

Tracking vaccination coverage and pertussis incidence in Brazil before and after dTPA vaccine implementation

Aila Alves Souza

Escola Bahiana de Medicina e Saúde Pública

Lara Barreto da Fonseca

Escola Bahiana de Medicina e Saúde Pública

Suzana Ramos Ferrer

Escola Bahiana de Medicina e Saúde Pública

Caroline Alves Feitosa

Escola Bahiana de Medicina e Saúde Pública

Galileu Barbosa Costa

galileuk1@hotmail.com

St. Jude Children's Research Hospital

Viviane de Matos Ferreira

Escola Bahiana de Medicina e Saúde Pública

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Abstract

Pertussis (or whooping cough) is an acute infectious disease of respiratory tract. The introduction of pertussis vaccination has substantially reduced incidence rates and mortality associated with the disease. Despite the vaccination, pertussis has reemerged in several countries, particularly affecting infants under six months of age. In November 2014, the Brazilian Ministry of Health (BMH) implemented the tetanus-reduced diphtheria toxoid-acellular pertussis (dTpa) vaccine, targeting individuals at high risk such as pregnant women and healthcare professionals. Here, we evaluated the incidence of pertussis and vaccination coverage during a period of 17 years, before and after the introduction of dTpa. An observational, ecological time-series study was conducted using secondary data collected from the National Notifiable Diseases Information System (SINAN). Descriptive statistics and regression analysis to estimate increases or reductions in the mean incidence over time were performed. Our findings highlight the implications regarding shifts in disease incidence, the importance of continuous surveillance, and supporting strategies for pertussis prevention and control, mainly focused on strengthening vaccination strategies and increasing vaccination awareness and coverage.

Introduction

Whooping cough is an acute infection that affects the respiratory system and is caused by the bacterium *Bordetella pertussis*, a gram-negative, strictly aerobic coccobacillus that grows best at temperatures between 35–37°C. *B. pertussis* produces several factors that contribute to its virulence, such as pertussis toxin, adenylate cyclase toxin, filamentous hemagglutinin, and hemolysin. It is a severe, highly contagious respiratory disease that spreads rapidly among unvaccinated individuals. Severe complications include bronchopneumonia and acute encephalopathy [1, 4].

The genus *Bordetella* includes the species *B. pertussis* and *B. parapertussis*, both of which cause pertussis in humans. *B. pertussis* is transmitted from person-to-person through close contact, especially via respiratory droplets or aerosols released during coughing episodes [1, 4, 21]. After the incubation period ends, the disease begins with the catarrhal phase. This phase lasts one to two weeks and usually presents initially as a common cold, manifesting as a low-grade fever, a feeling of malaise, a runny nose, and a dry cough. Over time, the symptoms intensify, leading to more severe coughing fits [3, 5, 21].

The subsequent paroxysmal phase, which lasts between two and four weeks, is characterized by bouts of intense, spasmodic coughing. The cough becomes extremely strong and uncontrollable, with sudden, rapid episodes that can result in vomiting, difficulty breathing, facial congestion, cyanosis, and a high-pitched sound during inhalation [3, 5]. During the convalescent phase, which can last from one to three weeks, a gradual reduction in coughing is observed until the patient returns to their normal state. The frequency and intensity of the cough begin to decrease, although they may persist for days or up to three months [3, 5]. Infants under one year of age are at higher risk of developing severe forms of the disease, which can often be fatal [6, 21]. These severe cases may present with coughing fits, difficulty breathing,

sweating, and vomiting. In addition, episodes of apnea, respiratory arrest, seizures, and dehydration resulting from repeated vomiting may also occur [5, 6].

According to the most recent data released by the World Health Organization (WHO), there were 941,582 cases of pertussis worldwide in 2024, representing a 5.8-fold increase compared to the 163,388 cases reported in 2023 and 265,317 cases in 2025. The highest numbers were observed in the WHO Western Pacific Region, with 593,659 cases, and the European Region, with 298,612 cases [7]. During 2015–2019 in the Americas, there was a steady decline in the number of cases reported annually, as well as a further drop during 2021–2022, when cases reached their lowest point, totaling 3,284. However, starting in 2023, a considerable increase was noted, with 11,202 cases that year, rising to 66,184 in 2024, followed by a slight decrease in 2025, when 46,870 cases were recorded [7].

In Brazil, the current Childhood National Immunization Program (PNI) includes three doses of the pentavalent vaccine, which provides protection against diphtheria, tetanus, pertussis, infections caused by *Haemophilus influenzae* type b, and hepatitis B [5, 8, 9, 21]. The recommended age group for vaccination includes children from 2 months of age up to 6 years, 11 months, and 29 days [5, 8, 9]. The primary schedule consists of three doses, administered at 2 months, 4 months, and 6 months of age, with a minimum interval of 30 days and an ideal interval of 60 days between doses. The third dose should not be administered before the child reaches 6 months of age [9, 20]. As for boosters, two doses are recommended, with the first scheduled for 15 months and the second for 4 years of age, using the DTP (triple bacterial) vaccine [9, 20]. A booster with the DTP vaccine is recommended after completion of the primary series with the three doses of the pentavalent vaccine [9, 20]. These booster doses may be administered until the child reaches 6 years, 11 months, and 29 days of age, always observing a minimum interval of 6 months following the last dose of the initial schedule (the third dose of the pentavalent vaccine) and a 6-month interval between the two booster doses [9, 20].

In November 2014, the Brazilian Ministry of Health (Ministério da Saúde) launched the dTpa vaccine, which contains reduced tetanus-diphtheria toxoid and the acellular form of the pertussis vaccine, targeting high-risk groups such as pregnant women and healthcare workers [8, 10, 20]. The implementation of pertussis vaccination resulted in a significant decrease in disease-related incidence and mortality rates. However, even with vaccination, pertussis has reemerged in several countries, affecting especially children under six months of age. In this study, we assessed the incidence of pertussis and vaccination coverage over a 17-year period, before and after the introduction of the dTpa vaccine.

Materials and methods

Study Design

This observational and ecological study was conducted using secondary data collected from Brazil's National Notifiable Diseases Information System (SINAN), covering all regions of the country. Since this

study uses secondary data and in the public domain with no identification of individuals, approval by a Research Ethics Committee was not required (according to the Brazilian Nacional Health Council [CNS], resolution No. 510/2016) [16]. We also conducted this research in accordance with the principles outlined in the Declaration of Helsinki [17].

Data Collection

Data was obtained through the Generic Public Domain Health Information Tabulation tool (TABNET), maintained by the Department of Information Technology of the Unified Health System (DATASUS) of the BMH (<http://tabnet.datasus.gov.br>). Data was collected from the National Notifiable Diseases Information System (SINAN) database covering all Brazilian States and municipalities, from January 2009 through December 2025. The following stratified variables were collected: region/state, year of infection, sex, age group, skin color, and race. In Brazil, reporting of pertussis cases is mandatory, hence all confirmed cases were included. In addition, we included available records of vaccination coverage for the DTP (diphtheria, tetanus, and pertussis) vaccine and the acellular pertussis (dTpa) vaccine for each region from 2009 to 2019. Vaccination coverage data were obtained from the National Immunization Program Information System [18]. We also included available data on the number of doses of DTP, DTaP, Tetravalent, Pentavalent, and dTap vaccines -categorized by vaccination of children and adolescents versus adults and pregnant women- that were administered in each region during 2009–2022.

Study Variables

The incidence of pertussis was assessed year by year, comparing aggregated data for the pre-implementation period (2009–2014), the post-implementation period of the dTpa vaccine (2015–2019), and the pandemic period (2020–2025), according to age group and region of Brazil. Descriptive analysis was performed to assess temporal variations among the variables. To ensure that the normalization of years and the different regions of Brazil was performed equivalently, we gathered data on total populations, obtained from censuses and projections provided by IBGE (Brazilian Institute of Geography and Statistics) [19].

First, we accessed IBGE and explored the section dedicated to census statistics. The total population of each Brazilian region was obtained from the tables available in SIDRA, covering the years 2000–2025. We followed the same criteria to collect stratified population data, organizing the information by total number of women and men and total population by age group in each region during the specified period. We focused on collecting population data for each year across Brazil, followed by region-specific data collection. Data regarding skin color/ethnicity was not available for all years covered by this study.

Data Analysis

All collected data were extracted and organized into Excel spreadsheets, subsequently consolidated by year of occurrence and region/state. Univariate analysis was performed to estimate crude odds ratios (OR) and their respective 95% confidence intervals. Linear and logistic regression analyses were conducted to examine the association between the independent variables and the outcome of interest. Statistical analyses were performed using Microsoft Excel spreadsheet software.

The generative AI tool Claude (Anthropic) was used exclusively to generate the code (Python/matplotlib) employed to create the graphs in this study. Statistical analysis, interpretation of results, and manuscript drafting were carried out entirely by the authors, who assume full responsibility for the accuracy of the data and figures presented.

Results

Demographic characteristics of the study population

In Brazil, during the analyzed time series, of the 45,308 pertussis cases, the highest incidence of the disease occurred among females, totaling 25,060 cases (rate = 23.9 per 100,000). The highest incidence of this disease occurred in children under 1 year of age, who account for 23,292 cases (rate = 79.5 per 100,000). Also recorded were 7,058 cases (rate = 24.1) in children aged 1 to 4 years, 3,737 cases (rate = 12.7) in the 5–9 age group, 3,628 cases (rate = 11.3) among adolescents aged 10–14, 1,801 cases (rate = 5.6) in the 15–19 age group, 3,507 cases (rate = 5.6) among individuals aged 20–39, and, finally, 1,954 cases (rate = 3.9) in people aged 40–59. The highest incidence was observed in the population identified as white, which accounted for 50.5% of cases, totaling 22,894, followed by the mixed-race ("Parda") population, with 29.9% and a total of 13,577 cases.

Table 1
Description of sociodemographic characteristics.

Sociodemographic characteristics	North	Northeast	Southeast	South	Central-West	Total
Sex						
Female	14.6	18.4	23.6	41.6	21.8	23.9
Male	12.4	15.7	20.3	35.6	18.5	20.4
Age group						
< 1 year	40.3	66.1	83.8	130.3	77.2	79.5
1–4 years	16.1	17.4	26.6	41.5	17.9	24.1
5–9 years	8.7	9.4	13.3	23.5	9.7	12.7
10–14 years	4.17	5.74	12.2	28.7	7.47	11.3
15–19 years	1.1	2.2	5.2	17.9	5.1	5.6
20–39 years	1.2	3.3	5.6	11.2	4.4	5.3
40–59 years	0.6	1.8	4.2	8.3	3.1	3.9
Skin color/ethnicity						
White	19.7	13.8	26.3	39.3	17.6	26.9
Black	12.9	6.75	8.4	16.5	7.64	8.7
Asian-descent ("Amarela")	34.6	28.6	16.9	26.2	9.2	20.4
Mixed	13.1	19.7	15.1	22.3	16.3	16.9
Indigenous	84.4	15.8	32.2	95.4	29.8	51.6

It is possible to note in the Fig. 1 that the highest number of cases occurred between 2011 and 2014, with the < 1-year age group predominating significantly between 2009 and 2020, reaching its peak in 2014 with 5,033 cases (rate = 16.9). This was followed by the 1–4-year age group, with its largest peak in 2013 at 1,227 cases (rate = 4.1). After this period, a notable increase occurred in 2024, with a significant shift in which the 10–14-year age group jumped to 1,738 cases (rate = 5.8), surpassing all other groups, including children under 1 year.

Regional distribution of pertussis

Regarding the distribution of these cases across the country's different regions, the Southeast region shows the highest number of records, representing 41.8% of cases (n = 18,956). The South region follows with the next-highest number of recorded cases, at 25.1% (n = 11,410), followed by the Northeast

region with 20.9% (n = 9,509). The Central-West region accounts for 7% (n = 3,174), and the North region shows the smallest share, with 4.9% (n = 2,259) of recorded pertussis cases.

The data presented in Fig. 2A show that between 2009 and 2014, a gradual increase in the incidence rate was observed starting in 2011. The year 2012 recorded the largest increase in the South region (rate = 5.26), followed by the Southeast (rate = 3.31). In 2014, the Central-West region reached its incidence peak (rate = 5.19), with the Northeast (rate = 5.13) and South (rate = 5.04) close behind.

From 2015 to 2019 (Fig. 2B), a reduction in pertussis cases was observed across all regions during 2016. However, in 2017, the South region showed a significant increase, reaching an incidence of 1.95, surpassing the other regions. This trend continued in 2018, while the North region had the lowest rate (0.44) compared to the others. In 2019, the Northeast region stood out, recording the highest incidence (1.33).

During the 2020–2025 interval (Fig. 2C), incidence was low across all regions between 2020 and 2023. However, in 2024, there was a sharp increase in the South region, reaching 11.7, followed by the Southeast (3.75) and the Central-West (2.51). In 2025, incidence returned to low levels again.

During interval A (2009–2014), a statistically significant upward trend in the incidence rate was identified ($\beta = 0.8188$; 95% CI: 0.5088–1.1288; $p = 0.0018$), with a high coefficient of determination ($R^2 = 0.9308$). This suggests that approximately 93% of the observed variation in incidence was explained by the linear model. Throughout this period, the rate rose from approximately 0.5 to 4.2 cases per 100,000 inhabitants (Fig. 3A).

In interval B (2015–2019), a downward trend was identified, reflected by a negative slope coefficient ($\beta = -0.1088$). However, this decline was not statistically significant (95% CI: -0.4410 to 0.2234; $p = 0.37$), and the model showed low explanatory power ($R^2 = 0.2659$), indicating substantial annual variability in the incidence rate (Fig. 3B).

In interval C (2020–2025), an upward trend in the incidence rate was observed ($\beta = 0.4702$) without statistical significance (95% CI: -0.3662 to 1.3066; $p = 0.19$) with a moderate coefficient of determination ($R^2 = 0.3785$). Despite a considerable increase in the incidence rate in 2024, followed by a drop in 2025, the significant year-to-year variation resulted in the absence of a significant linear relationship (Fig. 3C).

Vaccination Coverage

DTP coverage percentages ranged from 81% in the North to 92% in the South, consistently below the 95% target suggested by WHO. The South and Central-West were the regions with the best results, while the North remained furthest from the target. Ideal coverage was not achieved anywhere during the period (Fig. 4A). The dTpa coverage showed significantly lower mean coverage rates, ranging from 37% in the Southeast to 44% in the Central-West (Fig. 4B).

It was observed that, despite the introduction of the DTP vaccine, the frequency of pertussis cases increased in all areas starting in 2012. In the North region, a decline in vaccination coverage is noted from 2009 to 2022 (Fig. 4A). Although there was a reduction in cases in the vaccine's introduction year, 2012 saw incidence grow and surpass vaccination coverage, reaching its peak in 2014. From 2015 onward, the incidence rate remained below vaccination coverage.

In the Northeast region, incidence declined after the vaccine's introduction, but in 2014 a significant increase in cases occurred, again surpassing vaccination coverage. In subsequent years, incidence remained below the vaccination rate. In the Southeast region, the number of cases remained well below the vaccination rate in the first three years after the vaccine's introduction. Between 2012 and 2014, incidence increased, surpassing vaccination coverage, but fell again in 2015.

In the South region, incidence also remained well below vaccination coverage in the vaccine's first three years. However, in 2012, incidence rose above vaccination coverage, and in 2013 incidence and coverage rates were equal. In 2014, another increase occurred, followed by a decline in 2015. In the Central-West region, disease occurrence decreased after the vaccine's introduction, but in 2014 a significant increase was recorded, surpassing vaccination coverage; in subsequent years, incidence again fell below vaccination levels. It was possible to observe that, from 2015 onward, all regions showed DTP vaccination coverage higher than disease incidence.

Regarding dTpa immunization (Fig. 4B), it was observed that the incidence rate remained considerably higher than the vaccination rate in 2013 and 2014. From 2015 onward, the pertussis rate began to fall as vaccination coverage grew, except in the North region, where the incidence rate fell below the vaccination rate only starting in 2016. Even so, no region achieved the 95% vaccination target set by WHO.

B: Incidence of pertussis (cases/100,000 inhabitants) and dTap vaccine coverage by region, 2013–2022.

Percentage of Doses Administered — DTP, DTPa, Tetravalent, Pentavalent, and dTpa Vaccines

Regarding the distribution of doses administered by age group, it is evident that DTP vaccination between 2009 and 2021 recorded the highest percentage among 1-year-olds, followed by those aged 4 years. However, in 2022, the 4-year age group surpassed the under-1-year group. It is also notable that, until 2016, the 5–6-year age group had the third-highest percentage of vaccines administered.

For the DTaP vaccine, the highest rates of doses administered were observed in the under-1-year category, with the 1-year-old group following through 2013. In 2014, a decrease was observed, coinciding with increased vaccination among non-pregnant women aged 15–49, a pattern that persisted through 2015. From 2016 onward, the vaccination percentage for those under 1 year began to grow again, followed by children aged 4 years and those aged 5–6 years. In 2022, the highest percentage was for the 5–6-year age group, with the 4-year age group close behind.

Regarding the dTpa vaccine, the largest proportion of doses administered is observed among pregnant women aged 15–49, with the non-pregnant population of the same age group in second place.

Regarding the Tetravalent vaccine, until 2013, the highest percentage of doses administered was in children under 1 year. In 2017 and 2018, the 1-year age group had the highest percentages, followed by the 4-year group. In 2020, the peak of doses administered for the 1-year-old population was observed, while in 2021 the highest number occurred among 4-year-olds, and in 2022 there was an increase in doses administered to the 3-year-old population. Regarding the Pentavalent vaccine, during the 2009–2022 period, the under-1-year age group had the highest percentage of doses administered.

Hospitalizations by Year of ICD-10 Processing

For pertussis-related hospitalizations, regarding hospitalizations due to pertussis (Fig. 5), analysis of the national pattern reveals a significant increase in 2014 (2.45 per 100,000), followed by a continuous decline until 2021 (0.09) and a slight recovery expected between 2024 and 2025 (0.35–0.40), although it still remains below the rates seen between 2012 and 2015. The national case fatality rate proved more constant than that of isolated regions, varying from 0.5% to 4.2%, with a peak in 2010 (4.2%) and a recent increase recorded in 2024. (2.96%), reflecting the trend observed in most regions.

In the North region, the numbers started low (0.5 per 100,000 in 2008) and reached a notable peak in 2014 (2.42 per 100,000), followed by a drastic drop that led to a rate of 0.05 in 2023, with a slight recovery predicted for 2024 and 2025. The case fatality rate, initially high (7.4% in 2009 and 9.4% in 2010), decreased in 2016, 2018, and 2020, but rose again to 2% in 2021. The Northeast region also reached its peak in... In 2014, the rate reached its highest level among all regions (3.01 per 100,000). After that year, the decline was practically continuous until reaching its lowest point in 2021 (0.10), with stabilization at low levels until 2023 and a gradual recovery predicted for 2024 and 2025 (0.32). The case fatality rate in this region had a smoother trajectory than in other areas, starting at 5.1% in 2010, with a consistent decrease that consolidated between 0.4–0.5% in 2018 and 2019, but rose again from 2020 to 2024, closing at 2.25%.

In the Southeast region, as in other areas, a peak was observed in 2014 (2.10 per 100,000), but there was also a second wave of high incidence in 2012 and 2013, almost as high as the main peak (2.68 and 2.96 per 100,000). After 2014, the decrease in hospitalizations was slower compared to other regions, with a highlight in 2019 (0.94) before falling to a historical minimum in 2021 (0.07). Regarding lethality, it started at zero in 2009 and rose unevenly over the years, reaching a significant increase in 2024 (4.76%), the highest recorded in the area during the entire period analyzed.

The Southern region also experienced a peak in 2014 (2.10 per 100,000), as well as a second wave of high incidence between 2012 and 2013, almost equivalent to the main peak (2.68 and 2.9 per 100,000). The decline after 2014 was slower than in other regions, with a notable reduction in 2019 (0.94) before reaching its lowest point in 2021 (0.07). The case fatality rate started at zero in 2009 and showed an irregular increase over the years, reaching a significant peak in 2024 (4.76%). The Central-West region followed a similar pattern, with a peak in 2014 (3.08 per 100,000) followed by a decline to the lowest

levels observed between 2020 and 2023 (0.06 to 0.10). The case fatality rate remained at zero for several years, but reached a peak in 2021 (10%).

Discussion

This study provides a 17-year, nationwide picture of pertussis incidence and vaccination coverage in Brazil, spanning the periods before (2009–2014) and after (2015–2019) dTpa introduction, and the pandemic and post-pandemic years (2020–2025). Consistent with the intended effect of the 2014 dTpa policy, incidence fell markedly in the years immediately following implementation, with the sharpest declines observed among infants under 1 year, the age group bearing the largest share of national disease burden throughout the entire series. However, this gain was not sustained: all Brazilian regions experienced renewed increases in pertussis incidence during 2020–2025, culminating in a pronounced 2024 outbreak concentrated in the South region (11.7 cases per 100,000), followed by the Southeast (3.75) and Central-West (2.51). This pattern closely mirrors the decade-long overview reported by Sansone et al. for the same 2024 resurgence, who documented the South and Southeast as the two most heavily affected regions nationally [8].

The timing and shape of this resurgence are consistent with the global pattern described since 2023 in the United Kingdom, Australia, China, and the Republic of Korea, where pertussis incidence fell sharply during COVID-19-related non-pharmaceutical interventions and then rebounded once these measures were lifted [11–13]. Two mutually reinforcing mechanisms have been proposed for this rebound: an "immunity debt" arising from reduced natural boosting of population immunity during a period of unusually low circulation, and the intrinsically time-limited protection conferred by acellular pertussis vaccines, which is known to wane within two to three years of the last dose [12, 13]. Both mechanisms are plausible contributors to the pattern observed here, and disentangling their relative contribution — which this ecological dataset cannot do directly — would be a valuable target for future serosurveillance or cohort studies in Brazil.

A particularly notable finding is the shift in age distribution during the 2024 outbreak: whereas infants under 1 year predominated throughout 2009–2020, the sharpest relative increase in 2024 occurred in the 10–14-year age group, which briefly surpassed even the historically dominant under-1 category. A similar age-shift toward older children and adolescents has been reported during the 2023–2024 resurgences in Europe and the Republic of Korea, where 10–19-year-olds and 13-year-olds, respectively, showed disproportionate increases in incidence [11, 12]. Because the Brazilian national immunization schedule provides a DTP booster at 4 years of age but no further scheduled pertussis-containing dose until adulthood, waning immunity in this age band is a plausible explanation, and one that would argue for evaluating a routine adolescent booster dose, as several of the countries cited above have already begun to do.

Vaccination coverage findings reinforce this interpretation. Neither DTP nor dTpa coverage reached the WHO-recommended 95% threshold in any Brazilian region during the study period, and dTpa (the vaccine

specifically intended to protect infants indirectly through maternal immunization) showed markedly lower coverage (37–44%) than the pediatric DTP series (81–92%). Maternal Tdap/dTpa vaccination during pregnancy has been shown in case-control and cohort studies to be 69–91% effective at preventing pertussis in infants during the first months of life, the period of greatest vulnerability before the primary series is completed [14]. Given that infants under 1 year accounted for over half of all cases nationally in the present study, the persistent shortfall in maternal dTpa coverage represents a substantial and addressable gap in the country's prevention strategy, rather than a failure of the vaccine itself.

Regional and sociodemographic heterogeneity add a further dimension to these findings. The South region stood out as the only one whose incidence did not change significantly across the three study periods, remaining elevated throughout – a pattern that warrants dedicated investigation into whether it reflects genuine sustained transmission, comparatively stronger case ascertainment and notification practices, or both. The elevated incidence observed among the Indigenous population (84.4 vs. 31.05 cases/100,000 in high- versus low-incidence years) did not reach statistical significance in the univariate analysis, likely reflecting the small number of notified cases in this subgroup, but is directionally consistent with previously documented disparities in vaccination access and health infrastructure affecting Indigenous communities in Brazil, including geographic isolation and limited primary care coverage documented in other national immunization programs [15]. Given the incompleteness of race/color reporting in some years noted in our Methods, this finding should be interpreted as hypothesis-generating rather than conclusive.

This study has limitations. First, the ecological design precludes individual-level causal inference; associations observed at the regional or annual level cannot be assumed to hold for individuals (ecological fallacy). Second, both logistic regression models presented here are exploratory: the regional model was fitted to only 15 observations, and the age-stratified model uses incidence in specific age bands to predict overall high-incidence years, a relationship that is partly definitional given that infants under 1 year alone account for roughly half of all national cases – this model should be read as a descriptive decomposition of which age groups drive high-incidence years, not as an independent predictive or causal finding. Third, SINAN is a passive surveillance system subject to underreporting, and this may have been differentially affected during the pandemic period, when reduced healthcare-seeking and diagnostic testing for non-COVID respiratory illness have been documented globally as a source of surveillance artifact in pertussis reporting [11, 13].

Conclusion

Over a 17-year period, the introduction of the dTpa vaccine in Brazil coincided with a substantial, if temporary, reduction in pertussis incidence, particularly among infants under 1 year. This gain was not sustained through the COVID-19 pandemic period: all regions experienced renewed increases in incidence during 2020–2025, with a marked outbreak in the South region in 2024 and an unexpected shift toward school-age children that has not previously been highlighted in Brazilian pertussis

surveillance. Neither pediatric DTP nor maternal dTpa vaccination reached the WHO-recommended coverage target in any region throughout the study period, and maternal dTpa coverage in particular remained well below levels shown elsewhere to be protective for young infants.

These findings support three concrete priorities for Brazilian public health policy: (1) renewed investment in maternal dTpa promotion and uptake, given its demonstrated effectiveness in the age group carrying the greatest disease burden; (2) evaluation of a routine adolescent pertussis booster, in light of the 2024 age-shift and international precedent; and (3) strengthening of continuous, harmonized surveillance to detect and respond to future resurgences earlier, including during periods of health-system disruption.

Declarations

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Conflicts of 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.

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Figures

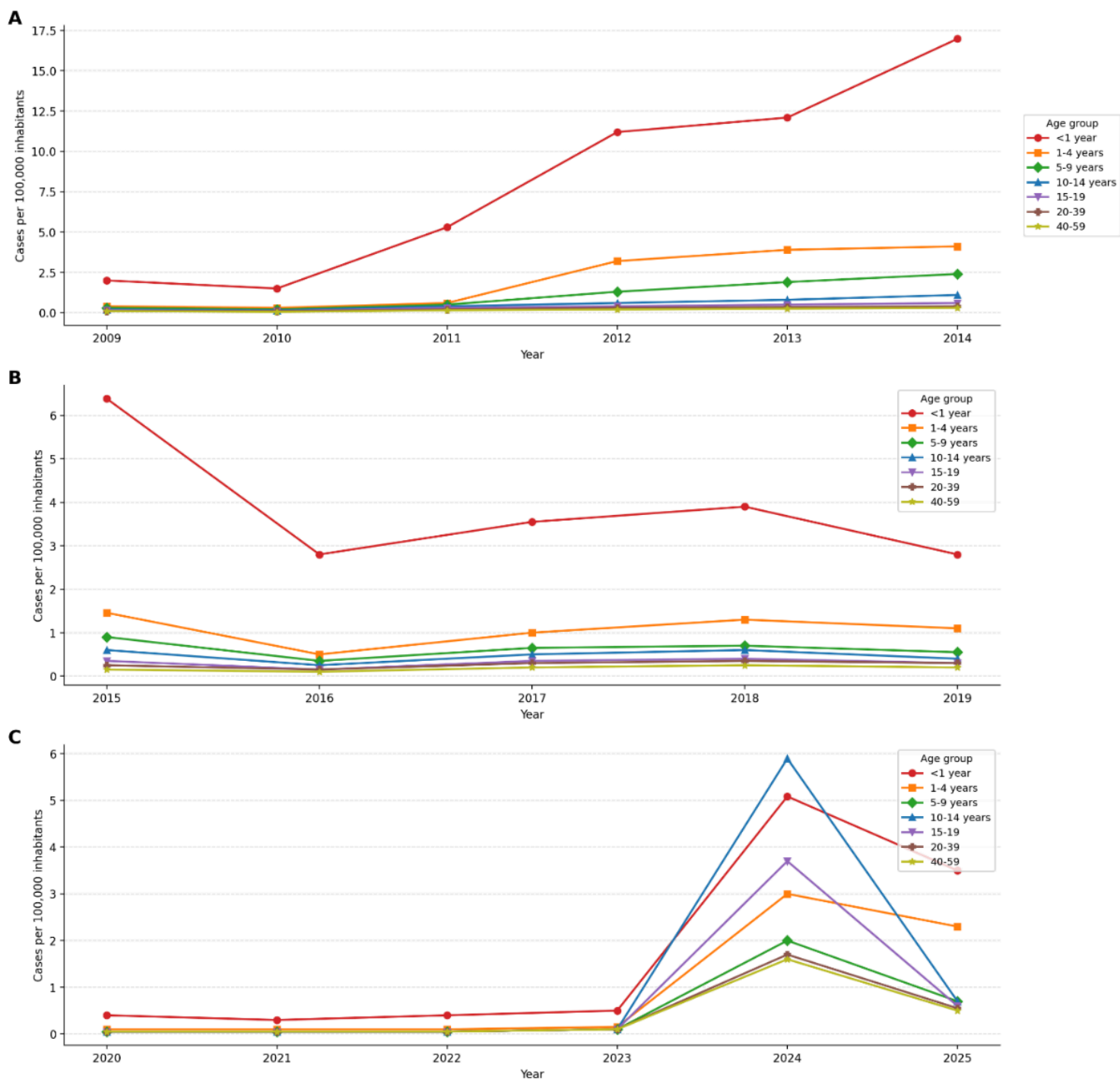


Figure 1

A: Incidence of pertussis by age group according to the year of onset of the first symptom. A: During the 2009 – 2014 period; B: During the 2015 – 2019; C: During the 2020 – 2025.

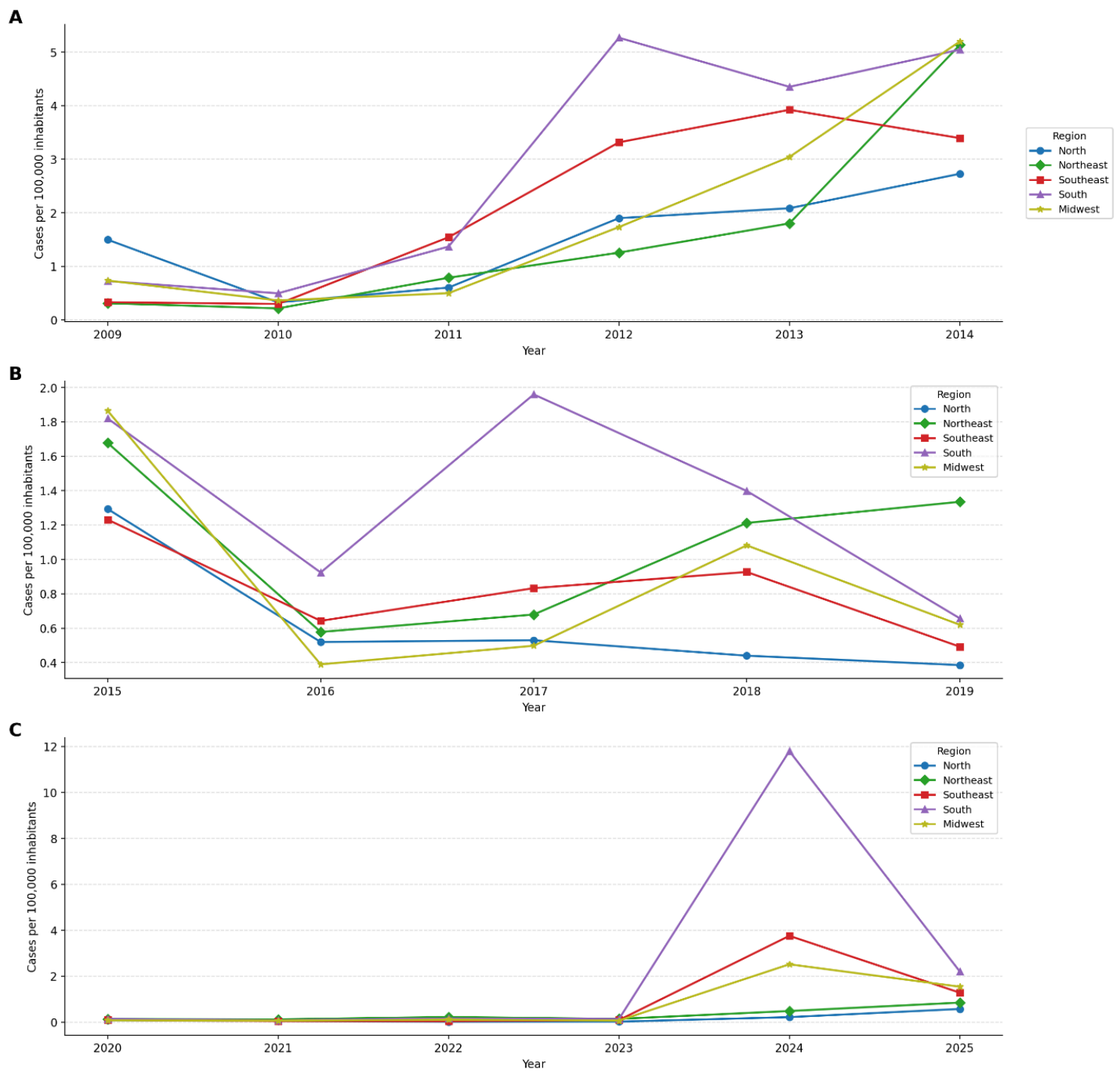


Figure 2

A: Confirmed cases per 100,000 inhabitants by region according to the year of onset of the first symptom. A: During the 2009 – 2014 period; B: During the 2015 – 2019 period; C: During the 2020 – 2025 period;

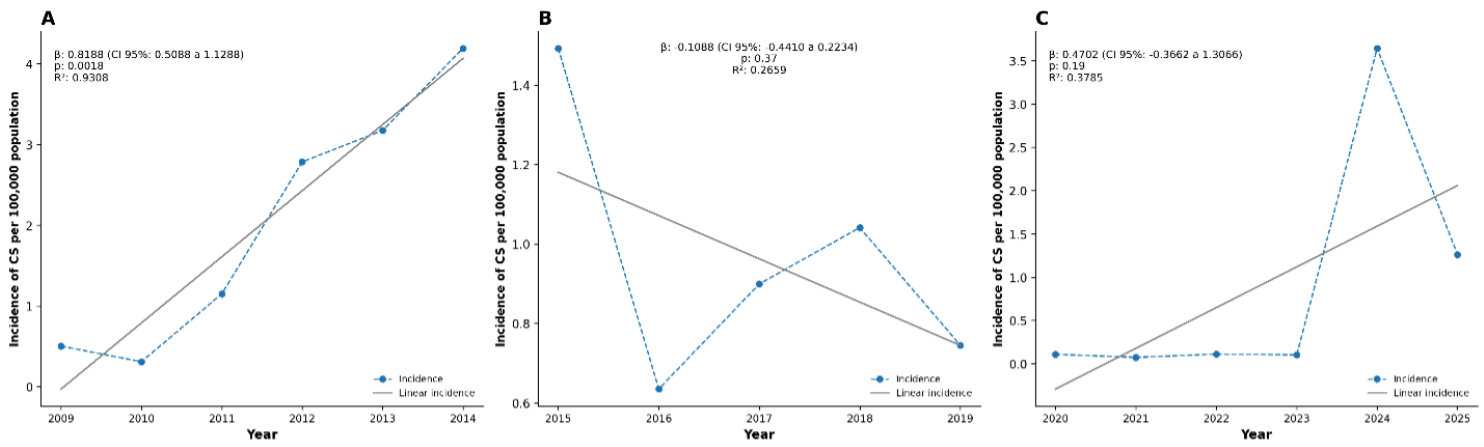


Figure 3

Rates and linear regression as a function of time of incidence of *Pertussis* from 2009 to 2025. β indicates the average of increase rate of syphilis annually; p value indicates the statistical significance; R^2 indicates the variation present in the data. A: During the 2009 –2014 period; B: During the 2015 – 2019; C: During the 2020 – 2025.

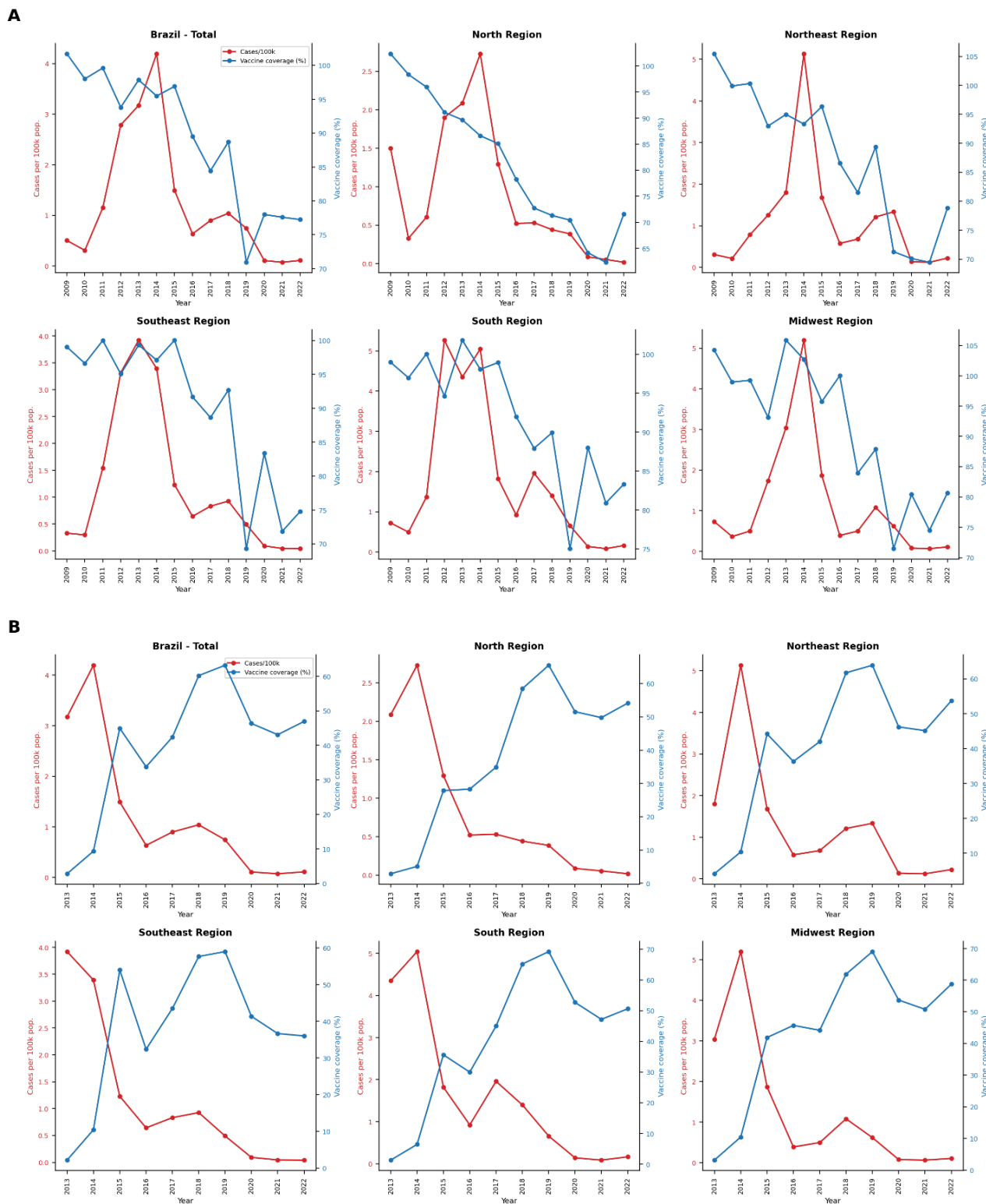


Figure 4

A: Incidence of pertussis (cases/100,000 inhabitants) and DTP vaccine coverage by region, 2009–2022;

B: Incidence of pertussis (cases/100,000 inhabitants) and dTap vaccine coverage by region, 2013–2022.

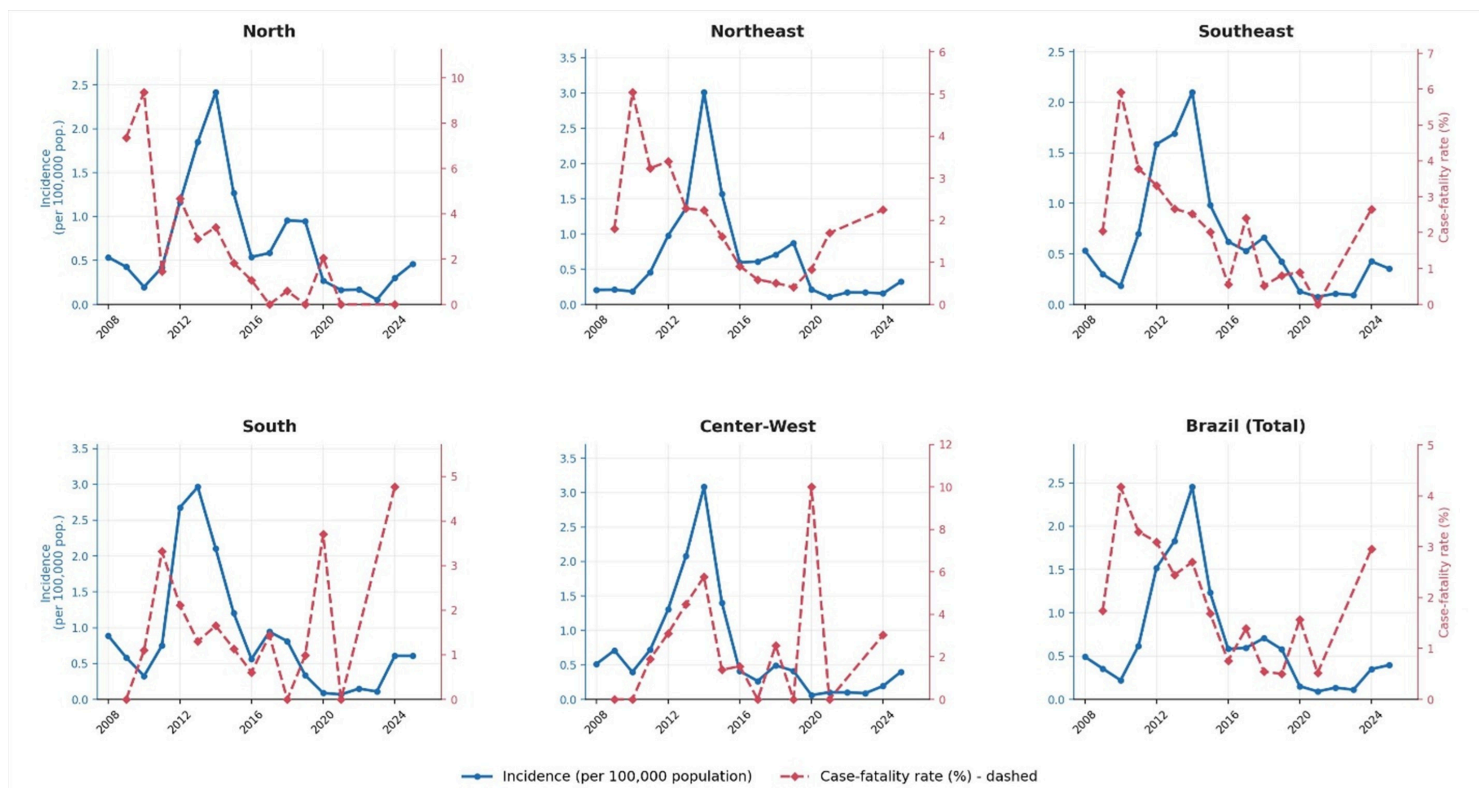


Figure 5

Incidence vs. Case fatality rate of Pertussis in Brazil analyzed by region.