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DTaP vaccination coverage in pregnant women: ecological study

Cobertura vacinal de dTpa em gestantes: estudo ecológico

Cobertura de vacunación con dTpa en mujeres embarazadas: estudio ecológico

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ABSTRACT

Objective: to determine DTaP vaccine coverage among pregnant women in the state of Paraná. **Method: an** ecological spatial study using secondary source data from the DataSUS website. The data were organized and tabulated in Microsoft Excel® and analyzed using the GeoDa® software. **Results:** few Paraná regions reached the Ministry of Health's recommendation of 95% coverage. Among the periods considered, the 2018-2019 biennium stood out with the highest number of municipalities that recorded adequate coverage. A progressive increase in the rate was observed between 2014 and 2019, followed by a decrease in the following two years. **Conclusion:** DTaP vaccination coverage increased in the first five years after its implementation; however, the action of several social, political and epidemiological factors resulted in a reduction in the vaccination coverage for this immunobiological during 2020 and 2021.

Descriptors: Pregnancy; Vaccination; Vaccination Coverage; Immunization Schedule; Diphtheria-Tetanus-acellular Pertussis Vaccines.

RESUMO

Objetivo: determinar a cobertura da vacina dTpa em gestantes no estado do Paraná. **Método:** estudo ecológico do tipo espacial, utilizando dados de fonte secundária do *website* DataSUS. Os dados foram organizados e tabulados no Microsoft Excel® e analisados através do software GeoDa®. **Resultados:** poucas regionais do Paraná atingiram a indicação do Ministério da Saúde de cobertura de 95%. Dentre os períodos considerados, destacou-se o biênio 2018-2019 com o maior número de municípios que registraram coberturas adequadas. Observou-se aumento progressivo da taxa entre os anos de 2014 a 2019, seguido por queda nos dois anos seguintes. **Conclusão:** a cobertura vacinal de dTpa apresentou uma crescente nos cinco primeiros anos após sua implantação, contudo, a atuação de diversos fatores sociais, políticos e epidemiológicos, resultou na queda da cobertura vacinal deste imunobiológico nos anos de 2020 e 2021.

Descritores: Gravidez; Vacinação; Cobertura Vacinal; Esquemas de Imunização; Vacina contra Difteria, Tétano e Coqueluche Acelular.

RESUMEN

Objetivo: determinar la cobertura de la vacuna dTpa en embarazadas del estado de Paraná. **Método:** estudio ecológico espacial, utilizando datos de fuentes secundarias del sitio web DataSUS. Los datos fueron organizados y tabulados en Microsoft Excel® y el análisis se realizó con el soporte del software GeoDa®. **Resultados:** pocas regiones de Paraná alcanzaron el porcentaje indicado por el Ministerio de Salud que recomienda una cobertura del 95%. Entre los períodos considerados, el bienio 2018-2019 se destacó con el mayor número de municipios que registraron una cobertura adecuada. Se observó un aumento progresivo de la tasa entre 2014 y 2019, seguido de una disminución en los dos años siguientes. **Conclusión:** la cobertura de vacunación con dTpa aumentó en los primeros cinco años de su implementación; sin embargo, la acción de varios factores sociales, políticos y epidemiológicos resultó en una caída en la cobertura de vacunación para este inmunobiológico en los años 2020 y 2021.

Descriptores: Embarazo; Vacunación; Cobertura de Vacunación; Esquemas de Inmunización; Vacunas contra Difteria, Tétanos y Tos Ferina Acelular.

INTRODUCTION

The importance of immunobiologicals is evidenced by the reduction in morbidity and mortality due to vaccine-preventable diseases[1]. Currently, 48 immunobiologicals are made available free of charge by the Unified Health System (*Sistema Único de Saúde*, SUS) in Brazil[2]. However, some studies have shown a decrease in Vaccination Coverage (VC), especially during the COVID-19 pandemic years[3,4].

Vaccination during pregnancy is an important strategy for protecting mothers and fetuses alike, as the gestational period is permeated by many physical and emotional changes that weaken women's immune status, rendering them more susceptible to various diseases, in addition to the fact that they may be more frequently exposed to infectious agents, making it essential that they are immunized against hepatitis, influenza and tetanus[5].

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Vaccination in pregnant women induces the production of antibodies that are transferred to the fetus/infant via the placenta or through breast milk[6,7], providing passive protection until the infants are old enough to receive the pentavalent and influenza vaccines. This passive protection is extremely important, especially in the first months of life when the immune system is still immature, which makes children more vulnerable to diseases, including vaccine-preventable ones such as pertussis, a bacterial disease with high incidence and a significant impact on infant morbidity and mortality[7].

Since November 2014, the Brazilian National Immunization Program (*Programa Nacional de Imunização*, PNI) has made the adsorbed diphtheria, tetanus and pertussis (DTaP) vaccine available to pregnant women. It should be administered from the 20th gestational week[8]. Introduction of this vaccine into the schedule was in response to the significant increase in pertussis cases among children in the country, especially those under one year of age, who are more vulnerable to complications from the disease[9].

A number of studies have shown that after pregnant women were immunized with the DTaP vaccine, there was a significant reduction in confirmed cases and hospitalizations of children due to pertussis[7,10]. It is noteworthy that this reduction was observed even though DTaP vaccination coverage was below 50% in the first three years after having implemented the vaccine[7]. Although a significant reduction in the number of pertussis cases was observed between 2014 and 2022, with records falling from 972 to five cases, a worrying increase was observed from 2023 onwards in the state of Paraná, with 17 confirmed cases. This resurgence can be related to low vaccination coverage, which favors the accumulation of susceptible individuals and reemergence of the disease[11].

In view of the above, the importance of immunization during pregnancy is acknowledged as an effective strategy for preventing diseases in mothers and children, especially those under one year of age. Understanding the factors that influence vaccination coverage will allow developing strategies focused on increasing vaccination adherence by women during pregnancy, thus favoring newborns' protection against preventable diseases. Therefore, the study objective was defined as follows: to determine the DTaP vaccine coverage among pregnant women in the state of Paraná.

METHOD

This is a quantitative, descriptive and ecological study that used municipalities in the state of Paraná as units of analysis. The data were collected from the National Immunization Program Information System (*Sistema de Informação do Programa Nacional de Imunizações*, SIPNI), via the Unified Health System's Information Technology Department (DataSUS)[12]. SIPNI is a computerized system decentralized to states and municipalities that allows monitoring vaccination indicators and assessing the impact of vaccination strategies on the Brazilian population[13].

Located in the Brazilian South region, the state of Paraná had a population of 11,443,208 inhabitants in 2022. Its Human Development Index (HDI) for 2021 was 0.769[14]. The state has 399 municipalities, which, within the health system scope and aiming at decentralization and capillarity of actions and services, are grouped into four macro-regions (North, Northwest, West and East) and 22 health regions.

The data considered were those regarding Vaccination Coverage (VC) of the DTaP vaccine administered to pregnant women from January 1st, 2015, to December 31st, 2022. This period took into account the fact that DTaP in pregnant women was included in the national immunization calendar in November 2014. Therefore, the subsequent year was the first full period of records[15].

The variable under analysis was the DTaP VC rate in pregnant women, calculated automatically in SIPNI: number of doses administered in a given year (single DTaP dose from the 20th gestational week onwards) in each municipality, divided by the target population living in the same place and period, and multiplying the result by 100. The variables related to the vaccine administration year were considered to describe the VC rates, according to the municipalities from the state of Paraná and the respective health regions.

The data were tabulated and organized in a Microsoft Excel® spreadsheet. Initially, the DTaP VC rates were presented year by year, according to health macro- and micro-regions. Subsequently, the rates were presented by municipality, considering the following time periods: 2015, 2016-2017, 2018-2019, 2020-2021 and 2022. For the biennia, the data were grouped by arithmetic mean. These periods were defined taking into account that the rates in the first full vaccination year, during the first COVID-19 pandemic years and in the last year of the pandemic might have suffered fluctuations and interferences in relation to the other years of the historical series.

To present the DTaP VC rates by municipality in the state of Paraná, the VC target was considered to be 95%, as recommended by the Brazilian Ministry of Health[16]. Thus, the DTaP VC rates were classified as follows: inadequate (<95%); adequate (≥95%); and overestimated (>120%)[16]. A spatial distribution map was created from the *shapefile* of the state's municipal grid obtained from the IBGE website, with support of the QGIS® software, version 3.26.3.

Research Article
Artigo de Pesquisa
Artículo de Investigación

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After the distribution of rates, spatial dependence analysis was performed using the Moran index, seeking to verify whether the data from each municipality were correlated with the rates found in neighboring municipalities, which were defined by the first-order *Queen* criterion. Initially, the global Moran index (I) was performed, which ranged from 0.00 to 1.00: the closer to 1.00, the greater the correlation, whether direct (+) or inverse (-)[14]. For I, a pseudo-significance test was applied with 999 permutations to verify whether the value was statistically significant ($p \leq 0.05$).

When significant, the local Moran index (I_i) was applied to verify which areas presented spatial autocorrelation. The municipalities were described in terms of clusters, namely: High-High, municipalities and neighbors with high VC rates; Low-Low, municipalities and neighbors with low VC rates; High-Low, municipalities with high VC rates and neighbors with low ones; Low-High, municipalities with low VC rates and neighbors with high ones; and Not significant, municipalities and neighbors without any evident spatial association[17]. The analysis was performed in the GeoDa® software, version 1.20.

As recommended by National Health Council Resolution No. 466 dated December 2012, this research was approved by the Human Research Ethics Committee of the Signatory Institution (Opinion No. 5,416,728). For involving public domain secondary data on the DataSUS website, use of an informed consent form was waived.

RESULTS

From 2015 to 2022, the mean DTaP VC among pregnant women in the state of Paraná was 51.40%, with 2019 as the year with the highest rate (68.89%) and 2016 as the one with the lowest one (30.94%), as shown in Table 1.

Table 1: Coverage rates for the adsorbed diphtheria, tetanus and pertussis vaccine administered to pregnant women, according to health macro- and micro-regions in Paraná. Paraná, Brazil, 2022.

Macro- and micro-regions	2015	2016	2017	2018	2019	2020	2021	2022
East	**28.34**	**28.94**	**57.37**	**71.29**	**69.25**	**51.23**	**47.94**	**51.08**
1st Paranaguá	20.92	10.18	25.02	59.40	46.31	31.24	24.89	17.84
2nd Metropolitan Region	42.23	27.22	39.70	49.00	50.26	40.14	39.37	43.58
3rd Ponta Grossa	57.99	14.12	47.19	62.45	70.92	64.05	60.25	60.22
4th Irati	26.77	65.43	95.36	89.64	84.39	56.38	59.91	73.87
5th Guarapuava	29.02	22.91	49.58	73.13	67.12	61.23	54.25	55.32
6th União da Vitória	12.87	42.33	73.69	84.20	82.71	54.90	56.40	56.53
21st Telemaco Borba	8.58	20.35	71.03	81.24	83.07	50.69	40.49	50.18
West	**37.82**	**38.34**	**77.00**	**84.72**	**87.16**	**58.44**	**54.44**	**57.78**
7th Pato Branco	50.34	46.85	70.28	81.94	84.94	61.32	53.55	51.80
8th Francisco Beltrão	28.20	63.07	84.30	95.10	90.99	57.38	59.29	72.02
9th Foz do Iguaçu	26.97	15.44	57.74	66.60	80.04	41,43	36.09	38.64
10th Cascavel	39.36	18.88	68.10	82.44	82.32	66.29	58.16	59.22
20th Toledo	44.22	47,48	104.59	97.50	97.54	65.79	65.11	67.23
Northwest	**22.88**	**33.63**	**69.43**	**82.37**	**81.07**	**53.43**	**51.80**	**57.61**
11th Campo Mourão	13.93	42.80	85.29	87.40	82.91	55.13	60.33	58.69
12th Umuarama	16.77	29.99	62.83	80.61	80.07	63.15	59.27	66.29
13th Cianorte	12.47	31.29	93.03	90.50	84.60	58,59	55.06	69.83
14th Paranavai	23.21	33.29	52.99	81.17	79.35	46.48	41.99	51.32
15th Maringa	48.01	30.77	53.02	72.15	78.45	43.77	42.37	41.92
North	**33.13**	**30.17**	**55.59**	**73.49**	**74.82**	**54.70**	**54.00**	**63.23**
16th Apucarana	42.50	29.63	52.44	71.35	67.00	35.64	41.99	52.85
17th Londrina	47.58	58.75	81.93	57.39	75.44	61.76	59.83	64.98
18th Cornélio Procópio	33.97	14.28	41.26	68.74	74.14	57.95	58.89	65.95
19th Jacarezinho	27.66	31.36	59.21	80.31	76.24	52.61	44.62	56.84
22nd Ivaiporã	13.94	16.82	43.10	89.64	81.29	65.52	64.67	75.52
Paraná	**37.65**	**30.94**	**56.37**	**66,66**	**68,69**	**50.46**	**48.28**	**52.16**

Among the health macro-regions, the West stood out with the highest mean value for the series analyzed (61.96%), as was the case with the East with the lowest mean value (50.68%). The health regions that recorded the highest rates were the following: Toledo (73.68%), Irati (68.97%) and Francisco Beltrão (68.79%); in turn, the lowest rates were detected in Paranaguá (29.48%) and in the Metropolitan Region (41.44%).

Research Article
Artigo de Pesquisa
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Figure 1 presents the analyses related to the DTaP VC rates by municipality in the state of Paraná.

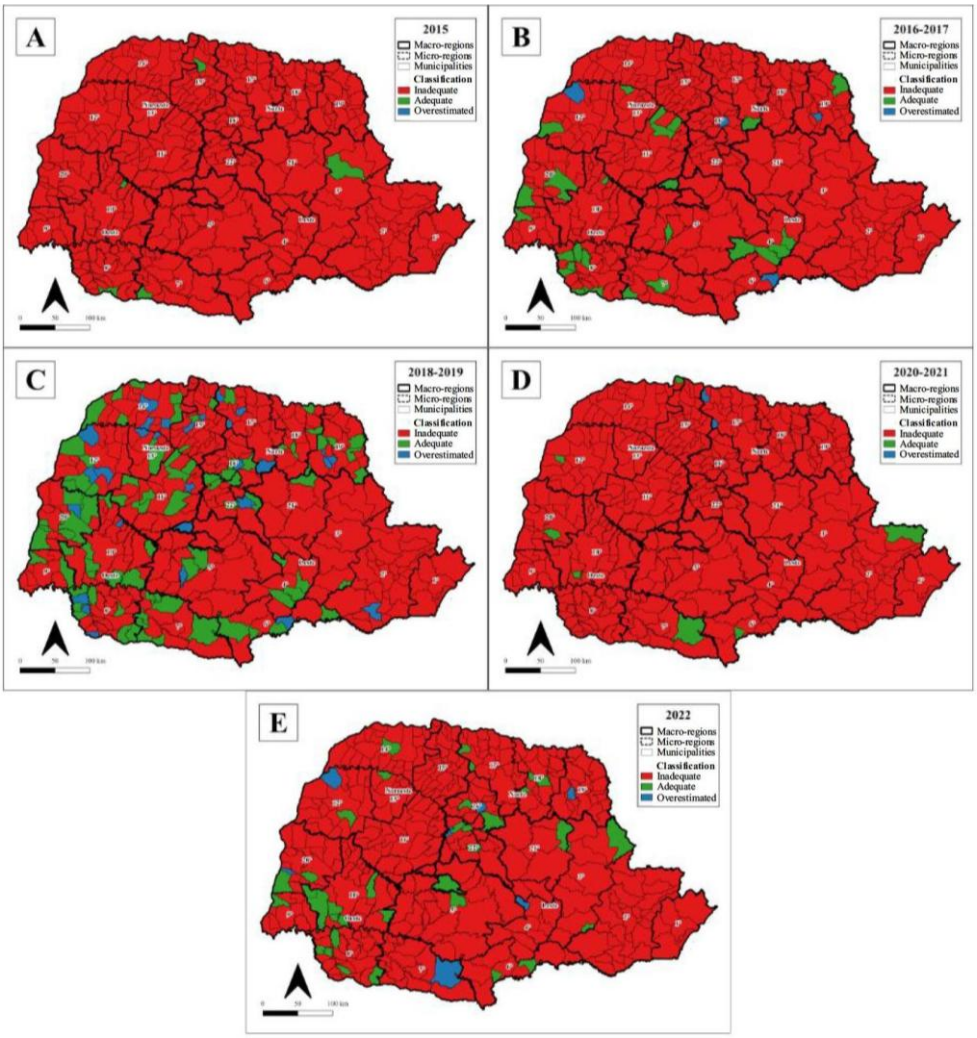

Figure 1: Spatial distribution of the coverage rates for the adsorbed diphtheria, tetanus and pertussis vaccine administered to pregnant women, according to Paraná municipalities. Paraná, Brazil, 2022.

It can be seen that few municipalities achieved the adequate classification of 95%. Among the periods considered, the 2018-2019 biennium stood out with the highest number of municipalities with adequate coverage, mainly in the West and Northwest macro-regions (Figure 1C). Table 2 shows the global and local Moran indices of the coverage rates for the adsorbed diphtheria, tetanus and pertussis vaccine administered to pregnant women in the period under study.

Table 2: Global and local Moran's index for the coverage rates of the adsorbed diphtheria, tetanus and pertussis vaccine administered to pregnant women, according to municipalities in Paraná. Paraná, Brazil, 2022.

			Municipalities by clusters				
Period	**I[a]**	**p-value[b]**	**High-High**	**Low-Low**	**Low-High**	**High-Low**	**Not significant**
2015	0.10	< 0.01	21	23	12	11	332
2016-2017	0.19	< 0.01	28	43	15	11	302
2018-2019	0.14	< 0.01	8	30	13	10	338
2020-2021	0.07	< 0.01	11	22	7	11	348
2022	0.11	< 0.01	20	25	11	10	333

Notes: [a]I - Global Moran index; [b]p-value: pseudosignificance test with 999 permutations.

Research Article
Artigo de Pesquisa
Artículo de Investigación

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When analyzing the global Moran index, spatial autocorrelation was found for all periods analyzed. Thus, the local index was applied to identify the clusters, as shown in Figure 2.

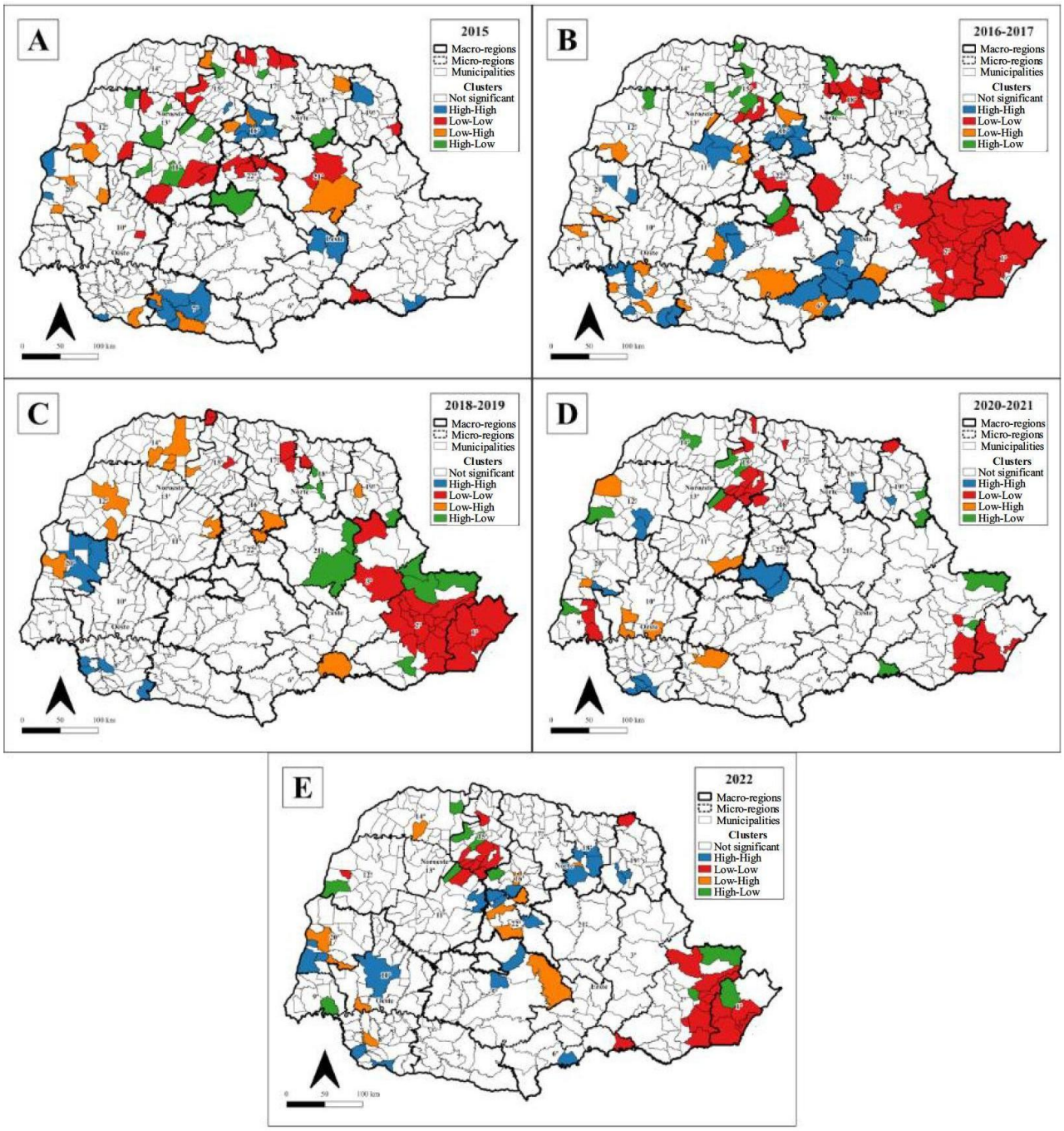

Figure 2: Spatial dependence for the coverage rates of the adsorbed diphtheria, tetanus and pertussis vaccine administered to pregnant women, according to Paraná municipalities. Paraná, Brazil, 2022.

In general, it can be stated that the behavior of the VC for this immunobiological agent showed weak spatial dependence. The highest number of significant clusters was observed in the 2016-2017 biennium, in which 43 clusters of low VC rates were observed, especially in the Metropolitan and Paranaguá regions (Figure 2B). Although with lower intensity, these clusters remained in subsequent years. Throughout the period, few municipalities with high DTaP VC rates were observed, and the largest number of clusters was also noticed in the 2016-2017 biennium.

Research Article
Artigo de Pesquisa
Artículo de Investigación

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DISCUSSION

Immunization is an effective method for preventing and reducing morbidity and mortality due to vaccine-preventable diseases such as diphtheria, tetanus and pertussis, which are prevented by the Pentavalent and DTP vaccines in children up to 4 years of age and by DTaP in pregnant and postpartum women, also allowing passive transplacental immunization or through breastfeeding[10].

Some studies show a reduction in the incidence, hospitalizations and deaths due to pertussis since DTaP was implemented in 2014. In Brazil, there was a reduction in the incidence of the disease among children under 1 year of age, considering the years following maternal vaccination with DTaP (2015 to 2018) as compared to previous ones, suggesting a relationship between vaccination and incidence of the disease in infants under 1 year of age[10]. In the South region, higher incidence rates of the disease between 2011 and 2014, followed by a significant 54.2% decrease in 2015, also suggest following the country's trends[7].

According to the Ministry of Health, the PNI recommends a target of 95% VC for the DTaP vaccine; however, Paraná failed to reach this target in all years since implementation in the vaccination calendar, following national rates. The highest mean VC was 87.16%, achieved in the West macro-region in 2019.

However, it is worth highlighting the VC reduction between 2020 and 2021, years when the isolation and prevention measures against COVID-19 affected the pace of society and vaccination rooms within Primary Health Care, with a nationwide reduction in immunization rates for practically all vaccines[3,4,18]. Similarly, a study suggested the following as possible factors involved in the VC reduction: the social and political conflicts that have intensified in the country in the last 5 years, with emphasis on the growth of the anti-vaccine movement that has contributed to spreading false information about possible adverse effects, in addition to questioning safety of the vaccines and attributing the government's encouragement of vaccination to alleged conspiracy plans[18].

In this regard, a study conducted in a capital city from the Brazilian Midwest region found that Nursing professionals working in vaccination rooms noticed an increase in vaccine hesitancy, especially in relation to COVID-19. They attributed this fact to fake news and to denialist actions, as they exert negative impacts the population's trust in vaccines and the professionals who administer them[19]. In addition, the underreporting possibility due to the pandemic, technical problems with availability of the vaccines and the fact that pertussis presents intermittent peaks in incidence every 4 to 5 years can also be related to the decline in VC[18].

Specifically regarding vaccination during pregnancy, a British study pointed out that low knowledge about prenatal immunization and related diseases is one of the reasons for non-acceptance of the vaccine among pregnant women. However, it found that socioeconomic factors and the professionals' attitude in recommending vaccination can positively influence adherence to immunization[20]. Vaccination recommendations by a medical professional, health promotion interventions that emphasize the safety of immunization during pregnancy and highlight the severity of the disease in children have shown a positive impact on vaccine acceptance among women during pregnancy, contributing to increased vaccination coverage[21].

A number of studies conducted to verify possible adverse effects and risks arising from the vaccine demonstrate its efficacy and safety[21-23]. A cohort study conducted in São Bernardo do Campo, SP, indicates the safety of vaccination during pregnancy, with no increased risk of adverse events related to pregnancy or neonatal events observed after immunization with DTaP[22]. Another study that compared the effects of the vaccine between pregnant and non-pregnant women observed rare episodes of adverse effects and, when present, they were mild and did not require medical care[23].

These findings highlight the need for effective guidance and monitoring of pregnant women during prenatal care. A reduced number of prenatal consultations may limit the provision of important information to these women, including information on immunization, making it difficult for them to be sufficiently informed about the safety and benefits of the vaccine for the mother-child dyad[24].

Study limitations

Some possible study limitations include having relied on secondary data from SIPNI, as recording errors, underreporting and quality issues may have affected the vaccination coverage rates. However, this study provides significant data on vaccination coverage throughout the state of Paraná, which allows comparisons in future studies. Furthermore, it may support proposing and developing strategies aimed at increasing demand for the DTaP vaccine, through greater awareness regarding the importance of this immunological agent among health professionals (especially nurses) and pregnant women themselves, resulting in an increase in the vaccination coverage rate.

Research Article
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CONCLUSION

The study showed that there was growth in the DTaP immunobiological VC until 2019 in the state of Paraná, when it reached the highest rate. However, there was a drop in this rate during 2020 and 2021, followed by a slight improvement in 2022. It can be inferred that, in addition to social and political issues, the COVID-19 pandemic may have exerted a negative influence on the VC reductions.

Knowing and studying vaccination coverage and its spatial behavior are essential to support new public health policies and strategies and can redirect and render health promotion and prevention actions more effective. Thus, the need to plan actions aimed at increasing vaccination coverage in the state is reinforced, through active search and reinforcement of the importance of updating the vaccination schedule for pregnant women during prenatal consultations, when safety of the vaccine for mothers and fetuses and its benefits should be highlighted.

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Author's contributions

Conceptualization, I.W. and S.S.M; methodology, I.W. and S.S.M; software, L.V.L; validation, E.F.T. and M.E.P.S.; formal analysis, L.V.L.; investigation, I.W., V.V.L., A.H.M., E.F.R.N. and S.S.M.; resources, I.W. and S.S.M.; data curation, L.V.L.; manuscript writing, I.W., V.V.L., A.H.M., E.F.R.N. and S.S.M.; review and editing, V.V.L., A.H.M., M.E.P.S., E.F.R.N., E.F.T. and S.S.M.; visualization, V.V.L.; supervision, E.F.R.N. and S.S.M.; project administration, S.S.M.; funding, S.S.M. All authors read and agreed with the published version of the manuscript.

Use of artificial intelligence tools

Authors declare that no artificial intelligence tools were used in the composition of the manuscript "DTaP vaccination coverage in pregnant women: ecological study".