Ethnic and Racial Inequalities in Notified Cases of Tuberculosis in Brazil

Paulo Victor de Sousa Viana1,4*, Maria Jacirema Ferreira Gonçalves2,3, Paulo Cesar Basta4

1 Centro de Referência Professor Hélio Fraga, Fundação Oswaldo Cruz, Rio de Janeiro, Rio de Janeiro, Brazil, 2 Instituto Leônidas e Maria Deane, Fundação Oswaldo Cruz, Manaus, Amazonas, Brazil, 3 Escola de Enfermagem de Manaus, Universidade Federal do Amazonas, Manaus, Amazonas, Brazil, 4 Escola Nacional de Saúde Pública Sergio Arouca, Fundação Oswaldo Cruz, Rio de Janeiro, Rio de Janeiro, Brazil

* paulo.viana@ensp.fiocruz.br

Abstract

Objective

This study analysed clinical and sociodemographic aspects and follow-up for notified cases of tuberculosis (TB) and explored inequalities in incidence rates and outcome by colour or race and the geographic macro-regions of Brazil.

Methods

This paper reports the results of a population-based descriptive epidemiological study of all notified cases of TB in Brazil during the period from 01/01/2008 to 31/12/2011. We analysed sociodemographic and clinical variables according to colour or race (white, black, Asian, mixed, and indigenous) and geographic macro-regions of the country (North, Northeast, Central-West, South, and Southeast).

Results

During the study period, the average incidence of TB in Brazil was 36.7 cases per 100,000 inhabitants, with the highest rates occurring in the North and Southeast regions. The analysis of TB notifications by colour or race revealed that the indigenous population presented the highest incidence rates in all macro-regions except the South, where higher rates were reported in black patients. ‘Cured’ was the most frequently reported treatment outcome for all skin colour categories. The highest cure rate occurred among the indigenous population (76.8%), while the lowest cure rate occurred among the black population (70.7%). Rates of treatment default were highest among blacks (10.5%) and lowest among the indigenous population (6.9%). However, the fatality rate was similar across race categories, varying between 2.8% and 3.8% for whites and the indigenous population, respectively. The lowest cure rates were observed when follow-up was inadequate (58.3%), and the highest was observed when the follow-up was classified as excellent (96.8%).
Conclusions
This study revealed that—apart from the heterogeneous distribution of TB among the Brazilian macro-regions—ethnic-racial inequalities exist in terms of clinical-epidemiological characteristics and incidence rates as well as follow-up for cases undergoing treatment. The highest rates of TB occurred among the indigenous people.

Introduction
Tuberculosis (TB) has been recognized as an important cause of illness and death in humans for thousands of years [1]. Even in the 21st century, the disease remains a contemporary health problem, especially in countries with high social inequality [2].

TB is endemic in Brazil. On average, there are 70,000 new cases and 4,000 deaths each year. In the last two decades, Brazil has made advances in controlling the disease, especially in mortality rate reduction and in expanding its direct treatment coverage in urban centres [3]. Most recently, the introduction of rapid molecular testing has simplified the process of diagnosing new cases. Despite these important advances, the disease remains one of the principal public health challenges in Brazil.

The main challenges in controlling the disease are high rates of treatment default, structural flaws in municipal control programmes, HIV co-infections, and—more recently—the emergence of drug-resistant bacterial strains, an association with diabetes mellitus, and the concentration of cases among vulnerable populations, mainly the homeless, migrant, refugee, prisoner, healthcare professional, and indigenous populations [2,4–7].

Research interest in TB among indigenous populations in Brazil has increased in recent years, especially after the official Manual of Recommendations for the Control of Tuberculosis (Manual de Recomendações para o controle da Tuberculose) highlighted their plight [8]. We now know that TB disproportionately affects indigenous populations; the incidence rates registered in these populations are systematically higher than those in the general population at both the regional and national levels [9–13].

Recently, the Ministry of Health, through the National Program for Tuberculosis Control (Programa Nacional de Controle da Tuberculose (PNCT)), ratified this situation by reporting that, based on colour and race category data from the System for Notifiable Disease (Sistema de Informação de Agravos de Notificações (SINAN)), the average TB incidence for patients who declared themselves ‘indigenous’ was 93.5/100,000 inhabitants in 2011, a figure nearly three times higher than the average registered for the entire population of the country during the same year [14]. Despite this knowledge, epidemiological studies aiming to explore and understand the roles of ethnic and racial inequality among risk factors for TB are scarce in Brazil [15,16].

In this context, the aim of this study is to analyse clinical and sociodemographic aspects and follow-up for reported cases of TB in Brazil and to explore inequalities in incidence rates and outcome according to colour or race and geographic macro-region.

Methods
Area, population, and study design
We carried out a descriptive population-based epidemiological study covering the entire national area. We analysed all notified cases of TB registered in the SINAN in Brazilian territory.
In Brazil, TB is a disease for which notification is compulsory and treatment is offered free of charge when a case is reported to the SINAN. Thus, all cases known to the Brazilian public health system (Sistema Único de Saúde (SUS)) during the study period were included.

Variables and criteria for inclusion and exclusion

The following variables were analysed: 1) sociodemographic factors, including sex, age group (0–9 years, 10–19 years, 20–44 years and ≥45 years), colour or race (white, black, Asian, mixed, and indigenous), educational level (illiterate, 1–8 years, 9–11 years, 12 or more years, unknown, and not applicable), origin (urban, rural, urban/rural and unknown), and macro-region (North, Northeast, Central-West, South, and Southeast); 2) clinical factors, including the clinical form of TB (pulmonary, extrapulmonary, both pulmonary and extrapulmonary) and the examinations used for diagnosis (bacilloscopy and sputum culture, thorax radiography, tuberculin test, HIV serology test); 3) follow-up variables, including control bacilloscopies in the 2nd, 4th, and 6th months of treatment, as well as data on supervised treatment and testing of contacts; and 4) treatment outcome, including cure, treatment default, death (from TB), and incidences of drug-resistant TB.

In Brazil, urban/rural areas are called “peri-urban” and are considered as areas located beyond the city suburbs—a space where rural and urban activities are mixed. Peri-urban areas make it difficult to determine the physical and social limits of urban and rural spaces.

We use the terminology formally adopted by the Brazilian Institute of Geography and Statistics (IBGE), which acknowledges the difficulty of measuring people’s race or ethnicity. Therefore, IBGE surveys instead ask people their phenotype, as expressed by skin colour. This allows health professionals and researchers to use the same terminology to facilitate data acquisition and question standardization and improves the ability to make data comparisons. Ethnicity is based on a person’s self-declared skin colour and includes the following categories: ‘white’, ‘black’, ‘mixed’, ‘Asian’, and ‘indigenous’ [17]. In Brazil, the “mixed” ethnic category is called “Pardo,” which means a mixture of European, black and Amerindian.

This study included all cases of TB where the variable ‘type of entry’ was designated as either ‘new case’ or ‘unknown’ and excluded cases where the ‘type of entry’ involved a diagnostic error and the variable ‘outcome’ was classified as ‘change of diagnosis’. The study period covered the period from 01/01/2008 to 31/12/2011.

The SINAN database, which includes notified TB cases in Brazil, was obtained from the PNCT in August 2013. Duplicate cases had already been removed.

Analysis

Following the recommendations of the PNCT [8], the incidence rate was calculated as a fraction using the total number of cases where ‘type of entry’ was classified as either ‘new case’ or ‘unknown’ as the numerator, while the denominator consisted of the total Brazilian population at risk during the calendar years 2008, 2009, 2010, and 2011, multiplied by 100,000.

To define the populations used to calculate the incidence rates, yearly population estimates by macro-region and for each colour/race category during the intercensus period were employed, using geometric interpolation for 2008 and 2009 and extrapolation for 2011, based on the demographic census results from 2000 and 2010 [18].

For the analysis of the operational indicators related to the follow-up of TB cases, we used an empirical classification system developed by Orellana et al. [19], which considers three recommendations from the ‘III Diretrizes para TB’ by the Brazilian Society for Pulmonology and Phthisiology (Sociedade Brasileira de Pneumologia e Tisiologia (SBPT)) [20]: 1) whether the notified case underwent control bacilloscopies at the 2nd, 4th, and 6th months of treatment; 2)
whether examinations of contacts were registered; and 3) whether the treatment occurred under supervision. Cases where none or only one of the three recommendations were performed were classified as ‘inadequate follow-up’. Cases where two of the recommendations were performed were classified as ‘poor follow-up’. Cases where all three recommendations were performed were classified as ‘good follow-up’. Finally, cases where treatment occurred under supervision, examinations of contacts were registered and at least two bacilloscopies were accomplished were classified as ‘excellent follow-up’.

All analyses conducted within this investigation were stratified to elucidate possible inequalities between the colour/race categories and the geographic macro-regions of Brazil.

The data were structured in electronic spreadsheets using Microsoft Excel 2010 (Microsoft Corp., Redmond, WA, USA), and analyses were carried out using the Statistical Package for the Social Sciences, version 20.0 (SPSS Inc., Chicago, IL, USA).

Ethical considerations

The study was approved by the Ethical Research Committee of the Escola Nacional de Saúde Pública/FIOCRUZ (CEP/ENSP), protocol number: CAAE: 14643713.0.0000.5240.

Results

During the study period, 278,674 new cases of TB in Brazil were reported to the SINAN. The number of new case notifications among the macro-regions was highest in the Southeast region (129,573 cases, 46.5%) and lowest in the Central-West region (12,367 cases, 4.4%).

During the study period, compliance in the completion of the field "colour or race" increased: the proportion of ‘unknown’ entries decreased from 16.2% in 2008 to 7.8% in 2011. Among the notified cases that presented valid information on this variable, an increase of 13.5% was observed in the proportion of the population referring to themselves as ‘mixed’ colour or race—from 36.6% in 2008 to 42.3% in 2011. Entries of ‘indigenous’ represented 1.1% of the notifications in 2008 and 1.2% in 2011 (Table 1).

The average incidence rate of all forms of TB in Brazil was 36.7 cases per 100,000 people from 2008–2011. The incidence rate decreased slightly during the study years, from 37.1/100,000 in 2008 to 36.7/100,000 in 2011. However, we found a heterogeneous distribution between the macro-regions. The North region presented the highest incidence rates of the country between 2009 (43.8/100,000) and 2011 (43.2/100,000); however, in 2008, the Southeast region had the highest incidence rate (41.5/100,000). In contrast, the lowest incidence rates were observed in the Central-West region, with 22.8/100,000 in 2008 and 22.2/100,000 in 2011 (Fig 1).

The indigenous population showed the highest incidence rates in all macro-regions except the South, where higher incidence rates were found in the black population: 83.9/100,000 in 2008 and 91/100,000 in 2011. The increase of 18.8% in the incidence rate for the indigenous population in the Central-West region between 2008 and 2011 stood out, increasing from 162.8/100,000 to 195.7/100,000 during that period. The lowest incidence rates were observed in individuals self-classified as ‘white’ in all the macro-regions except the South, where the ‘mixed’ population presented the lowest rates (Fig 1).

TB notifications were more frequent among men (65.7%) than among women, with an average national ratio of 1.9:1.0 (Table 2). The ratio between men and women varied according to the colour/race category and was highest among the black population (2.0:1.0) and lowest in the indigenous population (1.5:1.0).

Individuals aged 20–44 years comprised the majority of notified cases in all colour/race categories. Nevertheless, there were noteworthy variations, particularly in the numbers of notified
Table 1. Annual Distribution of Notified New Cases of Tuberculosis in Brazil, by Macro-Region and Colour or Race, in the Period 2008–2011.
Source: Sinan-TB/MS. Note: *In Brazil, the Mixed race category is called Pardo, which means a mixture of European, Black and Amerindian.

| Variables | 2008 | 2009 | 2010 | 2011 |
|-----------|------|------|------|------|
|           | N    | %    | N    | %    | N    | %    | N    | %    |
| Macro-Region | Colour or Race | N | % | N | % | N | % | N | % |
| North     | White | 1135 | 18.1 | 1051 | 15.4 | 885 | 13.2 | 932 | 13.3 |
|           | Black | 418 | 6.7 | 445 | 6.5 | 446 | 6.7 | 458 | 6.5 |
|           | Asian | 58 | 0.9 | 47 | 0.7 | 45 | 0.7 | 36 | 0.5 |
|           | Mixed* | 4269 | 68.0 | 4803 | 70.6 | 4902 | 73.3 | 5122 | 73.2 |
|           | Indigenous | 271 | 4.3 | 270 | 4.0 | 242 | 3.6 | 256 | 3.7 |
|           | Unknown | 130 | 2.1 | 188 | 2.8 | 167 | 2.5 | 197 | 2.8 |
| Subtotal  | 6281 | 100.0 | 6804 | 100.0 | 6687 | 100.0 | 7001 | 100.0 |
| Northeast | White | 3463 | 18.3 | 3551 | 18.2 | 3127 | 17.0 | 3176 | 16.6 |
|           | Black | 2732 | 14.4 | 2729 | 14.0 | 2468 | 13.4 | 2562 | 13.4 |
|           | Asian | 312 | 1.6 | 308 | 1.6 | 203 | 1.1 | 215 | 1.1 |
|           | Mixed | 10965 | 57.8 | 11400 | 58.3 | 11047 | 60.0 | 11700 | 61.3 |
|           | Indigenous | 127 | 0.7 | 131 | 0.7 | 107 | 0.6 | 129 | 0.7 |
|           | Unknown | 1371 | 7.2 | 1443 | 7.4 | 1451 | 7.9 | 1318 | 6.9 |
| Subtotal  | 18970 | 100.0 | 19562 | 100.0 | 18403 | 100.0 | 19100 | 100.0 |
| Central-West | White | 997 | 32.3 | 940 | 31.1 | 901 | 29.2 | 887 | 27.9 |
|           | Black | 362 | 11.7 | 340 | 11.3 | 321 | 10.4 | 344 | 10.8 |
|           | Asian | 49 | 1.6 | 47 | 1.6 | 49 | 1.6 | 30 | 0.9 |
|           | Mixed | 1347 | 43.6 | 1387 | 46.0 | 1459 | 47.4 | 1499 | 47.1 |
|           | Indigenous | 203 | 6.6 | 213 | 7.1 | 207 | 6.7 | 261 | 8.2 |
|           | Unknown | 130 | 4.2 | 91 | 3.0 | 144 | 4.7 | 159 | 5.0 |
| Subtotal  | 3088 | 100.0 | 3018 | 100.0 | 3081 | 100.0 | 3180 | 100.0 |
| Southeast | White | 11110 | 34.0 | 12613 | 39.3 | 13203 | 41.4 | 13474 | 41.0 |
|           | Black | 3886 | 11.9 | 4375 | 13.6 | 4401 | 13.8 | 4699 | 14.3 |
|           | Asian | 270 | 0.8 | 265 | 0.8 | 264 | 0.8 | 279 | 0.8 |
|           | Mixed | 7840 | 24.0 | 9177 | 28.6 | 9519 | 29.8 | 10609 | 32.3 |
|           | Indigenous | 138 | 0.4 | 127 | 0.4 | 144 | 0.5 | 186 | 0.6 |
|           | Unknown | 9407 | 28.8 | 5558 | 17.3 | 4382 | 13.7 | 3647 | 11.1 |
| Subtotal  | 32651 | 100.0 | 32115 | 100.0 | 31913 | 100.0 | 32894 | 100.0 |
| South     | White | 6166 | 75.3 | 6382 | 74.3 | 6296 | 74.4 | 6318 | 72.7 |
|           | Black | 892 | 10.9 | 1007 | 11.7 | 986 | 11.7 | 1012 | 11.7 |
|           | Asian | 40 | 0.5 | 41 | 0.5 | 47 | 0.6 | 46 | 0.5 |
|           | Mixed | 867 | 10.6 | 891 | 10.4 | 873 | 10.3 | 1039 | 12.0 |
|           | Indigenous | 27 | 0.3 | 39 | 0.5 | 48 | 0.6 | 32 | 0.4 |
|           | Unknown | 202 | 2.5 | 224 | 2.6 | 213 | 2.5 | 238 | 2.7 |
| Subtotal  | 8194 | 100.0 | 8584 | 100.0 | 8463 | 100.0 | 8665 | 100.0 |
| Brazil    | White | 22871 | 33.1 | 24537 | 35.0 | 24412 | 35.6 | 24787 | 35.0 |
|           | Black | 8290 | 12.0 | 8896 | 12.7 | 8622 | 12.6 | 9075 | 12.8 |
|           | Asian | 729 | 1.1 | 708 | 1.0 | 608 | 0.9 | 606 | 0.9 |
|           | Mixed | 25288 | 36.6 | 27658 | 39.5 | 27800 | 40.6 | 29969 | 42.3 |
|           | Indigenous | 766 | 1.1 | 780 | 1.1 | 748 | 1.1 | 864 | 1.2 |
|           | Unknown | 11240 | 16.2 | 7504 | 10.7 | 6357 | 9.3 | 5559 | 7.8 |
| **Total** | 69184 | 100.0 | 70083 | 100.0 | 68547 | 100.0 | 70860 | 100.0 |

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Fig 1. Incidence rate (per 100,000) of all clinical forms of tuberculosis, according to race and country macro-region, Brazil 2008–2011.

Note: Each letter represents one macro-region from the total area of Brazil: (A) North; (B) Northeast; (C) Southeast; (D) South; (E) Central-West; and (F) Brazil.

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cases for the age group 0–9 years. Indigenous children in this age group presented the highest rate (9.8%). In contrast, all other colour/race groups presented rates below 2.5%. Counterintuitively, the indigenous population had the lowest rate of TB cases in the age group 45 years or more (27.5%) (Table 2).

More than a third (38.3%) of the notifications included no data for the variable 'education', with similar percentages of missing information across all colour/race categories; the lowest rate was found in the 'mixed' population (29.9%) and the highest in the 'Asian' population (39.0%). The indigenous population had the highest proportion of illiterates (16.0%), followed by the black population (7.2%) (Table 2).

Regarding the variable 'area of residence' in the country as a whole, 66.3% of the notified TB cases occurred among people living in urban areas. This was true for all colour/race categories except 'indigenous', of whom 54.2% lived in rural areas (Table 2).

The first and second sputum smear samples for diagnosis were not performed in approximately one quarter of the cases; the lowest frequency occurred in diagnoses of white patients (23%). Sputum culture was not performed in 77.3% of cases, with the lowest percentage of non-compliance among the indigenous population (68.4%) and the highest among the 'mixed' population (80.3%) (Table 3).

Thorax radiography assessments revealed high rates of results suggestive of TB among all colour/race categories, with a slightly higher rate in the black population (81%). Tuberculin
| Year | White | Black | Asian | Mixed* | Indigenous | Unknown | Total |
|------|-------|-------|-------|--------|-----------|---------|-------|
|      | BK 1st sample |         |       |        |           |         |       |
|      | Cases % | Cases % | Cases % | Cases % | Cases % | Cases % | Cases % |
| Positive | 49144 50.9 | 19874 57.0 | 1516 57.2 | 61917 55.9 | 1499 47.5 | 17100 55.8 | 151050 54.2 |
| Negative | 25232 26.1 | 8464 24.3 | 596 22.5 | 27633 25.0 | 1074 34.0 | 6952 22.7 | 69951 25.1 |
| Not performed | 22231 23.0 | 6545 18.8 | 539 20.3 | 21165 19.1 | 585 18.5 | 6608 21.6 | 57673 20.7 |
| BK 2nd sample |         |       |       |        |           |         |       |
| Positive | 25522 26.4 | 12012 34.4 | 833 31.4 | 39490 35.7 | 893 28.3 | 5168 16.9 | 83918 30.1 |
| Negative | 15854 16.4 | 5950 17.1 | 371 14.0 | 20231 18.4 | 822 26.0 | 2571 8.4 | 45889 16.5 |
| Not performed | 25412 26.3 | 9729 27.9 | 720 27.2 | 30179 27.3 | 820 26.0 | 5704 18.6 | 72564 26.0 |
| Unknown | 29819 30.9 | 7192 20.6 | 727 27.4 | 20725 18.7 | 623 19.7 | 17217 56.2 | 76303 27.4 |
| Sputum culture |         |       |       |        |           |         |       |
| Positive | 12366 12.8 | 3588 10.3 | 240 9.1 | 9856 8.9 | 589 18.7 | 4160 13.6 | 30799 11.1 |
| Negative | 8105 8.4 | 2155 6.2 | 171 6.5 | 6212 5.6 | 266 8.4 | 2388 7.8 | 19297 6.9 |
| Ongoing | 3982 4.1 | 1801 5.2 | 141 5.3 | 5713 5.2 | 143 4.5 | 1413 4.6 | 13193 4.7 |
| Not performed | 72154 74.7 | 27339 78.4 | 2099 79.2 | 88934 80.3 | 2160 68.4 | 22699 74.0 | 215385 77.3 |
| RX of thorax |         |       |       |        |           |         |       |
| Suspect | 77341 80.1 | 28241 81.0 | 2115 79.8 | 87519 79.0 | 2426 76.8 | 22818 74.4 | 220460 79.1 |
| Normal | 6417 6.6 | 1787 5.1 | 139 5.2 | 5265 4.8 | 182 5.8 | 1622 5.3 | 15412 5.5 |
| Other pathology | 815 0.8 | 218 0.6 | 13 0.5 | 728 0.7 | 19 0.6 | 168 0.5 | 1961 0.7 |
| Not performed | 9725 10.1 | 4002 11.5 | 311 11.7 | 15341 13.9 | 484 15.3 | 4146 13.5 | 34009 12.2 |
| Unknown | 2309 2.4 | 635 1.8 | 73 2.8 | 1862 1.7 | 47 1.5 | 1906 6.2 | 6832 2.5 |
| TT |         |       |       |        |           |         |       |
| No reaction | 5357 5.5 | 1503 4.3 | 43 1.7 | 6122 5.5 | 222 7.0 | 834 2.7 | 14146 5.1 |
| Weak reaction | 2040 2.1 | 636 1.8 | 46 1.7 | 2237 2.0 | 86 2.7 | 300 1.0 | 3545 1.9 |
| Strong reaction | 11153 11.5 | 3982 11.4 | 287 10.8 | 12811 11.6 | 554 17.5 | 1709 5.6 | 30496 10.9 |
| Not performed | 9725 10.1 | 4002 11.5 | 311 11.7 | 15341 13.9 | 484 15.3 | 4146 13.5 | 34009 12.2 |
| Unknown | 28297 29.3 | 6225 17.8 | 647 24.4 | 17984 16.2 | 544 17.2 | 16887 55.1 | 70584 25.3 |
| Clinical form |         |       |       |        |           |         |       |
| Pulmonary | 76496 79.2 | 29304 84.0 | 2203 83.1 | 93534 84.5 | 2735 86.6 | 24995 81.5 | 229267 82.3 |
| Extrapulmonary | 16412 17.0 | 4446 12.7 | 384 14.5 | 14927 12.7 | 334 10.6 | 4992 15.0 | 40220 14.4 |
| Both pulmonary and extrapulmonary | 3679 3.8 | 1130 3.2 | 63 2.4 | 3116 2.8 | 89 2.8 | 1051 3.4 | 9128 3.3 |
| Unknown | 28297 29.3 | 6225 17.8 | 647 24.4 | 17984 16.2 | 544 17.2 | 16887 55.1 | 70584 25.3 |
| HIV test |         |       |       |        |           |         |       |
| Positive | 10035 10.4 | 3473 10.0 | 148 5.6 | 9008 8.1 | 93 2.9 | 3034 9.9 | 25791 9.3 |
| Negative | 52876 54.7 | 15610 44.7 | 1233 46.5 | 49513 44.7 | 1560 49.4 | 15531 50.7 | 136323 48.9 |
| Ongoing | 6335 6.6 | 3642 10.4 | 259 9.8 | 11031 10.0 | 232 7.3 | 2030 6.6 | 23529 8.4 |
| Not performed | 27361 28.3 | 12158 34.9 | 1011 38.1 | 41163 37.2 | 1273 40.3 | 10065 32.8 | 93031 33.4 |
| BK 2nd month |         |       |       |        |           |         |       |
| Positive | 5216 5.4 | 1778 5.1 | 127 4.8 | 5608 5.1 | 134 4.2 | 1402 4.6 | 14265 5.1 |
| Negative | 25354 26.2 | 9402 27.0 | 707 26.7 | 33430 30.2 | 1161 36.8 | 6775 22.1 | 76829 27.6 |
| Not performed | 45526 47.1 | 15460 44.3 | 1046 39.5 | 43748 39.5 | 1289 40.9 | 12134 39.6 | 119203 42.8 |
| Unknown | 20511 21.2 | 8243 23.6 | 771 29.1 | 27929 25.2 | 574 18.2 | 10349 33.8 | 68377 24.5 |

(Continued)
Tests were not performed in more than half (56.7%) of all notified TB cases, with the highest rates of non-compliance in the black and the ‘mixed’ populations (both 64.6%) (Table 3).

Pulmonary tuberculosis was reported in 82.3% of all cases, making it the most common clinical presentation of the disease among all colour/race categories. The highest rate of pulmonary tuberculosis was found in the indigenous population (86.6%). Extrapulmonary tuberculosis was predominantly reported in the white population (17%) compared to the other colour/race categories (Table 3).

In 33.4% of the notified cases, HIV testing did not take place. The lowest rates of HIV testing were found in the indigenous population (59.6%), while the highest rates of HIV testing were found in the white population (71.7%) (Table 3).

‘Cured’ was the most common outcome for all colour/race categories. The highest cure rate was observed in the indigenous population (76.8%), and the lowest rate was observed in the black population (70.7%). Treatment default rates were also highest in the black population (10.5%) and lowest in the indigenous population (6.9%). Death by TB was most common in the black population (7.5%) and least common in the indigenous population (2.8%) (Table 3).

Rates of cure were lower in cases where the follow-up was classified as inadequate (56.7%). High death rates and treatment default rates were remarkable in cases in which the follow-up was classified as inadequate (5.4% and 12.5%, respectively) in all colour/race categories (Fig 2).

### Table 3. (Continued)

|          | 2008–2011 BK 1st sample |          |          |          |          |          |          |          |
|----------|-------------------------|----------|----------|----------|----------|----------|----------|----------|
|          | White | Black | Asian | Mixed* | Indigenous | Unknown | Total |
|          | Cases | Cases | Cases | Cases | Cases | Cases | Cases | Cases |
| BK 1st sample |   |   |   |   |   |   |   |   |
| Negative  | 23989 | 8828  | 652   | 31503  | 1056   | 6384   | 20.8  | 72412   | 26.0  |
| Not performed | 47605 | 16031 | 1086  | 45415  | 1346   | 12218  | 39.8  | 123701  | 44.4  |
| Unknown   | 23913 | 9717  | 887   | 32815  | 731    | 11759  | 38.4  | 79822   | 28.6  |
|          |          |        |        |        |        |        |        |        |
| BK 6th month |          |        |        |        |        |        |        |        |
| Positive  | 548    | 161   | 19    | 561    | 13     | 130    | 0.4   | 1432    | 0.5   |
| Not performed | 25829 | 9615  | 742   | 34848  | 1229   | 6763   | 22.1  | 79026   | 28.4  |
| Unknown   | 27359 | 11116 | 977   | 37064  | 834    | 13104  | 42.7  | 90454   | 32.5  |
|          |          |        |        |        |        |        |        |        |
| Supervised treatment |          |        |        |        |        |        |        |        |
| Yes       | 35919  | 14181 | 1171  | 48989  | 2167   | 9513   | 31.0  | 111940  | 40.2  |
| No        | 43741  | 16820 | 977   | 50715  | 770    | 9364   | 30.5  | 122387  | 43.9  |
| Unknown   | 16947  | 3882  | 503   | 11011  | 221    | 11783  | 38.4  | 44347   | 15.9  |
| Outcome   |          |        |        |        |        |        |        |        |
| Cure      | 73238  | 24654 | 1963  | 80357  | 2426   | 21567  | 70.3  | 204205  | 73.3  |
| Default   | 7092   | 3657  | 199   | 9460   | 218    | 3124   | 10.2  | 23750   | 8.5   |
| Death by TB | 2896  | 1180  | 81    | 3623   | 89     | 1166   | 3.9   | 9035    | 3.2   |
| Death, other causes | 4582 | 1424 | 101   | 3994   | 75     | 1605   | 5.2   | 11781   | 4.2   |
| Transferred | 5320 | 2389 | 68    | 9097   | 249    | 1842   | 6.0   | 19109   | 6.9   |
| MDR-TB    | 210    | 78    | 8     | 256    | 6      | 22     | 0.1   | 580     | 0.2   |
| Unknown   | 3269   | 1501  | 87    | 3928   | 95     | 1334   | 4.4   | 10214   | 3.7   |
| Total     | 96607  | 34883 | 2651  | 3158   | 30660  | 278674 | 100.0 |        |        |

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It can be observed that treatment outcome is generally successful in cases with adequate follow-up. Better patient follow-up classifications resulted in higher cure rates (96.8) and lower rates of treatment default (Fig 2).

Discussion

Our findings confirmed that although TB remains at an endemic level in Brazil, its geographical distribution has become homogenous among the macro-regions of the country in recent years. Marked ethnic and racial inequalities were observed regarding the clinical, epidemiological, and operational aspects of the disease, the follow-up of cases in treatment and treatment outcomes.

As described by other authors [21,22], our findings note higher incidences of TB in the North and Southeast regions of Brazil and lower incidences in the Central-West region. However, when the data are stratified by ‘colour or race’ in these regions, hitherto unknown incidence patterns surface—in particular, the higher burden of disease among indigenous and black people compared to other categories. It is worth noting that in this study, the Central-West region—where the number of TB notifications has traditionally been low in comparison with other regions—registered the highest incidence rates of TB in the indigenous population: more than 6 times higher than the national average.

In turn, high incidence rates of TB were found in the black population, reaching a peak of 93.3/100,000 in 2009, which exceeded the average incidence rate in the general population more than three times. The highest rates were detected in the South region, which has the best
indicators of health and human development in the country [23]. Although the black population represents only approximately 4% of the population in the South region, 11.4% of TB case notifications during the period 2008–2011 occurred in this segment of the population in the South.

As was noted in a study by Chiavegatto-Filho and Laurenti [24], the inequalities in TB indicators between black patients and other patients can be explained by the more precarious living conditions among the black population, which include lower incomes and more limited access to health services.

The indigenous population’s vulnerability to TB bears similarities to the black population in the South region and can be explained similarly by poverty and limited access to health services as well as certain other characteristics of indigenous households. Generally, indigenous homes are small and crowded, with little natural light and ventilation. These characteristics contribute to the preservation of the TB bacillus in this environment and favour the spread of the disease [25].

Although approximately half of the notifications were concentrated in the age group 20–44 years in all colour/race categories, high morbidity rates in indigenous children were featured prominently in all regions. The rates of TB among indigenous children were substantially higher than the 5% expected by the PNCT among children up to 15 years in the general population of Brazil [8]. Cases of TB in children under 10 years of age, independent of colour or race, can be considered as an indicator for active transmission of TB in the community due to their contact with bacilliferous adults, and are a sign of failed contact surveillance, especially in indigenous villages located in the remote hinterland areas of Brazil [26].

From this perspective, the high rates of TB case notification among the indigenous population living in rural areas are startling [27]. Various studies based on primary data from the indigenous communities have revealed high TB incidence rates [15,16,28–30], particularly among children and adolescents [16,26,29,31], prevalence rates of latent TB infection surpassing 40% [32], and patterns of recent transmission in some indigenous villages in Brazil, supporting our hypothesis of continuous TB transmission in these locations [26,33].

In addition, some authors have proposed theories that these high incidence rates could be associated with genetic polymorphisms inducing an inefficient immune cell response that would direct the course of the infection and leave the indigenous population more vulnerable to the disease [34,35]. However, despite such theories, there is strong evidence that it is the situation of extreme poverty in which these populations live—where hunger, a permanent state of food insecurity, unemployment, and low income or no source of income are coupled with a high prevalence of malnutrition, anaemia, and intestinal parasites—that contributes to the continued high TB burden in the Indigenous Territories [13,27,36–40].

The highest rates of illiteracy were also found among the indigenous TB patients, followed by black patients. According to San-Pedro and Oliveira [41], these low educational levels are closely associated with the precarious socioeconomic conditions that further increase their vulnerability to TB infections as well as a host of other diseases related to poverty. A likely explanation for this disparity is that, for the indigenous population, access to formal education is still difficult, particularly in the North region of Brazil. However, the variable ‘education’ in the SINAN database is often omitted or only partially completed, which obstructs further analysis of this theme.

A higher number of negative results in the bacilloscopies of the 1st and 2nd sputum samples was observed in the indigenous population, which could be partly explained by inadequate orientation of the patient at the time of sample collection or—as proposed by recent studies—by inappropriate storage and transport of the samples and technical incompetence resulting in incorrect reading of the sputum smears [25,28,42].
According to the 'III Diretrizes para TB' by the SBPT, sputum culture is recommended for suspected cases of TB that present a negative bacilloscopy and is considered the most accurate diagnostic tool for TB [20]. Unfortunately, our analysis has shown that sputum culture is underused in practically the entire country. Given this finding, it was noteworthy that sputum culture was employed at the highest rate in the indigenous patient population, in contrast to the examination levels observed in the other colour/race categories.

It is also noteworthy that sputum culture occurred most frequently in the Central-West region of the country. According to recent studies, [24,26], the laboratory services for the diagnosis of TB in the indigenous population in the state of Mato Grosso do Sul, which is home to the 2nd-largest indigenous population contingent in Brazil, have been improving for at least a decade. This could partly explain our findings.

The predominance of thorax radiography over sputum bacilloscopy as a diagnostic examination for TB was also observed in all colour/race categories. These findings can probably be explained by its low cost, the availability of radiography equipment in the healthcare units, and the relative ease of performing this examination. When radiography is well indicated in diagnostic investigations of respiratory symptoms, the results can produce valuable clinical information [43].

Low rates of tuberculin tests were also found in all notified cases in the country. However, in cases where tuberculin tests were used, high rates of skin reactions above 10 mm were registered among indigenous patients. As has been proposed by other authors [28,34], this fact supports a scenario of high prevalence rates of *Mycobacterium tuberculosis* infection in this population.

Despite the recommendations by the World Health Organization (WHO) that all cases diagnosed with TB should be offered an HIV test [8], we found important inequalities in the access to this test among the colour/race categories. Most prominently, the lowest rates of HIV testing were found among the indigenous population, while the highest rates of HIV testing were found among the white population (28.3%). In a recent study, Basta et al. [16] identified a similar pattern of non-compliance with the recommendations for HIV testing in the indigenous population in Mato Grosso do Sul. HIV tests were not performed for approximately half of all notified TB cases among the indigenous population. As a result, the healthcare service misses out on the opportunity to detect, manage, and control TB/HIV co-infection in this population.

Performing control bacilloscopies in the 2nd, 4th, and 6th months of treatment is considered fundamental for successful follow-up of TB cases. However, our analysis showed that in more than 50% of the cases, there were no control test registrations. According to a study by Belo et al. [15], in municipalities in the Amazon region along the northern arch of Brazil's international borders, the cases where bacilloscopy was not performed or performed only once presented a 12-fold increased risk of treatment default compared to cases where two or more bacilloscopies were performed during the treatment schedule. These authors argue that performing control bacilloscopies is a potential way of creating a bond between the patients and the healthcare service, and thus, such procedures contribute to reducing the risk of treatment default.

In accordance with WHO recommendations, all cases of TB must receive directly observed treatment (DOT) [8]. However, our data reveal that DOT failed to reach 100% of cases in all colour/race categories. Despite this failure, the high rates of DOT among the indigenous population (in contrast to the black population, which presented the lowest rates) indicate that—at least in this respect—the healthcare service organizations have achieved a remarkable level of follow-up among the indigenous population. However, it is of concern that no specific policy
has been directed at the black population thus far, despite this population’s high vulnerability to TB [44].

The analysis of the outcomes of notified TB cases showed that no colour/race category reached the objectives for cure established by the PNCT [8]. Similar to findings from other studies [15,16], the highest cure rates were registered among the indigenous patients. We observed the lowest cure rates (70.7%) and the highest rates of treatment default (10.5%) and death by TB (3.4%) among the black population. These findings demonstrate that there is great disparity in treatment follow-up between the colour/race categories and call for additional efforts to reach the goals agreed on with the WHO, especially regarding TB control in populations who live in vulnerable situations.

Although exclusively empirical, the classification of the follow-up system for patients employed in this study is congruent with the evaluation logic of the PNCT, showing that treatment success is directly linked to the structuring and surveillance capacity of the healthcare service. Patients who undergo supervised treatment and are duly followed up with during treatment have higher rates of cure, lower rates of default, and lower frequencies of complications and death.

Even though this study yielded multiple findings, the following limitations must be mentioned. Studies based on secondary data are subject to under-registration of cases, classification and/or diagnostic errors, and low representativeness of specific population segments. Moreover, analyses are limited to the variables as they are structured in the information systems [45,46].

Although we have shown that important improvements have occurred in completing entries for the variable ‘colour or race’ in recent years, gaps still exist in completing entries for some other variables in the SINAN. In certain situations, it is possible that there has been systematic error in acquiring complete entries for variables in the SINAN, which would mean that the estimates are distorted. Theoretically, such errors compromise the identification of the true disease profile of TB in Brazil [45,47]. However, there is no reason to believe that possible classification errors have affected the registration of the variable ‘colour or race’. According to a recent document published by the Brazilian Ministry of Health [14], reasonable progress has been made in completing entries for the variable ‘colour or race’ in national health information systems. Moreover, the data make it possible to undertake analyses that aim to elucidate inequalities in indicators for various diseases and deaths in recent times. In this respect, we think that the analyses presented in this study are useful for demonstrating inequalities in the distribution of TB across categories of ‘colour or race’, both among and within the macro-regions of Brazil.

Another point to consider is that in the colour/race category, ‘indigenous’ covers the entire ethnic and cultural diversity of the indigenous peoples of Brazil. According to the last national census (2010), this is one of the most ethnically and culturally diverse populations on the planet; it includes more than 300 ethnic groups speaking more than 200 different languages [48]. The current categories available in the registration of disease and death in Brazil conceal this diversity. At least, regarding TB, it is known that the distribution of the disease is not homogenous among the indigenous peoples because concentrations of cases exist in some groups in the Amazon Basin and in the Central-West region of the country.

Considering the limitations outlined, the results presented here should be interpreted with caution. In particular, it is important to not speculate that the observed differences in TB disease indicators could be attributed to problems of a genetic or biological nature [49]. As in other parts of the world, the concept of ethnicity in Brazil is the product of complex historical and social constructions. From this perspective, the racial differences observed in the indicators for health seem to be more associated with socioeconomic inequalities and access to healthcare and educational services than with genetic risk markers or other biological parameters [50,51].
Conclusions

Our findings revealed, in an unprecedented manner, important ethnic and racial inequalities in the notification of cases of TB regarding both the follow-up of cases in treatment as well as the clinical and epidemiological parameters, with emphasis on the higher incidence rates among the indigenous and black populations.

Finally, it is important to consider that the control of TB in Brazil is a problem neither limited to the healthcare sector nor restricted to its actions and services. It is of vital importance for the PNCT to involve other government bodies in the design, implementation, and development of control strategies and to encourage social development initiatives to improve the general living conditions and health of the areas and specific segments of the population where TB is an important public health problem.

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Author Contributions

Conceived and designed the experiments: PVSV MJFG PCB. Performed the experiments: PVSV MJFG PCB. Analyzed the data: PVSV MJFG PCB. Wrote the paper: PVSV MJFG PCB.

References

1. Hershkovitz I, Donoghue HD, Minnikin DE, May H, Lee OY, Feldman M, et al. Tuberculosis origin: the neolithic scenario. Tuberculosis (Edinb). 2015; 95 Suppl 1: S122–S126.
2. WHO. Global tuberculosis report 2014. Geneva: WHO; 2014. pp. 171.
3. Barreto ML, Teixeira MG, Bastos FI, Ximenes RA, Barata RB, Rodrigues LC. Successes and failures in the control of infectious diseases in Brazil: social and environmental context, policies, interventions, and research needs. Lancet. 2011; 377: 1877–1889. doi:10.1016/S0140-6736(11)60202-X PMID: 21561657
4. Narasimhan P, Wood J, Macintyre CR, Mathai D. Risk factors for tuberculosis. Pulm Med. 2013; 2013: 37–46.
5. Jeon CY, Murray MB. Diabetes mellitus increases the risk of active tuberculosis: a systematic review of 13 observational studies. PLoS Med. 2008; 5: e152. doi: 10.1371/journal.pmed.0050152 PMID: 18630984
6. NBLacerda S, C de A Temoteo R, MRM de Figueiredo T, DT de Luna F, AN de Sousa M, C de Abreu L, et al. Individual and social vulnerabilities upon acquiring tuberculosis: a literature systematic review. Int Arch Med. 2014; 7: 35. doi: 10.1186/1755-7682-7-35 PMID: 25067955
7. Nava-Aguilera E, Andersson N, Harris E, Mitchell S, Hamel C, Shea B, et al. Risk factors associated with recent transmission of tuberculosis: systematic review and meta-analysis. Int J Tuberc Lung Dis. 2009; 13: 17–26. PMID: 19105874
8. Ministério Da Saúde. Manual de recomendações para o controle da tuberculose no Brasil. Brasilia: Ministério da Saúde. 2011. pp. 284.
9. Buchillet D, Gazin P. A situação da tuberculose na população indígena do alto rio Negro (estado do amazonas, Brasil). Cad Saúde Pública. 1998; 14: 181–185.
10. Filho ACM. Incidência da tuberculose em indígenas do município de são gabriel da cachoeira, AM. Rev Soc Bras Med Trop. 2008; 41: 243–246. PMID: 18719802
11. Escobar AL, Coimbra CEA Jr., Camacho LA, Portela MC. Tuberculose em populações indígenas de rondônia, Amazônia, Brasil. Cad Saúde Pública. 2001; 17: 285–296. PMID: 11283760
12. Sousa AO, Salem JJ, Lee FK, Verçosa MC, Cruaud P, Bloom BR, et al. An epidemic of tuberculosis with a high rate of tuberculin anergy among a population previously unexposed to tuberculosis, the Yanomami Indians of the Brazilian Amazon. Proc Natl Acad Sci U S A. 1997; 94: 13227–13232. PMID: 9371828

13. Croda MG, Trajber Z, Lima Rda C, Croda J. Tuberculosis control in a highly endemic indigenous community in Brazil. Trans R Soc Trop Med Hyg. 2012; 106: 223–229. doi: 10.1016/j.trstmh.2012.01.005 PMID: 22365154

14. Ministério Da Saúde. Indicadores de vigilância em saúde, analisados segundo a variável Raça/cor. Bol Epidemiol. 2015; 46: 1–35.

15. Belo EN, Orellana JDY, Levinio A, Basta PC. Tuberculose nos municípios amazônicos da fronteira Brasil-Colômbia-Peru-Venezuela: situação epidemiológica e fatores associados ao abandono. Rev Panam Salud Publica 2013; 34: 321–329.

16. Basta PC, Marques M, de Oliveira RL, Cunha EAT, Resendes AP da C, Souza-Santos R. Desigualdades sociais e tuberculose: análise segundo Raça/cor, mato grosso do sul. Rev Saude Publica. 2013; 47: 854–864.

17. Travassos C, Williams DR. The concept and measurement of race and their relationship to public health: a review focused on Brazil and the United States. Cad Saude Publica. 2004; 20: 660–678. PMID: 15263977

18. Instituto Brasileiro de Geografia E Estatística (IBGE). Sistema IBGE de recuperação automática: censos demográficos 2000 E 2010. Rio de Janeiro: IBGE. 2014.

19. Orellana JDY, Gonçalves MJF, Basta PC. Características sociodemográficas e indicadores operacionais do controle da tuberculose entre indígenas e não indígenas de rondonia, amazônia ocidental, Brasil. Rev Bras Epidemiol. 2012; 15: 846–856.

20. Conde MB, de Melo FAF, Marques AMC, Cardoso NC, Pinheiro VGF, Dalcin P de TR, et al. III Diretrizes para tuberculose da sociedade brasileira de pneumologia e tisiologia. J bras pneumol. 2009; 35: 1018–1048.

21. Bierrenbach AL, Gomes ABF, Noronha EF, de Souza M de FM. Incidência de tuberculose e taxa de cura, Brasil, 2000 a 2004. Rev Saúde Pública. 2007; 41: 24–33.

22. de Oliveira GP, Torrens AW, Bartholomay P, Barreira D. Tuberculosis in Brazil: last ten years analysis. Int J Tuberc Lung Dis. 2006; 10: 1354–1359. PMID:17167952

23. Ministério Da Saúde. Indicadores básicos para a saúde no Brasil: conceitos e aplicações. 2nd ed. Rede Interagencial de Informação Para a Saúde—Ripsa. 2008.

24. Chiavegatto Filho ADP, Laurenti R. Disparidades étnico-raciais em saúde autoavaliada: análise multivariável de 2.697 indivíduos residentes em 145 municípios brasileiros. Cad Saude Publica. 2013; 29: 1572–1582.

25. Basta PC, Coimbra CE Jr, Welch JR, Alves LCV, Santos RV, Camacho LAB. Tuberculosis among the xavante Indians of the Brazilian Amazon: an epidemiological and ethnographic assessment. Ann Hum Biol. 2010; 37: 643–657. doi:10.3109/03014460903524451 PMID: 20113213

26. Basta PC, Rios DPG, Alves LCC, Sant’Anna CC, Coimbra C Jr. Estudo clínico-radiológico de crianças e adolescentes indígenas suruí, Região Amazônica. Rev Soc Bras Med Trop. 2010; 43: 719–722.

27. Coimbra CE, Santos RV, Welch JR, Cardoso AM, de Souza MC, Gamelo L, et al. The first national survey of indigenous people’s health and nutrition in Brazil: rationale, methodology, and overview of results. BMC Public Health. 2013; 13: 52. doi:10.1186/1471-2458-13-52 PMID: 23331985

28. Rios DPG, Malacarne J, Alves LCC, Sant’Anna CC, Camacho LAB, Basta PC. Tuberculosis in indígenas da Amazônia Brasileira: estudo epidemiológico na região do alto rio negro. Rev Panam Salud Pública. 2013; 33: 22–29.

29. Basta PC, Coimbra CE Jr, Escobar AL, Santos RV. Aspectos epidemiológicos da tuberculose na população indígena suruí, Amazônia, Brasil. Rev Soc Bras Med Trop. 2004; 37: 338–342.

30. de P Melo TEM, dC Resendes AP, Souza-Santos R, Basta PC. Distribuição espacial e temporal da tuberculose em indígenas e não indígenas de Rondônia, Amazônia Ocidental, Brasil. Cad Saude Publica. 2012; 28: 267–280.

31. Gava C, Malacarne J, Rios DPG, Sant’Anna CC, Camacho LAB, Basta PC. Tuberculosis in indigenous children in the Brazilian amazon. Rev Saúde Publica. 2013; 47: 77–85. PMID: 23763153

32. Basta P, Coimbra C Jr, Santos R. Risk of tuberculous infection in an indigenous population from Amazonia, Brazil. Int J Tuberc Lung Dis. 2006; 10: 1354–1358. PMID: 17167952

33. Coimbra CE, Basta PC. The burden of tuberculosis in indigenous peoples in Amazonia, Brazil. Trans R Soc Trop Med Hyg. 2007; 101: 635–636. PMID: 17467759
34. Zembrzuski VM, Basta PC, Callegari-Jacques SM, Santos RV, Coimbra CE, Salzano FM, et al. Cytokine genes are associated with tuberculin skin test response in a native Brazilian population. Tuberculosis. 2010; 90: 44–49. doi:10.1016/j.tube.2009.11.002 PMID: 20005781

35. Longhi RMP, Zembrzuski VM, Basta PC, Croda J. Genetic polymorphism and immune response to tuberculosis in indigenous populations: a brief review. Braz J Infect Dis. 2013; 17: 363–368. doi:10.1016/j.bjid.2012.11.001 PMID: 23665009

36. Cunha EA, Ferrazoli L, Riley LW, Basta PC, Honer MR, Maia R, et al. Incidence and transmission patterns of tuberculosis among indigenous populations in Brazil. Mem Inst Oswaldo Cruz. 2014; 109: 108–113. doi:10.1590/0074-0276130082 PMID: 24270999

37. Horta BL, Santos RV, Welch JR, Cardoso AM, dos Santos JV, Assis A, et al. Nutritional status of indigenous children: findings from the first national survey of indigenous people's health and nutrition in Brazil. Int J Equity Health. 2013; 12: 23. doi:10.1186/1475-9276-12-23 PMID: 23552397

38. Bóia MN, Carvalho-Costa FA, Sodré FC, Porras-Pedroza BE, Faria EC, Magalhães GAP, et al. Tuberculosis and parasitism intestinal in an indigenous population in the Amazon region, Brazil. Rev Saude Publica. 2009; 43: 176–178.

39. Sacchi FP, Croda MG, Estevan AO, Ko AI, Croda J. Sugar cane manufacturing is associated with tuberculosis in an indigenous population in Brazil. Trans R Soc Trop Med Hyg. 2013; 107: 152–157. doi:10.1093/trstmh/trs089 PMID: 23306443

40. Coimbra CEA. Saúde e povos indígenas no Brasil: reflexões a partir do inquérito nacional de saúde e nutrição indígena. Cad Saude Publica. 2014; 30: 855–859.

41. Pedro A, de Oliveira RM. Tuberculose e indicadores socioeconômicos: revisão sistemática da literatura. Rev Panam Salud Pública. 2013; 33: 294–301. PMID: 2369179

42. Nobrega RG, Nogueira J de A, Netto AR, de Sa LD, da Silva ATMC, Villa TCS. The active search for respiratory symptoms for the control of tuberculosis in the potiguara indigenous scenario, Paraíba, Brazil. Rev Lat Am Enfermagem. 2010; 18: 1169–1176. PMID: 21340283

43. Capone D, Jansen JM, Lopes AJ, Sant'Anna CdC, Soares M, Pinto R dos S, et al. Diagnóstico por imagem da tuberculose pulmonar. Pulm RJ. 2006; 15: 166–174.

44. Batista LE. Masculinidade, raça/cor e saúde. Ciênc Saúde Colet. 2005; 10: 71–80.

45. Malhão TA, de Oliveira GP, Codenotti S, Moherdau F. Avaliação da completude do sistema de informação de agravos de notificação da tuberculose, Brasil, 2001–2006. Epidemiol Serv Saúde. 2010; 19: 245–256.

46. Pinheiro RS, Andrade V de L, de Oliveira GP. Subnotificação da tuberculose no sistema de informação de agravos de notificação (SINAN): abandono primário de bacilíferos e captação de casos em outras fontes de informação usando linkage probabilístico. Cad Saúde Pública. 2012; 28: 1559–1568.

47. Braz RM, de Oliveira P de TR, dos Reis AT, Machado NM da S. Avaliação da completude da variável raça/cor nos sistemas nacionais de informação em saúde para aferição da equidade étnico-racial em indicadores usados pelo índice de desempenho do sistema único de saúde. Saúde em Debate. 2013; 37: 554–562.

48. IBGE. Censo demográfico 2010: características gerais dos indígenas. Rio de Janeiro: Resultados Do Universo; 2012.

49. Gravlee CC. How race becomes biology: embodiment of social inequality. Am J Phys Anthropol. 2009; 139: 47–57. doi:10.1002/aja.20983 PMID: 19226645

50. Chor D, Lima CR de A. Aspectos epidemiológicos das desigualdades raciais em saúde no Brasil epidemiologic aspects of racial inequalities in health in Brazil. Cad Saúde Pública. 2005; 21: 1586–1594.

51. Chor D. Desigualdades em saúde no Brasil: é preciso ter raça. Cad Saúde Pública. 2013; 29: 1272–1275.