Does Social Isolation Really Curb Covid-19 Deaths? Direct Evidence from Brazil that it Might do the Exact Opposite

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Abstract

Objective

To evaluate the association between social isolation, defined as the percentage of individuals who stayed within 450 meters from their usual location or dwelling on a given day, and future Covid-19 deaths in Brazil.

Design

Population study with the observation of both the progression of social isolation and of Covid-19 deaths over time.

Setting

The country of Brazil from 02/01/2020 through 07/22/2020, according to the official epidemiological reports from the Brazilian Ministry of Health regarding the total number of Covid-19 deaths occurring on a given day and to the In Loco© consumer geo-tracking and advertising company regarding social isolation as estimated from mobile phone location data of over 60 million Brazilians. Restrictive measures were first announced in the country in March 13-16th of 2020.

Participants

The 82,241 Brazilians who died from Covid-19 between 03/12/2020 and 07/22/2020 and the over 60 million Brazilian cell phone users whose mobile devices used at least one of the over 600 applications that have incorporated the In Loco© API.

Main Outcome Measure

The number of individuals who died from Covid-19 on a given day (actual date of death, not of reporting).

Results

The degree of social isolation at a given date showed a strong positive correlation to Covid-19 deaths 39 days later (Spearman Rho=.85, p<.001). The number of deaths as a function of social isolation and number of days passed since 02/01/2020 indicated a specific trajectory of deaths over time for every level of social isolation, with more isolation being associated to a higher peak number of deaths, a sooner arrival of that peak and a higher number of accumulated deaths. A comparison between the daily Covid-19 deaths as projected from data before the implementation of restrictive measures in Brazil and the number of deaths actually observed showed that the increase in social isolation can be directly linked to 10.5% more deaths over the period of observation.

Conclusions

There appears to be strong empirical evidence that, in Brazil, the adoption of restrictive measures increasing social isolation have worsened the pandemic in that country instead of mitigating it, likely as a higher-order effect emerging from a combination of factors.

Keywords: Covid-19, Physical Distancing, Social Isolation, Social Distancing, Pandemic, Granger Causality, Brazil.

Introduction

The imposition of restrictive measures upon society to reduce the circulation of most or all individuals is touted as the primary means of controlling the progression of the current Covid-19 pandemic. The rationale is that, if enough people stay home, this would slow the rate of transmission, thereby "flattening" the series of new cases and deaths, thus, avoid overwhelming the healthcare system[1,2].

Social isolation obtained through societal restrictive measures, such as closing schools and business or issuing shelter-at-home orders, was initially proposed in 2006[3], but is questionable as a strategy for the current pandemic due to feasibility[2,3,4], very high contagiousness of the disease[5,6,7,8], potentially low percentage of susceptible individuals[9,10], herd immunity[11,12], and high rates of transmission at home[13,14]. Empirical studies on the efficacy of social isolation have shown mostly a beneficial effect, however, besides generally focusing on the number of cases rather than that of deaths, they tend to suffer from problems regarding biased data, untested assumptions, tautology and/or not measuring the actual distancing obtained[15,16,17,18,19,20]. Nevertheless, the imposition of social isolation is still the main strategy adopted worldwide and in Brazil to deal with the Covid-19 pandemic

Since 02/01/2020, the Brazilian consumer geo-tracking and advertising software vendor In Loco© has been collecting location data from over 60 million mobile phones in all

Brazil, calculating a Social Isolation Index (SII) that measures the population's degree of physical distancing in terms of the proportion of mobile phones in a given geographic area that remained within a radius of 450 m of their "habitual home" location during a given day[21]. This is roughly 29% of the population in a country where more than 90% of people use cell phones.

Such context offers a unique and ideal opportunity to directly assess the influence of the level of social isolation actually achieved by restrictive measures on the progression of the Covid-19 pandemic in Brazil.

Methods

The number of daily Covid-19 deaths from 03/12/2020 through 07/22/2020 was obtained from the Brazilian Ministry of Health[22], this metric being adopted not only because it is the most important outcome, but also to avoid the errors in assessments of the number of cases, which are strongly biased by self-exclusion, testing policy and infrastructure. The data used was ordered according to actual date of obit and not of reporting, so as to not artificially skew the progression curve due to delays in registration[23,24,25,26].

The daily values for the SII for Brazil from 02/01/2020 through 07/22/2020 were collected from the In Loco© website[27].

Spearman Correlation coefficients were calculated between the SII for a given day and the number of Covid-19 deaths from 01 to 45 days in the future, assessing a Granger-type causality[28] and also identifying the "n" number of days later when the association was the strongest. Then, an analysis was done associating time, SII and future Covid-19 deaths n-days later through a quadratic surface, which was then used to evaluate the general influence of social isolation the progression of the deaths. Finally, a realistic numerical estimate of the toll of social isolation on Covid-19 deaths was obtained comparing the observed series to one extrapolated from the initial days of the pandemic, before restrictive measures were adopted[29,30], according to the mathematical pattern of the SIR model[31].

Results

Covid-19 Deaths Over Time

Figure 1 shows the progression of the daily number of Covid-19 deaths in Brazil from 03/12/2020 through 07/27/2020 ordered by the actual date of obit, with a clear peak at 05/14/2020.

The last five days of the series were removed from further analysis due to likely underreporting that would substantially underestimate the number of deaths that will be known in the future, this range corresponding to a relevant discontinuity in the time series. Therefore, all subsequent analyses were performed using only the deaths recorded as occurring between 03/12/2020 and 07/22/2020.

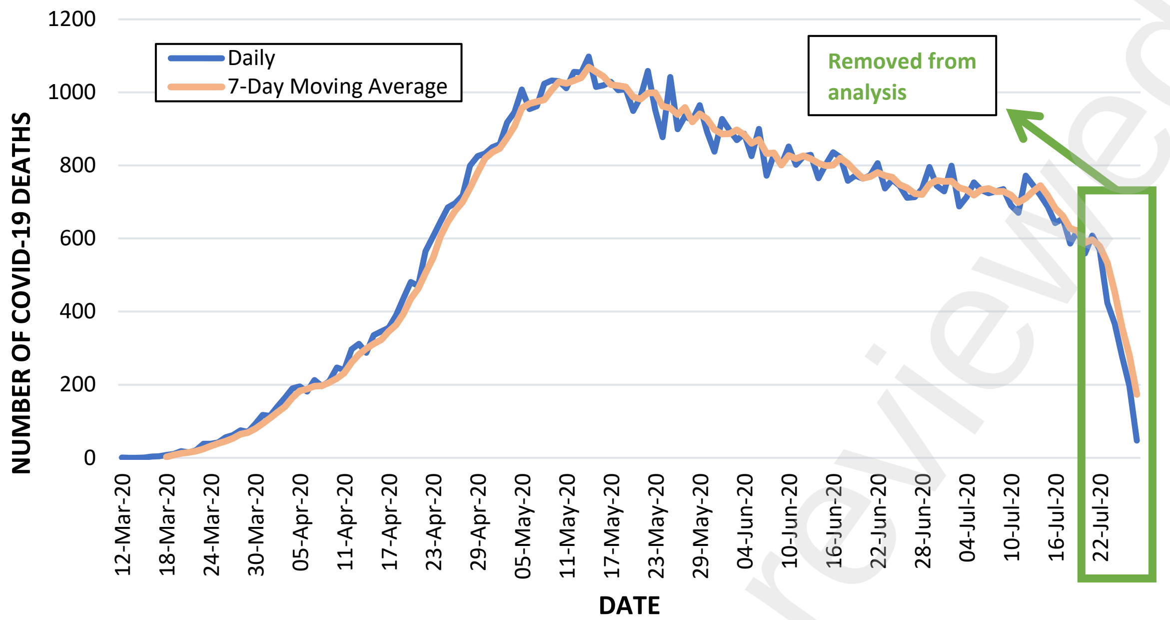

Figure 1: Covid-19 deaths in Brazil from 03/12/2020 through 07/27/2020 ordered by date of obit.

Social Isolation Over Time

Figure 2 shows the progression of the SII in Brazil from 02/01/2020 through 07/22/2020.

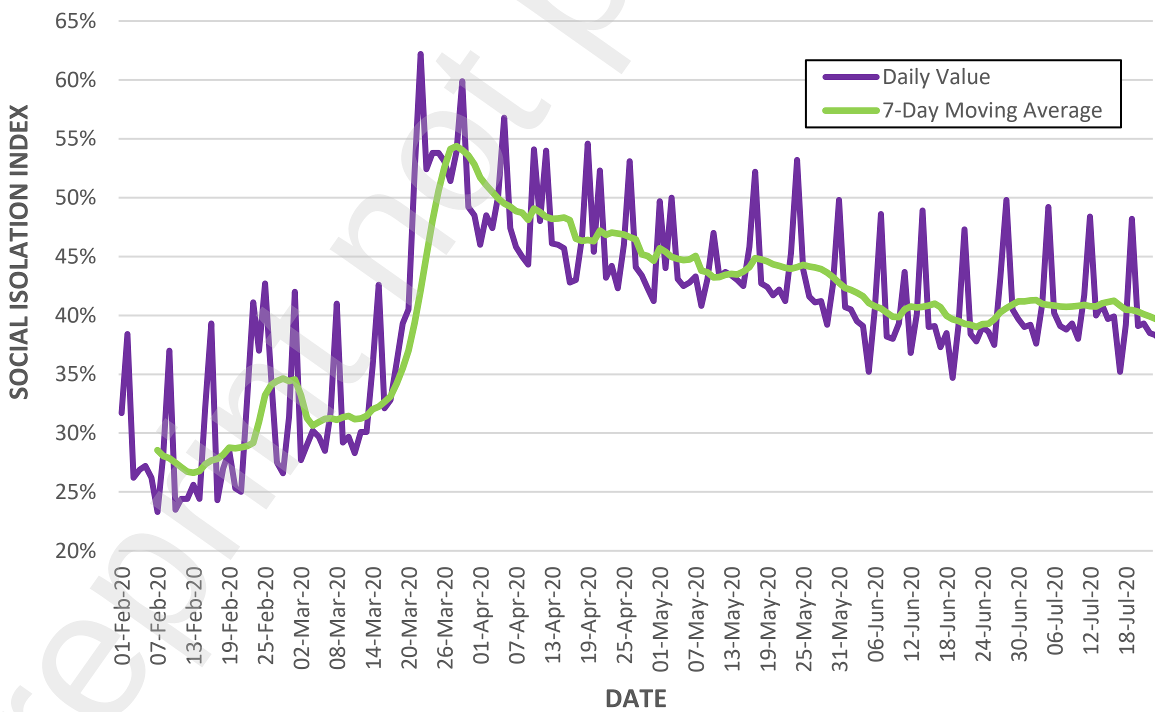

Figure 2: The Social Isolation Index in Brazil from 02/01/2020 through 07/22/2020.

The "spiked" aspect of the graph is due to a consistently higher rate of social isolation in weekends and holidays than in regular business or working days.

Up to 03/15/2020, the SII had a mean 7-day SII moving average of roughly 30%, with a minor "bump" of around 4% from 02/21/2020 through 02/26/2020 due to Carnival. After various restrictive measures were announced between 03/13/2020 and 03/16/2020[29,30], the SII rose to approximately 54%, then gradually dropped to around 41% in 07/22/2020.

Correlations Between Social Isolation and Future Deaths

Table 1 shows the correlations between the SII on a given day and the number of Covid-19 deaths 01 to 45 days in the future.

Table 1: Spearman correlations between the SII on a given day and the number of Covid-19 deaths 01 to 45 days later.

Days Later	Rho	p	Days Later	Rho	p	Days Later	Rho	p
1	-0.09	0.30	16	0.35	<.001	31	0.72	<.001
2	-0.06	0.51	17	0.36	<.001	32	0.76	<.001
3	-0.04	0.69	18	0.41	<.001	33	0.76	<.001
4	-0.01	0.94	19	0.42	<.001	34	0.78	<.001
5	0.02	0.82	20	0.43	<.001	35	0.80	<.001
6	0.04	0.61	21	0.48	<.001	36	0.83	<.001
7	0.09	0.32	22	0.51	<.001	37	0.83	<.001
8	0.14	0.10	23	0.53	<.001	38	0.84	<.001
9	0.17	0.05	24	0.55	<.001	39	0.85	<.001
10	0.19	0.03	25	0.58	<.001	40	0.85	<.001
11	0.22	0.01	26	0.60	<.001	41	0.83	<.001
12	0.24	0.01	27	0.62	<.001	42	0.84	<.001
13	0.26	0.002	28	0.66	<.001	43	0.84	<.001
14	0.30	<.001	29	0.69	<.001	44	0.82	<.001
15	0.34	<.001	30	0.70	<.001	45	0.80	<.001

OBS: For all correlations up to 40 days later, there were n=133 observations, but fewer for days 41 (n=132), 42 (n=131), 43 (n=130), 44 (n=129) and 45 (n=128).

The correlations were all statistically significant and positive from 09 days in the future onward, peaking at around 39-40 days and tending to drop off from there. Thus, one can make the argument for a Granger causality between SII and future Covid-19 deaths.

Figure 3 shows the scatterplot for the SII on a given day versus the number of Covid-19 deaths 39 days later.

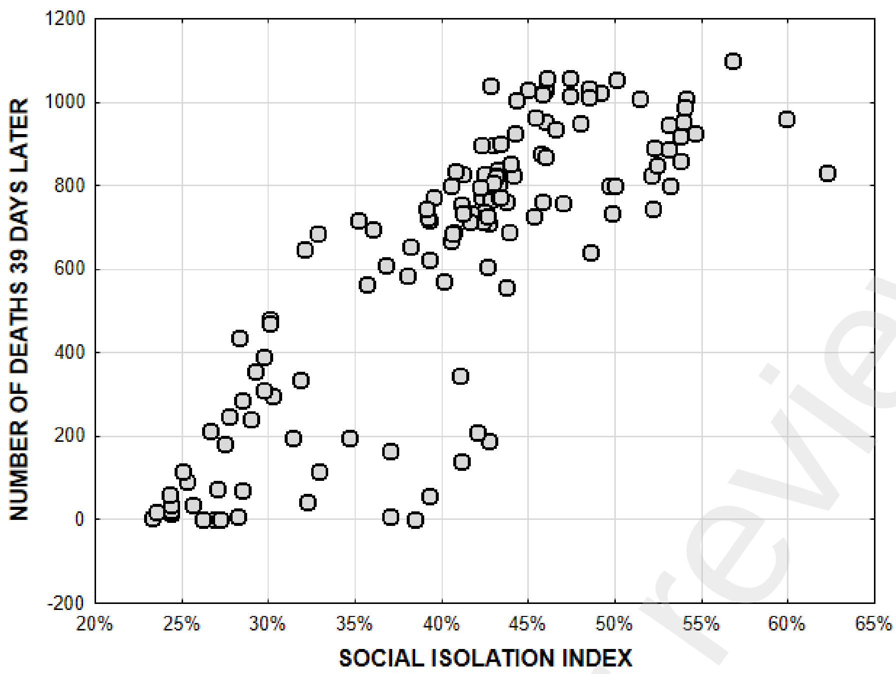

Figure 3: Scatterplot of social isolation versus Covid-19 deaths 39 days later in Brazil.

Time, Social Isolation and Future Covid-19 Deaths

Figure 4 shows the fitting of a quadratic surface for the number of Covid-19 39 days in the future as a function of the SII and the time passed since 02/01/2020.

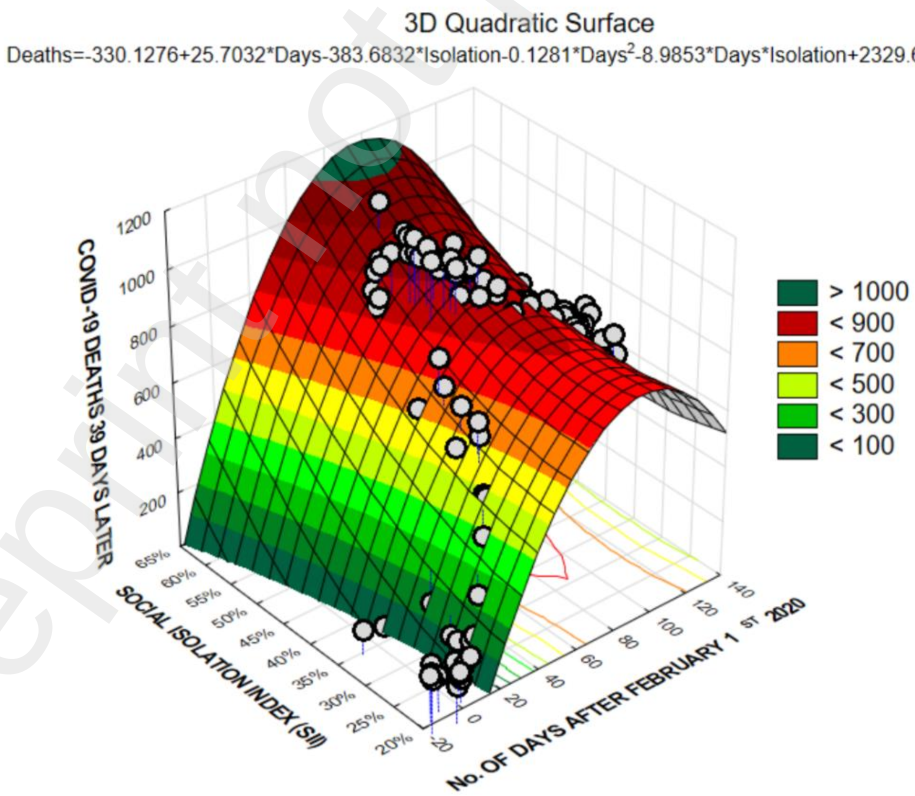

Figure 4: The quadratic fit for time, social isolation and Covid-19 deaths 39 days later in Brazil.

Using a quadratic loss function, the quadratic surface found showed a fit of R^2=.924 (p<.001) to the data.

Given that the progression of the SII and future Covid-19 deaths in Brazil followed a path along a surface that can be well approximated by a quadratic function, it follows that, for every level of social isolation, there is a trajectory of deaths over time that can be expressed as an inverted parabola. Of course, this is only a rough approximation, as the actual shape of such trajectories is not that of a quadratic function[31] (see Figure 5). Nonetheless, this is a mathematically simple way to identify at least the general direction of the responses to variations in the level of social isolation.

Using the equation shown in Figure 4, one can calculate, for each level of social isolation, the peak number of deaths (maximum value of the inverted parabola), when the peak occurs (the horizontal coordinate for the peak number of deaths), and of the total number of accumulated deaths (the area of the inverted parabola). Table 2 shows the results for fixed SII levels of 23%, 43% and 62% (the SII for Brazil varied from 23% to 62% within the observed period).

Table 2: The peak number of Covid-19 deaths, the time to reach the peak and the total number of deaths for different levels of social isolation as estimated by the quadratic surface.

Social Isolation Index	Peak No. of Deaths 39 Days Later	Time to Reach the Peak (Days)	Total No. of Deaths
23%	795.3	92.3 (+39)	83,543.8
43%	866.5	85.2 (+39)	95,018.2
62%	1,118.5	78.6 (+39)	136,852.3

It is clear from Table 2 that a higher SII is associated to a higher peak number of deaths 39 days later, a sooner arrival of that peak and a higher number of accumulated deaths, the effects being stronger closer to the higher range of isolation. However, if one requires a precise numerical calculation of the death toll associated to increased levels of social isolation, it is necessary to use a better model than that of a quadratic function.

Extrapolating Covid-19 Deaths Over Time for a Given Setting

The most accurate characterization of the progression of epidemics of infectious diseases over time is the SIR model, which is based on a system of differential equations[31]. However, since there is no closed analytical solution for that system, its numerical calculations require estimates of the number of susceptible individuals and the initial number of infected people, as well as of the rates of effective contact, recovery, lethality and mortality, i.e., strong assumptions as to the behavior of the disease in a specific scenario that can be difficult to empirically test or justify. A way to sidestep this problem is to use an equation that has the same mathematical pattern as a solution obtained from the SIR model but not the same requirements of prior knowledge.

The SIR model predicts a specific type of curve for the number of infected patients over time from which one can extract a curve of deaths over time[31]. The general geometrical pattern is that of initial increase with an upward concave, followed by a downward concave that forms a peak, and, finally, a decrease followed by another upward curvature. The curve can be either symmetrical or asymmetrical with regards to the peak, usually with a tail to the right. The degree of curvature of each concave can also vary. Figure 5 illustrates one of the typical shapes.

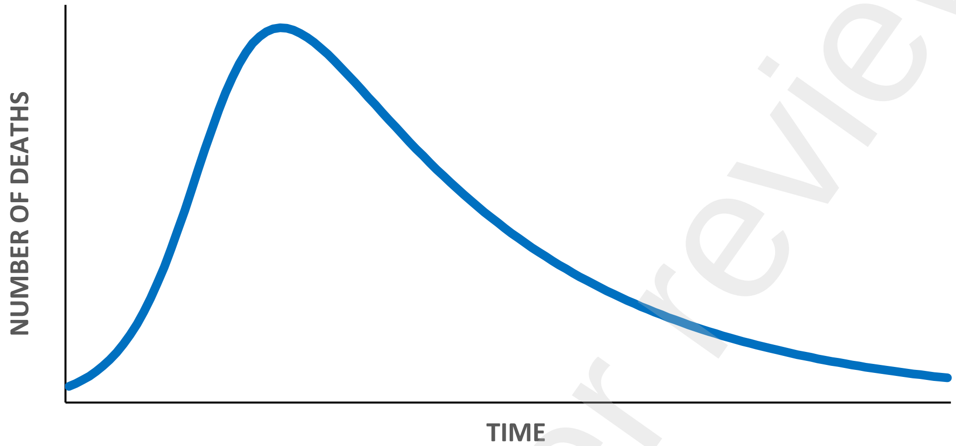

Figure 5: A visual illustration of a typical aspect of the number of deaths over time according to the SIR model.

A fairly simple and convenient mathematical equation that always conforms to all of the aforementioned properties of the number of deaths over time as predicted by SIR model is:

$$Deaths\ per\ Day = \frac{M\alpha\delta}{(t+\tau)^{\delta+1}} exp\left[-\frac{\alpha}{(t+\tau)^{\delta}}\right], \mathrm{M} > 0, \alpha > 0, \tau > 0, \delta > 0.$$

Through this expression, one can model trajectories for deaths along time with a very wide range of possibilities regarding the local curvature and coordinates of the inflection points, approximating a solution of the SIR model whatever its parameters and initial conditions might be. The coefficients for this formula can be statistically estimated from a set of observations so as to extract an equation that can be used to extrapolate the future progression of an epidemic according to the pattern in the SIR model with excellent precision even if the parameters and initial conditions of the equivalent SIR model are unknown.

Estimating the Actual Toll of Social Isolation on Covid-19 Deaths

Given what is shown in Figure 2 and the fact that the restrictive measures in Brazil were first announced between 03/13/2020 and 03/16/2020, one can consider the data regarding the first 44 days starting from 02/01/2020 as expressing the baseline behavior of the SII in Brazil.

Fitting the mathematical equation proposed here to the number of deaths 39 days later for the first 44 days, one can obtain an expression through which it is possible to extrapolate the progression of future Covid-19 deaths if no restrictive measures were taken and the SII remained close to the baseline. Using the least squares method with a quadratic loss function, one arrives at a curve with the parameters of M=133813.0, α=3012945, τ=78.19289, and δ=2.884102 that fits the first 44 days with R^2=0.999 (p<.001).

Figure 6 shows the plots for the extrapolated curve plus the observed series for the number of daily Covid-19 deaths 39 days later, along with the 7-day moving average for the SII and the moments when the first restrictive measures were announced[30,31].

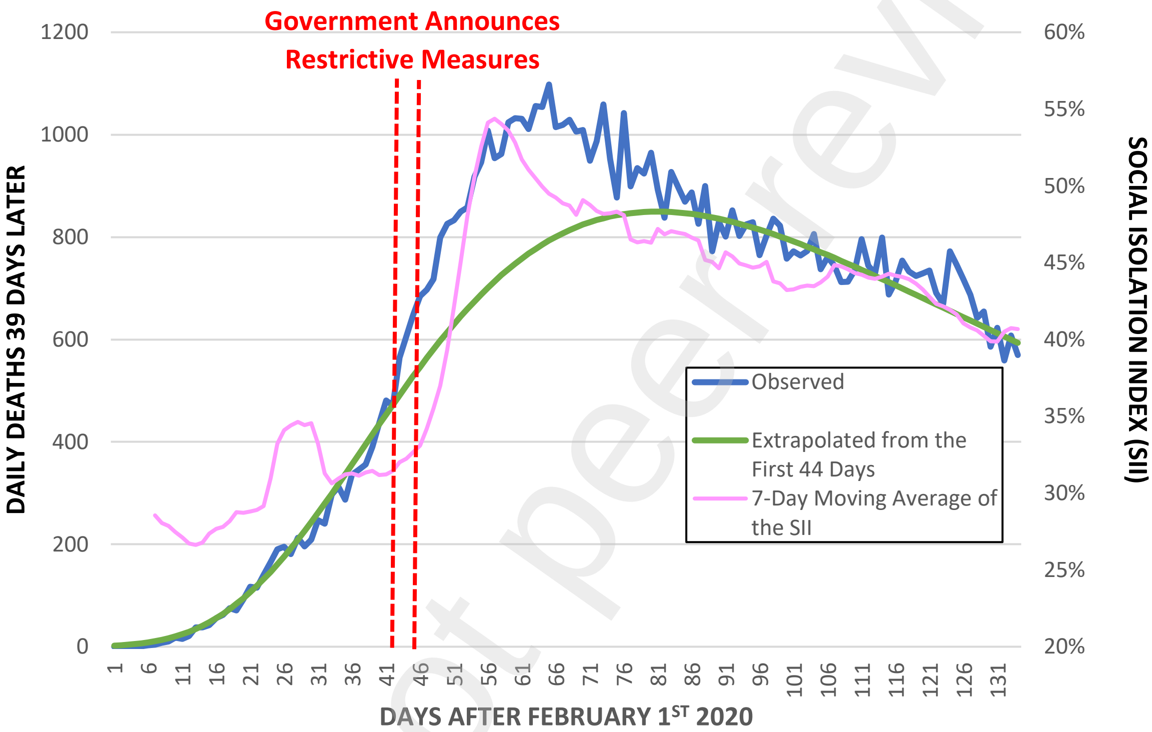

Figure 6: Daily Covid-19 deaths in Brazil extrapolated from the first 44 days (before the announcement of restrictive measures) versus the observed rates for the same period.

The observed and calculated curves for Covid-19 deaths bifurcate from day 45 onward, coinciding with the announcements of restrictive measures from the Brazilian Government and a sharp rise in the SII. At that same point, the observed curve surpasses the extrapolation from the first 44 days according to the pattern of the SIR model, the two meeting again only at around day 85.

The number of accumulated deaths between days 01 and 134 was 74,417 for the extrapolated curve and 82,241 for the observations, indicating an extra 7,824 Covid-19 deaths (10.5% more) following the implementation of restrictive measures that increased the level of social isolation in Brazil.

It is interesting to note that the minor bump in SII between days 21-26 did not translate into a noticeable change in the observed series of deaths. This is likely due to the small amplitude and short duration of said bump not being enough to substantially disturb the behavior of the system. The sharp rise in SII after day 44, on the other hand, is much higher and longer lasting. There is also the possible role of the fact that the first increase in SII was self-induced, whereas the later one was government-enforced.

Discussion

Comparison with Previous Research

Previous studies on the impacts of social distancing policies have mostly found that such initiatives tend to substantially curb the progression of the Covid-19 pandemic, though there has been some disagreement as to the effects of specific initiatives such as closing schools, limiting the use of public transportation and so forth[15,16,17,18,19,20]. The present paper, on the other hand, provides empirical evidence strongly suggesting that, at least in Brazil, the adoption of restrictive measures increasing social isolation has worsened the pandemic by: (a) raising the peak number of deaths, (b) reducing the time to reach that peak, and (c) increasing the total number of deaths by more than 10%.

The discrepancy between the present findings and those of previous research on the matter is likely due to a combination of, among other things:

- Using a very objective and specific definition of "social isolation" as opposed to a broad, ambiguous and polysemic concept;
- Using a precise and direct measure of effective social isolation achieved rather than of the mere implementation of a policy;
- Considering as the main metric the number of Covid-19 deaths per day and not of new cases;
- Using a data series that is ordered by actual date of occurrence and not of reporting;
- Considering a Granger-type analysis where an association between past and future events is suggestive of a causal relationship;
- Searching for the strongest association between past and future events within a fairly broad range of time instead of assuming a fixed time for effects to manifest;
- Making comparisons within one single country over time, instead on between different countries where definitions, behaviors and context can differ in very relevant ways;
- Relying on a very minimalist set of assumptions regarding the Covid-19 pandemic in Brazil, i.e., that it follows the overall mathematical pattern described by the SIR model.

Investigations that substantially differ from the present one in terms of the above definitions, assumptions and approaches cannot be expected to yield findings that are directly comparable to what has been reported in the present paper.

Strengths and Limitations of this Study

The present study made use of official data from the Brazilian Ministry of Health regarding the nationwide incidence of Covid-19 deaths according to the date in which they actually happened. This is an advantage particularly in the evaluation of phenomena that happens over time.

Another advantage is that the daily SII for the country was obtained from a widely cited source, which includes Brazilian municipal, state and federal governments, that produces information through a commercially successful data acquisition system that functions at an individual level and predates the current Covid-19 pandemic. One is hard pressed to find anywhere a measurement of social isolation that is more precise and has a smaller sampling error.

A limitation of the study is that it is restricted to one specific definition of social isolation and to what happened in Brazil. This makes unclear exactly how much could the findings be extrapolated to other aspects of social distancing and to different countries.

The data presently used undoubtably contains imprecisions and errors, as in any study involving observations that are recorded and measured. This is dealt with here and elsewhere through probabilistic reasoning and statistical techniques, but that can only compensate for so much, with biases arising from human misgivings, inadequate institutional practices and other sources being bound to happen. Regardless, it is reasonably expected that such inevitable shortcomings were not enough to compromise the overall findings.

Interpretation and Implications for Policy and Practice

The findings presented here not only challenge the automatic presupposition that social isolation is an effective means of slowing the progression of the Covid-19 pandemic but also reveal that it can substantially increase the number of deaths. One major implication from this is that widespread assumptions on the subject, along with the decisions and actions derived from them, must be immediately reappraised, under the penalty of increasing mortality instead of reducing it as intended. This does not mean that any and all restrictive measures that are currently in place necessarily have to be suspended, but it does imply that they cannot be automatically accepted without suspicion. A prompt and careful reevaluation of physical distancing strategies is mandatory, preferably with a burden of proof not only that they are beneficial, but also that they are not actively harmful.

Unanswered Questions and Further research

The present study is unable to specify the mechanisms and processes through which an increase in the Covid-19 death toll arises as a consequence of social isolation. There are indications from the literature that suggest possible causes, such as insufficient control of isolation[2,3,4], a high transmission rate[5,6,7,8], a low percentage of susceptible individuals[9,10], a delaying of herd immunity[11,12] and/or a greater level of transmission at home[13,14]. One can also venture the hypothesis that perhaps forced prolonged indoor contact with cohabitants increases the probability of transmission and also the viral loads, leading to a greater number of cases and a higher level of severity for the infections. But these are all speculations, and yet unknown elements might likewise be at play.

Future investigations on the matter must not only confirm the present findings and determine how much they can or not be extrapolated to other countries and settings, as well as to specific subpopulations, but also explore the possible mechanisms and processes involved in how the observed phenomenon works.

What is Already Known on this Topic

- Social isolation, particularly though restrictive measures designed to maximize the physical distancing behavior of society as a whole, is touted worldwide and in Brazil as the most effective strategy to deal with the current Covid-19 pandemic

- There are reasons to consider at least the possibility that such social isolation might not have the assumed effect of curbing the progression of the pandemic

- Previous studies on the efficacy of these interventions generally show a reduction in how much and/or how fast the pandemic progresses in a given location, but they tend to suffer from various issues that might have influenced their findings

What this Study Adds

- Data from Brazil regarding a direct and objective measure of social isolation over time, as well as the progression of Covid-19 deaths according to the date in which they occurred, indicates that a higher level of physical distancing on a given day is strongly associated to an increase in deaths 39 days later

- Different levels of social isolation were found to be related to different trajectories of deaths over time, with more isolation being associated to a higher peak number of deaths, a sooner arrival of that peak and a higher number of accumulated deaths

- The implementation of restrictive measures leading to higher levels of social isolation in Brazil was associated to an increase of 10.5% in the overall number of Covid-19 deaths

CRediT Author's Contribution Statement

Bruno Campello de Souza: Conceptualization, Methodology, Data Curation, Formal Analysis, Writing - Original Draft, Visualization, Supervision. **Fernando Menezes Campello de Souza:** Conceptualization, Methodology, Formal Analysis, Writing - Review & Editing.

Competing Interests Disclosure

The authors declare no support from any organization for the submitted work; no financial relationships with any organizations that might have an interest in the submitted work in the previous three years, no other relationships or activities that could appear to have influenced the submitted work.

Ethics Statement

As established by the ethical guidelines for scientific research with human subjects in Article 1, Subsections II, III and V, of Resolution no. 510 from the Brazilian National Council on Health, the present study was exempt from registration or evaluation from the country's Council of Ethics in Research and National Council of Ethics in Research due to the fact that it used publicly accessible information, public domain information and aggregate databases where individual identification is impossible.

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