SPATIAL ANALYSIS OF VACCINE COVERAGE FOR CHILDREN UNDER ONE YEAR OF AGE IN PERNAMBUCO

ANÁLISE ESPACIAL DA COBERTURA VACINAL DE MENORES DE UM ANO NO ESTADO DE PERNAMBUCO

ANÁLISIS ESPACIAL DE LA COBERTURA DE VACUNACIÓN DE MENORES DE UN AÑO EN EL ESTADO DE PERNAMBUCO

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ABSTRACT

To analyze vaccination coverage in children under one year of age in the state of Pernambuco. This is an ecological, quantitative study that analyzes and manages spatial/temporal data on vaccination coverage of three immunizers in children under one year of age in the state of Pernambuco. The temporal panorama of childhood vaccination in the state between 2012 and 2021, indicates that sharp drops in vaccination were recorded for the three immunizers (BCG, Poliomyelitis and Human Rotavirus). The reintroduction of eradicated diseases (measles and polio), as well as the Covid-19 pandemic, have accentuated the drops in childhood VC in Brazil, recorded since 2015. In this sense, it is essential for the SUS to promote equitable access for the population to primary health services. In other words, despite their success, vaccines do not dispense with the continuity of other health actions, especially prevention and promotion measures carried out in Primary Care.
Keywords: *Vaccination Coverage; National Immunization Program; Spatio-temporal Analysis.*

RESUMO

Analisar a cobertura vacinal em menores de um ano no estado de Pernambuco. Estudo ecológico, quantitativo, com análise e gerenciamento de dados espaço-temporais da cobertura vacinal de três imunizantes em menores de um ano no estado de Pernambuco. O panorama temporal da vacinação infantil no estado indica que, entre os anos de 2012 e 2021, foram registradas quedas bruscas na vacinação para os três imunizantes (BCG, Poliomielite e Rotavírus humano). A reintrodução de doenças erradicadas (sarampo e poliomielite), bem como a pandemia de Covid-19, acentuaram as quedas na CV infantil no Brasil, registradas desde 2015. Nesse sentido, torna-se primordial para o SUS promover o acesso equitativo da população aos serviços primários à saúde. Isto é, apesar de bem-sucedidas, as vacinas não dispensam a continuidade de outras ações em saúde, especialmente as medidas de prevenção e promoção realizadas na Atenção Primária.
Descritores: *Cobertura Vacinal; Programa Nacional de Imunização; Análise Espaço-temporal.*

RESUMEN

Analizar la cobertura de vacunación en menores de un año en el estado de Pernambuco. Estudio ecológico, cuantitativo, con análisis y gestión de datos espacio-temporales de la cobertura de vacunación de tres inmunizantes en menores de un año en el estado de Pernambuco. El panorama temporal de la vacunación infantil en Brasil indica que, entre los años 2012 y 2021, se registraron caídas bruscas en la vacunación para los tres inmunizantes (BCG, Poliomielitis y Rotavirus humano). La reintroducción de enfermedades erradicadas (sarampión y poliomielitis), así como la pandemia de Covid-19, acentuaron las caídas en la CV infantil en Brasil, registradas desde 2015. En este sentido, se vuelve primordial para el SUS promover el acceso equitativo de la población a los servicios primarios de salud. Es decir, a pesar de ser exitosas, las vacunas no dispensan la continuidad de otras acciones en salud, especialmente las medidas de prevención y promoción realizadas en la Atención Primaria.
Descriptores: *Cobertura Vacunal; Programa Nacional de Inmunización; Análisis Espacio-temporal.*

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INTRODUCTION

The National Immunization Program (PNI), created in 1973, has become a world reference in the control and eradication of diseases. In other words, this program is currently "the reflection" of the Brazilian Health System as well as of the Welfare State[1]. Currently, through the PNI, the population in the national territory has free access to all vaccines considered essential by the World Health Organization - WHO, being administered at the primary level of health care for the entire population (newborns, children, adolescents, adults and the elderly). There are 19 immunizers that fight more than 20 diseases[2].

So many advances have resulted in the greatest success in immunization with the eradication of poliomyelitis (infantile paralysis) in 1989, measles in 2015 and the elimination of smallpox from all over the planet[2]. However, in 2022, measles returned to the spotlight after a new outbreak, with 700 new cases confirmed in the states of Roraima, Amazonas, Rio de Janeiro, São Paulo, Rio Grande do Sul, Rondônia, and Pará, according to data from the Ministry of Health[3]. As for poliomyelitis, the Ministry of Health warned that more than 300 municipalities face the risk of the disease returning as a result of low vaccination rates[3].

Regarding the study period, this study collected information on the vaccination coverage of children under one year of age, before, during, and after the Covid-19 pandemic (2012-2021), which was responsible for the morbidity and mortality of millions of people worldwide, configuring itself as the epicenter of attention of health managers and workers[4]. Due to the impact of Covid-19 on the reallocation of human and material resources to combat its expansive advance throughout the national territory, other services and actions were put on the back burner, as was the case with Primary Care, and some of its main actions (such as vaccination)[5].

However, it should be noted that the present study cannot state that the Covid-19 pandemic directly caused the reduction in vaccination coverage in children under 1 year of age, and can only elucidate that there is a significant association6. Therefore, the objective of this study was to analyze vaccination coverage in children under one year of age in the state of Pernambuco. Using secondary data provided by the PNI Information System (SI-PNI), of the Department of Informatics of SUS-DATASUS.

METHODS

This is an ecological[7] study with a quantitative approach, which seeks to analyze the spatial distribution of vaccination coverage of children under one year of age (12 months) in the state of Pernambuco. The study population consisted of all children under one year of age (12 months) from the 184 municipalities of the state of Pernambuco, except for Fernando de Noronha Island.

All children under one year of age (12 months) of both sexes with a complete vaccination schedule were included in the study. Data collection was carried out on the website of the SUS - Department of Informatics of SUS (DataSUS), for the collection of Vaccination Coverage rates, the Information System of the National Immunization Program (SI-PNI) was used, in addition to the National System of Live Births for the population estimate of children under one year of age in the state[8].

It is considered essential to evaluate all immunobiologicals in the childhood vaccination schedule, recommended by the Ministry of Health. However, the present study selected three vaccines from the basic schedule, considering the warnings of the Pernambuco State Department of Health, on the history of low VC in children in the state, for the following immunobiologicals: vaccine against Bacillus of Calmette and Guérin (BCG); vaccine against poliomyelitis (VIP - inactivated) and human rotavirus, with rates below 70% (when the Ministry of Health's target is 95%)[9].

For a descriptive analysis of vaccination coverage, a comparative study was conducted between the three immunobiologicals and their temporal pattern over the years (2012-2021). The results are shown in a table, with relative frequencies (percentage) containing the vaccination targets (of the PNI by immunobiological), the years, the description of the immunobiological and its evolution over time. The purpose of this analysis is to compare which vaccines have reached the vaccination targets, which years have decreased, in which immunobiologicals the state has reached the vaccination target.

After collection, a database was created containing the state's cartographic data, vaccination coverage, and the local empirical Bayesian estimator. The spatial analysis of the data was performed in the TerraView software, from the National Institute for Space Research (INPE), to perform the local empirical Bayesian rates. Gross rates were obtained through the *Microsoft Office* Excel. After the analysis, thematic maps of the municipalities were constructed, where the spatial distribution of vaccination coverage in the years analyzed will be identified[10].

The adoption of the empirical Bayesian method of local smoothing presupposes the creation of a neighborhood matrix between the municipalities of the state, defined by an adjacency created from the Terraview Geographic Information System (GIS). In this sense, the method allows the researcher to develop a view of the territorial distribution of the disease or morbidity and mortality, expressed through the calculation of indicators, such as crude and smoother detection rates[10]. The method makes it possible to evaluate the differences between territorial areas (municipalities, states, neighborhoods) by identifying clusters with underreporting of cases or areas with high and medium risk of illness or development of an expanding phenomenon, through a real scenario[10].

This project does not consist of clinical, epidemiological or experimental research with humans and/or animals, and is aimed at the analysis of public and aggregated information from the Department of Informatics of the SUS. According to Resolution 510/2015 of CONEP, its submission is waived.

RESULTS

According to the Brazilian Institute of Geography and Statistics (IBGE), in 2022, the population of the state of Pernambuco is 9,051,113 inhabitants. Of these, 1,364,381 children were born in the state during the period from 2012 to 2021, 64,561 males and 61,632 females in 2021 (BRASIL, 2023).

The use of time series analysis (or historical series) was used to identify periods in which childhood vaccination had low coverage in the state of Pernambuco.

Table 1- Vaccination Coverage Indicator (%) in children under 1 year of age in the state of Pernambuco, according to immunizer, 2012-2021.

YEARS	POLIO Vaccination Coverage (%)	BCG Vaccination Coverage (%)	HUMAN ROTAVIRUS Vaccination Coverage (%)
2012	90,53	100,08	106,89
2013	94,63	101,06	105,68
2014	97,19	101,68	108,55
2015	100,78	109,29	110,06
2016	93,79	90,38	98,90
2017	83,35	84,67	97,25
2018	95,24	94,72	106,53
2019	86,73	85,64	92,07
2020	73,76	72,78	79,28
2021	68,76	69,01	82,62

Source: Sinan Online (Database updated on 26/04/2023). Sinan Net (Database updated on (31/03/2023).

There was a sharp drop in VC for the three immunizers, BCG in 2012 (100.08%) coverage for (69.01%) in 2021, Poliomyelitis in 2012 (90.53%), in 2021 it fell to (68.76%) and the human Rotavirus vaccine, which dropped from (106.89%) in 2012 to only (82.62%) in 2021. It is noteworthy that the PNI considers adequate coverage of 95% of the target audience.

The use of the Bayesian methodology was used to obtain information on the vaccination coverage of children under one year of age in the state of Pernambuco, in addition to locally estimating the spatial distribution of vaccination coverage of three immunobiologicals (human rotavirus, BCG and poliomyelitis) in children under one year of age.

Considering the administrative division of the 184 municipalities of Pernambuco, and the new management model with the creation of the 12 Regional Health Administrations (GERES) of the state. The study data were analyzed according to this division, and are described according to their headquarters: I Regional Health Management (Recife headquarters); II Regional Health Management (Limoeiro headquarters); III Regional Health Management (Palmares headquarters); IV Regional Health Management (Caruaru headquarters); V Regional Health Management (Garanhuns headquarters); VI Regional Health Management (Arcoverde headquarters); VII Regional Health Management (Salgueiro headquarters); VIII Regional Health Management (Petrolina headquarters); IX Regional Health Management (Ouricuri headquarters); X Regional Health Management (Afogados da Ingazeira headquarters); XI Regional Health Management (Serra Talhada headquarters); XII Regional Health Management (Goiana headquarters).

Figure 1 - Pernambuco's territorial division for health.

**Source:** Pernambuco Regionalization Master Plan, 2011.

SPATIAL DISTRIBUTION OF THE VC INDICATOR (BCG) IN THE STATE OF PERNAMBUCO, IN 2021

The BCG vaccine was created in 1921 by Albert Calmette and Camille Guerin, and since then it has been used to protect against and prevent cases of tuberculosis (TB) in humans, especially the most severe ones (*miliary tuberculosis and tuberculous meningitis*). Worldwide, tuberculosis is considered a serious public health problem. It is estimated that the disease affects 8.8 million people annually. The first person to receive a dose of the vaccine was in 1921 when they tested a child born to a mother with TB, as a result, the child did not develop the disease. It was only in 1927 that the vaccine was introduced in Brazil, brought by Arlindo de Assis[4].

The pattern of spatial distribution of vaccination coverage shows that of the 184 municipalities in the state, 44 (forty-four) had high vaccination coverage, with concentration in IX GERES and VII GERES, it is important to highlight that the metropolitan region that administratively corresponds to I GERES, presented a minimum standard of coverage when compared to other areas such as III and V GERES.

In **figure 2,** it is possible to identify municipalities with color (light blue), showed lower vaccination coverage, as is the case of Ouricuri, Araripina, Petrolina, Lagoa Grande, Santa Maria da Boa vista, Salgueiro, Flores, Triunfo, Santa Cruz da baixa verde and Tabira, Sertânia, Arcoverde, Buíque, Águas belas, Itaíba, Petrolândia, Pesqueira, Belo Jardim, Brejo da Madre de Deus, Santa Cruz do Capibaribe, Caruaru, Bezerros, Gravatá, Frei Miguelinho, Garanhuns and Correntes. In addition to these, regional I has a similar pattern, being composed of the municipalities of Abreu e Lima, Araçoiaba, Cabo de Santo Agostinho, Camaragibe, Chã Grande, Chã de Alegria, Glória de Goitá, Fernando de Noronha, Igarassu, Ipojuca, Itamaracá, Itapissuma, Jaboatão dos Guararapes, Moreno, Olinda, Paulista, Pombos, Recife, São Lourenço da Mata and Vitória de Santo Antão.

Figure 2 - Bayesian rate of vaccination coverage (BCG) in children under 1 year of age in the state of Pernambuco, 2021.
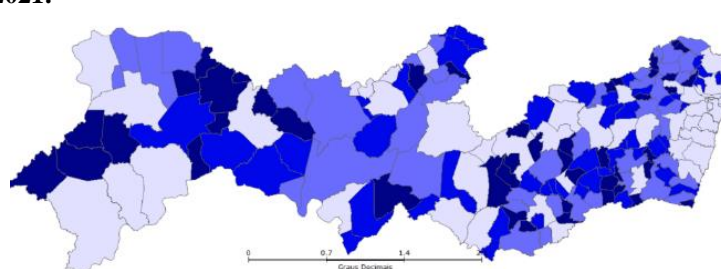
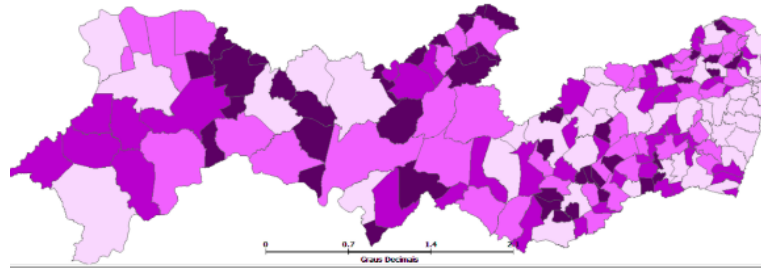**Source**: Authors' Production.

SPATIAL DISTRIBUTION OF THE VACCINATION COVERAGE INDICATOR (HUMAN ROTAVIRUS) IN THE STATE OF PERNAMBUCO, IN 2021

Rotavirus (RNA virus of the Reoviridae family, of the genus Rotavirus) is a viral agent that causes the so-called acute diarrheal diseases (ADD), and is the cause of severe cases of diarrhea in children under five years of age in developing countries. Although everyone is susceptible to the virus, children under five years of age are the most affected by the disease, in addition, newborns have milder or asymptomatic symptoms. The method of prevention is the administration of the human rotavirus G1P1[8] vaccine

(attenuated) in children under 1 year of age. The vaccination schedule occurs in two oral doses (first at 2 months and the second at 4 months of age)[5].

After analyzing the data using the Bayesian local smoothing model, it is noted that the distribution of the rates of the vaccination coverage indicator for human Rotavirus are less fragmented, and areas with a higher concentration of coverage identified by the darker colors can be identified **(Figure 3),** in all, there are 46 municipalities located mainly in the VII GERES (Serrita; Cedro; Terra Nova; Orocó; Verdejante; Mirandiba), XI GERES (Carnaubeira da penha; Itacuruba; Betânia; Calumbi e Santa Cruz da baixa verde), X GERES (Quixaba; Solidão; Ingazeira; Iguaraci; Iuperatama; Itapeti), V GERES (Paranatama; Saloá; Terezinha; Brejão; Jucati; Jupi; Calçado), IV GERES (Ibirajuba; Poção; Alagoinha), III GERES (Belém de Maria; Junqueira; São Benedito do Sul), II GERES (Vertentes; Machados; Buenos Aires; Lagoa do Carro; Tracunhanhém) e a XII GERES (Ferreiros e Camutanga).

Figure 3- Bayesian rate of vaccination coverage (human rotavirus) in children under 1 year of age in the state of Pernambuco, 2021.

Source: Authors' Production.

SPATIAL DISTRIBUTION OF THE VACCINATION COVERAGE INDICATOR (POLIOMYELITIS) IN THE STATE OF PERNAMBUCO, IN 2021

Poliomyelitis, popularly known as infantile paralysis, is an acute and contagious disease, caused by Poliovirus. The disease can affect both children and adults and, in the most severe cases, cause paralysis of the lower limbs. The form of transmission can occur through the direct contact with feces or secretions eliminated from the mouth of sick people and may or may not cause paralysis.

The only prevention measure is vaccination. The target audience is children under 5 years old. The scheme has been carried out since 2016, with three doses of the vaccine in injectable form: VIP (2, 4 and 6 months) and two more booster doses with the bivalent oral vaccine – VOP. In Brazil, through the vaccination campaigns carried out by the National Immunization Program (PNI), the disease has been eradicated since 1994, and there is no circulation of wild poliovirus in the country. However, in some countries the disease is still endemic, with 5 cases recorded in Afghanistan and Pakistan[5].In February 2022, the Malawian authorities in Africa warned of an outbreak of wild poliovirus (type 1), posing a collective risk to the entire population, through the infection of a 3-year-old child[6].

The results found in the study show that polio vaccination coverage varied between 2012 (90.53%) and 2021 (68.76%), with a significant drop since 2015. The

spatial analysis revealed, through the crude rates, that vaccination coverage was reached by approximately 44 municipalities throughout the state. These municipalities are mainly concentrated in X GERES (Itapetim; Brejinho; Santa Terezinha; São José do Egito; Tuparetama; Iguaraci; Solidão; Carnaíba e Quixaba), XI GERES (Macaparana; Itambé; Flores; Calumbi; Betânia);

VI GERES (Custódia; Inajá; Jatobá), VII GERES (Cedro; Serrita), XI GERES (Ipubi), VIII (Lagoa grande; Afrânio), IV GERES (Poção; Alagoinha; Sanharó; Tacaimbó), V GERES (Jucati; Jupi; Calçado; Brejão; Saloá; Iati; Brejão), IV GERES (São Joaquim do monte; Cupira), III GERES (Jaqueira), II GERES (Vertentes do Lério; João Alfredo; Salgadinho; Passira; Limoeiro; Machados; Lagoa do carro; Feira nova; Paudalho; Lagoa do Itaenga; Lagoa do Carro) e a I GERES (Glória do Goitá).

Figure 4 - Bayesian rate of vaccination coverage (Poliomyelitis) in children under 1 year of age in the state of Pernambuco, 2021.
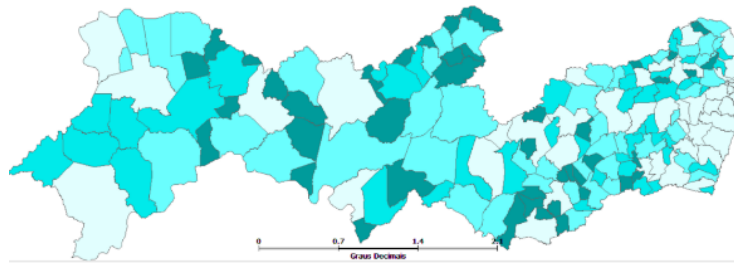
Source: Authors' Production.

DISCUSSION

Immunization is the most relevant method of preventing infectious diseases worldwide, through vaccination the population has been able to extinguish diseases that killed millions of people, in addition to reducing the incidence of numerous preventable diseases. Being considered the safest and most effective technology in the elimination and control of diseases, vaccination has been able to extinguish and reduce the incidence of various morbidity and mortality worldwide, especially in children in vulnerable countries[11].

With a geographical, social, cultural and economic impact on the lives of the population, vaccines can cause events at both the individual and collective levels. However, despite scientific evidence, some manifestations around the world have challenged the notion that vaccines are fundamental for disease control, which is the current public health problem[12-13].

In Brazil, the National Immunization Program (PNI) is considered a world reference in vaccination. Created in 1973, it became responsible for ensuring that the entire population has access to immunobiologicals considered essential, free of charge and decentralized in Primary Health Care services. That is, regardless of age, education, race/color or social class, vaccination is a constitutional right[14].

The PNI uses as an indicator of vaccination coverage the proportion of the target population that received the complete vaccine schedule. It is considered a sensitive indicator of the vulnerability of individuals. Currently, the PNI has incorporated 14

immunobiologicals into the childhood vaccination schedule - eight of them vaccines for children under 1 year of age, intended to prevent about 12 diseases[15].

In a recent study, researchers warned of a downward trend in the number of immunizations in Brazil[11]. The results show decreases of 0.9%, 1.3% and 2.7% per year for BCG, poliomyelitis and MMR, respectively. In addition, another characteristic found in the study refers to the heterogeneity among the Brazilian municipalities analyzed in the study. Therefore, these are the main vaccines (BCG; Polio; and MMR) that have caused alarm, due to the recent registration of new cases in some regions of the country, as is the case of measles.

For some authors, vaccines are important prevention tools in public health, however, they are not enough to combat/solve the complexity involved in the protection and prevention of diseases. In fact, even if successful, vaccines do not dispense with the continuity of other health actions, especially prevention and promotion measures carried out in Primary Care[16-13].

Millions of lives are saved annually due to vaccine prevention[17]. It is the vaccines, therefore, that prevent millions of deaths and illnesses in different parts of the world, and these are the most comprehensive representation of public health. Therefore, the vaccine represents an individual right, which, when manifested, results in collective responsibility[18].

Prior to the pandemic period (Covid 19 pandemic, registered in Brazil in 2020), some publications brought up the importance of maintaining the childhood vaccination schedule during this period. The concern about the return of diseases with the drop in the use of health services, especially Primary Care, was sufficient to emphasize the drastic drop in vaccination in all countries due to social distancing measures4. In a recent study[19], vaccination coverage rates in children under 12 months of age between 2013 and 2020 were analyzed. The findings indicate that among the years analyzed, levels below those recommended by the Ministry of Health were recorded.

In fact, the pandemic has changed the lives of countless people around the world, imposing new rules of social distancing, the impacts on mental health, work and the demand for health services, have brought new forms of communication through social media, whether for communication, school activities or news dissemination[20]. As a result, the circulation of fake news about vaccines on the internet in recent years has several sources of news circulation, on social networks (Facebook, Twitter and Whatsapp) with a high potential for dissemination to the community[21].

The false perception that we are free of some diseases was enough to instigate the invalidation of vaccines. In a recent study, 60% of parents said they postponed vaccination for children under 1 year of age due to the pandemic[19]. In this scenario, Primary Care becomes fundamental as a potential protagonist in the fight against diseases and fake news, and can have a significant impact, through the agreement of health surveillance and prevention measures, working with the PNI to reduce the risks of recurrence of recent cases of poliomyelitis, measles and severe cases of tuberculosis in children[22].

However, it should be noted that the recent "dismantling" of Primary Care was responsible for the difficulty of PHC providing adequate support in surveillance and

health promotion actions to face this new wave of diseases (especially after the Covid 19 pandemic), since there are countless attempts to dismantle this service, namely: the implementation of the new primary care financing model, based on payment by number of registrations; the reduction of Community Health Agents (CHA); the extinction of the More Doctors Program and the Expanded Family Health Center (NASF-AB23-24).

Currently, this is one of the greatest challenges for public health in Brazil, as health care services are facing a new threat, which is the return of diseases that have already been overcome or fought. The work of PHC can be systematized in four axes[25]: carrying out health surveillance activities in the territories; pay attention to users who are already sick; and provide social support to vulnerable groups. Discussing this role makes it possible to find new ways to manage the current situation, create paths, and define responsibilities for teams.

In addition, the Family Health Strategy (FHT) and Multiprofessional Teams (for the municipalities that have them) can perform some actions aimed at improving the performance of PHC, they are: the dissemination of available vaccines to the community; the monitoring of the vaccination card and the active search for absentees to update the vaccination card; as well as, the implementation of health education actions with a view to informing the population about the importance of vaccination[26-27].

CONCLUSION

Research on vaccination coverage is an important tool to help reduce the great challenge of effective vaccination coverage through equitable access, taking into account the differences between the municipalities of Pernambuco. It is believed that the present study may provide information for the area of public health, in order to contribute to the planning of health programs and actions, and may foster discussions between health managers and professionals on the subject, for the proper establishment of strategies aimed at expanding vaccination coverage in the state, as well as promoting the population's access to primary health services.

It is noteworthy that the data obtained in the study were collected from the SUS Information Technology Department, which performs the vaccination coverage indicator according to the registry of the municipalities, considering the total doses applied, divided by the number of people in the target population of the vaccine. In this sense, it is highlighted that this may be a weakness of the present study, since these values may undergo changes that underestimate or overestimate the vaccination coverage data, and may not reflect the reality of the municipalities.

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