Cogitare Enfermagem

ORIGINAL ARTICLE

Time trends and spatial patterns corresponding to maternal-child syphilis in the Brazilian North region: an ecological study

HIGHLIGHTS

1. A continuous increase in the number of Gestational Syphilis cases was noticed in the North region.
2. Different Congenital Syphilis patterns were identified across the states.
3. Low maternal schooling was associated with higher incidence of both diseases.

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ABSTRACT

Objective: To analyze time trends and spatial patterns corresponding to gestational and congenital syphilis in the Brazilian North region between 2014 and 2023. **Method:** A time-based ecological study conducted with secondary data from the National Live Births System and from the national panel of syphilis indicators. The gestational and congenital syphilis rates were analyzed by means of log-linear regression and "joinpoint" models to estimate the Annual Percent Change. The associations were estimated via fixed-effects count and population-based offset methods, in turn, spatial dependence was estimated through spatial autoregressive regressions. **Results:** Gestational Syphilis presented continuous growth in the historical series. Congenital Syphilis showed heterogeneity across the states, with an 80.5% annual increase in Amazonas until 2017, followed by a reverse trend after 2018; in turn, the increasing trend remained in Pará during the entire period. **Conclusion:** Social and territorial inequalities remain as core determinants of persistent mother-to-child syphilis transmission in the Brazilian Amazon.

DESCRIPTORS: Syphilis; Syphilis, Congenital; Amazon Ecosystem; Infectious Disease Transmission, Vertical; Socioeconomic Factors.

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INTRODUCTION

Both in Brazil and at the global level, syphilis still represents a significant burden for maternal-child health; despite structured clinical guidelines and health policies, mother-to-child *Treponema pallidum* transmission persists as a neonatal and perinatal morbidity determinant. The World Health Organization (WHO) and the Pan-American Health Organization (PAHO) define Elimination of Mother-to-Child Transmission (EMTCT) of syphilis as a priority target, which not only requires universal testing but also early diagnosis and timely treatment of pregnant women and their sex partner(s), in addition to effective coverage and quality at all care levels[1].

Worldwide, it is estimated that there are hundreds of thousand congenital syphilis cases a year, resulting in adverse outcomes such as stillbirths, prematurity, low birth weight and neonatal mortality[2]. Although many countries have made progress in expanding testing and access to the treatment, socioeconomic inequalities, geographical barriers and weaknesses in health systems continue to limit the effectiveness of the strategies aimed at preventing mother-to-child transmission[3]. These challenges are particularly evident in regions with major territorial and social inequalities such as the Brazilian Amazon, where structural factors exert a direct influence on access to diagnosis and timely treatment.

In line with international strategies (Target 3.3 from the Sustainable Development Goals), the Healthy Brazil Program (*Programa Brasil Saudável*, PBS) was created in the country. Syphilis is one of the five vertically transmitted infections comprising the program, where priorities were defined as for municipalities and actions with an inter-institutional work methodology. The decision to include syphilis in this context is warranted by its socially determined nature and by its persistent high incidence in the country, reflected in the continuous increase in the number of Gestational Syphilis (GS) and Congenital Syphilis (CS) notifications[4]. Recent ecological and time-based studies have revealed that, as a whole, the country presented notable growth in CS incidence between 2008 and 2018, with significant regional variations strongly related to socioeconomic inequalities and to low access to prenatal care[5,6].

Brazil still has no consistent plan for Congenital Syphilis elimination, whose parameters include rates below 0.5 cases per 1,000 live births (LBs), testing coverage ≥95% during the prenatal period and ≥95% adequate treatment for pregnant women and their partners. The gap to attain these goals evidences the persistence of social determinants that structure incidence of the disease, such as low schooling, territorial inequalities and barriers hindering timely access to health services and information[7,7].

In this scenario, Primary Health Care plays a central role in syphilis prevention and control actions. Nurses enjoy autonomy to carry out Nursing consultations, request rapid tests, interpret results and prescribe benzathine penicillin, expanding access to early diagnosis and timely treatment during the prenatal period[9].

In addition to that, spatial and time-based studies have contributed to understanding the territorial dynamics of syphilis, allowing to identify risk clusters and heterogeneous patterns regarding incidence of the disease[6]. These approaches are particularly relevant in vast and socially diverse regions, as they enable recognizing priority areas for intervention and devising better targeted epidemiological surveillance strategies[10].

Despite the overall growth in GS and CS rates in Brazil, there are still important knowledge gaps about the space-time dynamics of these diseases in the North region, especially regarding inflection points in time trends, heterogeneity across states and influence exerted by social factors such as maternal schooling. In this context,

understanding the spatial and time patterns of maternal-child syphilis becomes fundamental to support more effective public policies.

Given this fact, the objective of the current study was to analyze time trends and spatial patterns corresponding to gestational and congenital syphilis in the Brazilian North region between 2014 and 2023.

METHOD

An ecological and time-based panel study (Federation Unit [FU]×Year) encompassing all seven states from the Brazilian North region (Acre, Amapá, Amazonas, Pará, Rondônia, Roraima and Tocantins) during the 2014-2023 period. The outcome of interest was GS and CS incidence per 1,000 live births (LBs); in turn, the main ecological exposure was the percentage of low maternal schooling.

The regional clipping was defined *a priori* to answer the research question about inter-regional inequalities, maximizing comparability between neighboring FUs and avoiding dilution of effects due to nationwide aggregation.

The annual GS and CS rates by FUs were obtained from the Syphilis Indicators Portal belonging to the Ministry of Health[8]; in turn, maternal schooling and the Live Birth (LB) denominators were collected from the Live Births Information System (*Sistema de Informação sobre Nascidos Vivos*, SINASC/DATASUS)[11]. All the data were extracted on September 18th, 2025, and homogenized by acronyms by the Brazilian Institute of Geography and Statistics (*Instituto Brasileiro de Geografia e Estatística*, IBGE), as well as by calendar year. The outcome variables were calculated as rates per 1,000 LBs; in turn, ecological exposure was defined as follows:

$$prop\_low\_ed\_it = MW\_low,it \;/\; (MW\_low,it + MW\_high,it)$$

Maternal schooling was categorized as low (illiteracy and Complete or Incomplete Elementary School) and as more advanced schooling levels (High School or Higher Education). This classification was adopted because it represents a socioeconomic vulnerability indicator that is widely used in epidemiological studies about maternal and congenital syphilis in Brazil, where schooling levels up to Elementary School are associated with higher mother-to-child transmission risks and with worse indicators regarding access to prenatal care[12,13].

Two groups were consolidated to create the series: an FU×Year panel and an aggregated regional series, both with numerators (cases) and denominators (LBs). Haldane-Anscombe correction was employed to enable modeling at the logarithmic scale and avoid problems related to log(0). The annual time trend analysis for GS and CS was estimated by means of log-linear regression:

$$ln(y\_it) = \alpha + \beta t + \varepsilon\_it$$

where y is the rate (>0) in FU=i and Year=t. The ββ coefficient was converted into Annual Percent Change (APC):

$$APC = (e \hat{} \beta - 1) \times 100\%$$

For the sake of auto-correlation and heteroscedasticity robustness, the standard errors were corrected by means of Newey West with lag width, producing more reliable confidence intervals and tests without imposing any rigid parametric error structure. The time curvature possibility was researched by comparing BIC between the linear model and a quadratic model in log(y); when ΔBIC≤2, a sensitivity test was performed with GAMM(AR1) models combining non-parametric trend smoothing with autoregressive error of order 1, which mitigates bias due to residual serial dependence[14]. In order to detect trend changes at specific points of the period, a "joinpoint" model with a break in the logarithmic scale[15] was applied, presented in the original rate scale with the APCs per segment[16].

The association between syphilis and schooling was estimated by means of adequate count models for incidence data, specified as follows:

$$ln(y\_it) = ln(\hat{y}\_it) + \beta\, prop\_low\_ed\_it + \mu\_i + \varepsilon\_t$$

where μit is the mean number of GS (or SC) cases in FU=i in Year=t, log(NVit) is the offset that normalizes by the denominator, γi are FU fixed effects and δt are Year fixed effects. The Poisson model was used as starting point, applying a super dispersion test; when such dispersion was found, the Negative Binomial model was adopted[17]. Clustered robust standard errors by FUs were used in the inference, ensuring resilience to heteroscedasticity (or residuals heterogeneity). In this parametrization, eβ was interpreted as the Incidence Rate Ratio (IRR), reporting the relative variation of the incidence associated with the higher low schooling proportion over time.

A Queen contiguity neighborhood matrix was created to assess spatial dependence, with line standardization (line standardization using prop_low_ed). As a confirmatory stage, the spatial regressions were adjusted in the logarithmic scale of the rates (SAR-lag and SEM), adopting the model type according to robust LM tests (RLMlag and RLMerr).

In order to synthesize the mean regional trend and quantify heterogeneity across federation units, a random-effects meta-analysis was performed using the Restricted Maximum Likelihood (ReML) estimator. The β coefficients obtained in the log-linear regressions estimated for each state were combined; this allowed calculating a mean regional effect and assessing inter-state heterogeneity by means of the I^2 statistical value. The analyses were performed in the R software (version 4.1.1) using the *metafor* package.

This research study was exempt from appraisal by any Research Ethics Committee according to the national guidelines applicable to studies conducted with public and anonymized secondary data. Even so, we adopted good data protection practices foreseen in the Personal Data Protection Law (*Lei de Proteção de Dados Pessoais* [LGPD] or Law No. 13,709/2018), avoiding any connection attempt that might result in identifying individuals.

RESULTS

In all the North region states, the GS cases were mainly concentrated among women aged from 20 to 29 years old (≈45%-56%), with a relevant percentage of adolescents between the ages of 15 and 19 (≈24%-30%). As for schooling, predominance of the Elementary School and High School categories was observed. The brown race/skin color prevailed in the entire region (≈66%-82%), reflecting the regional demographic structure; in turn, a higher proportion of white race/skin color was observed in Rondônia (≈18%) (Table 1).

Table 1. Absolute and percentage distribution corresponding to the sociodemographic characteristics of the Gestational Syphilis cases, by North region states. Belém, Pará, Brazil, 2025

(continue)

Variables	AC	AP	AM	PA	RO	RR	TO
Maternal age (years old)							
Total n (%)	4,579 (100.0)	3,240 (100.0)	14,763 (100.0)	25,243 (100.0)	4,371 (100.0)	2,928 (100.0)	5,329 (100.0)
10-14	78 (1.7)	52 (1.6)	203 (1.4)	322 (1.3)	52 (1.2)	33 (1.1)	82 (1.5)
15-19	1,358 (29.7)	881 (27.2)	3,790 (25.7)	6,086 (24.1)	1,076 (24.6)	705 (24.1)	1,388 (26.0)
20-29	2,306 (50.4)	1,685 (52.0)	8,111 (54.9)	14,243 (56.4)	2,420 (55.4)	1,639 (56.0)	2,766 (51.9)
30 - 39	758 (16.6)	551 (17.0)	2,314 (15.7)	4,236 (16.8)	767 (17.6)	448 (15.3)	1,016 (19.1)
40+	79 (1.7)	71 (2.2)	345 (2.3)	356 (1.4)	56 (1.3)	103 (3.5)	77 (1.4)
Schooling							
Total n (%)	4,487 (100.0)	3,328 (100.0)	15,308 (100.0)	22,421 (100.0)	4,408 (100.0)	2,893 (100.0)	5,582 (100.0)
Illiterate	66 (1.5)	14 (0.4)	85 (0.6)	135 (0.6)	18 (0.4)	8 (0.3)	17 (0.3)
Incomplete Elementary School	747 (17.0)	824 (18.0)	4,786 (31.3)	2,275 (50.7)	1,084 (24.1)	444 (9.8)	683 (15.2)
Complete Elementary School	413 (9.2)	237 (7.1)	1,664 (10.9)	2,099 (9.4)	382 (8.7)	206 (7.1)	444 (8.0)
Incomplete High School	787 (17.5)	583 (17.5)	2,494 (16.3)	3,391 (15.1)	749 (17.0)	479 (16.6)	944 (16.9)
Complete High School	1,166 (26.0)	721 (21.7)	3,783 (24.7)	4,615 (20.6)	972 (22.1)	723 (25.0)	1,627 (29.1)
Incomplete Higher Education	157 (3.5)	92 (2.8)	479 (3.1)	378 (1.7)	103 (2.3)	55 (1.9)	159 (2.9)
Complete Higher Education	116 (2.6)	101 (3.0)	351 (2.3)	282 (1.3)	79 (1.8)	49 (1.7)	117 (2.1)
Unknown	736 (16.4)	786 (23.6)	1,666 (10.9)	3,453 (15.4)	1,021 (23.2)	929 (32.1)	1,081 (19.4)

Table 1. Absolute and percentage distribution corresponding to the sociodemographic characteristics of the Gestational Syphilis cases, by North region states. Belém, Pará, Brazil, 2025

(conclusion)

Variables	AC	AP	AM	PA	RO	RR	TO
Race/Skin color							
Total n (%)	4,858 (100.0)	3,374 (100.0)	14,425 (100.0)	26,191 (100.0)	4,549 (100.0)	3,138 (100.0)	5,363 (100.0)
White	358 (7.4)	274 (8.1)	1,137 (7.9)	1,975 (7.5)	823 (18.1)	178 (5.7)	584 (10.9)
Black	276 (5.7)	256 (7.6)	645 (4.5)	1,699 (6.5)	371 (8.2)	94 (3.0)	475 (8.9)
Asian	55 (1.1)	45 (1.3)	115 (0.8)	142 (0.5)	46 (1.0)	18 (0.6)	233 (4.3)
Brown	3,952 (81.4)	2,458 (72.8)	11,371 (78.8)	21,406 (81.7)	3,010 (66.2)	2,184 (69.6)	3,825 (71.3)
Indigenous	124 (2.6)	9 (0.3)	452 (3.1)	83 (0.3)	35 (0.8)	113 (3.6)	66 (1.2)
Unknown	93 (1.9)	332 (9.8)	705 (4.9)	886 (3.4)	264 (5.8)	551 (17.5)	180 (3.4)

Source: The authors, based on SINAN and SINASC/DATASUS data, 2014-2023.

In relation to CS, the vast majority of cases was recorded in children aged less than seven days (≈93%-97%), with small percentages between seven and 27 days old and between 28 and 364 days old, in addition to rare records in children aged at least one year old. The maternal age distribution was similar to the one observed for GS (Table 2).

Table 2. Absolute and percentage distribution corresponding to the sociodemographic characteristics of the Congenital Syphilis cases, by North region states. Belém, Pará, Brazil, 2025

(continue)

Variables	AC	AP	AM	PA	RO	RR	TO
Child's age							
Total n (%)	995 (100.0)	1,225 (100.0)	5,185 (100.0)	9,503 (100.0)	789 (100.0)	801 (100.0)	2,557 (100.0)
<7 days old	930 (93.5)	1,141 (93.1)	5,041 (97.2)	9,154 (96.3)	747 (94.7)	747 (93.3)	2,491 (97.4)
7-27 days old	26 (2.6)	40 (3.3)	51 (1.0)	146 (1.5)	15 (1.9)	17 (2.1)	22 (0.9)
28-364 days old	22 (2.2)	26 (2.1)	63 (1.2)	177 (1.9)	23 (2.9)	31 (3.9)	35 (1.4)
1 year old	17 (1.7)	17 (1.4)	16 (0.3)	15 (0.2)	3 (0.4)	3 (0.4)	4 (0.2)
2-4 years old	0 (0.0)	1 (0.1)	13 (0.3)	7 (0.1)	1 (0.1)	2 (0.2)	3 (0.1)
5-12 years old	0 (0.0)	0 (0.0)	1 (0.0)	4 (0.0)	0 (0.0)	1 (0.1)	2 (0.1)

Table 2. Absolute and percentage distribution corresponding to the sociodemographic characteristics of the Congenital Syphilis cases, by North region states. Belém, Pará, Brazil, 2025

(conclusion)

Variables	AC	AP	AM	PA	RO	RR	TO
Maternal age (years old)							
Total n (%)	820 (100.0)	1,157 (100.0)	4,260 (100.0)	6,885 (100.0)	707 (100.0)	860 (100.0)	2,750 (100.0)
10-14	14 (1.7)	22 (1.9)	52 (1.2)	67 (1.0)	19 (2.7)	12 (1.4)	40 (1.5)
15-19	275 (33.5)	313 (27.0)	1,160 (27.2)	1,912 (27.8)	166 (23.5)	241 (28.0)	610 (22.2)
20-29	375 (45.7)	593 (51.2)	2,142 (50.3)	3,636 (52.8)	367 (51.9)	448 (52.1)	1,596 (58.0)
30-39	120 (14.6)	192 (16.6)	734 (17.2)	1,086 (15.8)	131 (18.5)	133 (15.5)	423 (15.4)
40+	16 (2.0)	19 (1.6)	99 (2.3)	99 (1.4)	15 (2.1)	16 (1.9)	40 (1.5)
Unknown	20 (2.4)	18 (1.6)	73 (1.7)	85 (1.2)	9 (1.3)	10 (1.2)	41 (1.5)

Source: The authors, based on SINAN and SINASC/DATASUS data, 2014-2023.

The trend analysis indicated exponential growth in the GS rates throughout the historical series; in turn, the CS rates were more heterogeneous across the states. Inflection points with significant changes in trend directions were identified in Amazonas and Rondônia (Figures 1 A and B). The CS rates presented a significant increase in Amazonas (APC≈80.5%), but a reverse trend was noticed from 2018 onwards. A similar pattern was observed in Rondônia, with initial growth (APC≈12.3%) followed by an expressive reduction after 2018. In contrast, Pará maintained the continuous growth in terms of CS, even if with certain de-acceleration: the rate presented two increasing segments with APC values of approximately 5.8% until 2019 and 11.1% after that. In the North region as a whole, a marked initial rise was observed (21.6% a year), followed by a slower increase after 2018 (3.8% a year) (Figures 1 C and D).

The regression analyses evidenced a positive association between the low maternal schooling proportion and the syphilis rates. For CS, the combined effect was β=0.10 (95%CI: 0.01-0.19), which corresponds to a nearly 10% increase in the rate for every 10-percent-point increase in the proportion of low-schooled mothers. The association was even more intense in the case of GS, with β=0.18 (95%CI: 0.15-0.21), which is equal to an approximate 20% increase in the rates for every 10-percent-point increase in low schooling (Figures 2 A and B).

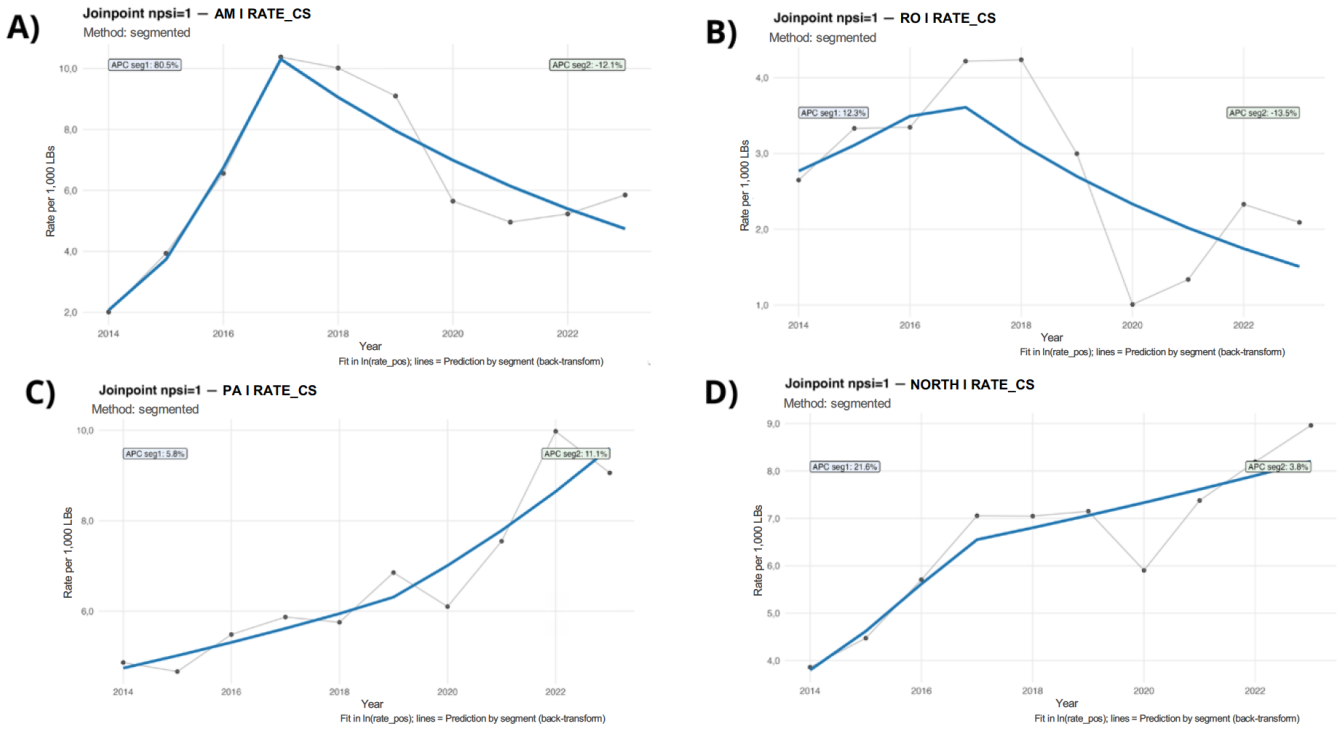

Figure 1. Time trends for CS in AM (A), RO (B) and PA (C), as well as in the North region as a whole (D). Belém, Pará, Brazil, 2025

Source: The authors (2025).

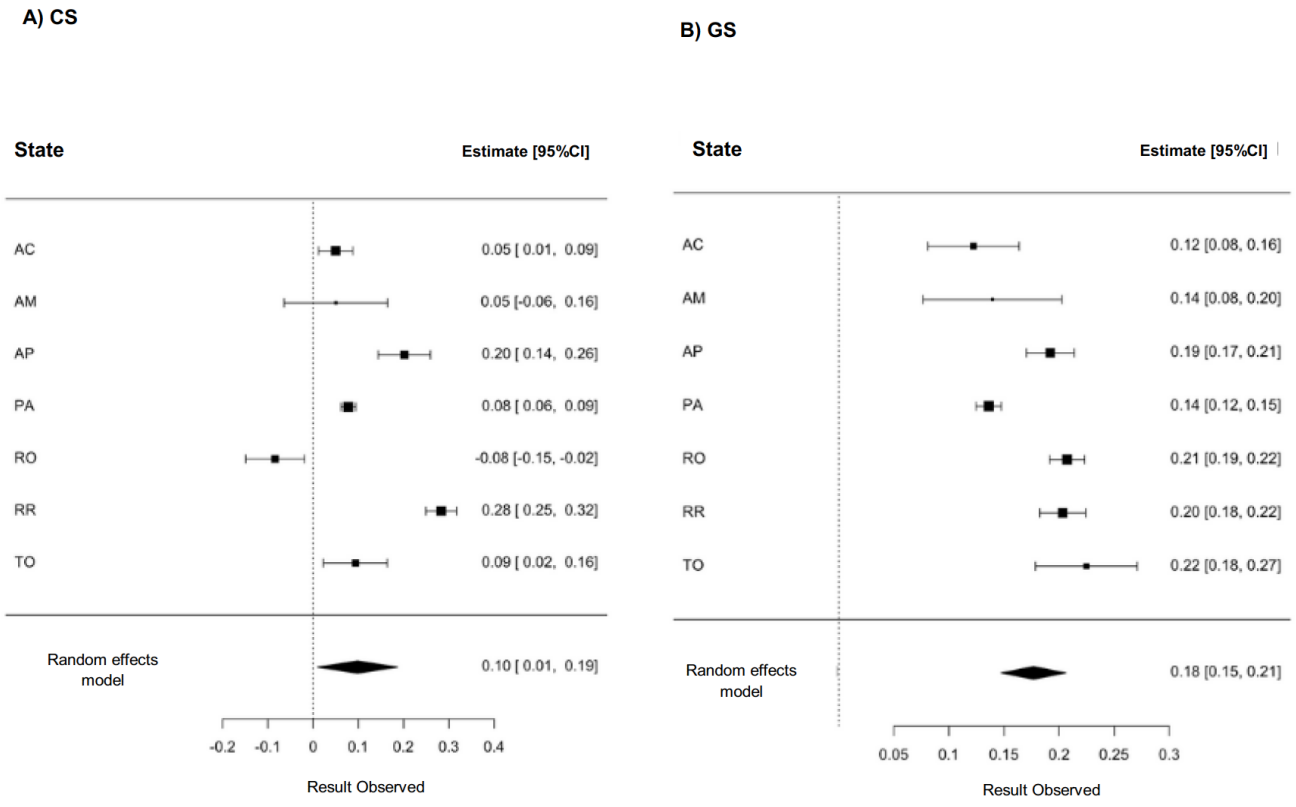

Figure 2. Association between low maternal schooling and incidence of CS (A) and GS (B) in the Brazilian North region. Belém, Pará, Brazil, 2025

Caption: CI = Confidence Interval.

Source: The authors (2025).

The linear models at the logarithmic scale were adjusted, with fixed effects by FUs and standard errors clustered by FUs (70 observations; 7 FUs×10 years), considering the "low maternal schooling" covariable standardized in 10-percent-point increases. For every 10-percent-point increase, a relative 1.8% increase in the syphilis rate was observed in the mothers (CS) (β=0.018; SE=0.040; IRR≈1.02; 95%CI: 0.94-1.10; p=0.65; R^2within=0.158), as well as a 5.0% increase in the Congenital Syphilis (CS) rate (β=0.049; SE=0.102; IRR≈1.05; 95%CI: 0.86-1.28; p=0,63; R^2within=0.095).

The thematic maps corresponding to the mean CS and GS rates by FUs evidenced the contrasts between TO (high CS rate) and AC (high GS rate) (Figures 3 A and B); in addition, the relationship between incidence and low maternal schooling stood out as more concentrated in the states of AC, AM and RO, which are also among those with the highest syphilis rates (Figure 3 C).

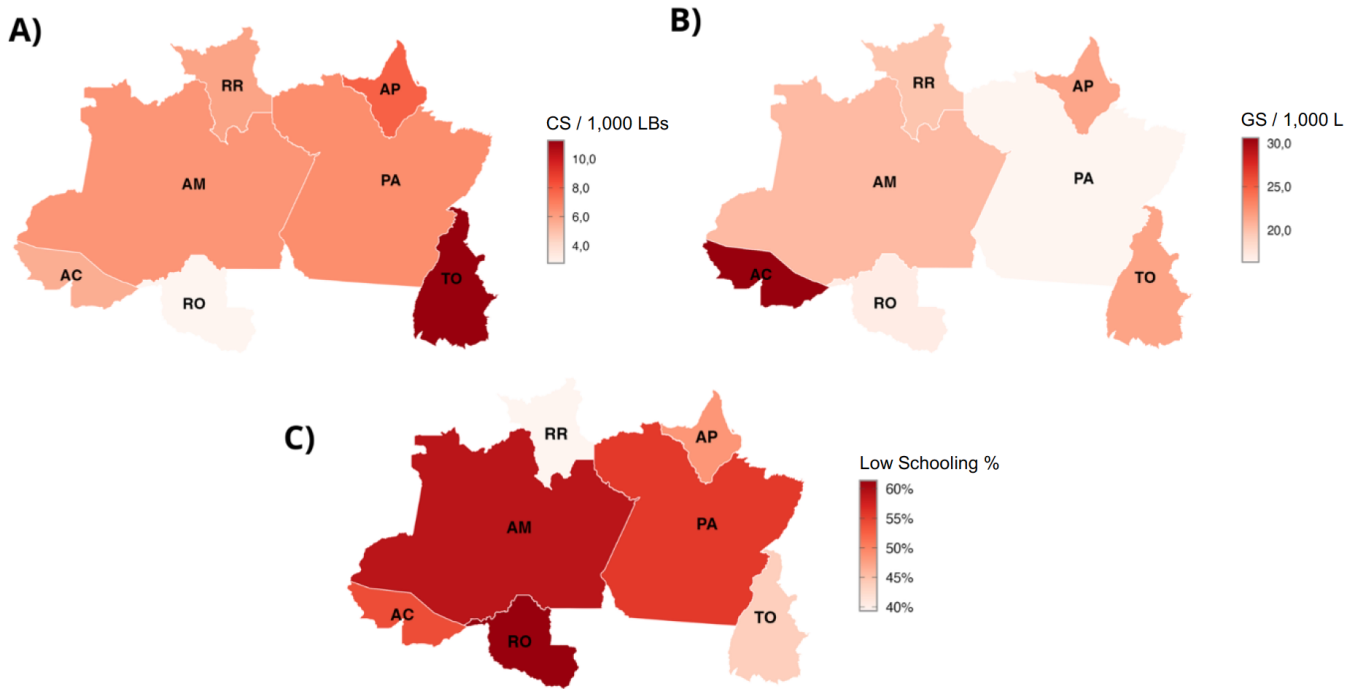

Figure 3. Mean incidence rates (1,000 LBs) for CS (A) and GS (B) and low maternal schooling distribution (%) (C) in the Brazilian North region. Belém, Pará, Brazil, 2025

Source: The authors (2025).

The comparison panel between CS and GS allows noticing the discrepancy between accelerated growth in the number of GS notifications and CS persisting at high levels.

The sensitivity analyses confirmed robustness of the results: (i) the quadratic and GAMM models with AR1 structure indicated a pronounced curvature in the GS trends but did not alter direction of the effects; and (ii) the spatial SAR/SEM models presented higher marginal fit values (lower AIC), but did not modify magnitude or direction of the associations.

DISCUSSION

The GS and CS concentration among women aged 20-29 years old (with a relevant percentage of adolescents between the ages of 15 and 19) is in line with the regional reproductive pattern, but reinforces persistent vulnerabilities in terms of prenatal care in

this population group. Although the predominance among adolescents is proportionally lower than in young adult women, its epidemiological relevance indicates failures in early recognition, sex education and qualified access to prenatal care in this age group, as described in recent nationwide analyses[18].

The predominance of women self-declared as brown-skinned is in line with the regional demographic composition; however, the proportionally relevant presence of indigenous population groups in some states evidences the need for culturally adapted strategies, expanding testing and treatment in remote areas and overcoming linguistic and geographical barriers[19]. This territorial aspect differentiates the North region from other Brazilian macro-regions and represents a relevant contribution of this study because it evidences intra-regional heterogeneities scarcely explored in aggregated nationwide analyses.

The high percentage of CS diagnosed during the first week of life suggests a detection flow concentrated on motherhood, which favors surveillance but does not substitute primary and secondary prevention during pregnancy[20]. This pattern indicates that the system is capable of identifying the outcome but fails to timely prevent mother-to-child transmission, a critical aspect for the elimination targets. From the time perspective, the ascending and non-linear progression of GS (associated with the inter-state heterogeneity presented by CS) is consistent with the national panorama described in Epidemiological Bulletins[20,21]. In turn, this study adds insights by showing that, even with the recent de-acceleration in states like Amazonas and Rondônia, sustained growth is still found in Pará, contributing to maintaining the increasing regional trend. Such persistence evidences that the states' responses have not been homogeneous or sufficient to alter the regional course of these diseases.

In 2024, the need was reinforced to uphold high screening and timely treatment coverage rates in order to break the mother-to-child transmission chain[22]. However, when the intra-regional singularities inherent to the Brazilian North region and marked by relevant sociocultural, demographic and logistic differences are considered, it is noticed that territorially-targeted strategies tend to be more effective than average state targets.

Diverse evidence coming from Amazonas indicates that many CS cases are recorded among low-schooled pregnant women living outside the capital city, with late diagnoses and partners not treated or subjected to inadequate treatments, which contributes to a persistent high risk in the inland, despite the reduction observed in part of the series[23]. In Pará, the continuous increase in the number of CS cases also evidences important disparities between coastline and riverside municipalities, with difficult access by water or land and health infrastructures that tend to be more precarious, with lower laboratory capabilities and fewer duly qualified professionals[5].

Despite the global progress made and the consolidation of programs targeted at eliminating mother-to-child syphilis transmission as a Public Health problem, the results obtained in this study indicate that the current efforts are still insufficient to modify this scenario. The persistent growth of GS and the heterogeneous CS patterns reinforce the gap in relation to the elimination track and evidence the need for specific state policies linked to nationwide actions.

Two contextual factors assist in interpreting the curvature observed. The scarcity of benzathine penicillin between 2014 and 2016 hindered timely treatments and may have had repercussions on subsequent years[24,25,26]. Later in time, the COVID-19 pandemic de-structured care flows and prevention activities, with impacts on maternal syphilis diagnosis and management[26–28].

More incident among low-schooled women, the social gradient observed reasserts syphilis as a structural inequality indicator. The Brazilian contemporary literature shows that schooling, race/skin color and territorial vulnerability overlap one another, increasing GS and CS risks[29].

Municipal and statewide studies reinforce this interpretation. In Amazonas, the persistence in terms of cases is associated with late diagnosis, with inadequate treatment of partners and with the disease concentrating in the inland[23]. In Bahia and São Paulo, a number of spatial analyses evidenced municipal clusters related to maternal low schooling and to inadequate prenatal care[29,30]. The findings are in line with this evidence and expand knowledge by showing that territorial disparities in the North region (especially in riverside and hard-to-access municipalities) play a central role in maintaining the CS rates.

When making a comparison with the post-pandemic literature, the track found in the North region converges with recent findings in Brazilian capital cities and metropolitan regions, where resuming prenatal care reorganized testing and treatment flows but failed to solve social asymmetry; therefore, care quality and logistics in remote areas continue to define whether CS is mitigated or remains at high levels[28].

The following can be mentioned as strengths of this paper: (a) full series (2014-2023) for all seven states; (b) FU×Year panel with offset, fixed effects and robust errors; (c) trend approach combining log-linear APCs, "joinpoints" and GAMM(AR1); and (d) spatial sensitivity analyses (Moran/LISA, SAR/SEM) and a meta-analysis on the effects exerted by schooling. The design and the analytical triangulation are in line with the best practices for short surveillance series (susceptible to auto-correlation and heteroscedasticity) and with the EMTCT validation guides, which demand more methodological consistency than policy inferences.

These results indicate that maternal-child syphilis control in the North region does not exclusively depend on expanding prenatal care coverage but also on reducing the social and territorial inequalities that structure the epidemiological risk. The persistence in terms of high rates in certain states suggests that consistent strategies may not suffice to alter the course of mother-to-child transmission. In contexts characterized by large geographical distances, population dispersion and barriers in terms of access to health services (such as the Brazilian Amazon), territorially-targeted interventions sensitive to local specificities become essential for syphilis prevention and control policies to be effective[6,24].

This study does have some limitations: (I): it is an ecological study at the FU level, subject to ecological fallacy; (ii): it depends on information systems (SINAN, SINASC) that may undergo variations in terms of completeness; (iii): relatively small annual series, reason why the uncertainty of joinpoints and smooth curves should be interpreted with caution.

CONCLUSION

Gestational Syphilis remained on the rise in the Brazilian North region; in turn, Congenital Syphilis presented marked heterogeneity across the states throughout the period analyzed. The association observed between higher proportion of low maternal schooling and increased syphilis rates evidences the central role played by social determinants in persistent mother-to-child transmission. These findings expand what

is known about the spatial-time dynamics of maternal-child syphilis in the Brazilian Amazon and indicate that the control strategies should consider territorial and social inequalities when organizing surveillance and prevention actions.

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Substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work - **Torres MKS, Neves LGS.** Drafting the work or revising it critically for important intellectual content - **Torres MKS, Parente AT, Aben-Athar CYUP, Botelho EP, Ferreira GRON.** Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved - **Torres MKS.** All authors approved the final version of the text.

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