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REVIEW

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The virus that stopped the world - an overview of the COVID-19 pandemic

O vírus que parou o mundo - um panorama sobre a pandemia de COVID-19

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ABSTRACT

Introduction: The COVID-19 pandemic continues to impact the lives of millions of people, from the health, social and economic point of view, with strong impact on social security, youth and adult education, and other areas that, combined, directly impact the world economy. **Objective:** To present a review of some relevant works on the COVID-19 pandemic in order to demonstrate effective actions to face the pandemic and its impact on public health. **Method:** Bibliographic analysis of cross-sectional cohort studies that use official data on the number of cases, number of deaths, and doses applied according to age, dose, and type of vaccine supported by epidemiological models. **Results:** Despite the more than 460 million doses applied, we still have significant portions of the population without the complete vaccination schedule, with a real possibility of a new wave of COVID-19 by the end of the year 2022. **Conclusions:** SARS-CoV-2 continues to circulate strongly throughout Brazil and the world, increasing the possibility of new variants that would result in new waves of the pandemic, which can be avoided by measures implemented by public authorities, such as intensified vaccination campaigns, non-pharmaceutical measures and public information campaigns.

KEYWORDS: COVID-19; SARS-CoV2; Epidemiological Modeling

RESUMO

Introdução: A pandemia de COVID-19 continua a impactar a vida de milhões de pessoas, sob o ponto de vista sanitário, social e econômico, com forte impacto na seguridade social, na educação de jovens e adultos, e outras áreas que, combinadas, incidem diretamente na economia mundial. **Objetivo:** Apresentar uma revisão de alguns trabalhos relevantes sobre a pandemia de COVID-19 no intuito de demonstrar ações efetivas de enfrentamento da pandemia e seu impacto na saúde pública. **Método:** Análise bibliográfica de estudos de coorte transversal que utilizam dados oficiais do número de casos, número de óbitos e doses aplicadas segundo a idade, dose e tipo da vacina apoiado em modelos epidemiológicos. **Resultados:** Apesar das mais de 460 milhões de doses aplicadas, ainda temos parcelas significativas da população sem o esquema vacinal completo, com real possibilidade de uma nova onda de COVID-19 até o final do ano de 2022. **Conclusões:** O SARS-CoV-2 continua a circular fortemente pelo Brasil e no mundo, aumentando a possibilidade de surgirem novas variantes que resultariam em novas ondas da pandemia, que podem ser evitadas por medidas implementadas pelo poder público, como: intensificação das campanhas de vacinação, medidas não farmacêuticas e campanhas de informação da população.

PALAVRAS-CHAVE: COVID-19; SARS-CoV2; Modelo Epidemiológico



INTRODUCTION

In this article we present a review of some works by our group, written during the Coronavirus Disease 19 (COVID-19) pandemic, demonstrating the impact of different measures adopted for its mitigation, analyzing successes and failures over the more than two years that have elapsed since the first case. COVID-19 is a viral disease caused by the Severe Acute Respiratory Syndrome 2 (SARS-CoV-2) virus, from the coronavirus class. The first reported case occurred in Wuhan, China, in December 2019, and quickly spread across the world, causing repeated outbreaks on all continents, now present in all countries. Worldwide, official data record more than 601 million cases and more than 6.4 million deaths¹. The first case was registered in the city of São Paulo, on February 26, 2020, and later spread to all Brazilian municipalities. After several waves, the country still accounts for high daily numbers of cases and deaths from COVID-19 but with a slow decrease.

Due to vaccination, the proportion of deaths is significantly lower than that observed in previous waves in 2020 and 2021, with most deaths occurring among people who have not been vaccinated or who have incomplete vaccination. Brazil currently occupies the 4th position in the world in the total number of cases, with around 34 million notifications, and the 2nd in the number of deaths, around 683,000. In proportional terms to the population, it occupies the 17th position in deaths per million inhabitants, 94th in cases per million and the 146th position in tests per million inhabitants. It is important to note that the actual number of cases is highly underestimated in the vast majority of countries, and may be up to 18 times the official amount depending on the country².

The current pandemic is similar to what the world faced in 1918 with the influenza pandemic, which spread rapidly across the globe and in eight months led to the deaths of between 50 and 100 million people. In Brazil, after just over a month of the arrival of the flu, about 60% of the population of Rio de Janeiro was infected with the virus, and there were at least 35,000 deaths in the city. Such a scenario was accompanied by reluctant behavior in relation to scientific discoveries and, at the same time, a collective behavior that sought, in a mixture of political positions and popular beliefs, a discursive link in which state power plotted against the population and had vested interests in conjunction with “foreign enemies” who tried to meddle in private lives through the invention of a virus or through the inappropriate behavior of already stigmatized peoples³. In short, an absence of dialogue between health and government authorities and the population causes a mistake both in the actions and policies to confront and in the economic support policies necessary for an extreme situation such as a pandemic. The same can be said for the current COVID-19 pandemic, more than a century after the Spanish flu.

Even with information available in real time, whether through the mainstream media or social networks, a significant part of the population was captured by a rhetoric, sometimes from government agents, that questioned ample sedimented scientific

evidence with the dissemination of false information without proper scientific evidence, combined with prejudices and pre-conceptions that pointed to alleged national and international enemies as villains.

Of all the observed behaviors, we list the ones that can be characterized as eugenic, among them that herd immunity would be enough to solve the pandemic problem: some will die, but all will be immune. This was a behavior used throughout history to combat smallpox and is known as variolation⁴, which consists of the

inoculation of material derived from smallpox scabs in healthy people in an attempt to produce a milder disease than the natural one. It was based on the observation that survivors of the disease did not get sick again and that people infected by other routes, such as the skin, had a milder disease. The method seems to have been developed independently in China and India in the 11th century, spreading to Asia (Egypt, 13th century), Europe (18th century), and Africa⁴.

In the case of SARS-CoV-2, this procedure would never be successful since it is an RNA virus with a great capacity for mutation that has allowed it to circumvent acquired immunity.

In Brazil, the b.1.1.28 variant of the SARS-CoV2 virus emerged during the first wave of infection in the country, which started in February 2020, and quickly became predominant. Subsequent mutations resulted in the Gamma variant, identified in October 2020, which remained the main cause of contamination for approximately one year. In the second half of 2021, the Delta variant arrived in Brazil and became dominant, causing more frequent reinfections. The Omicron variant arrived in the country in December 2021 and even more quickly became dominant, causing even more frequent reinfections. These occur mainly due to mutations in the spike protein, the main connection pathway of SARS-CoV-2 with the ACE2 receptor in human cells, which allows it to use the cell to replicate. The main mutations in SARS-CoV-2 occurred precisely in the region of the protein that interacts with this receptor. In turn, our immune system creates defenses to prevent this connection to the variants with which it has had contact, but mutations can circumvent them, with a lower probability of the immune system recognizing the virus as an invader⁵. This is one of the reasons for the successive waves of the pandemic caused by the appearance of new variants, making the concept of herd immunity obsolete and not applicable to the present situation. Unfortunately, herd immunity has been vigorously defended since the beginning of the pandemic by sectors that do not rely on scientific knowledge as a way to control the COVID-19 pandemic.

It is in this scenario that our research group, in an interdisciplinary effort with researchers from various institutions in Brazil and abroad, sought to inform the population and public health agencies, seeking whenever possible the correct information with direct and effective answers, in order to contribute to the fight against this pandemic, which is still present in Brazil and the world⁶.



METHOD

Epidemiological model

The SEIAHRV model (Susceptible, Exposed, Infected, Asymptomatic, Hospitalized, Recovered, and Vaccinated) is an extension of the model used by Rocha Filho et al.⁷, with compartments for individuals vaccinated with one and two doses, with the possibility of different vaccines with different efficiencies, any number of doses, in which the number of doses applied for each vaccine type is provided at prescribed time intervals, in such a way to re-plate the vaccination campaigns that have already taken place and simulate the evolution under different future scenarios. The model also considers the possibility of primary vaccination failure, assumes a homogeneous mix (mean field), and different age group groups, with their respective epidemiological characteristics, and a structure of contacts between different age groups.

The decomposition of compartments into age groups allows incorporating the structure of contacts estimated in a given population, represented here by a matrix of contacts $C_{i,j}$ which gives the average number of contacts per day of a single individual of the j -th age group, with any individual of the i -th age group. The authors are unaware of any estimate for the contact matrix in Brazil. This problem was circumvented by using the results of Mossong et al.⁸, for eight European countries obtained through fieldwork, taking the average of the contact matrices of each of the eight countries and, at the same time, adapting the result to the age distribution of the considered location. This is a reasonable assumption given the cultural similarities between Europe and Brazil. The age groups represented in the model are: 0 to 9, 10 to 19, 20 to 29, 30 to 39, 40 to 49, 50 to 59, 60 to 69, 70 to 79, and 80 years or older⁹. In addition to the contact matrix, we considered the time-dependent probability $P_c(t)$ of a susceptible individual being contaminated in contact with an infected individual. The model is then adjusted from previous real data, determining a functional form for $P_c(t)$.

The necessary epidemiological parameters are given in the literature^{10,11,12,13,14,15} and summarized in Tables 1 and 2 by Rocha Filho et al.⁹. The transfer diagram between the compartments, the corresponding time-delayed nonlinear differential equations, the functional form for $P_c(t)$, and their determination from the empirical data are described in Rocha Filho et al.⁹.

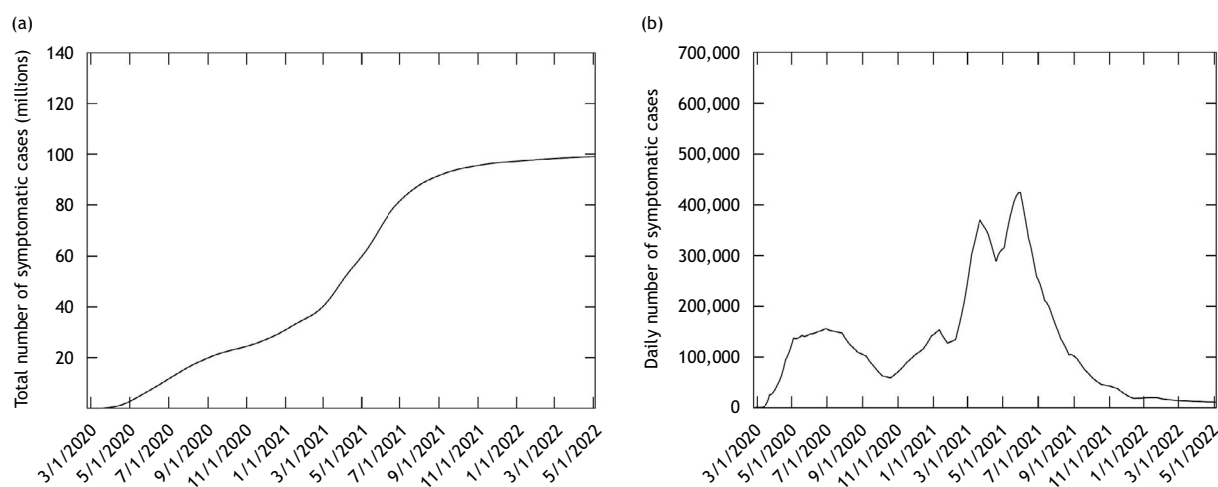
Data sources

Our analyzes are based on updated official data, released by each State Department of Health, and made available by the Ministry of Health¹⁶. The daily data collected were: (i) number of cases, (ii) number of deaths, (iii) vaccine shots applied according to age, dose, and type of vaccine. Data on the Brazilian population in each municipality were obtained from estimates of the Brazilian Institute of Geography and Statistics (IBGE) for 2020¹⁷.

RESULTS

Attack rate in Brazil

As mentioned above, underreporting of cases is huge worldwide, especially in places with little access to health care and few applied tests. The proposed compartmental model (SEIAHRV) can be adjusted from the series of deaths, which is much more reliable than that of cases. The model then provides an estimated series of real cases that occurred in the country, reflecting the known data about the virus. The estimated number of cases each day, from data up to June 27, 2021, is shown in Figure 1 (for total cases and cases per day), as well as the model forecast up to May 1, 2022. The forecast would then be for the end of the pandemic if all epidemiological conditions were maintained. However, some factors changed, modifying the dynamics of the pandemic: the important possibility of reinfection for individuals who had already contracted the virus and, mainly, the arrival of the Omicron variant at the end of 2021 and subsequently its subvariants,



Source: Elaborated by the authors, 2022.
(a) Total of cases; (b) New cases per day.

Figure 1. COVID-19 cases in Brazil from the SEIAHRV model, adjusted with the number of deaths up to June 27, 2021, and prognosis from that date.

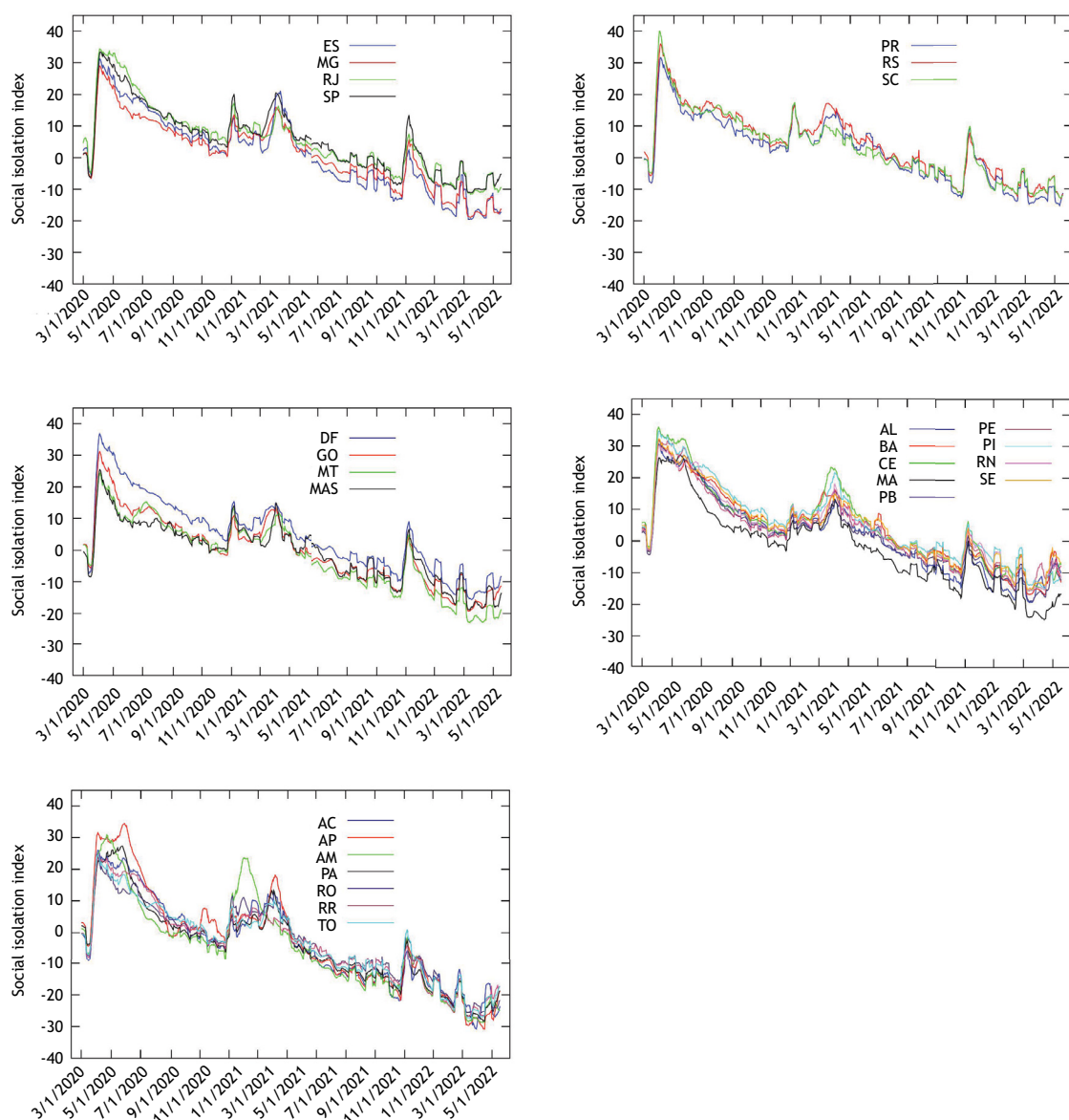


much more contagious and capable of more effectively circumventing acquired immunity. This caused important new outbreaks to occur, demonstrating quite clearly how the idea, often explicitly or implicitly propagated, of waiting for herd (or group) immunity to end the pandemic is completely wrong. Predictions of what will happen depend on many factors over which we have no control, leaving only mass vaccination and the development of really effective treatments as viable coping policies.

Social isolation

The degree of isolation can be characterized in several ways. In Rocha Filho et al.¹⁸, the authors defined a social isolation

metric relying on publicly available mobile phone mobility data¹⁹, defining an isolation index as a weighted average of the values (the weight is the number in parentheses) of the percentage variation in the length of stay in each type of location, with respect to baseline (from 3/1/2020 to 6/2/2020): workplaces (-9/24), residential areas (+12/24), retail and leisure (-0.5/24), markets and pharmacies (-1/24), parks (-0.5/24), public transport stations (-1/24). The results for all the federation units in Brazil are shown in the graphs in Figure 2. The higher the value, the higher the level of isolation, which, in general, has been falling systematically since the beginning of the pandemic. It should be noted that at no time were strict lockdown measures adopted as *in some European countries or*



Source: Elaborated by the authors, 2022.

AC: Acre; AL: Alagoas; AP: Amapá; AM: Amazonas; BA: Bahia; CE: Ceará; DF: Distrito Federal; ES: Espírito Santo; GO: Goiás; MA: Maranhão; MT: Mato Grosso; MS: Mato Grosso do Sul; MG: Minas Gerais; PA: Pará; PB: Paraíba; PR: Paraná; PE: Pernambuco; PI: Piauí; RR: Roraima; RO: Rondônia; RJ: Rio de Janeiro; RN: Rio Grande do Norte; RS: Rio Grande do Sul; SC: Santa Catarina; SP: São Paulo; SE: Sergipe; TO: Tocantins.

Figure 2. Isolation index¹⁸ in each Federation unit.



China, allowing the virus to circulate freely and an unnecessary loss of human life.

In the same reference¹⁸, a statistical analysis of COVID-19 data from different European countries, the United States and Brazil is presented, and in the case of the latter two, for their respective states. The results demonstrate the effectiveness of social isolation in controlling the spread of the virus, as well as the mandatory use of masks, measures that, unfortunately, are often contested by the authorities who should defend them.

Vaccination

Vaccination data in Brazil are available from the Ministry of Health²⁰. In Figures 3 and 4 we show the percentage of the population vaccinated in each of the age groups considered in the SEIAHRV model for complete vaccination (two doses or single dose), first and second booster doses (third and fourth doses), up to July 10, 2022. The first fact to be explained is that, in certain age groups and in particular in some states, the vaccinated population in the 60 to 69 age group exceeded 100%. This means that the IBGE estimates, based on extrapolations from the 2010 census, have an important error, which should be corrected with the 2022 census. Vaccination coverage for the first two doses can be considered good but it already fails in the younger age groups for the third dose, and it is very bad for the second booster dose. This reflects a certain disregard of the population in relation to the pandemic, which disappeared from the news, despite the still high number of cases and deaths, and also as a result of the disease being seen as commonplace, influenced by the absence of more effective and present information campaigns, and the insistent denialist discourse of some public authorities regarding the efficacy and safety of available vaccines.

Hospitalization

A retrospective cohort study of hospitalization due to COVID-19 in the Brazilian public health system, carried out by our group, considered more than 950,000 patients infected with SARS-CoV-2 from a national multicenter database, for the period from January 1, 2021 to March 23, 2022²¹. It tested whether the Omicron variant had reduced severity in outcomes different from the Gamma and Delta variants, using documented vaccination status in hospitalized patients and age. The outcome mortality of hospitalized patients was examined in the aforementioned time window, concluding that the variant Omicron statistically reduced in a significant way the effectiveness of the booster dose for vaccines CoronaVaC, Ad26. COV2.S, and AZD1222, and that the vast majority of deaths occurred in patients not fully vaccinated²¹.

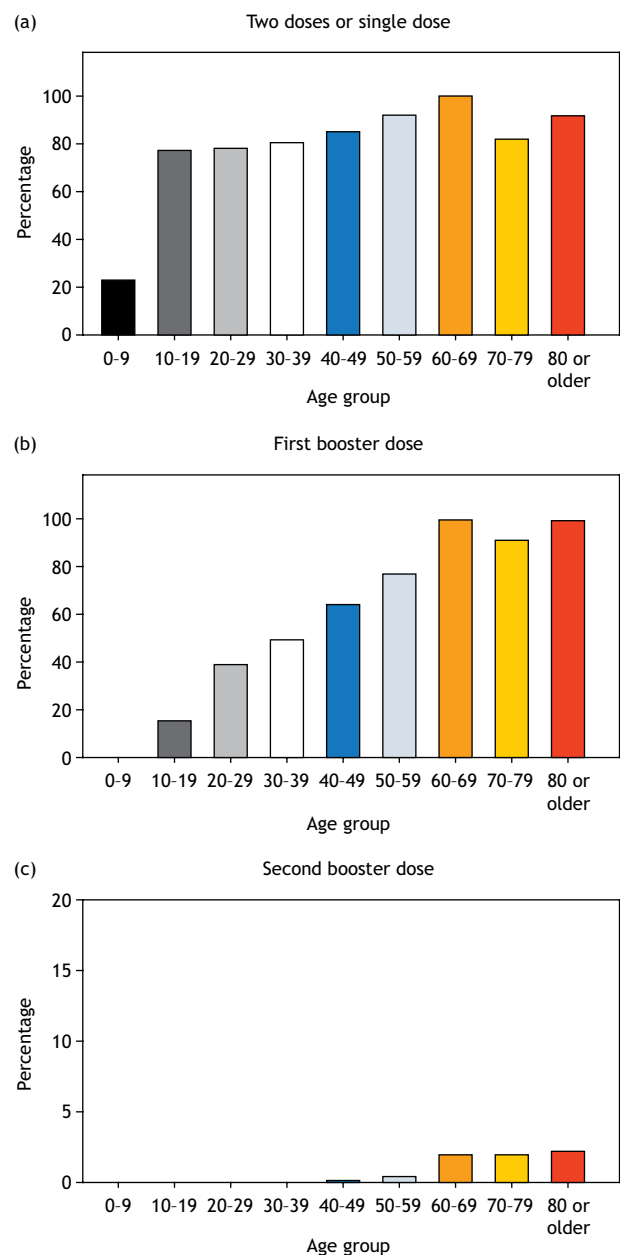
Popular interest in the term pandemic

Figure 4 shows the index of searches on the Google website for the term “pandemia” (pandemic), obtained from “Google Trends”²², for the period from September 5, 2021 to August 27,

2022, and points to a strong trend of loss of interest in the topic over time, accompanied by a forceful effort to ignore the related facts, disregarding the scientific information that the danger is still present, as demonstrated by the still growing number of cases, hospitalizations, and deaths.

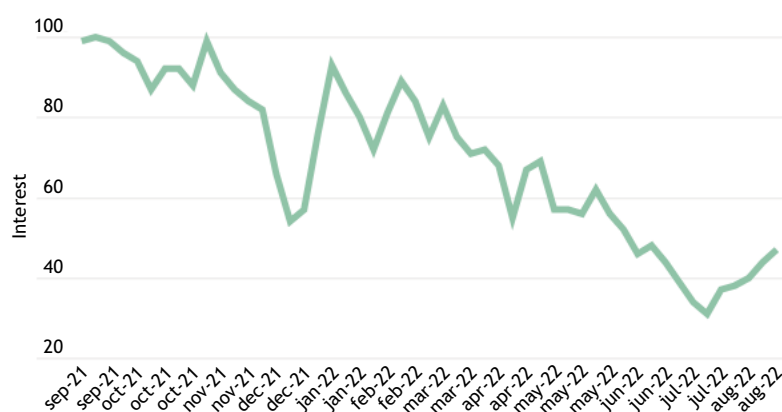
DISCUSSION

A third wave of the pandemic in Brazil, the largest in number of cases to date, occurred from December 2021 to the end of April 2022, followed by a fourth wave in a descending phase at



Source: Elaborated by the authors, 2022.

Figure 3. Percentage of population already vaccinated by age group with (a) two doses or single dose; (b) booster dose (third dose), and (c) second booster dose (fourth dose). Data from July 20, 2022.



Source: Elaborated by the authors, 2022.

Figure 4. Interest in the term “pandemia” (pandemic) in Brazil obtained from *Google Trends* with respect to the date from September 5, 2021 to August 27, 2022.

the time of writing (end of August, 2022), caused by the variant Omicron and subvariants. Despite the still significant number of deaths, this would have reached much higher levels if it were not for the number of doses of vaccine against the virus applied in Brazil. Despite this, we still have significant portions of the population with an incomplete vaccination schedule, which unfortunately results in the vast majority of the still high number of daily deaths from COVID-19 that occur in Brazil, with a moving average over seven days of 135 on August 30, 2022. Brazil as a whole has already surpassed the peak of the fourth wave, but there is no scientific basis to state that the current stage is a post-pandemic context, with the virus continuing to circulate and the possibility of the emergence of new variants.

Brazil has a long tradition of large-scale immunization campaigns, with speed and efficiency, achieved thanks to a solid public health system, the Unified Health System (SUS), an example for many countries. This could have been a virtuous scenario for the country to build opportunities for the dissemination of good practices, from a health point of view, conquered by decades of successful experiences in the control and prevention of several epidemics, which could have brought positive visibility to the nation. However, what happened was the transformation of this environment by public authorities into a collection of erratic and confusing decisions. For this reason, today we have poor vaccination coverage, with a significant portion of the population still not fully vaccinated (considering the respective booster doses), especially among young adults and children, as we can see in Figure 3. The very low adherence to the fourth dose of the vaccine only reinforces the above argument and points to an oversight in maintaining protection, aggravated by the fact that the country has not even started vaccinating children as young as 6 months old, as already authorized by the US Centers for Disease Control and Prevention (CDC). This situation is, therefore, worrying, aggravated by the absence of information campaigns that reinforce the central role of vaccination in controlling the pandemic, and informing about the consequences of contracting the virus.

As discussed above, we may still have difficult days ahead, with possible new waves, or outbreaks, showing yet another aspect of inefficiency from the point of view of planning, management, and control of the situation as a whole. To complete an already quite complex picture, the return to face-to-face classes across the country, without the necessary infrastructure changes, without the objective conditions for consistent and perennial social distancing, without correct information for teachers, parents, and students, turned teaching places into centers for the spread of the virus, facilitating its circulation not only among children and young people, but also for their families and the rest of society.

Non-pharmaceutical care, such as the mandatory use of masks, are being used less and less as strategies to contain the still persistent pandemic, contrary to what was proposed by states and municipalities, but not by the Federal Government, at the beginning of the pandemic²³. It should be noted that mandatory vaccination, especially among children, demonized by the central government, could have resulted in a significant reduction in cases and deaths. The continuous lack of awareness and guidance campaigns for the entire population, since the beginning of the pandemic, resulted in loss of life that could have been avoided with some easily implemented measures¹⁸. What was seen, and still continues, is a dispute permeated by effect phrases and propagation of speeches based on common sense, emptied of meaning and depth, using communication channels to build reckless and irresponsible resistance to vaccination and the use of masks, as well as other procedures.

Still under the lack of management of the pandemic, we can see that buildings and physical structures have not been properly changed, in a minimally responsible way, for a face-to-face return of educational, professional, commercial, and leisure activities, among others. We have, therefore, a critical picture, from the point of view of the organization of public spaces and, above all, the attitudes of those who are constitutionally imbued with the mission to protect and promote the well-being of the population²⁴.



CONCLUSIONS

Little is known yet about the sequels and consequences left by COVID-19, both from a health, social, and economic point of view. Even the discoveries that already exist do not circulate in a current way among the population and in the very structure of the state apparatus, showing a gap on the exact understanding of the impact that will have on social security, youth and adult education, and other areas, which combined, will directly affect the country's productivity, the increase in health spending, whether public or private. This context does not point to a promising picture for the country's

competitiveness, which, according to international rankings, is low and immediately needs actions that can contribute to mitigate this performance.

Different measures can be adopted, without significant negative impact on the country's economy, a constant concern²⁵, as long as public agents recognize the real health situation in the country. We conclude by reinforcing that the pandemic is far from over, the virus still circulates heavily in Brazil and in the world and there is the possibility of new variants emerging, which may be less dangerous or more deadly^{26,27}, a lottery that we shouldn't be playing.

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Author's Contributions

Gonçalves MAMS, Murari TB, Lucio ML, Rocha Filho TM - Conception, planning (study design), acquisition, analysis, data interpretation, and writing of the work. All authors approved the final version of the work.

Conflict of Interests

The authors inform that there is no potential conflict of interest with peers and institutions, politicians, or financial in this study.



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