Vaccine: X 17 (2024) 100430

Contents lists available at ScienceDirect

Vaccine: X

journal homepage: www.elsevier.com/locate/jvacx

Overview of childhood vaccination coverage in Brazil and the impact of the COVID-19 pandemic: Is our children's health at risk? A review of pre-COVID-19 periods and during the COVID-19 pandemic

Jéssica Paula Martins [1], Giulia Almeida Alatzatianos [1], Tais Mendes Camargo [1], Fernando Augusto Lima Marson [1,*]

Laboratory of Molecular Biology and Genetics, São Francisco University, Bragança Paulista, São Paulo, Brazil

ARTICLE INFO

Keywords:
Brazil
Epidemiology
Immunization
SARS-CoV-2
Vaccination
Vaccines

ABSTRACT

Introduction: The coronavirus disease (COVID)-19 has had a great impact on several aspects related to the population's health, including the vaccination adherence rate. This study describes how childhood vaccination coverage (CVC) in Brazil was affected by the pandemic in the period from 2020 to 2022 and explores the relationship between this data and the Human Development Index (HDI), and the number of votes received in the government with a right-wing political ideology.

Methods: An ecological analysis of CVC was carried out including 12 vaccines. The HDI was evaluated considering the HDI-General, HDI-Income, HDI-Longevity, and HDI-Education. The percentage of valid votes received by the former president (right-wing political ideology) was also obtained. Spearman correlation tests were applied to compare markers.

Results: During the period analyzed, it was observed a linear growth trend in CVC between 2015 and 2018 regarding all vaccines. However, from 2018 onwards, after the presidential elections in Brazil, the CVC reduced significantly, showing an even more pronounced decrease with the start of the COVID-19 pandemic. This reduction in CVC observed for some vaccines was related to the higher percentage of votes for the government with a right-wing political ideology, especially in relation to the BCG (bacillus Calmette and Guerin) and pentavalent (protecting against diphtheria, tetanus, pertussis, hepatitis B, and *Haemophilus influenzae* type b bacteria) vaccines. In addition, when analyzing the HDI, it was observed that the lowest values of this indicator were associated with a more expressive reduction in CVC, mainly related to yellow fever, pentavalent, 10-valent pneumococcal conjugate, Human rotavirus, and triple viral (protecting against measles, mumps, and rubella – MMR) vaccines.

Conclusion: Although Brazil has a successful and exemplary record in combating several diseases, mainly due to the high rate of CVC, the continuous reduction in this coverage must be thoroughly evaluated by health managers.

1. Introduction

Created in 1973, the National Immunization Program of the Brazilian Unified Health System is coordinated by the Ministry of Health in conjunction with the municipal and state health departments [1]. It is recognized worldwide for its relevant intervention in public health, contributing to the decrease in infant mortality and improving the life expectancy of the Brazilian population [1]. It is responsible for distributing vaccines to the whole Brazilian population, presents a successful history, and has well-succeeded experiences in terms of national vaccination campaigns [1–3]. Through this program, Brazil managed to eliminate and control several diseases and, due to its action, the epidemiological profile of vaccine-preventable diseases was greatly impacted in the country [3]. Considered a reference in other countries as one of

* Corresponding author at: São Francisco University, Postgraduate Program in Health Science, Laboratory of Molecular Biology and Genetics. Avenida São Francisco de Assis, 218. Jardim São José, Bragança Paulista 12916-900, São Paulo, Brazil.

E-mail addresses: jes.sy.paula@hotmail.com (J. Paula Martins), giulia.alatzatianos@mail.usf.edu.br (G. Almeida Alatzatianos), tais.camargo@usf.edu.br (T. Mendes Camargo), fernando.marson@usf.edu.br, fernandolimamarson@hotmail.com (F. Augusto Lima Marson).

[1] The authors contributed equally to this study.

https://doi.org/10.1016/j.jvacx.2024.100430
Received 9 October 2023; Received in revised form 23 December 2023; Accepted 3 January 2024
Available online 9 January 2024
2590-1362/© 2024 The Author(s). Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

the largest vaccination programs in the world, the National Immunization Program provides, free of charge, ~ 45 immunobiological agents for different age groups [3–5]. However, since 2017, the levels of vaccine doses applied have decreased and, as a consequence, childhood vaccination coverage in the vaccination calendar has shown a sharp drop. This scenario was worsened by the coronavirus disease (COVID)-19 pandemic [6–8].

With the outbreak of the COVID-19 pandemic, several preventive measures were applied in an attempt to stop the propagation of the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) [9–11]. The development of new vaccines was among these measures [12,13]. Therefore, in January 2021, the Brazilian National Health Surveillance Agency granted emergency approval to the CoronaVac vaccine, developed by the Chinese pharmaceutical company Sinovac in partnership with the Butantan Institute, and to the Covishield vaccine, produced by the pharmaceutical company Serum Institute of India, in partnership with AstraZeneca/Oxford University and Oswaldo Cruz Foundation [14]. Those vaccines were distributed and applied following a list of priority groups defined by the Ministry of Health [15,16], and from February 2021 onwards, other vaccines started to be used in Brazil, such as the Comirnaty vaccine, produced by the North American pharmaceutical industry Pfizer, in partnership with the German biotechnology laboratory BioNTech [17]. Even, the Flu vaccination was able to promote better outcomes among patients hospitalized due to COVID-19, mainly in patients who received both vaccines – against Flu and COVID-19 [18].

Even facing an optimistic scenery as a result of the COVID-19 vaccines, the pandemic provoked interruptions in non-emergency health services, including immunization services with a consequent reduction in vaccination coverage mainly among children [19–23]. This fact might have been worsened by the population's reluctance to seek health services due to the risk of contamination by the new virus (SARS-CoV-2) in health units or when sharing means of transport to these locations [24]. Other factors might also have influenced the decrease in vaccine coverage in Brazil, including the dissemination of political and defamatory news about ineffective medicines and dubious treatments for the management of respiratory disease and about the development, origin, and implementation of COVID-19 vaccines [10,11,16,25–27]. This created distrust in society, regarding how to act in relation to the new vaccines, and also generated uncertainty in relation to other vaccines already included in the Brazilian vaccination calendar [7,28–32].

In such a context, official data published by the United Nations Children's Emergency Fund (UNICEF), the Pan American Health Organization (PAHO), and the World Health Organization (WHO), demonstrated that 23 million children did not receive basic vaccines from routine health services in 2020. This was the highest number since 2009, and was up 3.7 million from 2019 figures, which resulted in a growing number of children at risk of devastating, but avoidable diseases [33,34]. Due to the reduction in vaccination coverage in Brazil, in May 2022, PAHO classified the country as a place at high risk for the reintroduction of eradicated diseases such as polio. These reports reinforce the urgency of investigating and synthesizing the reasons why the effectiveness of the Brazilian National Immunization Program decreased sharply before, during, and after the COVID-19 pandemic, more specifically when observing the childhood vaccination calendar, with the purpose of developing plans and methods to recover the history of successful experiences in campaigns that the Brazilian Unified National Health System (SUS, Sistema Único de Saúde) has provided to the population [1]. Thus, it seems relevant to highlight that the data presented and analyzed, as well as the considerations in this article, add invaluable information to support issues related to health policies, mainly public ones, aiming at the guidance of the vaccination strategies in Brazil.

Taking that into consideration, this study aimed to verify the probable increase in hesitancy with the childhood vaccination schedule during the COVID-19 pandemic in Brazil among the Brazilian population, from 2015 to 2022, and associate these values with the Brazilian Human Development Index (HDI) by federative unit and with political issues associated with the Brazilian federal government.

2. Methods

This study developed an epidemiological analysis of the ecological character of data from the Brazilian Health Ministry available on Tab-Net – a generic public domain tabulator that allows quick organization of data according to the desired search. Tab-Net was developed by Data-SUS (Department of Informatics of the Brazilian Unified National Health System) to gather information from the SUS databases (https://datasus.saude.gov.br/acesso-a-informacao/imunizacoes-desde-1994/; accessed on 25th April 2023) [35]. Its immunization information platform has been collecting and storing information such as vaccination coverage data, number of doses applied, and dropout rate since 1994. This study obtained data on childhood vaccination coverage (CVC) based on three analysis periods with data found on the government platform regarding vaccination: (period 1) 2018 and 2015 (pre-pandemic period with a government during a left-wing political ideology), (period 2) 2020 and 2018 (pre-pandemic period with a government during a right-wing political ideology), and finally (period 3) 2022 and 2020 (pandemic period with a government during a right-wing political ideology).

Among the immunizers, the following vaccines were investigated considering CVC: (i) BCG (bacillus Calmette and Guerin) vaccine, (ii) DTP [triple bacterial vaccine to prevent diphtheria, tetanus, and pertussis] vaccine, (iii) yellow fever vaccine, (iv) hepatitis B vaccine, (v) meningococcal C conjugate vaccine, (vi) pentavalent (protecting against diphtheria, tetanus, pertussis, hepatitis B, and *Haemophilus influenzae* type b bacteria) vaccine, (vii) 10-valent pneumococcal conjugate [protecting against the invasive pneumococcal disease, pneumonia, and acute otitis media caused by *Streptococcus pneumoniae* of serotypes 1, 4, 5, 6B, 7F, 9V, 14, 18C, 19F, 23F, and serotype 19A (cross protection)] vaccine, (viii) oral poliovirus vaccine, dose 1 (15 months old), (ix) oral poliovirus vaccine – booster dose (four years old), (x) Human rotavirus vaccine, (xi) tetravalent (protecting against diphtheria, tetanus, pertussis, and meningitis) vaccine, and (xii) triple viral vaccine (protecting against measles, mumps, and rubella – MMR) vaccine. The CVC (%) of each vaccine was obtained from 2015 to 2022 and by the federation unit (States and Federal District) in Brazil. The change in CVC by periods was also presented, that is, period 1, period 2, and finally period 3 as previously described.

The HDI values considering the country and its federative units were evaluated using four markers: (i) HDI-General, (ii) HDI-Income (dimension: decent standard of living; indicator: gross national income per capita), (iii) HDI-Longevity (dimension: long and healthy life; indicator: life expectancy at birth), and (iv) HDI-Education (dimension: knowledge; indicator: expected years of schooling and average years of schooling). The dataset was obtained from the Atlas Brasil webpage (https://www.atlasbrasil.org.br/ranking; accessed on 25th April 2023) [36], which stores data from the Brazilian Institute of Geography and Statistics that portray sustainable human development and inequalities in Brazil. The HDI values presented in the study refer to 2021, which is the last year with data stored by the system. In addition, the percentage (%) of valid votes in 2018 and 2022 for the government with a right-wing political ideology was obtained, for both rounds of the presidential elections in Brazil, that is, the first and second rounds. The data containing the number of valid votes was obtained in accordance with data provided by the Brazilian Superior Electoral Court. These data were used to evaluate whether the ideological dispute, the discourses against the COVID-19 vaccination, and the political measures by the federal government through right-wing political ideology to manage the health crisis and to perform vaccination might have influenced the vaccination situation in the country, that is, the CVC reduction according to the childhood vaccination calendar. The data about HDI and percentage (%)

of valid votes in the presidential elections in Brazil are presented according to the population of the country and its federative units.

As for HDI (General, Education, Income, and Longevity) in the year 2021 and the percentage (%) of valid votes for the government with a right-wing political ideology in the years 2018 and 2022, they were correlated with the CVC reduction for different vaccines in the Brazilian federative units.

The statistical analysis was done using the Statistical Package for the Social Science software (IBM SPSS Statistics for Macintosh, version 27.0). The Spearman correlation tests were applied to compare HDI (General, Education, Income, and Longevity) in the year 2021 and the percentage (%) of valid votes for a government with a right-wing political ideology with CVC rates. To evaluate the possible CVC reduction rate, two moments were chosen in our study: (moment 1 – equal to period 2) decrease/increase of the adhesion in the vaccination calendar (pre-pandemic period and government with a right-wing political ideology) between the periods from 2020 to 2018 – aiming to evaluate only the influence of the ideological dispute, the discourses against the COVID-19 vaccination, and the political measures of the federal government to manage the health crisis and perform vaccination; and (moment 2 – equal to period 2 plus period 3) decrease/increase of the adhesion in the vaccination calendar (pre-pandemic and pandemic periods and government with a right-wing political ideology) between the periods from 2022 to 2018 – aiming to investigate the influence of a right-wing political ideology as described above and the outbreak of the COVID-19 pandemic.

In the Spearman correlation, it was considered the following cut-off points: (i) ± 0.90–1.0, very high positive–negative correlation index; (ii) ± 0.70–0.90, high positive–negative correlation index; (iii) ± 0.50–0.70, moderate positive–negative correlation index; (iv) ± 0.30–0.50 low positive–negative correlation index; and (v) 0.00–0.30, insignificant positive–negative correlation index. An alpha error of 0.05 was employed in the statistical analysis. Our research group used a statistical approach similar to that used in two previous studies, namely, one of them associated the number of deaths of patients undergoing hospital treatment for acute respiratory syndrome caused by COVID-19 in Brazil and the HDI, while the other associated the number of deaths due to the clinical evolution of cystic fibrosis [Online Mendelian Inheritance in Man (OMIM) no 219700] and HDI [37,38].

The graphical presentation was elaborated using GraphPad Prism version 8.0.0 for Mac, GraphPad Software, San Diego, CA, USA, accessed on April 25th, 2023 at: https://www.graphpad.com. Also, XY graphs were used to describe the relation between the CVC reduction/increase for the different vaccines and the years of data analyzed. In addition, the correlation matrix graph was used to present correlations by the federative unit in Brazil, between a) HDI-General, HDI-Education, HDI-Income, HDI-Longevity and the CVC reduction/increase for different vaccines, b) percentage (%) of valid votes and CVC reduction/increase for different vaccines, and c) HDI and percentage (%) of valid votes.

The data used in our study are publicly available. As it is anonymous, this is a study exempt from consent since it does not present any risk to research participants and was approved by the Research Ethics Committee of the São Francisco University [Certificate of Presentation of Ethical Review no 67241323.0.0000.5514].

3. Results

3.1. Childhood vaccination coverage in Brazil

Although twelve different vaccines were included in the study, three of them were not used in the final analysis [DTP (missing data from 2017 to 2020, and vaccination instructions changed for adults and pregnant women), oral poliovirus vaccine – booster dose (four years old) (missing data from 2015 and 2016 – despite the motivation for the first dose, the booster dose is currently available for application in health units), and tetravalent vaccine (data described only for the years 2015 and 2016, with complete data for the triple viral (MMR) vaccine only in the following years)]. The CVC evolution for the remaining vaccines is shown in Fig. 1 and Supplementary Tables 1-9. In Fig. 1, the data portrays CVC according to the total population of the country and by year of analysis. Therefore, it was observed that in the period under evaluation, the CVC was practically linear from 2015 to 2018 for all vaccines, except for yellow fever, which presented increased coverage. However, in 2018, after the presidential elections in Brazil, a reduction in CVC was observed, which worsened after the COVID-19 pandemic outbreak. Curiously, after 2021, a slight increase in the CVC was observed.

When considering all vaccines, few showed values over than 95% CVC in the period investigated. These vaccines were (2015) BCG vaccine, meningococcal C conjugate vaccine, 10-valent pneumococcal conjugate vaccine, oral poliovirus vaccine dose 1, and Human rotavirus vaccine; (2016) BCG and pentavalent vaccines; (2017) BCG vaccine; and (2018) BCG and pentavalent vaccines. In the period from 2018 to 2022, no vaccine presented values over than 95% CVC (Fig. 1). Data referring to each federative unit in the country and by year of evaluation are presented in Supplementary Tables 1-9.

3.2. Overview of reduction in childhood vaccination coverage in Brazil

The study evaluated the CVC reduction/increase in periods 1 (2018–2015), 2 (2020–2018), and finally, 3 (2022–2020). In period 1 investigated, a decrease in CVC was observed for all vaccines [BCG, hepatitis B, meningococcal C conjugate, 10-valent pneumococcal conjugate, oral poliovirus vaccine dose 1, Human rotavirus, and triple viral (MMR)], except for pentavalent and yellow fever vaccines, which followed an increasing trend reaching of, respectively, 1.03% and 13.19% (Figs. 1 and 2). The greatest decrease in CVC occurred in period 1 for meningococcal C conjugate vaccine (-9.70%), oral poliovirus vaccine dose 1 (-8.75%), and 10-valent pneumococcal conjugate vaccine (-7.81%) when pre-pandemic period with a government with left-wing political ideologies was in force (Figs. 1 and 2). In period 2 investigated, a decrease in CVC was observed for all vaccines, with a greater decrease in CVC for the hepatitis B vaccine (–22.63%), the BCG vaccine (–22.58%), and the Human rotavirus vaccine (-13.99%) when pre-pandemic period with a government with right-wing political ideologies was in force (Figs. 1 and 2). Next, a slight increase in CVC was observed in period 3 for four vaccines [hepatitis B (16.60%), BCG (12.67%), yellow fever (3.00%), and oral poliovirus vaccine dose 1 (0.33%)], and a slight decrease for the other ones [pentavalent (-0.62%), meningococcal C conjugate (-0.69%), 10-valent pneumococcal conjugate (-0.70%), Human rotavirus (-1.41%), and triple viral (MMR) (-3.44%)] (Figs. 1 and 2) when pandemic period with a government with right-wing political ideologies was in force.

3.3. Correlation between childhood vaccination coverage reduction and HDI (General, Education, Income, and Longevity) and the percentage (%) of valid votes for a government with right-wing political ideologies

Table 1 shows the HDI values and its components, as well as the percentage (%) of valid votes for ae government with right-wing political ideologies in the presidential elections (both rounds of the 2018 and 2022 elections) according to the federative units of the country. Table 2 presents the decreased/increased CVC values (%) in Brazil considering the different vaccines investigated and the moments selected for the study [Moment 1 (M1): from the year 2020 to the year 2018 (equal to period 2) and Moment 2 (M2): from the year 2022 to the year 2018 (equal to period 2 plus period 3)].

The Spearman correlation matrix between the percentage (%) of votes for right-wing political ideology and the CVC variation (%) per vaccine included in the study is shown in Fig. 3, while the correlation between the HDI values and its components with the CVC variation (%) is shown in Fig. 4. Positive correlation values indicate that the increase in the percentage (%) of votes or the HDI were responsible for the

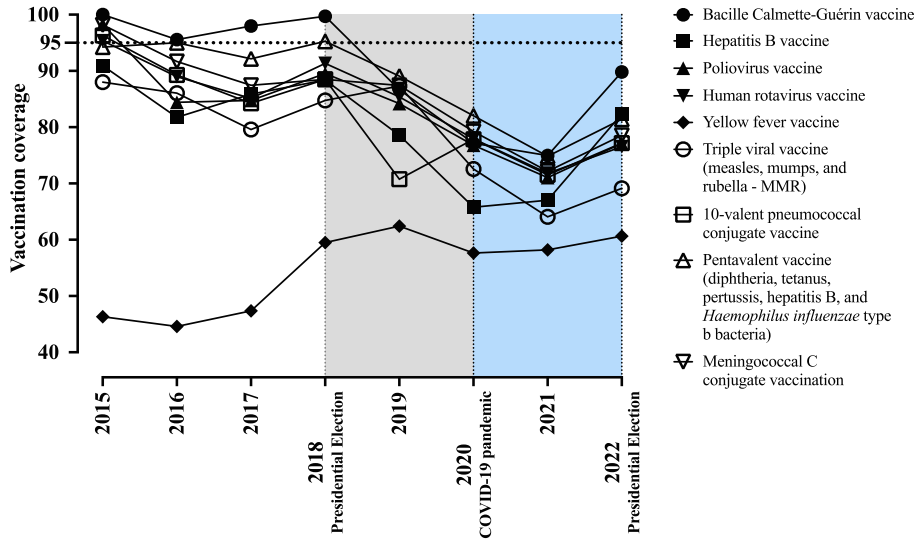

Fig. 1. Childhood vaccine coverage in Brazil considering the vaccines evaluated in the study. Each line indicates a vaccine and its evolution within the study period regarding vaccination coverage. The image shows a 95% coverage (horizontal broken line), which indicates one of the main metrics to evidence the vaccination campaign's success. Axis x shows the evaluation years and the following markers (continuous lines): (2018) presidential elections in Brazil; (2020) outbreak of the coronavirus disease (COVID)-19 pandemic in Brazil; and (2022) new presidential elections in Brazil. The data were obtained from the Data-SUS (Department of Informatics of the Brazilian Unified National Health System) to generate information from the Brazilian Unified Health System database (https://datasus.saude.gov.br/acesso-a-informacao/imunizacoes-desde-1994/; accessed on April 25th, 2023). 10-valent pneumococcal conjugate vaccine provides protection against the invasive pneumococcal disease, pneumonia, and acute otites media caused by *Streptococcus pneumoniae* of serotypes 1, 4, 5, 6B, 7F, 9V, 14, 18C, 19F, 23F, and serotype 19 (cross protection).

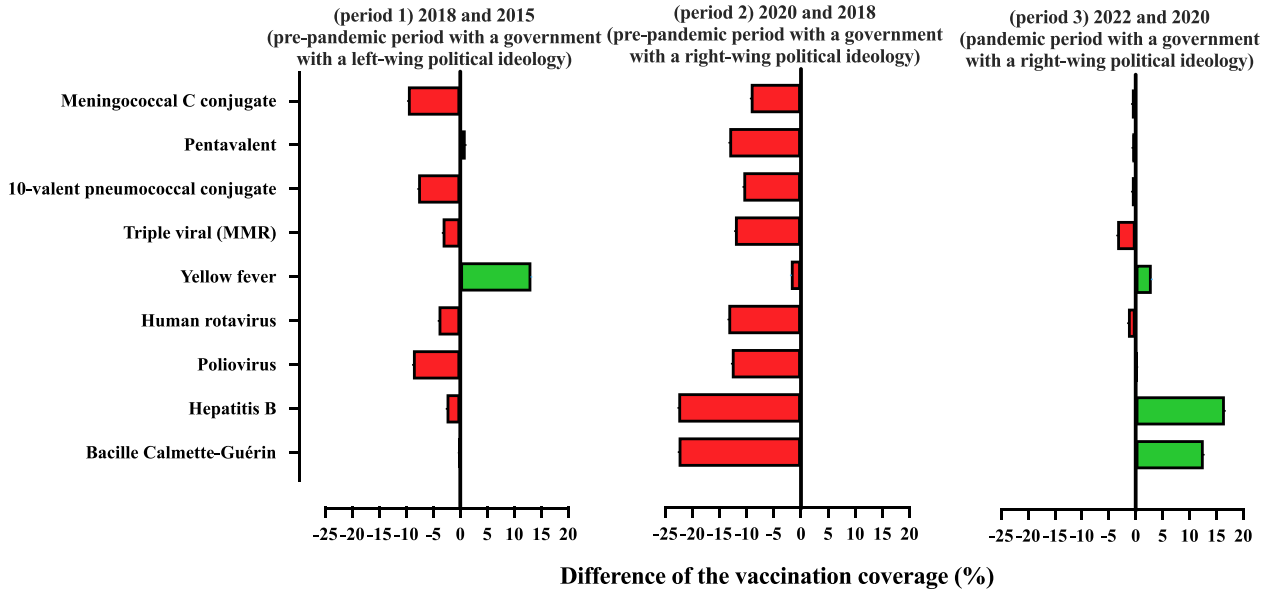

Fig. 2. Variation of the vaccination coverage (%) regarding the vaccines evaluated in the study. The data are presented by periods, as follows: (period 1) 2018 to 2015 (pre-pandemic period with a government with a left-wing political ideology), (period 2) 2020 to 2018 (pre-pandemic period with a government with a right-wing political ideology), and finally (period 3) 2022 to 2020 (pandemic period with a government with a right-wing political ideology). In this graph, negative values indicate that the difference between the years was associated with a decrease in the childhood vaccination coverage, that is, the initial values were higher than those observed in the other years (2018, 2020, and 2022). The data are presented using the percentage (%) of change in vaccination coverage between years. The green color indicates an increase in vaccination coverage; the red color indicates a decrease in vaccination coverage. The data were obtained from the Data-SUS (Department of Informatics of the Brazilian Unified National Health System) to generate information from the Brazilian Unified Health System database (https://datasus.saude.gov.br/acesso-a-informacao/imunizacoes-desde-1994/; accessed on April 25th, 2023). Pentavalent vaccine provides protection against diphtheria, tetanus, pertussis, hepatitis B, and *Haemophilus influenzae* type b bacteria; 10-valent pneumococcal conjugate vaccine provides protection against the invasive pneumococcal disease, pneumonia, and acute otitis media caused by *Streptococcus pneumoniae* of serotypes 1, 4, 5, 6B, 7F, 9V, 14, 18C, 19F, 23F, and serotype 19 (cross protection); triple viral vaccine provides protection against measles, mumps and rubella – MMR. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Table 1
Percentage (%) of votes for a government with a right-wing political ideology in the 2018 and 2022 presidential elections in Brazil and Human Development Index and its components in 2021 according to Brazilian federative units (States and Federal District).

States and Federal District***	2018* election		2022* election		Human Development Index**			
	1R	2R	1R	2R	General	Income	Education	Longevity
11 Rondônia	62.24	72.18	64.36	70.66	0.700	0.677	0.694	0.731
12 Acre	62.24	77.22	62.50	70.30	0.710	0.655	0.692	0.788
13 Amazonas	43.48	50.27	42.81	48.90	0.700	0.641	0.720	0.744
14 Roraima	62.97	71.55	69.57	76.08	0.699	0.680	0.673	0.745
15 Pará	36.19	45.19	40.27	45.25	0.690	0.645	0.686	0.744
16 Amapá	40.74	50.20	43.41	51.36	0.688	0.648	0.647	0.778
17 Tocantins	44.64	48.98	44.00	48.64	0.731	0.684	0.732	0.779
21 Maranhão	24.28	26.74	26.02	28.86	0.676	0.603	0.716	0.715
22 Piauí	18.76	22.95	19.90	23.14	0.690	0.649	0.698	0.726
23 Ceará	21.74	28.89	25.38	30.03	0.734	0.658	0.766	0.784
24 Rio Grande do Norte	30.21	36.59	31.02	34.90	0.728	0.692	0.680	0.819
25 Paraíba	31.30	35.02	29.62	33.38	0.698	0.653	0.669	0.779
26 Pernambuco	30.57	33.50	29.92	33.07	0.719	0.647	0.721	0.797
27 Alagoas	34.40	40.08	36.05	41.32	0.684	0.630	0.679	0.748
28 Sergipe	27.21	32.46	29.16	32.79	0.702	0.662	0.684	0.764
29 Bahia	23.41	27.31	24.31	27.88	0.691	0.648	0.659	0.772
31 Minas Gerais	48.31	58.19	43.60	49.80	0.774	0.718	0.762	0.846
32 Espírito Santo	54.76	63.06	52.23	58.04	0.771	0.715	0.742	0.864
33 Rio de Janeiro	59.79	67.95	51.09	56.53	0.762	0.759	0.758	0.769
35 São Paulo	53.00	67.97	47.71	55.24	0.806	0.771	0.839	0.810
41 Paraná	56.89	68.43	55.26	62.40	0.769	0.744	0.780	0.785
42 Santa Catarina	65.82	75.92	62.21	69.27	0.792	0.759	0.790	0.827
43 Rio Grande do Sul	52.63	63.24	48.89	56.35	0.771	0.767	0.750	0.797
50 Mato Grosso do Sul	55.06	65.22	52.70	59.49	0.742	0.733	0.741	0.751
51 Mato Grosso	60.04	66.42	59.84	65.08	0.736	0.720	0.758	0.730
52 Goiás	57.24	65.52	52.16	58.71	0.737	0.714	0.778	0.721
53 Federal District	58.37	69.99	51.65	58.81	0.814	0.821	0.817	0.803

1R, first round; 2R, second round.
*, Data regarding to the percentage of valid votes were obtained from the official data set published by the Superior Electoral Court of Brazil.
**, This dataset were obtained from the Atlas Brasil webpage (https://www.atlasbrasil.org.br/ranking; accessed on April 25th, 2023). The HDI values considering the country and its federative units were evaluated using four markers: (i) HDI-General, (ii) HDI-Income (dimension: decent standard of living; indicator: gross national income per capita), (iii) HDI-Longevity (dimension: long and healthy life; indicator: life expectancy at birth), and (iv) HDI-Education (dimension: knowledge; indicator: expected years of schooling and average years of schooling).
***, numeric codes represent the codes used by the Brazilian Institute of Geography and Statistics.

increase in the CVC reduction.

Regarding the percentage of votes obtained in the presidential elections in Brazil, the following data presented a statistically significant correlation (Fig. 3):

a) 1st round – 2022 with BCG vaccine – M2 [*P-value* = 0.046; CC = 0.388 (95%CI = (-)0.001 to 0.676) – low correlation index];
b) 1st round – 2018 with the yellow fever vaccine – M2 [*P-value* = 0.017; CC = 0.457 (95%CI = 0.081 to 0.789) – low correlation index];
c) 2nd round – 2018 with the yellow fever vaccine – M2 [*P-value* = 0.048; CC = 0.385 (95%CI = (-)0.006 to 0.674) – low correlation index];
d) 1st round – 2022 with the yellow fever vaccine – M2 [*P-value* = 0.009; CC = 0.494 (95%CI = 0.129 to 0.741) – low correlation index];
e) 2nd round – 2022 with the yellow fever vaccine – M2 [*P-value* = 0.008; CC = 0.498 (95%CI = 0.133 to 0.734) – low correlation index];
f) 1st round – 2018 with the pentavalent vaccine – M1 [*P-value* = 0.016; CC = (-)0.459 (95%CI = (-)0.720 to (-)0.083) – low correlation index];
g) 2nd round – 2018 with the pentavalent vaccine – M1 [*P-value* = 0.005; CC = (-)0.524 (95%CI = (-)0.759 to (-)0.168) – moderate correlation index];
h) 1st round – 2022 with the pentavalent vaccine – M1 [*P-value* = 0.010; CC = (-)0.485 (95%CI = (-)0.736 to (-)0.118) – low correlation index];
i) 2nd round – 2022 with the pentavalent vaccine – M1 [*P-value* = 0.013; CC = (-)0.471 (95%CI = (-)0.727 to (-)0.098) – low correlation index].

As for the HDI and its components, the following data presented a statistically significant correlation (Fig. 4):

a) HDI-Longevity with yellow fever vacccine – M1 [*P-value* = 0.004; CC = (-)0.537 (95%CI = (-)0.767 to (-)0.186) – moderate correlation index];
b) HDI-General with the pentavalent vacccine – M1 [*P-value* = 0.003; CC = (-)0.554 (95%CI = (-)0.777 to (-)0.210) – moderate correlation index];
c) HDI-Income with the pentavalent vacccine – M1 [*P-value* = 0.005; CC = (-)0.528 (95%CI = (-)0.721 to (-)0.173) – moderate correlation index];
d) HDI-Education with the pentavalent vacccine – M1 [*P-value* = 0.025; CC = (-)0.430 (95%CI = (-)0.703 to (-)0.049) – low correlation index];
e) HDI-Longevity with the 10-valent pneumococcal conjugate vaccine – M2 [*P-value* = 0.019; CC = 0.449 (95%CI = 0.072 to 0.714) – low correlation index];
f) HDI-General with the Human rotavirus – M1 vaccine [*P-value* = 0.015; CC = (-)0.465 (95%CI = (-)0.724 to (-)0.714) – low correlation index];
g) HDI-Income with the Human rotavirus vaccine – M1 [*P-value* = 0.038; CC = (-)0.402 (95%CI = (-)0.685 to (-)0.014) – low correlation index];

Table 2
Reduction in childhood vaccination coverage (%) in Brazil considering the different vaccines evaluated in the study and the selected moments (2020–2018 and 2022–2018)*,**.

States and Federal District***	BCG		YF		HB		MC		Penta		10P		Polio		Rota		MMR	
	M1	M2	M1	M2	M1	M2	M1	M2	M1	M2	M1	M2	M1	M2	M1	M2	M1	M2
11 Rondônia	18.53	6.39	17.43	19.79	20.70	29.2	14.27	14.00	14.15	17.30	22.71	5.79	16.92	20.22	13.20	13.56	15.93	21.52
12 Acre	29.13	20.56	17.29	12.46	27.09	17.89	9.29	1.99	5.96	1.66	5.43	10.47	15.90	19.55	16.34	12.95	26.65	23.64
13 Amazonas	5.05	3.03	9.61	7.74	4.29	9.58	2.19	1.25	13.49	0.71	17.32	8.99	8.33	10.29	8.85	8.35	19.32	20.13
14 Roraima	0.24	14.87	21.78	28.17	3.24	18.26	2.84	19.47	6.28	23.08	9.91	8.70	1.21	4.82	16.74	34.84	26.34	41.27
15 Pará	14.75	5.03	13.65	12.84	14.80	4.20	0.12	4.79	1.92	7.95	8.64	17.62	8.99	12.15	8.51	4.70	10.05	19.83
16 Amapá	9.33	10.31	28.14	21.14	8.35	3.64	18.50	11.70	23.30	10.55	17.50	9.44	8.06	6.91	28.58	22.06	25.45	22.13
17 Tocantins	8.05	0.00	9.45	11.43	10.56	0.00	7.08	8.34	2.37	4.93	11.43	19.77	8.34	4.93	9.28	9.21	9.54	18.39
21 Maranhão	34.19	16.68	20.55	13.67	35.36	18.14	14.38	4.56	28.74	6.16	4.47	9.11	13.58	11.98	20.63	13.72	15.46	10.43
22 Piauí	18.11	2.10	13.35	5.79	15.78	6.12	7.69	2.86	23.78	1.32	11.91	8.65	3.26	4.80	11.23	2.13	12.62	10.46
23 Ceará	29.78	0.00	8.72	50.96	32.06	3.16	8.01	14.12	15.42	13.45	47.80	65.08	17.28	16.61	9.51	16.77	16.74	21.72
24 Rio Grande do Norte	14.85	0.00	2.23	21.66	19.53	3.46	9.20	6.60	21.55	13.69	25.12	28.27	3.14	10.23	11.78	10.45	9.04	13.43
25 Paraíba	32.52	6.12	12.55	50.23	35.12	15.66	18.11	22.47	17.97	19.03	65.89	72.69	6.81	3.37	19.53	25.07	16.61	18.71
26 Pernambuco	20.72	1.08	26.73	51.48	21.86	8.97	18.90	17.82	23.92	17.68	60.45	69.30	8.85	8.71	21.48	22.17	20.62	21.40
27 Alagoas	27.85	0.00	5.80	52.16	33.43	4.97	23.70	13.56	20.88	11.88	57.13	65.72	8.59	6.91	22.10	14.41	20.61	14.23
28 Sergipe	22.15	0.00	0.25	18.88	22.94	1.82	17.29	8.39	17.55	11.38	20.70	27.27	6.57	9.56	21.22	14.33	14.84	10.45
29 Bahia	5.84	1.85	6.95	8.45	2.90	1.51	4.42	1.86	7.63	1.50	9.96	6.59	3.37	3.01	7.76	6.17	6.06	9.43
31 Minas Gerais	16.86	4.58	13.21	19.15	15.48	0.68	10.90	15.05	9.05	15.24	18.47	4.10	14.37	14.56	11.77	16.97	6.16	13.62
32 Espírito Santo	13.14	36.21	9.14	9.55	22.05	41.19	5.13	10.15	2.46	10.58	31.64	0.60	31.04	30.61	11.86	14.44	7.99	16.32
33 Rio de Janeiro	35.94	23.91	8.08	6.09	36.97	12.92	29.36	27.80	30.96	30.20	6.83	21.71	14.88	17.28	31.49	30.61	33.49	26.35
35 São Paulo	28.55	18.07	9.08	4.18	36.34	16.22	6.05	10.86	1.81	14.95	20.40	15.05	5.36	1.27	10.80	15.49	8.98	14.95
41 Paraná	7.96	7.92	0.35	1.54	4.89	17.58	2.40	4.94	2.53	6.13	19.12	3.41	22.52	23.71	4.89	7.59	4.53	8.67
42 Santa Catarina	9.53	7.81	18.10	12.63	7.32	4.79	1.89	3.17	5.92	7.10	17.42	15.80	1.62	2.31	4.42	6.01	1.15	4.15
43 Rio Grande do Sul	3.38	2.53	2.33	0.58	2.26	7.52	5.27	1.40	1.84	6.38	8.10	0.82	8.92	13.90	5.89	11.42	3.68	10.39
50 Mato Grosso do Sul	35.26	15.98	22.64	18.85	40.69	22.67	8.75	5.95	11.27	8.95	3.82	12.90	16.72	13.72	12.75	12.21	25.64	29.35
51 Mato Grosso	15.02	4.42	13.30	14.03	22.41	10.96	3.80	1.35	11.79	3.38	3.07	12.68	9.61	7.58	9.80	9.28	7.78	18.10
52 Goiás	13.42	14.00	12.29	15.02	11.03	3.45	5.64	7.54	7.30	7.71	11.57	7.48	4.09	4.26	8.01	9.43	9.54	14.84
53 Federal District	1.82	10.50	9.13	11.70	13.65	0.00	5.68	7.39	2.50	8.05	11.70	4.31	7.39	8.05	6.68	8.19	11.98	10.85

M1 (moment 1 – equal to period 2) decrease/increase of the adhesion in the vaccination calendar (pre-pandemic period and government with a right-wing political ideology) between the periods from 2020 to 2018 – aiming to evaluate only the influence of the ideological dispute, the discourses against coronavirus disease (COVID)-19 vaccination, and the political measures of the federal government to manage the health crisis and perform vaccination; M2 (moment 2 – equal to period 2 plus period 3) decrease/increase of the adhesion in the vaccination calendar (pre-pandemic and pandemic periods and government with a right-wing political ideology) between the periods from 2022 to 2018 – aiming to investigate the influence of a right-wing political ideology as described above and the outbreak of the COVID-19 pandemic; BCG, Calmette and Guérin bacillus vaccine; YF, yellow fever vaccine; HB, hepatitis B vaccine; MC, meningococcal C conjugate vaccine; penta, pentavalent (protecting against diphtheria, tetanus, pertussis, hepatitis B, and *Haemophilus influenzae* type b bacteria) vaccine; 10P, 10-valent pneumococcal conjugate [protecting against the invasive pneumococcal disease, pneumonia, and acute otitis media caused by *Streptococcus pneumoniae* of serotypes 1, 4, 5, 6B, 7F, 9V, 14, 18C, 19F, 23F, and 19A (cross protection)] vaccine; Polio, oral poliovirus vaccine dose 1; Rota, Human rotavirus vaccine; MMR, Triplice Viral (protecting against measles, mumps, and rubella) vaccine.

*Data were obtained from Data-SUS (Department of Informatics of the Brazilian Unified National Health System) to generate information from the data basis of the Brazilian Unified Health System (https://datasus.saude.gov.br/acesso-a-informacao/imunizacoes-desde-1994/; accessed on April 25th, 2023).

**Values marked in grey indicate that there was an increase in childhood vaccination coverage in the period evaluated. The data were presented in this format to favor the understanding of the correlation analysis between the markers.

***Numeric codes represent the codes used by the Brazilian Institute of Geography and Statistics.

h) HDI-Education with the Human rotavirus vaccine – M1 [*P-value* = 0.005; CC = (-)0.523 (95%CI = (-)0.758 to (-)0.167) – moderate correlation index];
i) HDI-General with the triple viral (MMR) vaccine – M1 [*P-value* = 0.018; CC = (-)0.451 (95%CI = (-)0.716 to (-)0.075) – low correlation index];
j) HDI-Income with the triple viral (MMR) vaccine – M1 [*P-value* = 0.029; CC = (-)0.421 (95%CI = (-)0.696 to (-)0.036) – low correlation index];
k) HDI-Education with the triple viral (MMR) vaccine – M1 [*P-value* = 0.033; CC = (-)0.411 (95%CI = (-)0.691 to (-)0.026) – low correlation index].

4. Discussion

The results reported in this article emphasize a growing concern regarding the evident deterioration of the globally recognized success history of childhood vaccination programs in Brazil, even before the COVID-19 pandemic onset in the country. The analyzed data revealed that several types of recognized vaccines that eradicated several diseases recorded a noticeable decrease in CVC, mainly after the election of right-wing political ideology in the Federal government and the COVID-19 outbreak, which generated a public health emergency in Brazil.

In the first months of the pandemic, Brazil already occupied the top positions in the number of confirmed cases and deaths due to COVID-19 and, following international protocols, social distancing was adopted throughout the country. However, adherence was partial, which reflected a scenario of conflicts between government authorities [mayors, governors, and president], in which the federal government aimed to return to routine as it did not consider it necessary to stop activities and social isolation [39]. As a consequence of this new virus, Brazil faced a health crisis that generated an increase in unemployment, an overload of health systems, and an increase in poverty [11,40]. Associated with this, Brazil did not have sufficient resources to diagnose the population, which may also have contributed to cases of underreporting, thus fostering a panorama of uncertainty regarding the real incidence and mortality rates in the country [40,41].

Faced with so many uncertainties, epidemiological divergences, political conflicts, and a long waiting time for the federal government to recognize the seriousness of the situation, the result could not be different: failures in the implementation of public policies aimed at controlling the disease (COVID-19). However, we cannot just hold the authorities responsible, given that part of the Brazilian population also contributed to the spread of fake news, in addition to the fact that there was low adherence by citizens to security measures [39,40]. With the development of vaccines, hope was reborn for a moment [10,40], but other challenges were to come: the scientific community developed a vaccine against COVID-19 in record time, but some conventional steps were skipped [as the objective was to immunize the population against the virus as quickly as possible], but not everyone supported such a measure, especially the former president, who claimed: I was already infected and I have antibodies. So, what's the point of taking the

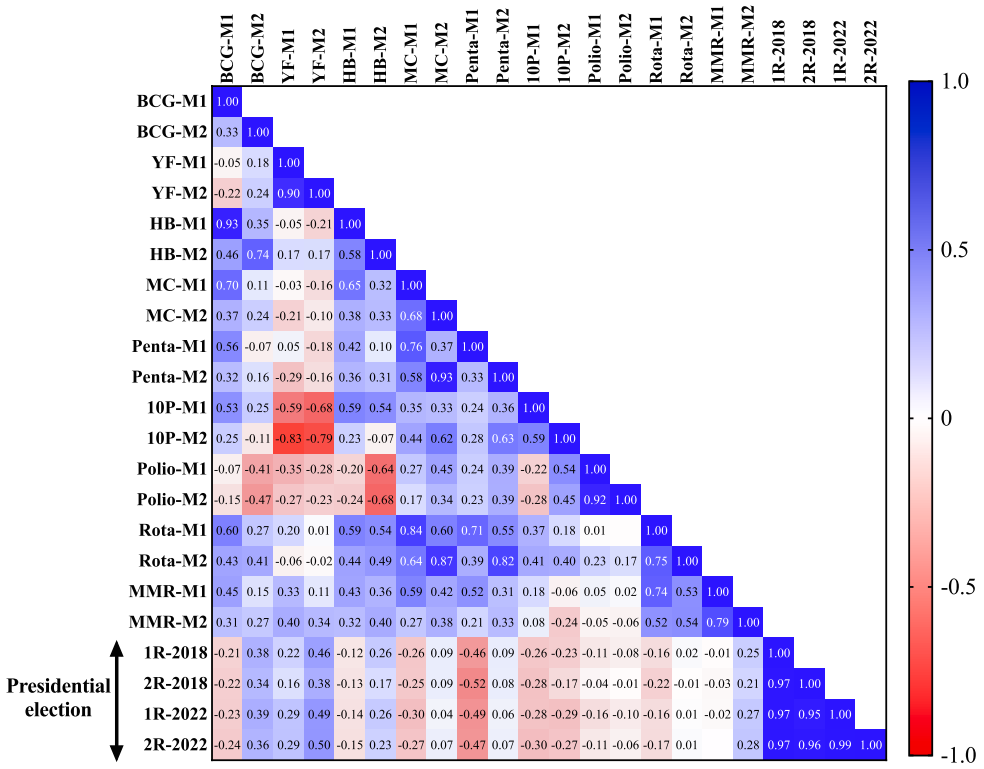

Fig. 3. Correlation matrix between the percentage (%) of votes for the government with a right-wing political ideology in Brazil and the variation of the childhood vaccination coverage (%) regarding the vaccines evaluated in this study. Positive correlation values indicate that the increase in the percentage (%) of votes was responsible for a greater reduction in the childhood vaccination coverage. Data acquisition: The data regarding the percentage of valid votes were obtained according to the official data published by the Brazilian Superior Electoral Court. Data on the childhood vaccination coverage were obtained from the Data-SUS (Department of Informatics of the Brazilian Unified National Health System) to generate information from the Brazilian Unified Health System database (https://datasus.saude.gov.br/acesso-a-informacao/imunizacoes-desde-1994/; accessed on April 25th, 2023). The statistical analysis was carried out using the Spearman correlation test. In the Spearman correlations, it was considered the following cut-off points: (i) ± 0.90–1.0, very high positive–negative correlation index; (ii) ± 0.70–0.90, high positive–negative correlation index; (iii) ± 0.50–0.70, moderate positive–negative correlation index; (iv) ± 0.30–0.50 low positive–negative correlation index; and (v) 0.00–0.30, insignificant positive–negative correlation index. A 0.05 alpha error was used in the statistical analysis. Significant values were described in the text. M1 (moment 1 – equal to period 2) decrease/increase of the adhesion in the vaccination calendar (pre-pandemic period and government with a right-wing political ideology) between the periods from 2020 to 2018 – aiming to evaluate only the influence of the ideological dispute, the discourses against the coronavirus disease (COVID)-19 vaccination, and the political measures of the federal government to manage the health crisis and perform vaccination; M2 (moment 2 – equal to period 2 plus period 3) decrease/increase of the adhesion in the vaccination calendar (pre-pandemic and pandemic periods and government with a right-wing political ideology) between the periods from 2022 to 2018 – aiming to investigate the influence of a right-wing political ideology as described above and the outbreak of the COVID-19 pandemic; BCG, Calmette and Guérin bacillus vaccine; YF, yellow fever vaccine; HB, hepatitis B vaccine; MC, meningococcal C conjugate vaccine; penta, pentavalent (protecting against diphtheria, tetanus, pertussis, hepatitis B, and *Haemophilus influenzae* type b bacteria) vaccine; 10P, 10-valent pneumococcal conjugate [protecting against the invasive pneumococcal disease, pneumonia, and acute otitis media caused by *Streptococcus pneumoniae* of serotypes 1, 4, 5, 6B, 7F, 9V, 14, 18C, 19F, 23F, and 19A (cross protection)] vaccine; Polio, oral poliovirus vaccine dose 1; Rota, Human rotavirus vaccine; Triplice viral [protecting against measles, mumps, and rubella – MMR] vaccine; 1R, first; 2R, second round. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article).

vaccine? [10].

The former president also contributed to the spread of fake news and, using various media outlets, stated that he would not vaccinate his daughter. On several occasions, he questioned the effectiveness of vaccines and the scientific evidence for their commercialization, in addition to not supporting the recommendations proposed by the WHO [42,43], such as social isolation and the use of masks [10]. This type of behavior from a government authority may have influenced the Brazilian population's vaccine hesitancy in recent times, considering that this phenomenon includes cultural, religious, and political issues and disbelief in medicine. However, it is worth highlighting the need for educational awareness among the Brazilian people, considering that denial is often motivated by erroneous interpretations of the safety of vaccines [26,42].

The misuse of social media leads to the spread of anti-vaccine movements, in which there are those who believe that the pharmaceutical industry only aims for profit and does not care about the side effects resulting from vaccination [26]. The former president also contributed by instilling fear in people, in which he exposed that empty coffins were being buried and that COVID-19 was nothing more than the flu [10]. It is suggested that the Brazilian population is influenced by fake news and in the literature, it was mentioned that hesitancy to vaccinate children is greater among young mothers and fathers with a low educational level [11,44]. Thus, the speeches and attitudes of a former governor who minimized the pandemic, associated with a low degree of education and prolonged exposure to social media can be considered factors that drive low adherence to vaccination, as there are supporters of the former president who reproduced his speeches and behaviors [44].

One study specifically analyzed the impact of COVID-19 on CVC in Brazil and its findings confirmed the results reported in our study, showing that the pandemic had a negative impact on CVC [8]. The results of the presidential election in Brazil also contributed to the population's low adherence to vaccination campaigns against COVID-19,

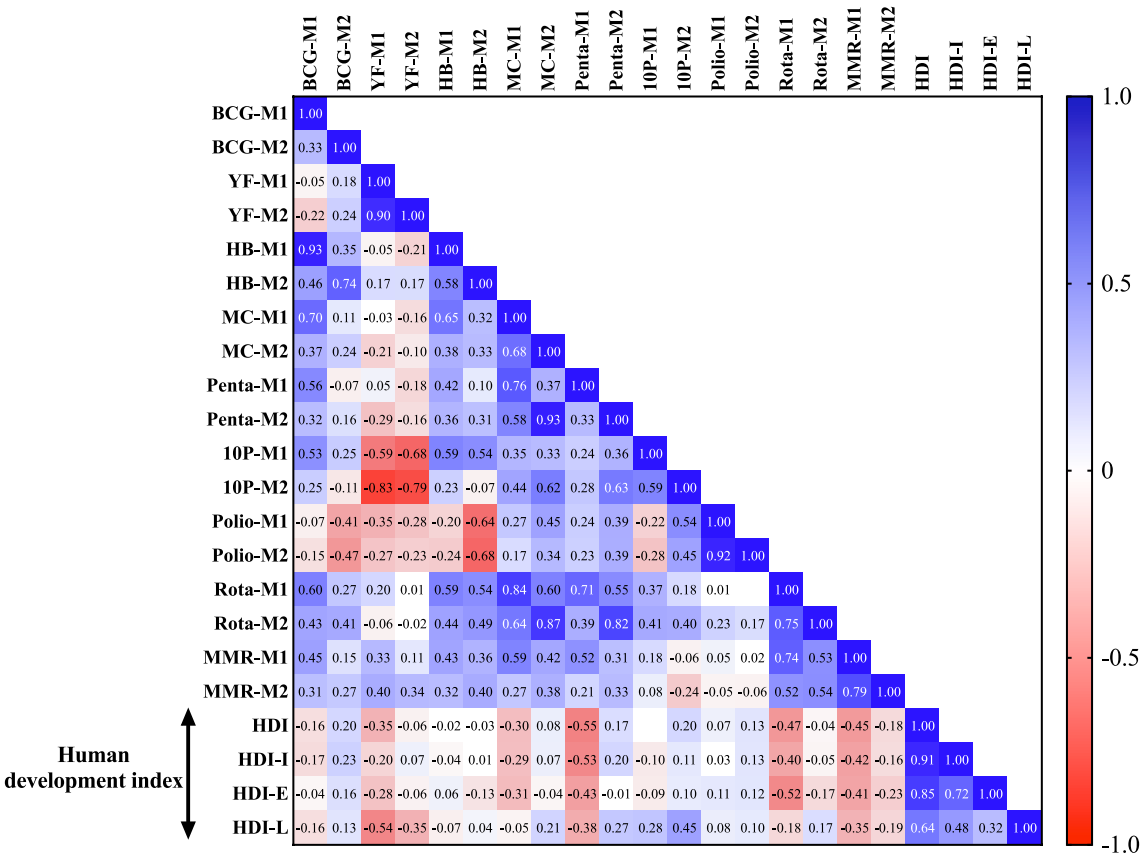

Fig. 4. Correlation Matrix between the Human Development Index [HDI (General) and its components: HDI-I (Income), HDI-E (Education), and HDI-L (Longevity) and the variation in childhood vaccination coverage (%) for the vaccines evaluated in the study. Positive correlation values indicate that increased HDI percentage was responsible for a greater reduction in the childhood vaccination coverage. Significant values were described in the text. Data acquisition: The data set was obtained from the Atlas Brasil webpage (http://www.atlasbrasil.org.br/ranking; accessed on April 25th, 2023). Data referring to the vaccination coverage rates were obtained from the Data-SUS (Department of Informatics of the Brazilian Unified National Health System) to generate information from the Brazilian Unified Health System database (https://datasus.saude.gov.br/acesso-a-informacao/imunizacoes-desde-1994/; accessed on April 25th, 2023). The statistical analysis was carried out using the Spearman correlation test. In the Spearman correlations, it was considered the following cut-off points: (i) ± 0.90–1.0, very high positive–negative correlation index; (ii) ± 0.70–0.90, high positive–negative correlation index; (iii) ± 0.50–0.70, moderate positive–negative correlation index; (iv) ± 0.30–0.50 low positive–negative correlation index; and (v) 0.00–0.30, insignificant positive–negative correlation index. A 0.05 alpha error was used in the statistical analysis. M1 (moment 1 – equal to period 2) decrease/increase of the adhesion in the vaccination calendar (pre-pandemic period and government with a right-wing political ideology) between the periods from 2020 to 2018 – aiming to evaluate only the influence of the ideological dispute, the discourses against the coronavirus disease (COVID)-19 vaccination, and the political measures of the federal government to manage the health crisis and perform vaccination; M2 (moment 2 – equal to period 2 plus period 3) decrease/increase of the adhesion in the vaccination calendar (pre-pandemic and pandemic periods and government with a right-wing political ideology) between the periods from 2022 to 2018 – aiming to investigate the influence of a right-wing political ideology as described above and the outbreak of the COVID-19 pandemic; BCG, Calmette and Guérin bacillus vaccine; YF, yellow fever vaccine; HB, hepatitis B vaccine; MC, meningococcal C conjugate vaccine; penta, pentavalent (protecting against diphtheria, tetanus, pertussis, hepatitis B, and *Haemophilus influenzae* type b bacteria) vaccine; 10P, 10-valent pneumococcal conjugate [protecting against the invasive pneumococcal disease, pneumonia, and acute otitis media caused by *Streptococcus pneumoniae* of serotypes 1, 4, 5, 6B, 7F, 9V, 14, 18C, 19F, 23F, and 19A (cross protection)] vaccine; Polio, oral poliovirus vaccine dose 1; Rota, Human rotavirus vaccine; Triplice viral [protecting against measles, mumps, and rubella – MMR] vaccine. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article).

since the former president neglected the severity of the disease, disseminated the use of non-validated medications to treat it, and did not invest in public health policies [11]. As a result of the government's negationist attitude, the population started to doubt the effectiveness of vaccines and CVC rates dropped even before the pandemic period and during the pandemic period remained low over time [8,45].

Within such context, it was verified that the 10-valent pneumococcal conjugate vaccine, which was pre-qualified by the WHO in 2009 [46] and included in the Brazilian vaccination calendar for all children under two years old in 2010 [47], showed Brazil as a pioneer in its vaccination calendar with 95% related CVC. However, in 2022, its coverage decreased to ~ 80%. Data collected in Finland, where the same vaccine was introduced in their National Vaccination Program in 2010, showed a great positive impact of this vaccine, with efficacy estimated to be ~ 93% [48,49]. Likewise, in the Netherlands, the 10-valent pneumococcal conjugate vaccine is highly efficient regarding its action in the protection of children below five years old against pneumococcal diseases, with limited serotype substitution after the substitution of the 7-valent pneumococcal conjugate with the 10-valent pneumococcal conjugate vaccine [50]. These findings reveal the importance of this vaccine, since pneumococcal infections are a serious public health issue around the world, causing high morbidity and mortality in small children who suffer from diseases such as pneumonia, meningitis, and sepsis, which might result in up to a million deaths in children below five years old [51,52].

Before the COVID-19 pandemic onset and during the COVID-19 pandemic, the pentavalent and triple viral (MMR) vaccines also recorded a significant decrease in application. When analyzing the pentavalent vaccine data, for example, evidence showed that the chances of getting pertussis up to 2018 were higher. However, one study showed

that the vaccination hesitation became a relevant factor in the significant increase of babies and children at high risk of being affected by pertussis. It has been suggested that there is a higher probability of children with pertussis not having been vaccinated, rather than having only been partly vaccinated, which might result in a worrying trend called "intentional childhood unvaccination". The existence of such a phenomenon might be explained by several factors including philosophical, religious, or personal beliefs, cultural norms, lack of vaccination schedule, and hesitation related to vaccine suppliers [53]. All these factors suggest that there might have been a decrease in the pertussis CVC during the pandemic in Brazil. When analyzing the pandemic impacts on the triple viral (MMR) vaccine scheme in the country, it seems relevant to emphasize that children's vaccination was negatively affected. A UNICEF report from 2019 warned the community that over 20 million children worldwide had not been properly vaccinated, which raised concern about the appearance of measles cases since this disease could be easily prevented by vaccination. One evident example of this concern was observed in Argentina, where there was a measles outbreak in late August 2019, indicating evidence of a possible vaccination hesitation and that the CVC reduction has created risk for the population [54].

Other vaccines reported, such as pentavalent/hexavalent (protecting against diphtheria, tetanus, pertussis, poliomyelitis, *Haemophilus influenzae* type b bacteria, and hepatitis B), measles and BCG vaccines already showed CVC reduction in some Latin-American countries even before the pandemic, showing that adherence the vaccination calendar is a dynamic and multifactorial process, and the COVID-19 pandemic reinforced a worse scenario in vaccination adherence [7]. It seems relevant to mention that the data found in Latin America are similar to the findings from Europe and the United States of America since the COVID-19 pandemic promoted a reduction in vaccination coverage regarding vaccines included in the childhood vaccination calendar [19,55].

Unlike the other vaccines, the yellow fever vaccine presented a significant CVC increase during the COVID-19 pandemic, with only a slight reduction during period 2, where the unique factor evaluated was the change to a right-wing political ideology in the Federal government in Brazil. This fact might be associated with the intensification of vaccination due to the re-emergence of the yellow fever virus in Brazil, along with the increased number of cases in humans and epizootic diseases in non-human apes [56]. In addition, the mandatory to present proof of vaccination (International Certificate of Vaccination and Prophylaxis) to travel to some countries contributed to the increase in vaccination [57]. Although some tropical areas are free of this disease transmission, the virus might still find favorable ecological conditions for its propagation, which might include high population density, environmental factors, and the competence of the disease vector [58]. Thus, aiming to prevent the risk of introduction or reintroduction of the virus in other places, the WHO International Health regulations recommend this vaccine to any person traveling to areas at risk for yellow fever, except for those with counterindication as reported in the literature [59].

Although there is no doubt that vaccinating a great part of the population can protect the whole group due to "flock immunity" or "collective immunity", which reduces the circulation of the pathogen among immunized individuals, such process has been harmed by the unjustified increase in resistance to vaccination. This results in low vaccination rates, mainly regarding childhood vaccination [60,61]. In addition to the pandemic impact, other factors affecting Latin America include the high birth rate, lack of access to health services, and lack of resources in the health area [7].

Vaccines have been used safely for a long time and since they have practically extinguished several diseases, some people consider their use unnecessary. The absence of diseases prevented by these vaccines made most people ignore their importance, while the lack of trust in their effects generated fear in relation to the diseases that vaccines prevent [62]. Moreover, parents tend to worry about the number of vaccines applied in a single visit to the health service, which might provoke (expected) side effects. Such concern might lead to refusal or delay in complying with full coverage of the childhood vaccination calendar [63]. Thus, how can we evaluate accurately the sharp decrease in the vaccination coverage in Brazil?

Some factors were identified that may explain the childhood vaccination decrease in a country considered a model of vaccination coverage such as Brazil. They can be described as follows: a) the COVID-19 pandemic has exponentially increased childhood vaccination hesitation, mainly due to the influence of a political-ideological anti-vaccine movement; b) widespread publication and circulation of fake news, causing disinformation, mainly regarding side effects associated with the vaccination, which resulted in the creation of official agencies directing to the WHO and the European Center for Disease Prevention and Control to prevent disinformation; c) personal beliefs mainly associated with previous experiences with different vaccines; d) concern about the risks and benefits of vaccination, mainly due to lack of knowledge about this topic; and e) barriers associated to religion, gender, socioeconomic, and cultural conditions [16,31,63–72]. In this sense, it was interesting to notice that many times the vaccine became a victim of its own success since illnesses that became rare or absent were thought to make the vaccination unnecessary. Thus, considering the scenario presented, it is fundamental to elaborate and implement strategies seeking to broaden the efforts of government agencies along with society to prevent the vaccination hesitation from scaring the population. Adopting guidelines of coordinated response between the government agencies is necessary to provide planning, set schedules, and broad and suitable dissemination of information. Such guidelines should be expanded aiming to strengthen epidemiological surveillance, guarantee access to vaccination, and strengthen the ability of states and municipalities to keep the CVC all over the country. In addition, public health experts, medical doctors, and individuals who defend vaccination must unite to fight the dissemination of misinformation and correct false statements, mainly those found online. The social media companies can also help to stop misinformation, by implementing and applying policies that limit the dissemination of this type of information on their platforms [73].

5. Conclusions

Although Brazil has kept a successful and exemplary history of combat to several diseases, mainly as a result of the CVC efficiency, the steady decrease in this coverage must be thoroughly analyzed by public health managers in the country. Many factors might be associated with the reduction in the adhesion to children's vaccination, they might include socioeconomic and political issues. Thus, public health managers must be attentive to the need to promote information to guide the population, mainly parents and guardians of young children, aiming to prevent worse health conditions from affecting this age group.

Declarations

Ethics approval and consent to participate: The Ethics Committee of São Francisco University approved the research [Certificate of Presentation of Ethical Review no 67241323.0.0000.5514].

Funding

JPM received a study grant from *Conselho Nacional de Desenvolvimento Científico e Tecnológico* (Brazilian National Council for Scientific and Technological Development), grant number 8887.823904/2023–00.

CRediT authorship contribution statement

Jéssica Paula Martins: Conceptualization, Data curation,

Investigation, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing. **Giulia Almeida Alatzatianos:** Conceptualization, Investigation, Resources, Validation, Visualization, Writing – original draft, Writing – review & editing. **Tais Mendes Camargo:** Conceptualization, Data curation, Validation, Writing – original draft, Writing – review & editing. **Fernando Augusto Lima Marson:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available upon request.

Acknowledgments

We acknowledge Lono Rinaldi Foutie Varejão for the assistance in revising the English version of the study.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jvacx.2024.100430.

References

[1] Domingues CMAS, Maranhão AGK, Teixeira AM, Fantinato FFS, Domingues RAS. The Brazilian National Immunization Program: 46 years of achievements and challenges. Cad Saude Publica. 2020;36Suppl 2 Suppl 2:e00222919.
[2] Barreto ML, Teixeira MG, Bastos FI, Ximenes RAA, Barata RB, Rodrigues LC. Successes and failures in the control of infectious diseases in Brazil: social and environmental context, policies, interventions, and research needs. Lancet 2011;377:1877–89.
[3] PNI: entenda como funciona um dos maiores programas de vacinação do mundo. Ministério da Saúde. https://www.gov.br/saude/pt-br/assuntos/noticias/2022/agosto/pni-entenda-como-funciona-um-dos-maiores-programas-de-vacinacao-do-mundo. Accessed 2 Aug 2023.
[4] Programa Nacional de Imunizações - Vacinação. Ministério da Saúde. https://www.gov.br/saude/pt-br/acesso-a-informacao/acoes-e-programas/programa-nacional-de-imunizacoes-vacinacao/programa-nacional-de-imunizacoes-vacinacao. Accessed 2 Aug 2023.
[5] Programa Nacional de Imunizações é um marco histórico na saúde pública brasileira. Fiocruz. https://portal.fiocruz.br/noticia/programa-nacional-de-imunizacoes-e-um-marco-historico-na-saude-publica-brasileira. Accessed 2 Aug 2023.
[6] Sato APS. Pandemic and vaccine coverage: challenges of returning to schools. Rev Saude Publica. 54:115.
[7] Castrejon MM, Leal I, de Jesus Pereira Pinto T, Guzmán-Holst A. The impact of COVID-19 and catch-up strategies on routine childhood vaccine coverage trends in Latin America: A systematic literature review and database analysis. Hum Vaccin Immunother. 18:2102353.
[8] Moura C, Truche P, Sousa Salgado L, Meireles T, Santana V, Buda A, et al. The impact of COVID-19 on routine pediatric vaccination delivery in Brazil. Vaccine 2022;40:2292–8.
[9] Marson F a. L, Ortega MM. COVID-19 in Brazil. Pulmonology. 2020;26:241–4.
[10] Boschiero MN, Palamim CVC, Ortega MM, Mauch RM, Marson FAL. One Year of Coronavirus Disease 2019 (COVID-19) in Brazil: A Political and Social Overview. Ann Glob Health 2021;87:44.
[11] Martins JP, Siqueira BA, Sansone NMS, Marson FAL. COVID-19 in Brazil: A Three-Year Update. Diagn Microbiol Infect Dis 2023;116074.
[12] Li M, Wang H, Tian L, Pang Z, Yang Q, Huang T, et al. COVID-19 vaccine development: milestones, lessons and prospects. Signal Transduct Target Ther 2022;7:146.
[13] Ralise AEG, Camargo TM, Marson FAL. Phase 4 clinical trials in the era of the Coronavirus Disease (COVID-19) pandemic and their importance to optimize the COVID-19 vaccination. Hum Vaccin Immunother 2023;19:2234784.
[14] Uso emergencial: confira votos, relatório e apresentações da reunião — Agência Nacional de Vigilância Sanitária - Anvisa. https://www.gov.br/anvisa/pt-br/assuntos/noticias-anvisa/2021/confira-materiais-da-reuniao-extraordinaria-da-dicol. Accessed 2 Aug 2023.
[15] Entenda a ordem de vacinação contra a Covid-19 entre os grupos prioritários. Ministério da Saúde. https://www.gov.br/saude/pt-br/assuntos/noticias/2021/janeiro/entenda-a-ordem-de-vacinacao-contra-a-covid-19-entre-os-grupos-prioritarios. Accessed 2 Aug 2023.
[16] Boschiero MN, Palamim CVC, Marson FAL. The hindrances to perform the COVID-19 vaccination in Brazil. Hum Vaccin Immunother. 17:3989–4004.
[17] Comirnaty bivalente (Pfizer) — Agência Nacional de Vigilância Sanitária - Anvisa. https://www.gov.br/anvisa/pt-br/assuntos/paf/coronavirus/vacinas/comirnaty-bivalente-pfizer. Accessed 2 Aug 2023.
[18] Sansone NMS, Boschiero MN, Darrieux M, Marson F a L. Effectiveness of influenza vaccination against coronavirus disease (COVID)-19 outcomes in hospitalized individuals in Brazil: an epidemiological study. Public Health 2023;225:8–11.
[19] Bramer CA, Kimmins LM, Swanson R, Kuo J, Vranesich P, Jacques-Carroll LA, et al. Decline in child vaccination coverage during the COVID-19 pandemic - Michigan Care Improvement Registry, May 2016-May 2020. Am J Transplant 2020;20:1930–1.
[20] Contarino F, DI Pietro E, Bella F, Randazzo C, Contrino ML. Childhood immunization coverage during the COVID-19 pandemic in the province of Siracusa, Italy. J Prev Med Hyg. 2022;63:E513–9.
[21] Kim S, Headley TY, Tozan Y. Universal healthcare coverage and health service delivery before and during the COVID-19 pandemic: A difference-in-difference study of childhood immunization coverage from 195 countries. PLoS Med 2022;19:e1004060.
[22] Martínez-Marcos M, Zabaleta-Del-Olmo E, Gómez-Durán E-L, Reñé-Reñé A, Cabezas-Peña C. Impact of the COVID-19 lockdown on routine childhood vaccination coverage rates in Catalonia (Spain): a public health register-based study. Public Health 2023;218:68–74.
[23] Moreno-Montoya J, Ballesteros SM, Rojas Sotelo JC, Bocanegra Cervera CL, Barrera-López P, De la Hoz-Valle JA. Impact of the COVID-19 pandemic on routine childhood immunisation in Colombia. Arch Dis Child 2022;107:e4.
[24] Nelson R. COVID-19 disrupts vaccine delivery. Lancet Infect Dis 2020;20:546.
[25] Maciel E, Fernandez M, Calife K, Garrett D, Domingues C, Kerr L, et al. The SARS-CoV-2 vaccination campaign in Brazil and the invisibility of science evidences. Cien Saude Colet 2022;27:951–6.
[26] de Oliveira IS, Cardoso LS, Ferreira IG, Alexandre-Silva GM, de Jacob BC da S, Cerni FA, et al. Anti-vaccination movements in the world and in Brazil. Rev Soc Bras Med Trop 2022;55:e0592.
[27] Boschiero MN, Palamim CVC, Marson F a L. COVID-19 vaccination on Brazil and the crocodile side-effect. Ethics Med. Public Health 2021;17:100654.
[28] Massarani LM, Leal T, Waltz I, Medeiros A. Infodemia, desinformação e vacinas: a circulação de conteúdos em redes sociais antes e depois da COVID-19. Liinc em Revista 2021;17:e5689–.
[29] Moore DCBC, Nehab MF, Camacho KG, Reis AT, Junqueira-Marinho M de F, Abramov DM, et al. Low COVID-19 vaccine hesitancy in Brazil. Vaccine 2021;39:6262–8.
[30] Chaves ÍE de S, Brito PRP, Rodrigues JGB de A, Costa MS, Cândido EL, Moreira MRC. Hesitation regarding the COVID-19 vaccine among medical students in Brazil. Rev Assoc Med Bras (1992). 2021;67:1397–402.
[31] Galhardi CP, Freire NP, Fagundes MCM, Minayo MC de S, Cunha ICKO. Fake News and vaccine hesitancy in the COVID-19 pandemic in Brazil. Cien Saude Colet 2022;27:1849–58.
[32] Fernandes Q, Inchakalody VP, Merhi M, Mestiri S, Taib N, Moustafa Abo El-Ella D, et al. Emerging COVID-19 variants and their impact on SARS-CoV-2 diagnosis, therapeutics and vaccines. Ann Med 2022;54:524–40.
[33] A pandemia de Covid-19 leva a um grande retrocesso na vacinação infantil, mostram novos dados da OMS e do UNICEF. https://www.unicef.org/brazil/comunicados-de-imprensa/pandemia-de-covid-19-leva-a-um-grande-retrocesso-na-vacinacao-infantil. Accessed 2 Aug 2023.
[34] Immunization coverage. https://www.who.int/news-room/fact-sheets/detail/immunization-coverage. Accessed 2 Aug 2023.
[35] Imunizações – desde 1994 – DATASUS. https://datasus.saude.gov.br/acesso-a-informacao/imunizacoes-desde-1994/. Accessed 2 Aug 2023.
[36] Atlas Brasil. http://www.atlasbrasil.org.br/ranking. Accessed 2 Aug 2023.
[37] de Azevedo LVF, Cruz FCRM, Martins JP, Marson FAL. Cystic Fibrosis: A Descriptive Analysis of Deaths in a Two-Decade Period in Brazil According to Age, Race, and Sex. Diagnostics (Basel) 2023;13:763.
[38] Palamim CVC, Boschiero MN, Valencise FE, Marson FAL. Human Development Index Is Associated with COVID-19 Case Fatality Rate in Brazil: An Ecological Study. Int J Environ Res Public Health 2022;19:5306.
[39] Marson FAL. COVID-19 – 6 million cases worldwide and an overview of the diagnosis in Brazil: a tragedy to be announced. Diagn Microbiol Infect Dis 2020;98:115113.
[40] Lima TM, Palamim CVC, Melani VF, Mendes MF, Pereira LR, Marson FAL. COVID-19 Underreporting in Brazil among Patients with Severe Acute Respiratory Syndrome during the Pandemic: An Ecological Study. Diagnostics (Basel) 2022;12:1505.
[41] Palamim CVC, Siqueira BA, Boschiero MN, Marson FAL. Increase in COVID-19 underreporting among 3,282,337 Brazilian hospitalized patients due to SARS: A 3-year report and a major concern for health authorities. Travel Med Infect Dis 2023;54:102616.
[42] Seara-Morais GJ, Avelino-Silva TJ, Couto M, Avelino-Silva VI. The pervasive association between political ideology and COVID-19 vaccine uptake in Brazil: an ecologic study. BMC Public Health 2023;23:1606.
[43] Daniels JP. Health experts slam Bolsonaro's vaccine comments. Lancet 2021;397:361.

[44] Gramacho W, Turgeon M, Santos Mundim P, Pereira I. Why did Brazil fail to vaccinate children against COVID-19 during the pandemic? An assessment of attitudinal and behavioral determinants. Vaccine. 2023;:S0264-410X(23)01432-9.
[45] Xavier DR, Lima E Silva E, Lara FA, E Silva GRR, Oliveira MF, Gurgel H, et al. Involvement of political and socio-economic factors in the spatial and temporal dynamics of COVID-19 outcomes in Brazil: A population-based study. Lancet Reg Health Am. 2022;10:100221.
[46] Centers for Disease Control and Prevention (CDC). Invasive pneumococcal disease in young children before licensure of 13-valent pneumococcal conjugate vaccine - United States, 2007. MMWR Morb Mortal Wkly Rep. 2010;59:253–7.
[47] Manual de Normas e Procedimentos para Vacinação.
[48] Rinta-Kokko H, Auranen K, Toropainen M, Nuorti JP, Nohynek H, Siira L, et al. Effectiveness of 10-valent pneumococcal conjugate vaccine estimated with three parallel study designs among vaccine-eligible children in Finland. Vaccine 2020;38:1559–64.
[49] Rinta-Kokko H, Palmu AA, Auranen K, Nuorti JP, Toropainen M, Siira L, et al. Long-term impact of 10-valent pneumococcal conjugate vaccination on invasive pneumococcal disease among children in Finland. Vaccine 2018;36:1934–40.
[50] Peckeu L, van der Ende A, de Melker HE, Sanders E a. M, Knol MJ. Impact and effectiveness of the 10-valent pneumococcal conjugate vaccine on invasive pneumococcal disease among children under 5 years of age in the Netherlands. Vaccine. 2021;39:431–7.
[51] O'Brien KL, Wolfson LJ, Watt JP, Henkle E, Deloria-Knoll M, McCall N, et al. Burden of disease caused by Streptococcus pneumoniae in children younger than 5 years: global estimates. Lancet 2009;374:893–902.
[52] Pneumococcal conjugate vaccine for childhood immunization–WHO position paper. Wkly Epidemiol Rec. 2007;82:93–104.
[53] Phadke VK, Bednarczyk RA, Salmon DA, Omer SB. Association Between Vaccine Refusal and Vaccine-Preventable Diseases in the United States. JAMA 2016;315:1149–58.
[54] Lüthy IA, Kantor IN. Measles. Medicina (B Aires) 2020;80:162–8.
[55] Chiappini E, Parigi S, Galli L, Licari A, Brambilla I, Angela Tosca M, et al. Impact that the COVID-19 pandemic on routine childhood vaccinations and challenges ahead: A narrative review. Acta Paediatr 2021;110:2529–35.
[56] Giovanetti M, de Mendonça MCL, Fonseca V, Mares-Guia MA, Fabri A, Xavier J, et al. Yellow Fever Virus Reemergence and Spread in Southeast Brazil, 2016–2019. J Virol 2019;94:e01623–1719.
[57] Capa CIVP — Agência Nacional de Vigilância Sanitária - Anvisa. https://www.gov.br/anvisa/pt-br/assuntos/paf/certificado-internacional-de-vacinacao. Accessed 2 Aug 2023.
[58] Reno E, Quan NG, Franco-Paredes C, Chastain DB, Chauhan L, Rodriguez-Morales AJ, et al. Prevention of yellow fever in travellers: an update. Lancet Infect Dis 2020;20:e129–37.
[59] Hamer DH, Angelo K, Caumes E, van Genderen PJJ, Florescu SA, Popescu CP, et al. Fatal Yellow Fever in Travelers to Brazil, 2018. MMWR Morb Mortal Wkly Rep 2018;67:340–1.
[60] André FE. Vaccinology: past achievements, present roadblocks and future promises. Vaccine 2003;21:593–5.
[61] Hakim H, Provencher T, Chambers CT, Driedger SM, Dube E, Gavaruzzi T, et al. Interventions to help people understand community immunity: A systematic review. Vaccine 2019;37:235–47.
[62] Salmon DA, Dudley MZ, Glanz JM, Omer SB. Vaccine Hesitancy: Causes, Consequences, and a Call to Action. Am J Prev Med 2015;49(6 Suppl 4):S391–8.
[63] McClure CC, Cataldi JR, O'Leary ST. Vaccine Hesitancy: Where We Are and Where We Are Going. Clin Ther 2017;39:1550–62.
[64] Lafnitzegger A, Gaviria-Agudelo C. Vaccine Hesitancy in Pediatrics. Adv Pediatr Infect Dis 2022;69:163–76.
[65] Kricorian K, Civen R, Equils O. COVID-19 vaccine hesitancy: misinformation and perceptions of vaccine safety. Hum Vaccin Immunother 2022;18:1950504.
[66] Dubé È, Ward JK, Verger P, MacDonald NE. Vaccine Hesitancy, Acceptance, and Anti-Vaccination: Trends and Future Prospects for Public Health. Annu Rev Public Health 2021;42:175–91.
[67] Fedele F, Aria M, Esposito V, Micillo M, Cecere G, Spano M, et al. COVID-19 vaccine hesitancy: a survey in a population highly compliant to common vaccinations. Hum Vaccin Immunother 2021;17:3348–54.
[68] Cataldi JR, O'Leary ST. Parental vaccine hesitancy: scope, causes, and potential responses. Curr Opin Infect Dis 2021;34:519–26.
[69] de Medeiros PM, Muniz de Medeiros P. Fake news mediate the relationship between sociopolitical factors and vaccination intent in Brazil. Health Promot Int. 2022;37:daac110.
[70] Neto M, Lachtim SAF. COVID-19 Vaccination Campaign: Fake News Infodemic. Rev Bras Enferm 2022;75:e750401.
[71] Wilson SL, Wiysonge C. Social media and vaccine hesitancy. BMJ Glob Health 2020;5:e004206.
[72] Montagni I, Ouazzani-Touhami K, Mebarki A, Texier N, Schück S, Tzourio C, et al. Acceptance of a Covid-19 vaccine is associated with ability to detect fake news and health literacy. J Public Health (Oxf) 2021;43:695–702.
[73] Garett R, Young SD. Online misinformation and vaccine hesitancy. Transl Behav Med 2021;11:2194–9.