadas e os modelos matemáticos foram avaliados para se ajustarem às curvas de estimativa de mortalidade. O modelo otimista foi fundado no período de abertura da distância social e, portanto, na menor mobilidade (40-60%). O modelo realista foi calculado de acordo com medidas de distanciamento social relaxado (<40%) e o modelo pessimista foi calculado com base em R0 entre 2-3. Sob essa situação, o modelo matemático realista estimou 40.623 mortes em 9 de junho de 2020, enquanto o modelo pessimista antecipou 64.310 mortes e o modelo otimista projetou 31.384. Até hoje (24 de maio de 2020), um total de 22.965 foram relatadas, enquanto nosso modelo projetou 17.452 para o modelo otimista, 22.623 para o modelo realista e 32.825 para o modelo pessimista. Observamos movimento reduzido ao longo deste período. Em resumo, o modelo matemático sugere que a mobilidade reduzida da comunidade diminuiu o total estimado de mortes relacionadas à COVID-19 no Brasil. Enfatizamos que mais procedimentos metodológicos serão necessários para confirmar esta teoria.

Palavras-chave: Beta-coronavírus, Centros de Controle e Prevenção de Doenças (EUA), Coronavírus, Infecções por Coronavírus, Morte, Vírus SARS.