HEALTH SCIENCES | ORIGINAL ARTICLE

Tuberculosis trend among the indigenous peoples of the Brazilian Amazon from 2001 to 2022

Leny Meire Correa Molinari CARRASCO[1,3,6] , Gabriel Lopes RODRIGUES[1*] ,
Hendrega Nadynne de Oliveira SANTOS[1] , Giovanna Machado MARINHO[1] ,
Thayza Miranda PEREIRA[2,4] , Lorena Dias MONTEIRO[1,5]

[1] Afya Faculdade de Ciências Médicas, Escola de Medicina. Palmas, Tocantins, Brazil

[2] Universidade Federal do Tocantins, Escola de Enfermagem, Palmas, Tocantins, Brazil

[3] Instituto Federal do Tocantins, Diretoria de Ensino Superior, Palmas, Tocantins, Brazil

[4] Fundação Oswaldo Cruz –Fiocruz, Brasília, Distrito Federal, Brazil

[5] Secretaria de Estado de Saúde do Tocantins – SES-TO, Escola Tocantinense do Sistema Único de Saúde, Palmas, Tocantins, Brazil

[6] Secretaria Municipal de Saúde de Palmas – SEMUS-TO, Palmas, Tocantins, Brazil.

*Corresponding author: gabriellopesrodrigues23@gmail.com

ABSTRACT

Tuberculosis (TB) remains a significant public health concern among indigenous peoples in the Brazilian Amazon. This study aimed to describe the epidemiological characteristics and temporal trends of TB indicators within this population from 2001 to 2022. We analyzed data on new self-reported TB cases by indigenous people in the area of the Legal Amazon from the DATASUS database of the Brazilian Health Ministry. TB indicators were calculated, and temporal trends were analyzed using joinpoint regression. A total of 9,245 TB cases were registered among indigenous residents. Men were the most affected from 2001 to 2022, except in 2019. TB cases significantly decreased from 2001 to 2022 [average annual percent change (AAPC) = -2.7%; 95% confidence interval (CI) = -3.6 to -1.7]. A considerable decline in incidence was observed in the states of Rondônia (APC = -7.4%, CI = -1.0 to -4.8) , Acre (APC = -3.2%, CI = -5.4 to -0.9), Amazonas (APC = -4.1%, CI = -4.9 to -3.3%) and Tocantins (APC = -3.3%, CI = -5.8 to -0.7). In Mato Grosso state, a significant increase occurred from 2012 to 2015 (APC = 46.6%, CI = -28.4 to 200.0). TB incidence remains high among indigenous peoples in the Legal Amazon compared to the general population of the region and Brazil, despite declining trends in the period.

KEYWORDS: Public health, respiratory disease, epidemiology, time series studies, epidemiologic surveillance

Tendência da tuberculose entre os povos indígenas da Amazônia brasileira de 2001 a 2022

RESUMO

A tuberculose (TB) continua sendo uma preocupação significativa de saúde pública entre os povos indígenas na Amazônia brasileira. Este estudo teve como objetivo descrever as características epidemiológicas e as tendências temporais dos indicadores de TB nessa população de 2001 a 2022. Analisamos dados de novos casos de TB autodeclarados por indígenas na área da Amazônia Legal a partir do banco de dados DATASUS do Ministério da Saúde do Brasil. Os indicadores de TB foram calculados e as tendências temporais foram analisadas usando regressão joinpoint. Um total de 9.245 casos de TB foram registrados entre os residentes indígenas. Os homens foram os mais afetados de 2001 a 2022, exceto 2019. Os casos de TB diminuíram significativamente de 2001 a 2022 [mudança percentual média anual (AAPC) = -2,7%; intervalo de confiança (IC) de 95% = -3,6 a -1,7]. Foi observada uma considerável redução na incidência nos estados de Rondônia (APC = -7,4%, IC = -1,0 a -4,8), Acre (APC = -3,2%, IC = -5,4 a -0,9), Amazonas (APC = -4,1%, IC = -4,9 a -3,3%) e Tocantins (APC = -3,3%, IC = -5,8 a -0,7) . No estado de Mato Grosso, ocorreu um aumento significativo de 2012 a 2015 (APC = 46,6%, IC = -28,4 a 200,0). A incidência de TB continua alta entre os povos indígenas na Amazônia Legal em comparação com a população geral da região e do Brasil, apesar das tendências de declínio no período.

PALAVRAS-CHAVE: Saúde pública, doença respiratória, epidemiologia, estudos de séries temporais, vigilância epidemiológica

INTRODUCTION

Tuberculosis (TB) is a critical public health problem, particularly in regions with adverse socioeconomic conditions, such as the Brazilian Amazon. This infectious disease, caused by the bacillus *Mycobacterium tuberculosis*, was discovered by Robert Koch in 1882 (Worboys 1990). It finds allies for its spread in poverty, malnutrition, and limited access to health services (Welch and Coimbra Jr 2011; Ferraz and Valente 2014; WHO 2022). Indigenous populations are especially vulnerable due to specific socioeconomic and health conditions, and represent a priority group in the context of TB in the Brazilian Amazon (Levino and Oliveira 2007; Marques *et al.* 2010).

Recent research highlights the high incidence of TB among indigenous peoples in the Amazon, shedding light on both the epidemiological dimension of the disease and the challenges related to its diagnosis and treatment in these communities (Rios *et al.* 2013; Santos *et al.* 2020). The epidemiological profile of TB among indigenous peoples reveals a predominance of the pulmonary form of the disease, with a high mortality rate and transmission mainly among men and productive age groups (Lachi and Nakayama 2015; Faria 2020). Spatial distribution of cases and identification of high-risk areas are essential for directing intervention strategies and prevention (Ferraz and Valente 2014).

The analysis of gender, age, and geographic location is essential for understanding the dynamics of TB among indigenous populations. These factors are expected to influence TB incidence, with potential disparities based on regional healthcare access, age-related diagnostic challenges, and gender-related differences in health-seeking behavior. These hypotheses will be explored further in the discussion section. Studies point to a direct relationship between TB incidence and factors such as low income, poverty, and lack of education (Rios *et al.* 2013; Ferraz and Valente 2014). The highlighted disparities reinforce the need for specific approaches adapted to the cultural and social realities of these communities. The long-term trend analysis of TB in indigenous peoples is fundamental for the planning and implementation of effective public policies (Marques *et al.* 2010; Dehghani *et al.* 2018). The integration of public health strategies that consider the specific cultural, social, and economic aspects of indigenous populations is vital for the success of the interventions. In this context, this study aimed to analyse the trend of TB in indigenous peoples of the Brazilian Amazon during the period of 2001-2022, seeking to understand the epidemiological patterns of the disease in order to provide support for the development of more assertive and culturally adapted public policies for TB control in this region (Costa *et al.* 2022; Pascoal *et al.* 2022; Aguiar *et al.* 2023).

MATERIAL AND METHODS

TB data were analyzed for the indigenous population of the Legal Amazon, an administrative macro-region that covers approximately 5.217.423 km², representing about 61% of Brazil's area, including the whole Brazilian area of the Amazon biome. It fully includes the states of Acre, Amapá, Amazonas, Pará, Rondônia, Roraima, Tocantins, Mato Grosso and significant parts of Maranhão. In 2022, the indigenous population in the region was 26.7 million (IBGE 2022). This region exhibits a complex socio-environmental fabric, with the coexistence of dense urban centres and traditional communities in inaccessible rural zones, reflecting a mosaic of social and economic indicators.

We carried out an ecological time series analysis of new TB cases in indigenous residents of the Legal Amazon from January 1, 2001, to December 31, 2022. The data were obtained from the Department of Informatics of the Unified Health System (DATASUS) of the Health Ministry of Brazil. The data comes from compulsory notifications, which consist of a standardised form filled out by health professionals with sociodemographic, clinical, and treatment information (Brasil 2024). Individuals self-identifying as indigenous during disease notification were classified as such. Cases not presenting data or categorised as unknown in the race/color variable were not included in the analysis (IBGE 2022). Population data were obtained from the Instituto Brasileiro de Geografia e Estatística (IBGE), based on state census data from 2000, 2010, and 2022, and population estimates for the intercensal years (2001-2009 and 2011-2021) (IBGE 2022).

In the descriptive analysis, TB incidence coefficients were calculated for three distinct groups: the indigenous population of the Legal Amazon, the general population of the Legal Amazon, and the Brazilian population. Incidence coefficients were determined as the number of new TB cases per population multiplied by the constant 100,000.

Between 2000 and 2010, the indigenous population had an average annual geometric growth rate of 2.4%, which increased to 3.0% between 2010 and 2022. These estimates were crucial for adjusting demographic parameters in indicator calculations, ensuring more accurate projections of the indigenous population and reliable calculations of TB incidence rates (IBGE 2022). To determine the average incidence coefficient of TB, the arithmetic mean was employed by adding the annual incidence coefficients and subsequently dividing them by the number of observations in the analysed period. The standard deviation, minimum, and maximum values were calculated for the TB incidence rates among the three population levels analysed. These indicators were computed to provide a comprehensive understanding of central trends and the variability of the collected data. The proportion of TB cases by gender in the Indigenous population was calculated by dividing the new cases in men or women by the total number of cases, multiplying the result by 100. Additionally, incidence coefficients were calculated by age group in the categories of 0 to 14 years, 15 to 24 years,

25 to 34 years, 35 to 44 years, 45 to 54 years, 55 to 64 years, and 65 years or more.

For the trend analysis of TB incidence coefficients, the segmented linear regression technique (Clegg *et al.* 2009) was used in the Joinpoint software version 4.2.0 (Kim *et al.* 2000). The evaluated indicators included incidence coefficients of TB in Brazil, in the Legal Amazon as a whole, in the indigenous population of the Legal Amazon, and for the indigenous population of each Amazonian state. In the segmented linear regression analysis, TB incidence coefficients were considered as dependent variables, while the year of occurrence was the independent variable. The Monte Carlo permutation test was used to determine the optimal model fit, prioritising the one with the highest coefficient of determination (R^2) for the residuals.

The analysis of trends was quantified by the annual percent change (APC) and its 95% confidence interval (95% CI), considering an APC significant with $p < 0.05$ that did not include the zero value. Significant trends were interpreted as increasing (positive APC) or decreasing (negative APC), while non-significant trends were classified as stable. The average annual percent change (AAPC) was estimated as the weighted geometric mean of the APCs, with the weights corresponding to the length of each segment in the time interval (Kim *et al.* 2000; Clegg *et al.* 2009).

RESULTS

From 2001 to 2022, a total of 1,597,889 new TB cases were identified in Brazil, 239,983 of these in the Legal Amazon, of which 9,278 (3.85%) occurred among the indigenous population. The average incidence coefficient of TB was 102.51 ± 22.17 per 100,000 inhabitants among indigenous peoples of the Legal Amazon (Table 1). The standard deviation of 22.17 indicated variability in the indicator within the indigenous population, with a range from 63.2 to 152.1 per 100,000 inhabitants over the evaluated years. In comparison, the general population of the Legal Amazon had a lower average and variability (42.05 ± 2.92 per 100,000 inhabitants) (Table 1). The general population of Brazil presented the lowest average incidence, with 37.33 ± 3.09 per 100,000 inhabitants, suggesting a more stable incidence coefficient.

Table 1. Tuberculosis incidence coefficient among indigenous peoples of the Legal Amazon, the general population of the Legal Amazon, and the general population of Brazil in the period 2001-2022.

Population	Average	Standard deviation	Minimum	Maximum
Indigenous peoples of the Legal Amazon	102.51	22.17	63.2	152.1
General population of the Legal Amazon	42.05	2.92	37.8	46.8
General population of Brazil	37.33	3.09	32.3	43.9

In the indigenous population, the TB incidence peaked in 2003 with 152.1 cases per 100,000, followed by a general declining trend that reached the lowest value of 63.2 in 2021, and a subsequent increase to 75.5 in 2022, still maintaining a hyperendemic status (Figure 1). The general population of the Legal Amazon had an incidence of 46.8 cases per 100,000 inhabitants in 2022, indicating a relatively stable variation over the period. For the general population of Brazil, the incidence coefficient showed a relative stability over the years.

In 2001, the proportion of indigenous males with TB was 61.2%, compared to 38.8% among females (Figure 2). Over the years, these percentages varied, with a trend of decrease for males until 2009 and a subsequent increase for females, culminating in a reversal of this trend in 2019, when females had a higher percentage than males (51.6% and 48.4%, respectively). In the following years TB incidence was higher in males again. In 2022, TB incidence was 56.8% for males and 43.2% for females.

The linear joinpoint regression between 2001 and 2022 revealed a significant declining trend in the TB incidence rate in the general Brazilian population, with an annual percent change (APC) of -1.0% (95% CI = -1.3 to -0.6) (Table 2). For the general population of the Legal Amazon, two distinct trends were identified. From 2001 to 2015 there was a significant decrease in the TB incidence coefficient, with an APC of -3.6% (95% CI = -4.2 to -3.1) (Table 2), while from 2015 to 2022 the trend was stable, with an APC of -1.0% (95% CI = -2.4 to 0.3) (Table 2). The overall trend for the period from 2001 to 2022 was of significant decrease, with an AAPC of -2.8% (95% CI = -3.3 to -2.3) (Table 2). Among the indigenous population of the Legal Amazon from 2001 to 2022, there was a significant decrease in TB incidence, with an AAPC of -2.7% (95% CI = -3.6 to -1.7) (Table 2).

In the indigenous population, there was a significant decline in the TB incidence coefficient of -7.4% (95% CI = -1.0 to -4.8) in Rondônia, -3.2% (95% CI = -5.4 to -0.9) in Acre, -4.1% (95% CI = -4.9 to -3.3) in Amazonas, and -3.3% (95% CI= -5.8 to -0.7) in Tocantins (Table 2). In Roraima, the TB incidence exhibited a declining trend of -5.9% (95% CI = -10.1 to -1.6) in the period 2001-2014, and a trend to stability in 2014-2022, with an APC of 5.7% (95% CI = -2.8 to 14.9) (Table 2). In Pará and Amapá, the TB incidence coefficient was stable over the whole period, with an APC of 0.9% (95% CI= -0.8 to 2.8) and -2.4% (95% CI = -6.8 to 2.2) (Table 2). In Maranhão, the incidence was stable from 2001 to 2003 (APC = 69.4%, 95% CI = -31.0 to 315.7), and decreased significantly from 2003 to 2022 (APC =-5.7% 95% CI = -7.6 to -3.7) (Table 2). In Mato Grosso, the incidence was stable from 2001 to 2012 (APC = -2.8%; 95% CI = -9.2 to 4.1), increased significantly from 2012 to 2015 (APC = 46.6%; 95% CI = -28.4 to 200.0), and decreased
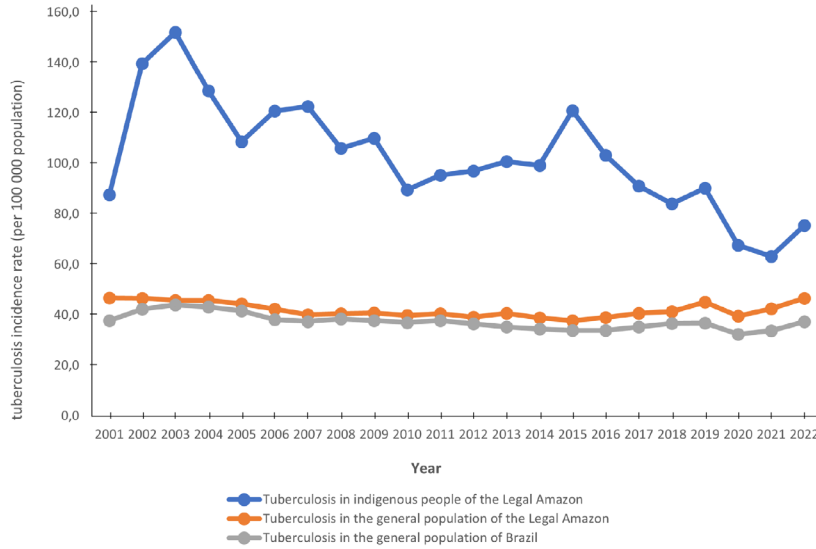
Figure 1. Temporal evolution of the tuberculosis incidence coefficient in the indigenous population of the Legal Amazon, the general population of the Legal Amazon, and the general population of Brazil in the period 2001-2022.
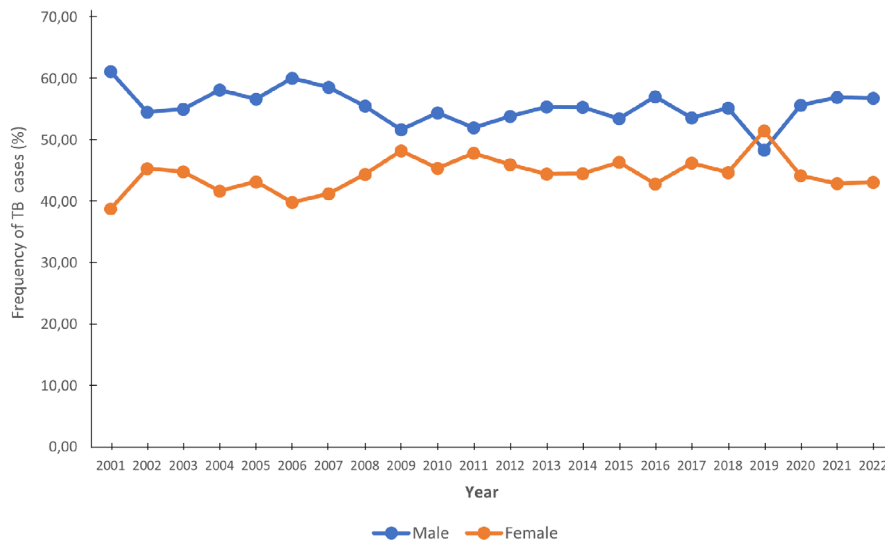

Figure 2. Trend of the proportion of new tuberculosis (TB) cases by gender among indigenous peoples of the Legal Amazon in the period 2001-2022.

significantly from 2015 to 2022 (APC = -20.2%; 95% CI = -27.4 to -12.3) (Table 2).

Regarding age groups, there was a significant declining trend in TB incidence from 2001 to 2012 for indigenous individuals under 15 years, followed by an expressive but not significant increase from 2012 to 2015, and a return to significant decline from 2015 to 2022 (Table 2). Over the total period, there was a declining trend in the under-15 age group, with an APC of -5.6%. Individuals aged 15 to 24 years had a significant increase from 2001 to 2003, followed by a continuous and significant decline from 2003 to 2022, but

an APC of -0.3%, suggesting stability in TB incidence in this group. In the age groups of 35 to 44 years and 45 to 54 years, there was a continuous and significant decline in TB incidence throughout the entire period (Table 2). Individuals aged 55 to 64 years experienced a significant decrease in TB incidence over the entire period, indicating a continuous and significant declining trend. Among individuals aged 65 years or older, there was a trend of decline from 2001 to 2016, followed by a more significant and sharp reduction from 2016 to 2022. The overall trend for this group was a significant decrease in incidence, with an APC of -4.3%.

DISCUSSION

This study revealed a significant disparity in the TB incidence coefficient of the indigenous population of the Legal Amazon and the general population of both the Legal Amazon and Brazil from 2001 to 2022. These findings align with previous studies documenting the larger vulnerability of indigenous populations to TB, attributed to social and health determinants such as living conditions, access to healthcare, and socioeconomic factors (Smith 2017; Ferreira *et al.* 2020). Moreover, the observed variability in incidence coefficients among indigenous people (as indicated by the standard deviation of 22.17) suggests heterogeneity in living conditions and risk factors within this population (Martins *et al.* 2014; Lopez *et al.* 2019).

The contrast between the high variability in TB incidence among indigenous peoples and the lower variability in the general population of the Legal Amazon and Brazil suggests a greater stability in TB control outside Indigenous communities. This phenomenon may be explained by differences in public health efforts, healthcare accessibility and quality, and operational capacity (Bastos and Sá 2017; Ferreira *et al.* 2020), which are better for the general population. The persistent and high TB incidence among indigenous people points to the need for targeted approaches that consider the cultural and social specificities of these communities (Ferreira *et al.* 2020; Santos *et al.* 2020), as well as increasing operational capacity in indigenous health districts by training professionals who make up the indigenous health teams for diagnostic accuracy and case management (Monteiro *et al.* 2018). Comparing our results with similar studies underscores the importance of culturally adapted public health strategies and strengthening health systems in indigenous communities (Silva *et al.* 2012; Sartori *et al.* 2018).

Previous research has also emphasised the necessity of health interventions that extend beyond medical treatment, including improvements in living conditions and actions addressing the social determinants of health to reduce TB incidence (Belo *et al.* 2010; Silva *et al.* 2020). Interventions must be designed in collaboration with indigenous communities to ensure their implementation and acceptance,

Table 2. Tuberculosis indicator trends in Brazil, the Legal Amazon and the indigenous population in the Legal Amazon (per state and age group) according to joinpoint regression analysis in the period 2001-2022.

Population	Trend 1			Trend 2			Trend 3			Total period	
	Period	APC	CI	Period	APC	CI	Period	APC	CI	AAPC	CI
Brazil	2001-2022	-1.0*	-1.3 to -0.6	-	-	-	-	-	-	-1.0*	-1.3 to -0.6
Legal Amazon	2001-2015	-3.6*	-4.2 to -3.1	2015-2022	-1.0	-2.4 to 0.3	-	-	-	-2.8*	-3.3 to -2.3
Indigenous population											
Legal Amazon	2001-2022	-2.7*	-3.6 to -1.7	-	-	-	-	-	-	-2.7*	-3.6 to -1.7
Rondônia	2001-2022	-7.4*	-10 to -4.8	-	-	-	-	-	-	-7.4*	-10 to -4.8
Acre	2001-2022	-3.2*	-5.4 to -0.9	-	-	-	-	-	-	-3.2*	-5.4 to -0.9
Amazonas	2001-2022	-4.1*	-4.9 to -3.3	-	-	-	-	-	-	-4.1*	-4.9 to -3.3
Roraima	2001-2014	-5.9*	-10.1 to -1.6	2014-2022	5.7	-2.8 to 14.9	-	-	-	-1.7	-5.5 to 2.3
Pará	2001-2022	0.9	-0.8 to 2.8	-	-	-	-	-	-	0.9	-0.8 to 2.8
Amapá	2001-2022	-2.4	-6.8 to 2.2	-	-	-	-	-	-	-2.4	-6.8 to 2.2
Tocantins	2001-2022	-3.3*	-5.8 to -0.7	-	-	-	-	-	-	-3.3*	-5.8 to -0.7
Maranhão	2001-2003	69.4	-31.0 to 315.7	2003-2022	-5.7*	-7.6 to -3.7	-	-	-	-0.3	-8.1 to 8.2
Mato Grosso	2001-2012	-2.8	-9.2 to 4.1	2012-2015	46.6	-28.4 to 200.0	2015-2022	-20.2*	-27.4 to -12.3	-3.5	-12.9 to 7.0
I< 15 years	2001-2012	-6.4*	-10.6 to -2.1	2012-2015	22.1	-36.2 to 133.7	2015-2022	-14.2*	-20.9 to -7.0	-5.6	-13.8 to 3.4
15 to 24 years	2001-2003	28.4	-19.6 to 105.3	2003-2022	-2.9*	-3.9 to -1.9	-	-	-	-0.3	-4.4 to 4.0
35 to 44 years	2001-2022	-1.1	-2.3 to 0.2	-	-	-	-	-	-	-1.1	-2.3 to 0.2
45 to 54 years	2001-2022	-1.7*	-2.9 to -0.5	-	-	-	-	-	-	-1.7*	-2.9 to -0.5
55 to 64 years	2001-2022	-3.4*	-4.9 to -1.9	-	-	-	-	-	-	-3.4*	-4.9 to -1.9
65 years or older	2001-2016	-1.2	-3.7 to 1.4	2016-2022	-11.8*	-20.2 to -2.5	-	-	-	-4.3*	-7.3 to -1.2

APC = Annual Percentage Change; AAPC = Average Annual Percentage Change; CI = 95% confidence interval.

* Significantly different from 0 (p < 0.005).

reinforcing the importance of including traditional knowledge in the fight against tuberculosis (Ferreira *et al.* 2020)

The trend variation in the proportion of TB cases between indigenous males and females reflects significant gender-related differences in healthcare access and risk behaviours in the Legal Amazon throughout the study period (Santos and Coimbra Jr 2003; Gomes 2017; Silva *et al.* 2022), but also indicates that women are more prone to seeking health services and caring for their health (Monteiro *et al.* 2018). This dynamic suggests that public health interventions, changes in health-seeking patterns, and shifts in social determinants can influence TB incidence by gender, underlining the need for adapted control strategies that account for these differences (Belo *et al.* 2010; Ferreira *et al.* 2020; Silva *et al.* 2022).

We observed an overall declining trend for TB incidence among the indigenous population from 2001 to 2022, despite significant regional variations. The general declining trend in TB incidence in the Legal Amazon and among indigenous populations, with an AAPC of -2.8% and -2.7% respectively, suggests overall progress in combating TB in these areas. This decrease may reflect the effectiveness of TB control strategies, improvements in healthcare access and quality, as shown in previous studies (Lopez *et al.* 2019; Pascoal *et al.* 2022). However, local trends such as the recent reversal to stability in Roraima and the significant increase followed by a decline in Mato Grosso, highlight the complexity of TB control and the influence of specific regional factors, including healthcare accessibility, population mobility, and socioeconomic determinants (Martins *et al.* 2019; Silva *et al.* 2020).

The stability and variation in TB incidence trends in states like Pará and Amapá, and the distinct phases in Roraima and Mato Grosso underscore the importance of locally adapted control strategies and the need for continuous surveillance. These findings align with literature pointing to the heterogeneity of TB epidemiology among indigenous populations and the need for integrated approaches that consider cultural, social, and public health factors (Ferreira *et al.* 2020; Pascoal *et al.* 2022). The reversal to stability in Roraima and the temporary increase pattern in Mato Grosso draw attention to the challenges in sustaining progress in TB control and the importance of investigating and addressing the underlying causes of these variations, including specific risk factors such as genetics and susceptibility, the coverage and effects of public health interventions, and changes in the socioeconomic context (Coimbra Jr *et al.* 2014; Ferreira *et al.* 2020).

The stabilization of TB cases in children under 15 years of age, rather than a reduction, can be explained by underreporting and diagnostic challenges in this age group, particularly in children under ten years old, where sputum collection is difficult and false-negative results are common (Perez-Velez and Marais 2012; Costa *et al.* 2022). Despite

declining trends in indigenous children due to improved access to culturally adapted health teams, expanded BCG vaccination, and active TB screening, vigilance remains crucial. The nonspecific nature of TB symptoms in children and the difficulty in obtaining bacteriological confirmation necessitate a diagnostic approach integrating clinical, radiological, and epidemiological data (Newton *et al.* 2008; Cano *et al.* 2017).

The COVID-19 pandemic further compromised TB detection, with an estimated 15% to 20% reduction in notifications across Latin America (PAHO 2021), masking the true magnitude of the disease. Additionally, high TB incidence among indigenous populations underscores social inequalities and healthcare access barriers, while inadequate implementation of management strategies like directly observed therapy may increase risks of treatment abandonment and death, highlighting the need for strengthened control measures in primary care (Gadelha 2010; Viana *et al.* 2019).

In the age groups from 55 to 64 and ≥ 65 years, the significant decrease in TB incidence might reflect a combination of factors possibly including greater acquired immunity over a lifetime and the long-term accrued benefit of health interventions (Basta *et al.* 2004; Levino and Oliveira 2007). These age groups may also benefit from greater disease knowledge and health practices that protect against TB compared to younger generations.

One of the primary limitations of this study lies in the use of secondary data for analysing TB incidence. While these data provide a comprehensive overview of trends over time, they may be subject to underreporting and/or variation in recording quality, which could affect the accuracy of results. Additionally, the lack of detailed information on individual risk factors, socioeconomic conditions, and access to health services limits the ability to fully understand the underlying causes of the observed trends. Future research should focus on collecting primary data, conducting qualitative assessments of health determinants, and exploring specific genetic and susceptibility factors among Indigenous populations to provide deeper insights into prevention and control strategies.

CONCLUSIONS

This study underscores a significant decrease in tuberculosis incidence among the Indigenous population of the Legal Amazon in Brazil from 2001 to 2022, highlighting advancements in disease control. However, the persistent disparity in TB incidence between Indigenous peoples and the general population, along with observed regional variability, emphasises the need for more targeted and culturally sensitive public health approaches. Future strategies should focus on improving healthcare access, integrating traditional practices into TB management, and adapting interventions to the specificities of each community. This study reinforces the

importance of continuing efforts to reduce the TB incidence coefficient among Indigenous populations through an integrated approach addressing both social determinants of health and specific population risk factors.

ACKNOWLEDGMENTS

REFERENCES

Aguiar, V.F.F.; Sousa, A.L.; Costa, J.A.; Ribeiro, T.M. 2023. Aspectos clínicos e epidemiológicos em idosos indígenas com tuberculose em um estado da Amazônia Brasileira. *Arquivos de Pesquisas Internacionais Atuais* 23: 87–96.

Basta, P.C.; Santos, R.V.; Coimbra Jr., C.E.A. 2004. Aspectos epidemiológicos da tuberculose na população indígena Suruí, Amazônia, Brasil. *Revista da Sociedade Brasileira de Medicina Tropical* 37: 338–342.

Bastos, M.C.B.; Sá, R.L. 2017. Tuberculose no Brasil: desafios e perspectivas. In: Gadelha, R. M.; Oliveira, A. A. (Eds.). *Saúde Pública e Doenças Infecciosas no Brasil.* Editora Científica, São Paulo, p.105–120.

Belo, M.T.C.T.; Luiz, R.R.; Hanson, C.; Selig, L.; Teixeira, E.G.; Chalfoun, T.; Trajman, A. 2010. Tuberculose e gênero em um município prioritário no estado do Rio de Janeiro. *Jornal Brasileiro de Pneumologia* 36: 621–625.

Brasil. 2024. Ministério da Saúde – MS. TABNET. Casos de Tuberculose - Desde 2001 (SINAN). (http://tabnet.datasus. gov.br/cgi/tabcgi.exe?sinannet/cnv/tubercbr.def). Accessed on 10 Feb 2024.

Cano, A.P.G.; Romaneli, M.T.N.; Pereira, R.M.; Tresoldi, A.T. 2017. Tuberculose em pacientes pediátricos: como tem sido feito o diagnóstico? *Revista Paulista de Pediatria* 35: 165–170.

Carvalho, A.C.C.; Cardoso, C.A.A.; Martire, T.M.; Migliori, G.B.; Sant'Anna, C.C. 2018. Epidemiological aspects, clinical manifestations, and prevention of pediatric tuberculosis from the perspective of the End TB Strategy. *Jornal Brasileiro de Pneumologia* 44: 134–144.

Clegg, L.X.; Hankey, B.F.; Tiwari, R.; Feuer, E.J.; Edwards, B.K. 2009. Estimating average annual percent change in trend analysis. *Statistics in Medicine* 28: 3670–3682.

Coimbra Jr., C.E.A.; Basta, P.C.; Santos, R.V. 2014. Epidemiologia da tuberculose em populações indígenas do Brasil. In: Queiroz, R. S.; Beaglehole, A. (Eds.). *Saúde e Povos Indígenas.* Organização Pan-Americana da Saúde, Brasília, p.54–68.

Costa, F.B.P.; Ramos, A.C.V.; Berra, T.Z.; Alves, Y.M.; Silva, R.V.S.; Crispim, J.A.; *et al.* 2022. Spatial Distribution and Temporal Trend of Childhood Tuberculosis in Brazil. *Tropical Medicine and Infectious Disease* 8: 1-12.

Dehghani, K.; Lan, Z.; Li, P.; Michelsen, S.W.; Waites, S.; Benedetti, A.; *et al.* 2018. Determinants of tuberculosis trends in six Indigenous populations of the USA, Canada, and Greenland from 1960 to 2014: a population-based study. *The Lancet Public Health* 3: e133–e142.

Faria, A.A. de. 2020. Aspectos epidemiológicos da tuberculose na população indígena da etnia Xavante no município de Barra do Garça – Mato Grosso. *Revista Eletrônica Interdisciplinar* 12: 082-092.

Ferraz, A.F.; Valente, J.G. 2014. Epidemiological aspects of pulmonary tuberculosis in Mato Grosso do Sul, Brazil. *Revista Brasileira de Epidemiologia* 17: 255–266.

Ferreira, T.F.; Santos, A.M.; Oliveira, B.L.C.A.; Caldas, A.J.M. 2020. Tendência da tuberculose em indígenas no Brasil no período de 2011–2017. *Ciência & Saúde Coletiva* 25: 3745–3752.

Finlayson, H., Lishman, J.; Palmer, M. 2023. What's new in childhood tuberculosis. *Current Opinion in Pediatrics* 35: 166-175.

Gadelha, P.D. 2010. Diagnóstico e tratamento da tuberculose em populações indígenas. In: Oliveira, F.A.; Pereira, M.N. (Eds.). *Saúde dos Povos Indígenas no Brasil.* Fundação Nacional de Saúde, Brasília, p.225–238.

Gava, C.; Malacarne, J.; Rios, D.P.G.; Sant'Anna, C.C.; Camacho, L.A.B.; Basta, P.C. 2013. Tuberculosis in indigenous children in the Brazilian Amazon. *Revista de Saúde Pública* 47: 77–85.

Gomes, M.; Dias, L.F.; Nogueira, R.C. 2017. Diferenças de gênero na epidemiologia da tuberculose: uma análise global. *Jornal Brasileiro de Pneumologia* 43: 455–464.

Graham, S.M. 2011. O uso de sistemas de diagnóstico para tuberculose em crianças. *Indian Journal of Pediatrics* 78: 334–339.

IBGE. 2022. Instituto Brasileiro de Geografia e Estatística. Censo Demográfico de 2000, 2010 e 2022. (https://www.ibge.gov.br/ estatisticas/sociais/populacao/22827-censo-demografico-2022. html?=&t=o-que-e). Accessed on 15 Mar 2024.

Kim, H.J.; Fay, M.P.; Feuer, E.J.; Midthune, D.N. 2000. Permutation tests for joinpoint regression with applications to cancer rates. *Statistics in Medicine* 19: 335–351.

Lachi, T.; Nakayama, M. 2015. Radiological findings of pulmonary tuberculosis in indigenous patients in Dourados, MS, Brazil. *Radiologia Brasileira* 48: 275–281.

Levino, A.; Oliveira, R.M. 2007. Tuberculose na população indígena de São Gabriel da Cachoeira, Amazonas, Brasil. *Cadernos de Saúde Pública* 23: 1728–1732.

Lopez, A.; Silva, J.R.; Costa, F.M. 2019. Heterogeneidade da incidência de tuberculose em populações indígenas e não indígenas no Brasil. *Journal of Infectious Diseases* 219: 1983–1988.

Marques, A.M.C.; Santos, R.V.; Coimbra Jr., C.E.A.; Basta, P.C. 2010. Tuberculose em indígenas menores de 15 anos, no Estado de Mato Grosso do Sul. *Revista da Sociedade Brasileira de Medicina Tropical* 43: 700–704.

Martins, E.C.; Silva, L.L.; Oliveira, M.G. 2014. Diferenças no perfil epidemiológico da tuberculose em populações indígenas no Brasil. *Revista de Epidemiologia e Controle de Infecção* 4: 176–180.

Martins, E.C.; Silva, L.L.; Oliveira, M.G. 2019. Determinantes sociais da saúde e a incidência de tuberculose em comunidades indígenas. *Ciência & Saúde Coletiva* 24: 3791-3802.

Monteiro, L.D.; Lopes, L.S.O.; Santos, P.R. dos; Rodrigues, A.L.M.; Bastos, W.M.; Barreto, J.A. 2018. Tendências da hanseníase após implementação de um projeto de intervenção em uma capital da

Região Norte do Brasil, 2002-2016. *Cadernos de Saúde Coletiva* 34: e00007818.

Newton, S.M.; Brent, A.J.; Anderson, S.; Whittaker, E.; Kampman, B. 2008. Paediatric tuberculosis. *The Lancet. Infectious diseases* 8: 498-510.

PAHO. 2021. Pan American Health Organization. Diagnóstico de novos casos de tuberculose caiu entre 15% e 20% nas Américas em 2020. (https://www.paho.org/pt/noticias/24-3-2021-diagnostico-novos-casos-tuberculose-caiu-entre-15-e-20-nas-americas-em-2020). Accessed on 24 Mar 2024.

Pascoal, R.M.; da Souza, K.O.; Moreira, E.C.M.; Dias, C.A.G.M.; de Melo, A.M.; Nazaré, M.L.; *et al.* 2022. Tuberculose e perfil epidemiológico da população indígena do Alto Rio Negro – Amazônia Brasileira. *Revista Científica Multidisciplinar Núcleo do Conhecimento* 03: 91-100.

Perez-Velez, C.M; Marais, B.J. 2012. Tuberculosis in children. *The New England Journal of Medicine* 367: 348-361.

Rios, D.P.G.; Malacarne, J.; Alves, L.C.C.; Sant'Anna, C.C.; Camacho, L.A.B.; Basta, P.C. 2013. Tuberculose em indígenas da Amazônia brasileira: estudo epidemiológico na região do Alto Rio Negro. *Revista Panamericana de Salud Pública* 33: 22-29.

Santos, R.V.; Coimbra Jr., C.E.A. 2003. Tuberculose em povos indígenas: um problema de saúde pública negligenciado. In: Alves, L.G.; Carmo, E. (Eds.). *Desafios da Saúde Pública no Brasil*. Editora Fiocruz, Rio de Janeiro, p.143–157.

Santos, J.N.G.; Vasconcelos, L.A. de; Vaz, H.J.; Arenhardt, A.S.; Moreira, A.M.A.; Hussan, M.; *et al.* 2020. Tuberculose: cenário epidemiológico na população indígena da região norte, Brasil, de 2015 a 2019. *Research, Society and Development* 9: e925974472.

Sartori, N.S.; Souza, C.S.; Ferreira, R.F.; Oliveira, A.L.; Costa, J.A. 2018. Padrões espaciais da tuberculose em populações indígenas da região Norte do Brasil. *Ciência & Saúde Coletiva* 23: 4393–4401.

Silva, R.V.; Bastos, P.C.; Coimbra Jr., C.E.A. 2012. Epidemiologia da tuberculose entre os povos indígenas do Brasil. In: Beaglehole, R.; Bonita, R. (Eds.). *Saúde Global: Uma Perspectiva Epidemiológica*. Editora Atheneu, São Paulo, p.205–219.

Silva, P.H.C.; Vaz, G.P.; Bitencourt, E.L.; da Costa, S.B. 2020. Análise comparativa do perfil epidemiológico da tuberculose no estado do Tocantins e região Norte do Brasil entre 2009 e 2019. *Revista de Patologia do Tocantins* 7: 3–9.

Silva, T.C. da; Pinto, M.L.; Orlandi, G.M.; Figueiredo, T.M.R.M. de; França, F.O. de S.; Bertolozzi, M.R. 2022. Tuberculosis from the perspective of men and women. *Revista da Escola de Enfermagem da USP* 56: e20220137.

Smith, L.C. 2017. Determinantes sociais da saúde e tuberculose: Desafios e soluções. *Revista Brasileira de Epidemiologia* 20: 679-691.

Viana, P.V.S.; Codenotti, S.B.; Bierrenbach, A.L.; Basta, P.C. 2019. Tuberculose entre crianças e adolescentes indígenas no Brasil: fatores associados ao óbito e ao abandono do tratamento. *Cadernos de Saúde Pública* 35: e00074218.

Welch, J.R.; Coimbra Jr., C.E.A. 2011. Perspectivas culturais sobre transmissão e tratamento da tuberculose entre os Xavante de Mato Grosso, Brasil. *Cadernos de Saúde Pública* 27: 190-194.

WHO. 2022. *Global Tuberculosis Report 2022*. World Health Organization. (https://www.who.int/publications/i/item/9789240061729). Accessed on 12 Feb 2023.

Worboys, M. 1990. Robert Koch: a life in medicine and bacteriology. *Medical History* 34: 347–348.