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Impact of the COVID-19 pandemic on the vaccination of children 12 months of age and under: an ecological study

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Abstract *This study aimed to evaluate the impact of the COVID-19 pandemic on the vaccination numbers for immunization geared toward individuals under 12 months of age in Brazil. This study analyzed the numbers of the nationwide vaccination coverage of ten vaccines present in the calendar from the National Immunization Program (NIP) over the past eight years (2013-2020). This is an ecological study, and all data were taken from the NIP. In comparison to the previous years, 2020 recorded the lowest figures of vaccination coverage (VC) of the average of the group of studied vaccines – 79.07% – while in 2019, this same index was 84.44%, resulting in a drop of 11.10% between these two periods. Moreover, during the year of the pandemic, of the ten analyzed vaccines, nine recorded their lowest historical VC figures, all of which were at least 14 percentage points below the goals set by the Brazilian Ministry of Health (MS, in Portuguese). Although there had already been a tendency toward a decline in VC, for various reasons, the present study illustrates that the numbers recorded in 2020 were significantly lower, a phenomenon also reported in other countries. Therefore, although it is impossible to affirm that the COVID-19 pandemic and its distancing measures are the causes for the drop in the immunization numbers, it can be inferred that there is indeed an association.*
Key words *Vaccination coverage, Immunization programs, Physical distancing*

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Introduction

Vaccination is considered to be one of the methods that most prevents deaths in the world today[1], and offers an excellent cost-benefit relationship[2]. Immunization campaigns in Brazil have made it possible for a wide range of preventable diseases to be controlled, or even eradicated, as is the case of smallpox[3]. The Immunization Agenda for 2030 from the World Health Organization (WHO) places vaccination plans as a crucial point to guarantee access to the fundamental right of physical and mental health, demonstrating its underlying importance for society as a whole[1].

In Brazil, The National Immunization Program (NIP) plays a key role in the distribution and expansion of access to vaccines, especially for those distributed during early childhood, overcoming challenges and achieving goals over the years[4,5]. In 2013, the Pentavalent vaccine was introduced into the National Vaccination Calendar, through Decree 1498, from July 19, 2013[6]. Since then, few upgrades have been implemented to the calendar, including the change in the third dose against oral poliomyelitis (OPV), to an injectable dose (IPV); the suppression of the third dose of 10-valent pneumococcal vaccine (PCV10); and the early application of the booster dose of the meningococcal C vaccine from the 15th to the 12th month of life[7], according to Chart 1, which shows the immunizations of these two calendars.

In February 2020, by means of Decree 188[8], the Ministry of Health (MS, in Portuguese) declared a Nationwide State of Emergency in Public Health due to the human infections caused by the new coronavirus. Since then, the population's daily routine has changed drastically due to the protective measures taken against COVID-19, even increasing sedentary lifestyles among the Brazilian population[9]. With this, the search for healthcare services and vaccine rates have declined. In the United Kingdom, the search for emergency pediatric care fell 90%, and 60% of the parents reported that they had contemplated postponing their own children's immunizations[10]. Brazilian studies in the field of oncology have identified a 45% decline in the number of doctor's appointments[11], while in the area of cardiology, a 90% drop has been seen in the total number of outpatient appointments and a 45% decline in the search for cardiology clinics[12].

Prior publications during the pandemic had already warned of the need to maintain a normal calendar of children's immunizations, and expresses the concern over a possible drop in vaccinations during this period[13]. Nevertheless, publications with complete data regarding the NIP's national calendar of immunizations in 2020, discussing possible relationships with the COVID-19 pandemic in Brazil, are still scarce. In this light, the present study aims to establish and evaluate relationships between the COVID-19 pandemic and its developments with the indexes of vaccination coverage (VC) for all immunizations made available by the Brazilian Unified Health System (SUS, in Portuguese), via NIP, whose target-public is children 12 months of age and under.

Methodology

An ecological study was conducted from 2013 to 2020, covering the entire Brazilian territory. The VC of the indicated immunizations for children 12 months of age and under was considered, following that established in the MS's National Vaccination Calendar, considering the entire population who, according to the Immunization Program Evaluation System, should receive the vaccines.

From 2013 to 2015, records only considered the data referent to immunization for BCG, hepatitis B, rotavirus, pentavalent, PCV10, poliomyelitis, meningococcal C, the first dose of the MMR vaccine, and the booster dose of the PCV10, since these were present in the calendar in effect at the time[6], not including the vaccine against yellow fever, whose calendar presents several peculiarities. There are studies that point out the need for the application of vaccines only in endemic risk regions of the diseases. Nonetheless, the occurrence of an outbreak of yellow fever between December 2016 and June 2017 considerably impacted the VC rates of the following years. Hence, it was decided that it should be excluded from this analysis, as it would influence the results in an improper manner[14]. However, from 2016 to 2020, all of the aforementioned vaccines, plus the booster dose of the meningococcal C vaccine, were considered, in accordance with the calendar in effect at the time[7].

Through the design of this study, our research team decided to analyze all of the immunizations made available to children 12 months of age and under, and only considering data recorded as of 2013, since it was in this year that the calendar in effect was most similar to that used in 2020, providing a more reliable and realistic analysis. Nev-

Chart 1. Age of vaccination according to the different NIP calendars.

AGE	2013-2015	2016-2020
	Vaccines	**Vaccines**
Upon birth	BCG (single dose) Hepatitis B	BCG (single dose) Hepatitis B
2 months old	1st dose rotavirus RV1 1st dose pentavalent 1st dose 10-valent pneumococcal 1st dose inactive poliomyelitis (IPV)	1st dose rotavirus RV1 1st dose pentavalent 1st dose 10-valent pneumococcal 1st dose inactive poliomyelitis (IPV)
3 months old	1st dose meningococcal C	1st dose meningococcal C
4 months old	2nd dose rotavirus RV1 2nd dose pentavalent 2nd dose 10-valent pneumococcal 2nd dose inactive poliomyelitis (IPV)	2nd dose rotavirus RV1 2nd dose pentavalent 2nd dose 10-valent pneumococcal 2nd dose inactive poliomyelitis (IPV)
5 months old	2nd dose rotavirus RV1	2nd dose rotavirus RV1
6 months old	3rd dose Pentavalent 3rd dose 10-valent pneumococcal 3rd dose oral poliomyelitis (OPV)	3rd dose pentavalent 3rd dose inactive poliomyelitis
9 months old	Initial dose yellow fever	Initial dose yellow fever
12 months old	Booster dose 10-valent Pneumococcal 1st dose MMR vaccine	Booster dose 10-valent Pneumococcal Booster dose meningococcal C 1st dose MMR vaccine

Source: Authors.

ertheless, in 2013, due to data availability problems, the VC for hepatitis B was not considered. In the period between 2013 and 2015, the VC of the booster dose of the meningococcal C vaccine was not counted, as it did not exist at that time.

The data were collected from the Immunization Program Evaluation System, organized by the General Administration of the National Immunization Program (CGPNI, in Portuguese) and were made available by means of a public domain databank through the Department of Informatics of SUS (DATASUS, in Portuguese), on April 12, 2021. According to the technical note, the VC is calculated by dividing the number of applied vaccines by the number of individuals present in the target population, multiplying the result by 100[15]. The calculation of the total of each vaccine is done directly through the platform, representing the quotient between the total number of applied doses and the target population of the period, and not merely an arithmetic average of the value of each year.

For vaccines that are applied in more than one dose, as is the case with pentavalent, rotavirus, and poliomyelitis, the VC value is relative to the index of application of the final dose, thus counting the total effective immunization. By contrast, the 10-valent pneumococcal vaccine and the meningococcal C, which are also applied in multiple doses, appear twice in each analysis: one, under the name "pneumococcal" and "meningococcal C", relative to the second of the two initial doses of each, and the other containing the term "(1st booster)", referent to the first booster dose.

The absolute VC numbers are calculated by the Immunization Program Evaluation System. In the cases of immunizations that focus on individuals 12 months of age and under, are used as an information source for the target population of the data from the Information System on Live Births (SINASC, in Portuguese). By contrast, the quantity of applied doses is determined by the data that is extracted from the Daily Bulletins of Administered Doses of Vaccines, sent by the Municipal Departments of Health to the MS[15]. Numbers of above 100% in the VC can represent inaccuracies in population estimates and/or in the information concerning administered doses[16].

All of the data were collected through DATASUS in Excel, and were stored and processed, using the statistics tools from the Microsoft Excel 2019 software. For the calculations, up to twelve decimal places were considered, but only two decimal places are shown herein. Descriptive analyses were performed using the already calculated and collected data, a graph of the results over the years, and comparisons with the goals defined by the MS for the results of each vaccine.

This study used only data from the public domain that had already been anonymized, with no type of individual identification. The project was approved by the Research Commission of the institution and logged under protocol number 006/2021.

Results

In Brazil, during the evaluated period, an average VC was observed for all of the vaccines present in the NIP calendar within the scope of this study – 88.81%.

Analyzing the average of all vaccines in each year in Table 1 and specifically the results of each year in Graph 1, it is possible to note that it was in 2020 that we fell to the lowest average annual VC figure, which was of only 75.07%, as compared to the highest numbers recorded in 2013 of 98.92%. In addition, oscillations were recorded over the studied period. This can be observed in the period from 2017 to 2018, in which the VC showed the highest increase (4.35%), and between 2015 and 2016, which presented the largest drop (6.11%), these being the two largest variations since 2013. By contrast, from 2019 to 2020, the decline recorded in the average overall VC was of 11.10%, an exceptionally high value that had never before been recorded, falling from 84.44% to 75.07%.

In 2020, nine of the ten vaccines outlined in this study recorded the lowest historical numbers of VC; only the pentavalent vaccine did not reach this mark, as can be seen in Chart 2. These same nine vaccines presented a drop in VC between 2019 and 2020, considering that all fell by 9%, and four by more than 14% (BCG, Hepatitis B, booster dose of PCV10, and the first dose of the MMR vaccine). Figure 1 shows this relationship even more clearly. The numbers from 2020, represented by the four black boxes, rank below the minimum numbers of these nine vaccines and can be considered to be outliers, but they still clearly illustrated a pattern this year. Even in the Pentavalent vaccine, in which the 2020 VC is no less than the minimum, the value ranks in the top fourth, distant from the main numbers. The gray lines represent MS's VC goals for each vaccine – 90% for BCG and Human Rotavirus, and 95% for the others[5]. It should also be noted that in 2020, no vaccine achieved the goal established by the MS.

When comparing 2019 and 2020, the largest fall was recorded by the hepatitis B vaccine, 20.4% (78.57 in 2019 to 62.54 in 2020), whereas the lowest drop was recorded by the anti-pneumococcal vaccine, with an expression reduction of 9.08% (89.07 in 2019 to 80.98 in 2020).

Another observation that should be made concerns the dispersion measurements of the VC numbers. The population standard deviation (SD) for each vaccine varied from 4.45% (pneumococcal) to 11.02% (BCG). In the total of all of the vaccines, the average variability was of 7.33%.

Table 1. Vaccination coverage from 2013 to 2020.

Vaccine	2013	2014	2015	2016	2017	2018	2019	2020	Averagea
BCGb	107.42	107.28	105.08	95.55	97.98	99.72	86.67	72.98	96.56
Hepatitis B	ND	88.54	90.93	81.75	85.88	88.40	78.57	62.54	82.35
Human rotavirus	93.52	93.44	95.35	88.98	85.12	91.33	85.40	76.96	88.74
Meningococcal C	99.70	96.36	98.19	91.68	87.44	88.49	87.41	78.18	90.92
Pentavalent	95.89	94.85	96.30	89.27	84.24	88.49	70.76	76.89	87.06
Pneumococcal 10-valent	93.57	93.45	94.23	95.00	92.15	95.25	89.07	80.98	91.71
Poliomyelitis	100.71	96.76	98.29	84.43	84.74	89.54	84.19	75.81	89.27
Pneumococcal 10-valent (1st booster)	93.11	87.95	88.35	84.10	76.31	81.99	83.47	71.20	83.29
Meningococcal C	ND	ND	ND	93,86	78,56	80,22	85,78	75,67	82,85
(1st booster)	ND	ND	ND	93.86	78.56	80.22	85.78	75.67	82.85
MMR vaccine 1st dose	107.46	112.8	96.07	95.41	86.24	92.61	93.12	79.45	95.36
Average of the group of evaluated vaccines	98.92	96.83	95.87	90.00	85.87	89.60	84.44	75.07	88.81

[a]Average of the accumulated period, extracted directly from the DATASUS system. [b]Numbers above 100% point to a possibility of inaccuracies in population estimates and/or in information about administered vaccines.

Source: Authors.

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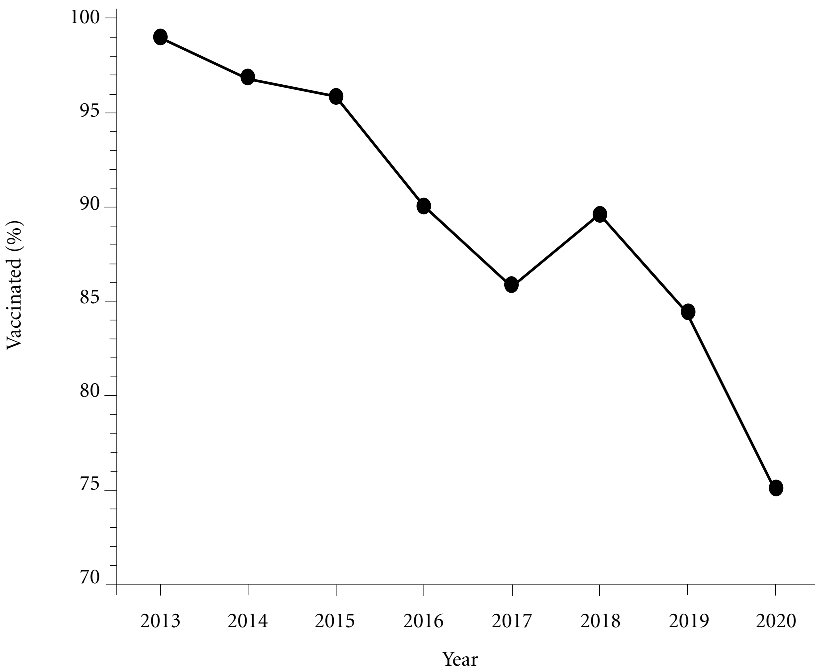

Graph 1. Average vaccination coverage of the ten vaccines studied between 2013 and 2020.

Source: Authors.

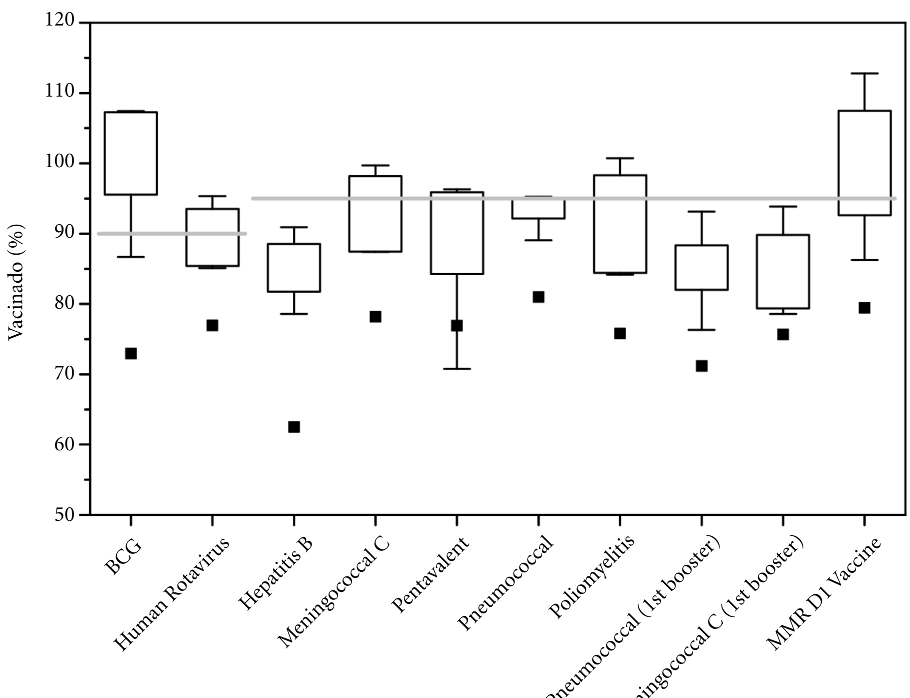

Figure 1. Boxplot of the VC up to 2019 of all of the studied vaccines, in black squares, numbers from 2020; the gray line represents the MS's ideal reference value.

Source: Authors.

Discussion

The present study sought to establish and evaluate possible impacts on the VC in 2020 throughout Brazil regarding the COVID-19 pandemic, analyzing the indicated immunizations for individuals under 12 months of age. Based on the data presented in the results section, one can verify that there was a worrisome reduction in the VC of the analyzed vaccines.

The VC recorded in the NIP databank does not necessarily correspond to the number of individuals who are not susceptible to those diseases for which they were vaccinated. In addition to the possible flaws in the filling out of NIP data, which influences the data analysis[17], the vaccines do not present an absolute effectiveness. BCG, for example, presents a nearly 86% protection against more severe forms of tuberculosis, but it is insufficient in the total prevention against simpler cases of this disease[18]. By contrast, the vaccine against Hepatitis B VrHB-IB, produced by the Butantan Institute, presents a serum protection of nearly 100% in newborns[19], and it thus considered to be an extremely effective vaccine. For these reasons, respecting the individuality of each vaccine, it is essential to determine the VC goals of the MS in order to achieve collective protection. For immunization against Human Rotavirus and BCG, the MS defines that the ideal numbers are those of at least 90%, and for the other vaccines, 95%[5].

Bearing this in mind, one can see, that, progressively from 2013 to 2020, based on the data presented above, the number of analyzed vaccines that meet the goals dropped consistently. In 2013, for example, six of the studied vaccines reached the levels established as the ideal by the NIP. By contrast, in 2016, only three; in 2017, only one; and in 2018, again only three reached the established goal. In 2019 and 2020, none of the ten vaccines analyzed by this study met the MS goals. In the total value of the period for each vaccine, only two of the ten reached the reference value. Therefore, it can be affirmed that the VC for the outlined immunizations had already presented numbers below the goals established by the MS, and was in decline.

In 2020, this reduction in VC was expressively greater than the previous levels. In general, the variations ranged from approximately six percentage points in 2019 to an impressive 11.10% on average in 2020. If analyzed individually, one can see that, in some cases, as in the case of Hepatitis B, this value was even greater, approximately 20.40%.

It is important to highlight that declines in VC had already been identified in the country, though not as accentuated as recorded in 2020, with the outbreaks in measles, a disease that had been eradicated, directly related to these gradual declines in VC[20]. Among other reasons for the low adherence to vaccination is the dissemination of fake news in digital medias concerning possible side effects attributed to vaccines and the questioning of their safety, consequently promoting the phenomenon of hesitation and vaccine refusal[21-24]. The disclosure of disinformation is linked to anti-vaccine, anti-science, and conspiracy theory movements around the world, which act to spread fake news, movements which have grown greatly over the past five years[25]. It is important to highlight that the beliefs that lead to the phenomenon of vaccine refusal had already been in existence for more than two decades; however, with the advent of digital media, their dissemination was further facilitated[26]. Such movements are extremely prejudicial for public health, taking into account that studies show that the phenomenon of vaccine refusal raises the risk of avoidable diseases not only for unvaccinated children, but also for the entire community[27,28].

In addition to social and political issues, technical questions from the NIP itself have also contributed to the decline in VCs. Problems concerning the production, distribution, and administration of the vaccines may have been connected to the drops in vaccination rates[5]. One study, conducted by researchers from the Federal University of Piauí, interviewed parents who did not vaccinate or who delayed the vaccination of their children, and revealed that 36.4% of the participants claimed that the flaw in the calendar was caused by a lack of vaccines in the public health units[29]. This same cause was the most reported in another study conducted in Cuiabá, Mato Grosso, showing just how relevant this issue is to VC rates[30]. In 2019, for example, the data showed a significant decline in pentavalent vaccine vaccination rates. Coincidence or not, in the second semester of that same year, Brazil also suffered from a lack of this vaccine[31], which may well have been a potential cause of these vaccination numbers.

As mentioned above, the reasons behind vaccination refusal, especially due to social and political questions, have existed for more than two decades, and have been exacerbated over the past five years. Moreover, specific technical problems of NIP can and do occur quite often. Even before 2013, the beginning date of this study, the VC numbers in Brazil had suffered from these

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variables[5,20,26,32]. Nonetheless, in 2020, a new factor arose to further impact the decline in VC, the COVID-19 pandemic and the disease control measures. The promotion of physical distancing for the epidemiological control of the disease has been associated with the drop in the search for vaccines overseas, in countries such as the United Kingdom[10], Pakistan[33], and Singapore[34]. This can be explained through theories that postulate that, parallel to the COVID-19 pandemic, there is also a fear pandemic[35], which generates the feeling of distrust in those responsible for children, especially as regards just how safe it is to expose children to the risk of being vaccinated. Even though the displacement of children and their guardians to a public health unit may imply health risks due to COVID-19, one study published in the journal *The Lancet Global Health*, conducted in African countries, showed that there are more advantages than disadvantages in this practice[36].

Therefore, the need for an increase in VC is clear; however, due to the continuance of the pandemic and the lack of emphatic national health reinforcement actions concerning the importance of childhood vaccines, it is not possible to affirm that the VC goals for 2021 will be achieved. One document published by the MS listed ten steps to expand VC, including the easing and extending of vaccination hours; taking advantage of doctor's appointments and procedures at public health clinics as vaccination opportunities; eliminating barriers to immunization, such as the need to prove one's residency; and combating disinformation and fake news about vaccines[37]. International studies highlight the importance of a reminder system for vaccination deadlines and the follow-up on individuals who did not complete the vaccination calendar, emphasizing positive results[38,39]. Another alternative that is being discussed is mandatory vaccination in order to register students in schools, bearing in mind that studies suggest that this option is effective in increasing VC[40,41]. However, such measures are controversial, since the right to education cannot be denied to anyone.

It is important to mention that, in an attempt to mitigate the consequences of non-vaccination of children and teenagers, the MS, since 2012, has been carrying out a yearly National Campaign for Multivaccination, which has the objective of expanding the population's access to vaccines and updating the vaccine scenario of individuals under 15 years of age[42]. In 2021, this campaign was conducted in October. However, in order to achieve a greater quantity of vaccinated individuals, the campaign was extended nationally until the end of November of the same year, a measure that hopes to increase VC in both children and teenagers[43].

One point that is commonly mentioned, and which is even included in the MS's ten steps toward increasing adherence to the vaccination calendar, is the adoption of marketing campaigns. However, one study published in the journal *Pediatrics*, conducted in the United States, showed that the current means of communication used by the American sanitation authorities to inform about vaccines may not only be ineffective, but also counterproductive[44]. Although this study is being conducted in another country, their culture is similar to the Western Brazilian culture, and their reality, therefore, can be applied to Brazil. Nonetheless, further studies on the official communication about vaccines and their effects in Brazilian society are necessary.

The main limitation of this study is the use of secondary data, extracted from DATASUS. According to the technical note from MS, the number of vaccines are launched manually in the system by the Municipal Health Secretaries[15], which are subject to errors and delays in filing. Another limitation concerns that calendar, which suffered a minor modification between 2015 and 2016, which caused data from 2013 to 2015 regarding the booster dose of the meningococcal vaccine to be disregarded for analysis. The main strong points of the study are the number of analyzed vaccines (all of which are amply recommended by NIP), the national coverage of the analysis, the reading of more than five years of data, as well as our revealing of concrete data on consecutive drops in vaccination.

In this sense, it can be concluded that the COVID-19 pandemic imposed challenges to the expansion of the National Vaccination Calendar for children 12 months of age and under, as well as to achieving the goals set by the NIP in 2020. The nationwide drop in VC concerning immunizations geared toward this population had already been perceived, even if the expressive drop in 2020 is possibly the consequence of the pandemic and the subsequent distancing measures. In addition, it can also be concluded that this phenomenon is not exclusive to Brazil, as it has also been recorded in other countries around the world.

Collaborations

All authors contributed to the design of the project, data analysis, writing and review of the article, and also approved the final version to be published.

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